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Adaptation of new buildings for climate change

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This report ('**Report**') has been prepared by WSP exclusively for BRANZ Inc. ('**Client**') in relation to a research study into the adaptation of new buildings for climate change ('**Purpose**') and in accordance with the BRANZ Inc. Contract LR13685, dated 3 May 2021. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

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Executive Summary

Climate change predictions for New Zealand suggest wind speeds could increase by up to 10% in some parts of the country. To understand how such a change could impact the design and construction of buildings this research has analysed the effect of increasing wind speeds by 5%, 10% and 15% on design solutions from key building Standards, NZS 3604, NZS 4223.4, NZS 4211, and E2/AS1.

It finds that New Zealand's light timber-framed buildings are well placed to stand up to the impacts of increased wind speeds due to climate change based on current climate change projections.

Some changes may be required. But these would be minor changes in the dimensions and/or sizes of building members and components needed to resist a 15% increase in the design wind speed.

The costs associated with these minor changes are likely to be minimal. Some components are conservatively designed for use in all wind zones, so increasing wind speeds will generally have no effect.

However, costs will increase where wind speeds increase to levels that exceed the Extra High wind zone in the Standards, which would then require specific engineering design (SED). In these circumstances, the additional costs of SED arise from specialist design input and different building consent processes. At present, only 3.4% of existing buildings are estimated to be zoned as SED.

The research has also shown that a methodology using sensitivity analysis works well for Standards with an analytical basis, such as NZS 3604 and NZS 4223.4. Incremental changes in wind speeds could, in theory, be assessed for any projected change in the wind climate. A key benefit of using sensitivity analysis is that as climate data is updated or amended, the analysis remains valid. It can be easily applied to the most recent projections and the results are not limited to a particular set of modelling assumptions or targets. Sensitivity analysis also allows a risk-based approach to managing climate adaptation. In practical terms, this means that only significant changes to the cost and construction of building, rather than changes in the design inputs, require attention.

The research has also confirmed that this approach cannot be applied universally. Design methods that incorporate empirically developed parameters and solutions require a comparative analysis to assess the impact of changes in climate.

Finally, we note that this research has only looked at the impact of changes to the wind climate. As New Zealand moves to firm up its plans around climate change adaptation further work should be undertaken to complete the full picture around the implications of climate events on buildings.

The IPCC (2021) identifies the following future climatic changes for New Zealand. These provide a starting point for future research:

- increases in the mean temperatures and extreme heat (high confidence)
- decreases in cold spells and frosts (high confidence)
- increases in mean precipitation in the south and west of New Zealand and a decrease in the north and east (medium confidence)
- increase in river floods (medium confidence)
- increase in fire weather (medium confidence)
- decrease in snow (medium confidence)
- increase in relative sea level (high confidence)
- increase in coastal flooding (high confidence)
- increase in coastal erosion (high confidence)

All these climate parameters affect the performance of New Zealand buildings to a greater or lesser degree - depending on their location in New Zealand. All should be explored regarding how best we can adapt our buildings to climate change.

Work has already been undertaken in some of these areas - for example, the BRANZ “Flood It” project and analysis conducted around the implications on occupant comfort as a result of changes in temperature.

As a next step we believe that the IPCC projections should be mapped against research undertaken or underway. This would provide the basis for the prioritisation of action required to address any gaps.

1 Adaptation to climate change

The need for action to limit climate change is well established and is governed internationally by the 2015 Paris Climate Change Agreement. The primary aim of the Paris Agreement is to limit the rise in global temperatures to 1.5°C above pre-industrial levels, with the most recent Conference of the Parties, COP26, reaching agreement on the detailed rules that implement the Paris Agreement. The United Nations Framework Convention on Climate Change (UNFCCC) Secretariat report on adaptation to climate change and its financing was a focus for discussions at COP26, as many countries are having to deal with increasingly hostile climate impacts.

1.1 New Zealand's response to climate change

New Zealand, under the Paris Agreement, has committed to reduce greenhouse gas (GHG) emissions by 30% below 2005 levels by 2030. The Climate Change Response (Zero Carbon) Amendment Act 2019 provides the overarching framework for how New Zealand will deliver on its commitment. The Act sets a target of net zero emissions of all greenhouse gases (except biogenic methane) by 2050. A range of work is underway across many parts of the economy, with the Climate Change Commission playing a key role in shaping New Zealand's response and coordinating government and industry responses.

MBIE Building System Performance (BSP) has initiated the Building for Climate Change programme. This has two key elements reflecting the two strands of New Zealand's response under the Climate Change Response (Zero Carbon) Amendment Act 2019 - mitigation and adaptation.

Mitigation is critical to New Zealand achieving its declaration of a 30% cut in GHG emissions, and for the global effort to limit the extent of change in the climate. Mitigation will only reduce the extent of climate change, not eliminate it. For that reason, adaptation is essential in living with the changes that will occur in the climate.

1.2 Mitigation

For the built environment, mitigation is strongly focused on transitioning to low-carbon buildings and building use. Significant research has been done, and is ongoing, on how buildings and construction can be decarbonised and ultimately transitioned to have net-zero impact. In the building industry, significant effort in recent years has focused on preparing for the shift to low-carbon buildings. In New Zealand for example, BRANZ is leading a programme of work drawing on expertise from New Zealand and internationally to support this change. Called the Transition to Zero Carbon Built Environment Programme, it aims to collaboratively support industry to transition to net zero carbon buildings by 2050.

1.3 Adaptation

Adaptation is concerned with the changes in building performance that are needed to reduce the impact of the changing climate and more extreme weather events.

Within the building industry, adaptation has had less focus because efforts have been predominantly directed at reducing carbon emissions. In addition, many important adaptation measures can only be effectively resolved at a city or neighbourhood level (for example, coastal inundation). Adaptation that will be needed for individual buildings has received less attention, but is an area that requires attention to help our understanding of what action, if any, is needed at this scale. This is the focus of this research.

New Zealand's first National Climate Change Risk Assessment (NCCRA) was released in 2020 and includes the adaptation of buildings as a priority risk. The NCCRA identifies one of the most significant risks to New Zealand's built environment as being the risk to buildings from extreme weather events, droughts, increased fire weather and ongoing sea-level rise.

The urgency needed is rated as being extreme by 2050, with an emphasis on both action (to adapt buildings) and research. The Climate Change Adaptation Technical Working Group noted, "New Zealand is starting to adapt – but it's not enough. New Zealand is only in the early stages of planning to adapt to the impacts of climate change. We need to do more, earlier, and take action to reduce risks and build resilience to our changing climate."

Adaptation planning requires a good understanding of both the changes in the climate and environment that will occur and the response to the altered climate. The response can be to adapt buildings and construction to perform in the altered climate, or adapt cities and societies using land use planning, insurance, etc. This research looks at what adaptation could be needed to buildings and construction.

The Climate Changes, Impacts & Implications project that NIWA completed in 2016 has provided improved projections of climate change trends and changes in extreme weather for New Zealand. The recent IPCC Assessment Report 6 provides regional projections for New Zealand that appear to be based on the earlier work of NIWA. While research from The Deep South Science Challenge will provide extreme climate and weather projection for New Zealand in the next year or two, and updates are also planned for NIWAs climate projections, currently the 2016 projections appear to provide the best basis for estimating the future climate impacts on buildings.

The vulnerability of buildings to climate change is being widely investigated. Research is being undertaken through programmes like The Deep South and the Resilience to Natures Challenges National Science Challenges. Councils and businesses are also planning for climate impacts. Most of this work is focused on city or neighbourhood impacts on buildings, such as coastal inundation, flooding, drought and wildfire.

The purpose of this research has been to investigate the wind-related implications of climate change on the design and construction of the buildings themselves. More specifically, the effects of future increases in wind speeds on the structural design of light timber framed buildings. Both wind and light timber-framed buildings are an important subset of building design in New Zealand and the Standards that cover their design are well established. This pilot study is intended to show how a climate adaptation analysis could be performed more broadly for building and construction in New Zealand.

2 Research scope

The construction industry needs to have confidence that the buildings being designed and built today are going to be fit for purpose in the future. At present there is a lack of evidence around whether the current building code and standards set an appropriate level of performance for new buildings when exposed to New Zealand's future climate.

Estimates of what the climate will look like in the future are being refined, and if buildings do require upgrading to cope with the changing climate, then evidence is needed to provide the basis for adjustments to design settings. Information is needed to decide at what point (and if) changes in regulation and practice might be required.

The aim of this research has been to determine if current design and construction practices employed on light timber-frame buildings have sufficient conservatism so that projected changes in wind speed due to climate change can be accommodated. If the methodology adopted is successful, it could be applied more widely to assess whether the design and construction of light-weight timber-framed buildings will be able to stand up to our changing climate.

Put simply, if the current Building Code, standards and practices are sufficiently conservative then when climate impacts materially worsen, our current approaches will produce buildings that are inherently resilient. If not, we must understand the scale and timing of the changes that are necessary to ensure buildings designed and constructed today are inherently resilient.

2.1 Timber framed buildings

A focus on light timber-frame buildings and the design implications of wind was chosen for this study. This is because timber-frame buildings are the dominant form of low-rise residential construction in New Zealand. In addition, future market and government signals make it likely that construction practices will extend the boundaries of timber construction as a mechanism to minimise the carbon footprint of buildings. This relatively simple type of construction also allows a manageable analysis of design impacts to be carried out.

2.2 Wind effects

Wind is one of the main considerations in the structural design of timber-frame buildings in New Zealand and can be the dominant load for many structures and sub-assemblies. Wind provides a useful case study for design implications of climate change because it is a well-defined structural load that has a clear analytical basis, and it is expected to change, to some extent, with climate change. The serviceability of buildings is also affected by wind, which is a design input into the weathertightness (along with rainfall), natural ventilation and acoustic performance of buildings. Wind around a building can also play a role in the amenity and safety of outdoor areas around buildings where people live and work.

It is important to recognise that the wind impact of climate change on existing buildings is more likely to be related to serviceability and deflections rather than structural failure or collapse of a building. This is primarily due to the likelihood that ultimate limit state design loads are rarely, if ever, experienced by an existing building. By definition, ultimate limit state loads are extremely unlikely to occur for a specific building. However, serviceability level wind speeds are experienced by existing buildings, and changes in these wind speeds and loads may impact on the performance of existing buildings.

2.3 Existing buildings

While some upgrading of existing buildings may be warranted if the design loads increase substantially with climate change, the analysis of when such intervention is appropriate will be determined as much by the condition of the existing building as it will be by the change in climate. This variability in the condition, and therefore performance, of existing buildings makes them considerably more complex to assess. In general, the relatively large cost of upgrading existing buildings also makes the economic hurdles more difficult to overcome compared to improving the performance of new buildings. The important question of whether climate risks to existing building are better managed by physically upgrading the buildings or by insurance is not addressed in this report. This research considers the impact of climate change only on new building design, as design impacts can be consistently assessed.

We note that if action to mitigate climate change sees a requirement for greater use of existing buildings, then the question of adaptation of these existing structures will need revisiting.

2.4 Future research

This report presents the results of research into the adaptation of new timber-framed building designs to the effects of wind and climate change in New Zealand.

Further research is needed to establish the impact of other climate change effects such as increased rainfall intensity, or changes in extreme temperatures and snowfall. Climate change impacts on the design of different types of buildings (for example, concrete or steel framed buildings, multi-storey buildings) are also needed to provide a complete picture of the adaptation that the building industry may need to make.

As climate change projections are updated and improved, the impacts on building design can also be updated using the results of the sensitivity analysis to provide more accurate estimates of the actual impacts and costs.

3 Research approach

Adaptation of new buildings for climate change has been investigated by looking at four design Standards that are widely used for light timber-frame buildings. These have been analysed to establish how changes in climate parameters, specifically wind, affect the design solutions for light timber-frame buildings and the products and components used in them.

The four standards analysed in this research are NZS 3604, NZS 4223.4, NZS 4211 and E2/AS1. They are outlined in Section 3.1.

The extent to which design wind speeds will increase as result of climate change is discussed in Section 4. Current projections are variable over different time scales and across different regions in New Zealand. There is a lack of specific information on the peak wind speeds at return periods used for structural design. This uncertainty in the projections limits their usefulness in determining a specific wind speed increase to apply to the analysis as the impact on design is expected to scale with the size of change in wind speed.

To overcome this barrier a sensitivity analysis has been used in this research. This approach determines the sensitivity of design outputs to increases in wind speeds of 5%, 10% and 15%. This range of wind speed increases comfortably covers the estimated speeds in current climate change projections.

3.1 Design Standards

There are many Standards, specifications and technical documents that are used in the design of light timber-frame buildings in New Zealand. The following four commonly used standards have been analysed for this research (note, these standards are referred throughout this report using the bold abbreviation below):

- **NZS 3604**:2011 Timber-framed buildings
- **NZS 4223.4**:2008 Glazing in Buildings, Part 4: Wind, dead, snow and live actions.
- **NZS 4211**:2008 Specification for performance of windows
- Acceptable Solution **E2/AS1** - For New Zealand Building Code Clause E2 External Moisture

These standards have been reviewed for this research because they,

1) have design requirements that are affected by wind, and can therefore show the impact on design if wind speeds increase with climate change, and
2) illustrate different types of design requirements that have been developed and incorporated into design standards, which range from analytical methods through to empirically derived solutions. These different types of standards will allow us to test how effectively the impacts of climate change on the design of new buildings can be investigated.

Standards that are based on analytical methods, such as NZS 3604 and NZS 4223.4, can be analysed to determine how building designs change as design inputs, such as wind speed, change. Such analysis allows the impacts of changes in the environment (for example, increasing design wind speeds) on building designs to be determined analytically. This approach has been applied to NZS 3604 and NZS 4223.2 to show what changes, to the timber framing and glass sizing, would occur if wind speeds increase by 5%, 10% and 15%.

NZS 3604 provides structural requirements for light timber-framed buildings, and includes tables of design data for sizing the framing members and connections. These tables are based on engineering analyses (refer Shelton 2013) that have been used to recalculate the framing requirements when design wind speeds are increased by 5%, 10% and 15%, as outlined in Section 6.

NZS 4223.4 provides analytical methods for determining the maximum span of a glass pane given its thickness, the aspect ratio of the glass pane and the design wind pressure (and the snow load for sloped overhead glazing). Design charts and equations are provided in NZS 4223.4 that allow the maximum glass spans to be calculated. These design charts have been used to calculate the effect of increasing design wind speeds by 5%, 10% and 15%, as reported in Section 7.

NZS 4211 and E2/AS1 provide solutions that are empirically developed and cannot be derived purely from engineering analysis. As such, the effects of changing input parameters (such as wind speed) on the design cannot be determined by calculation. However, the effects of increasing design wind speeds by 5%, 10% and 15%, have been discussed by considering the impacts that such a change would have on the wind zones that are used in these standards.

NZS 4211 is a test specification for windows that sets limits on the minimum strength, maximum deflection and maximum leakage of air and water under given wind pressures and water spray. The test pressures applied to windows correspond to the wind zones defined in NZS 3604. Windows that achieve the required test performance for a given wind zone are rated as suitable for use in that wind zone (or a lower wind zone). Because NZS 4211 uses physical testing to rate the performance of a window, rather than calculation, the effect of changes in wind speeds on design cannot be determined analytically. However, changes in wind speed will directly affect the wind zones used to rate the performance of windows, and this effect is discussed in Section 8.

E2/AS1 provides design solutions for the weathertightness of buildings. A risk-score is used to determine the level of weathertightness detailing that is required for a particular building, and is partly dependent on the wind zone, as defined in NZS 3604, in which the building is located. The weathertightness details specified in E2/AS1 have been developed empirically through testing and in-service history, rather than by engineering analysis and calculation. This means that the effects of changes in wind speed on the weathertightness design of a building cannot be determined analytically from E2/AS1. However, changes in wind speed will directly affect the wind zones used to derive the risk score. This effect is discussed in Section 8.

4 Climate change projections of wind speeds

The effect of climate change on wind speeds throughout New Zealand is uncertain, with variations in magnitude and the extent of predicted changes.

The most recent modelling estimates of wind speeds come from work published by The Ministry for the Environment (MfE) in a report "Climate Change Projections for New Zealand: Atmospheric projections based on simulations undertaken for the IPCC 5th Assessment" that was prepared by NIWA in 2016 (Mullan et al (2016)). The report estimates potential future changes in the New Zealand wind climate for several different climate change scenarios. The most severe scenario is described as a representative concentration pathway with a radiative forcing of 8.5 W/m2, or RCP8.5. Figure 4.1 shows the percentage changes in the 99th percentile daily-mean wind speed that are predicted to occur under RCP8.5. The changes are estimates of the wind speeds in 2090 compared to the daily 99th percentile mean speed in the baseline period from 1986–2005.

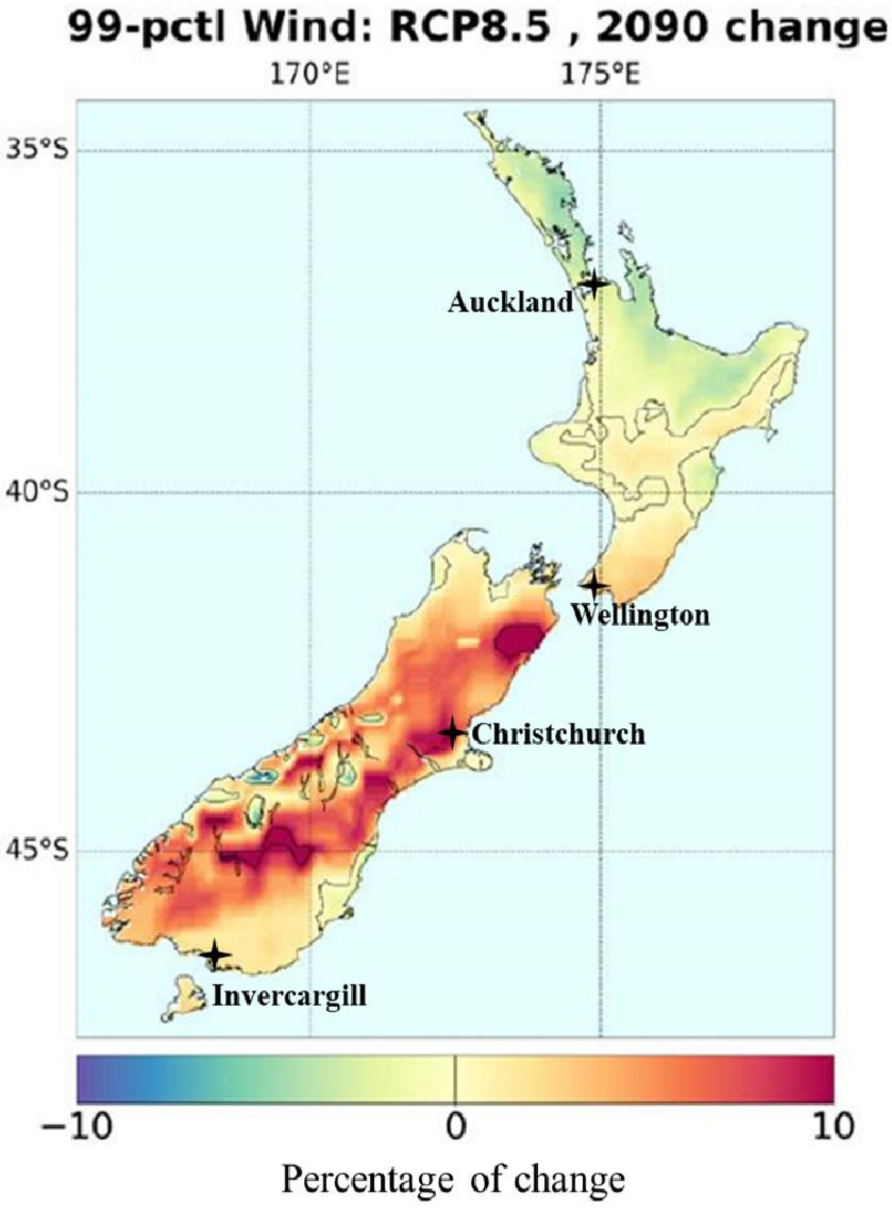


Figure 4.1 **Predicted change in the 99th percentile daily mean wind speed.** From Ministry for the Environment (2018)

The MfE report summarises the predicted changes in wind speeds as follows,

> "For most of the RCPs and time periods, the southern half of the North Island and all the South Island are shown as having stronger extreme daily winds in future. This is especially noticeable in the South Island, east of the Southern Alps. The regional model is able to resolve speed-up in the lee of the mountain ranges, and shows increases of up to 10 per cent or greater in Marlborough and Canterbury by the end of the century under the highest RCP8.5 forcing. There is, however, a decrease in extreme winds in the North Island from Northland to Bay of Plenty, probably because of increasing anticyclonic conditions."

The report also notes that some localised extreme winds are not resolved by the modelling. At this point, it is useful to note that the daily 99th percentile mean speed modelled for the predictions is not equivalent to the gust speed that is used to define design wind speeds for buildings. The extent to which changes in the daily 99th percentile mean speed are representative of changes in extreme gust speeds at return periods used for building designs is not reported and is an important question that future research and validation will hopefully answer. In the meantime, some correlation between the projected mean wind speeds and the design gust speeds is assumed and is used to define the relative change in design wind speed for the sensitivity analysis of climate change effects. The range of wind speed increases that have been considered in the sensitivity analysis comfortably exceeds the current climate projections and is likely to cover any updated climate change projections in future.

A study of long term trends in New Zealand wind speeds is reported by Pirooz et al (2019). A rigorous analysis of wind records from 1972 – 2017 for Auckland, Wellington, Christchurch and Invercargill was undertaken to establish trends in the magnitude and frequency of extreme wind speeds (comparable to the design wind speeds for buildings). The study summarises the results as follows:

> "Generally, trends in both magnitudes and frequencies of maximum gust wind speeds were negative. Annually, the strongest downward trends in the magnitudes of extreme winds were observed at Christchurch and Invercargill. In addition, autumn and winter experienced strongest negative magnitude and frequency trends compared to other seasons. The results demonstrated that the trends in the frequency of the upper tail of extreme wind speed distributions (i.e. 95th and 99th), which are important in the estimation of design wind speeds, have not changed significantly. It is worth noting that our analysis supports a decreasing trend in wind speeds reported by many researchers around the globe (Azorin-Molina et al., 2016; McVicar et al., 2012)."

A report from the Ministry for the Environment and Stats NZ called "New Zealand's Environmental Reporting Series: Our atmosphere and climate 2020" also reports a decreasing trend overall in the maximum annual wind gusts and the frequency of extreme wind speeds across New Zealand.

The opposing trends in wind speeds that are seen in climate modelling compared to analyses of historical weather data highlights the complexity and difficulty of accurately predicting extreme gust speeds. Further work to update estimates of climate change effects on extreme wind speeds in New Zealand is being commissioned by the Ministry of Business, Innovation and Employment , and will progress over the next couple of years.

Extreme weather events that drive design wind speeds are rarely observed because they occur so infrequently. Estimating such events relies on modelling and extreme value analysis of historical weather records. Accurate estimates of design wind speeds are important to ensure wind loads are not underestimated to ensure the safety and reliability of buildings into the future, but not overly conservative, which would impose unnecessary costs on the economy. Given the range of predicted changes in wind speeds, , there seems little point in placing too much reliance on a single projection of the effects of climate change. To avoid the uncertainty of picking a single climate projection, a sensitivity analysis has instead been used for this research to show the effect that different levels of wind speed changes would have on design.

The most recent revision of the wind loading Standard AS/NZS 1170.2:2021 has included provision for climate change multipliers, which essentially scale up the regional wind speed by a set multiplier. However, in the 2021 revision, only the cyclone regions in Australia have climate change multipliers that are greater than 1.0 (i.e., they increase the regional wind speeds). This suggests that currently there is not enough evidence to increase design wind speeds to specifically account for climate change.

5 NZS 3604 analysis

An engineering analysis of NZS 3604 has been done to establish the sensitivity of the design tables in NZS 3604 to changes in wind speed, which could be expected to occur with climate change. Because climate change estimates of future wind speeds are variable, the analysis has not used wind speeds from a specific climate change scenario. Instead, it has determined the effects of a few different wind speed changes that are believed to be within the range of likely future changes.

A key advantage of this approach is that it allows the results to be applied relatively easily to future estimates of design wind speeds as the climate models are refined and updated.

5.1 Assumptions:

The engineering analysis has investigated the effect of increasing wind speeds by 5%, 10% and 15% uniformly across New Zealand. The effects of increasing wind speeds have been determined for several of the selection tables in NZS 3604 that were judged to be both influenced by wind speeds and likely to have an influence on building costs.

For example, floor joists are not directly affected by wind loading and so were not analysed. Similarly, building components (or members) such as sill trimmers will have an insignificant influence on costs compared to other components such as studs. The design tables in NZS 3604 that have been analysed are listed in Table 5.1 below.

The analysis and the description of the impact of increasing wind speeds correspond to the specific format of the design tables in NZS 3604. For example, the stud tables provide the required timber size as the output (the design inputs are height, spacing, wind zone and loaded dimension), and so the impact of increasing wind speed is reported as instances where the timber size increases. Alternatively, lintels tables provide the maximum span that can be used as the output (the design inputs are timber size, loaded dimension, roof weight, etc), and so the impact of increasing wind speed is reported as the reduction in the maximum span permissible. While most structural design will be made to architectural designs, this research is presented as reductions in the maximum span (as opposed to an increase in the timber size) to show the size of the change more accurately. In addition, some designs will be unaffected by reduced maximum spans, because the design dimensions will fall below both the current and reduced maximum span.

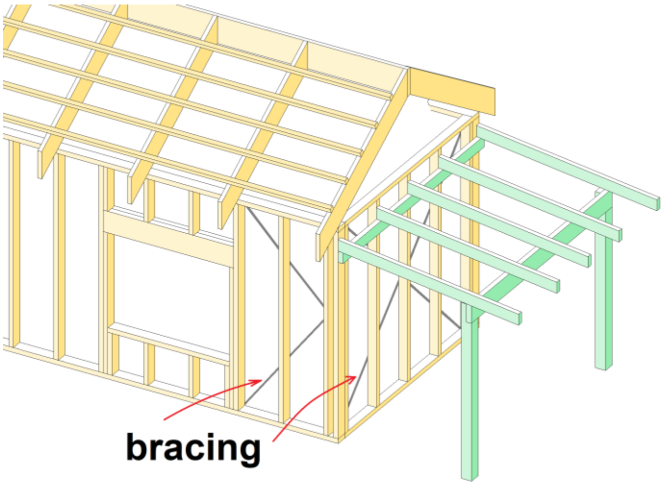
Underpurlins, underpurlin struts and strutting beams were considered but not analysed because their loading is dominated by gravity and snow. They are also rarely used in contemporary houses and unlikely to be used in new builds (although they may be used in renovation work).

In some cases, only snow loads of 1.0 kPa were considered in the analyses. This is because NZS 3604 provides factors for reducing spans, member sizes and fixings for 1.5 and 2.0 kPa snow loads and it is assumed that these factors are similar for the scenarios with increased wind speeds.

While rafters are not commonly used in new construction, they are considered to be a good proxy for the more commonly used trusses in roof systems, and are therefore included in the analysis.

Many of the tables in NZS 3604 cover all wind zones up to extra high (EH) which means that buildings in lower wind zones have a degree of conservatism built into the particular members. However, as buildings in all wind zones use the same provisions, the effect of increasing wind speeds would still impact designs countrywide. This ‘in built’ conservatism is a function of the simplicity inherent in non-specific design standards like NZS 3604, compared to the optimisation that can occur with specifically designed structures.

5.2 Bracing



Increased wind speeds will require greater bracing resistance when wind, rather than seismic, is the governing aspect of bracing design. This increased bracing would be reflected in the bracing demands calculated in NZS 3604, which would need to be resisted using a bracing system selected by the designer.

Therefore, in the case of increased wind speeds, the design of new buildings would require additional bracing resistance, which could be achieved using different bracing systems or using longer lengths of bracing systems within a building. Different bracing systems could include those using different types of plasterboard (bracing plasterboard versus standard plasterboard) or other products such as plywood, to achieve greater resistance.

However, the additional bracing required because of the higher wind speeds will be somewhat mitigated by two factors, described below.

Firstly, in general there is a reasonable amount of additional bracing that is unaccounted for within many 3604 buildings because many components (such as partition walls and framing around windows) are not included within bracing calculations. These components do provide resistance to wind and earthquake loads. Some evidence of this additional bracing capacity was provided through full-scale testing conducted by the New Zealand Ministry of Education on timber-framed school buildings (refer Carradine (2013), Carradine (2015) and Carradine et al (2016)).

Secondly, bracing systems in NZS 3604 are limited to 120 BU/m for timber floors and 150 BU/m for concrete floors. Many bracing systems have capacity beyond these limits and therefore can potentially resist additional lateral loads, but would still be limited by the flooring systems supporting them. It should be noted that P21 testing (conducted to determine bracing system capacity) does not include contributions from cladding, wall and door framing, roof and upper storey overburdens or other non-structural components. Therefore, results for bracing systems tested using a P21 test are likely to be conservative for most bracing applications.

While the above considerations give some reassurance that existing timber-framed buildings will have some redundancy in their lateral load capacity (to withstand higher wind speeds), new designs will not be helped unless Standards and design calculations are updated to account for the additional bracing performance. Therefore, new building designs are likely to need additional bracing capacity to comply with Standards if wind speeds increase significantly.

5.3 Studs

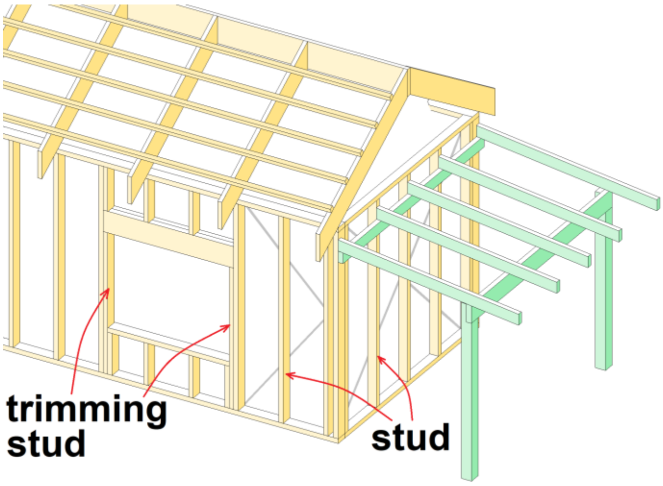


Table 8.2. in NZS 3604 lists the required standard timber size of studs for different stud heights, stud spacings, wind zones and loaded dimensions of the wall. The effects of increasing wind speed are described in Table 5.1 in terms of the number of entries in the table where the standard timber size changes with the increased wind speed.

Our analysis has assumed that all wind zones increase by the same proportion (i.e., 5%, 10% or 15%).

Results are listed for only studs up to 3 metres high, as taller studs are rarely used. In addition, only the results for studs supporting a roof are listed in this report, although similar results are achieved for studs in a lower storey of 2 stories, and studs in subfloors beneath 2 stories. Most of the increases are one timber size (e.g., 90x45 to 90x70).

Stud tables are widely used in new buildings, by all frame and truss fabricators.

5.4 Trimming studs

Table 8.5 of NZS 3604 gives the total thickness required for trimming studs beside window or door openings. Depth is the same as the rest of the wall. Trimming stud thicknesses are based on the thickness of the ordinary stud for the wall if no opening was present. The increase in thickness is related to the width of the opening based on the assumption that wind face loading on the window or door is mostly resisted by the trimming stud. Because any wind speed increases are already accounted for in the ordinary stud sizes, the effect on the trimming studs would be in the same proportion as for ordinary studs in Table 5.1.

5.5 Lintels supporting roof only

Table 8.9. in NZS 3604 lists the maximum span of a lintel supporting a roof only, for different loaded dimensions of the lintel, timber sizes and roof weights. The effects of increasing the wind speed are described in Table 5.1 in terms of the reduction in the maximum span allowable.

Wind increases are only considered for the extra high wind zone (EH).

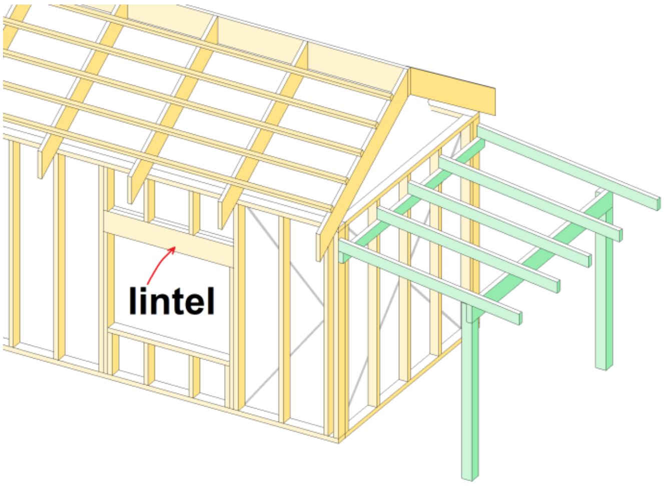
Only light roof scenarios are affected by changes to the wind speed. No span reductions occur from increased wind speeds when snow loads of 1.5 kPa and 2.0 kPa are included.

5.6 Lintels supporting roof and wall

Table 8.10. in NZS 3604 lists the maximum span of a lintel supporting a roof and wall, for different loaded dimensions of the lintel, timber sizes, roof weights and wall weights. The effects of increasing the wind speed are described in Table 5.1 in terms of the reduction in the maximum span allowable.

Wind increases are only considered for the extra high wind zone (EH).

Only light roof and light wall combinations are affected by increased wind speeds. No span reductions occurred from increased wind speeds when snow loads of 1.5 kPa and 2.0 kPa are included.



5.7 Lintels supporting roof, wall and floor

Table 8.11. in NZS 3604 lists the maximum span of a lintel supporting a roof, wall and floor, for different loaded dimensions of the lintel, timber sizes, roof weights, wall weights and for a floor loading up to 2kPa. The effects of increasing the wind speed are described in Table 5.1 in terms of the reduction in the maximum span allowable.

Wind increases are only considered for the extra high wind zone (EH).

Only light roof and light wall combinations are affected by increased wind speeds. No span reductions occur from increased wind speeds when snow loads of 1.5 kPa and 2.0 kPa are applied, or when floor loads increase to 3 kPa.

5.8 Lintels supporting wall and floor

Table 8.12. in NZS 3604 lists the maximum span of a lintel supporting a wall and floor, for different timber sizes, wall weights and for a loaded dimension of the lintel of 3.0m and floor loading up to 2kPa. The effects of increasing the wind speed are described in Table 5.1 in terms of the reduction in the maximum span allowable.

Wind increases are only considered for the extra high wind zone (EH).

No span reductions occur from increased wind speeds in Table 8.12 for floor loads of 2kPa or 3 kPa.

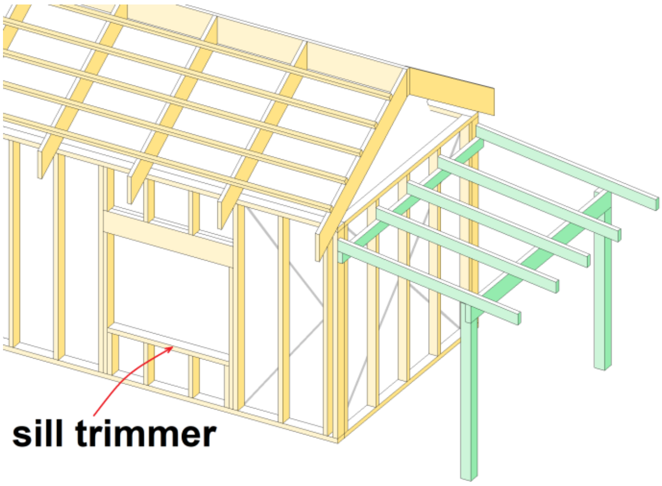
5.9 Lintel fixings

Table 8.14. in NZS 3604 lists the maximum span of lintels that either require uplift alternative fixing or do not (and can rely on typical fixings), for different loaded dimension of the lintel, wind zones and roof weights. The effects of increasing the wind speed are described in Table 5.1 in terms of the reduction in the maximum span allowable.

Wind speed increases are considered for all 5 wind zones (L, M, H, VH, EH). The reduction in lintel spans were consistent across the different increases in wind speed, with only slight additional reductions occurring with increased wind speed.

5.10 Sill trimmers

Sill trimmers are not used often in a typical house. Table 8.15 in NZS 3604 provides the required timber size for sill and head trimmers for a given opening width. The effects of increasing wind speeds are described in Table 5.1 in terms of the increase in timber size for a given opening width. The table covers all wind zones up to extra high (EH).

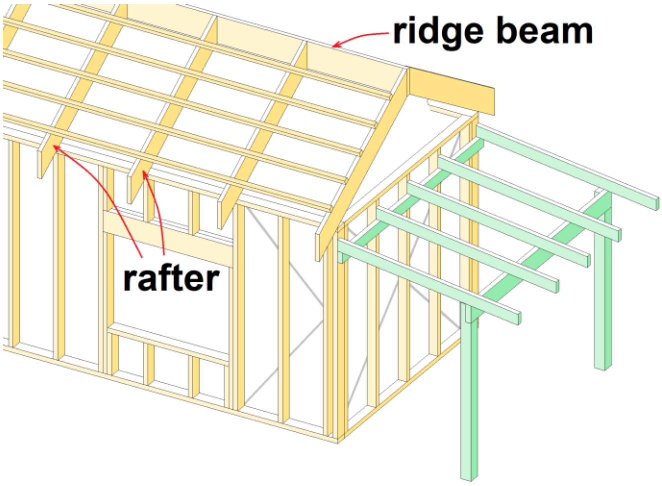


5.11 Rafters

Table 10.1. in NZS 3604 lists the maximum allowable rafter spans for each commonly available timber size and rafter spacing. The effects of increasing wind speed are described in Table 5.1 in terms of the span reduction due to increased wind speed rather than changes to timber sizes.

The rafter tables in NZS 3604 cover all wind zones up to extra high, EH, which means that rafters used in lower wind zones have a degree of conservatism built in. However, as buildings in all wind zones use the same provisions, the effect would still be countrywide.

Some table entries would have very little usage (i.e., 290x90 rafters), so the actual impact on designs may not be a large as suggested by the numbers of entries in the table that are affected by increasing wind speeds.



The effects of increasing wind speed on fixings are negligible, as the contributing spans are reduced, thus reducing the loads on the fixings.

Rafter tables are typically not used in new building design, as trusses are used instead, which are specifically designed by engineers. However, the analysis of rafters is expected to be representative of the effects on the design of trusses. A discussion with In Ling Ng from MiTek, who provides truss designing software for the frame and truss industry in New Zealand, indicated that increases in wind speed would be addressed in the following ways for trusses:

- Going up in timber grade, for instance from SG10 to SG12
- Increase number of web members to essentially decrease lengths of bottom and top chords
- Increase timber depth, so from 90 x 45 to 140 x 45
- Increase size of nail plates at joints
- Increase fixing capacity at points of uplift

5.12 Ridge beams

Table 10.2 in NZS 3604 lists the maximum allowable ridge beam spans for each commonly available timber size and different loaded dimensions of the ridge beam. The effects of increasing wind speed are described in Table 5.1 in terms of the span reduction due to increased wind speed rather than changes to timber sizes.

The ridge beam table in NZS 3604 covers all wind zones up to extra high, EH, which means that ridge beams used in lower wind zones have a degree of conservatism built in. However, as buildings in all wind zones use the same provisions, the effect would still be countrywide.

When higher snow loads are applied (1.5 and 2.0 kPa), similar span reductions occur with increasing wind speeds although fewer table entries are affected, because snow loading dominates.

5.13 Verandah Beams

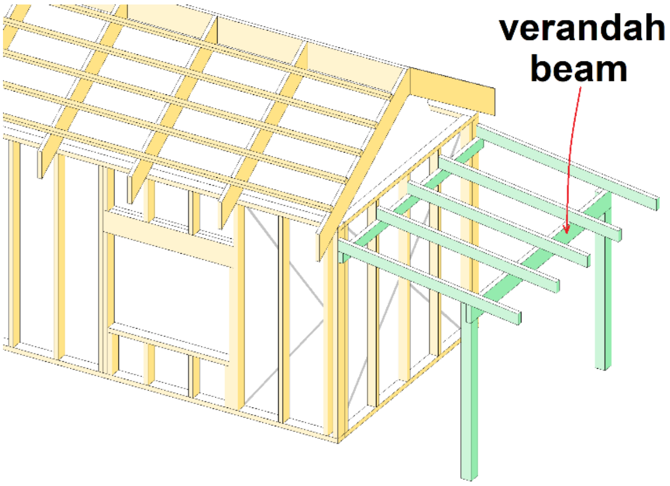


Table 10.8 in NZS 3604 lists the required fixings and maximum verandah beam spans for each commonly available timber size, different loaded dimensions of the verandah beam and roof weights. The effects of increasing wind speed are described in Table 5.1 in terms of the span reduction due to increased wind speed rather than changes to timber sizes.

The verandah beam table in NZS 3604 covers all wind zones up to extra high, EH, which means that ridge beams used in lower wind zones have a degree of conservatism built in. However, as buildings in all wind zones use the same provisions, the effect would still be countrywide. Wind increases have only been analysed for the extra high wind zone.

When heavy snow loads are applied, similar span reductions occur with increasing wind speeds although fewer table entries are affected, but not by very much because snow loading dominates.

5.14 Purlins on their flat

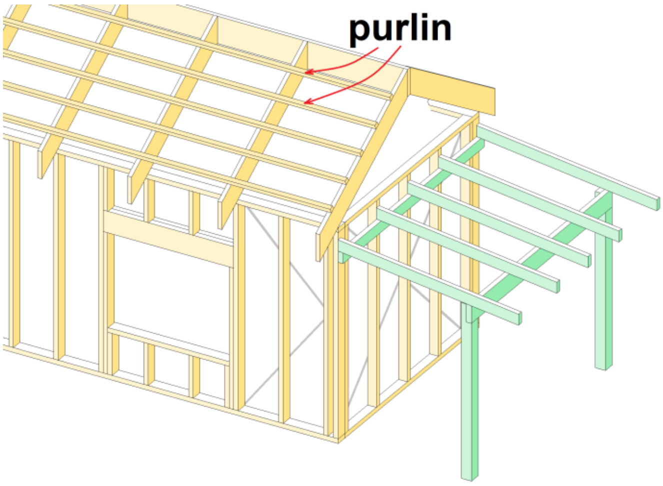


Table 10.10 in NZS 3604 lists the required fixings and maximum spacing for purlins on their flat, for different timber sizes, spans (i.e., rafter spacing) and wind zones. The effects of increasing wind speed are described in Table 5.1 in terms of the span reduction due to increased wind speed rather than changes to timber sizes.

The analysis assumed that all wind zones would increase by the same amount (5%, 10% or 15%), and only light roofs were analysed.

Applying snow loads (1.5 and 2 kPa) as well as the increased wind speeds gives similar results, although there are fewer table entries affected (the maximum number of entries with reduced spans are 17% for an increase in wind speed of 15%). This reflects the fact that many of the spans are already reduced because of the higher snow loads.

Very few fixings changed because the member spans are reduced.

5.15 Purlins on edge

Table 10.11 in NZS 3604 lists the required fixings and maximum spacing for purlins on their edge, for different timber sizes, and purlin spacing. The effects of increasing wind speed are described in Table 5.1 in terms of the span reduction due to increased wind speed rather than changes to timber sizes.

The purlins on their edge table in NZS 3604 covers all wind zones up to extra high, EH, which means that purlins used in lower wind zones will have a degree of conservatism built in. However, as buildings in all wind zones use the same provisions, the effect would still be countrywide. Wind increases have only been analysed for the extra high wind zone.

When snow loads of 1.5 kPa and 2 kPa are applied to the roof, increasing the wind speed gives similar results, although there are fewer table entries where the span is reduced (the maximum span reduction is 19% for a 15% wind speed increase, with a 1.5 kPa snow load). For a 2 kPa snow loading there are no span reductions but some changes in fixings required. This shows that many of the purlin spans are already reduced because of the snow loads.

5.16 Impact on design of light timber-frame structure

The overall impact on designs of light timber-framed structures when design wind speeds increase by 5%, 10% and 15% are minor.

The impact is variable for different framing members – some have no change (for example, lintels supporting a roof, wall and floor) and others change for all wind speed increments (for example, studs and purlins). For specific framing members, the maximum span decreases by up to 0.2m when speeds increase 5%, and decreases by up to 0.5m when speeds increase by 15%.

Fixings are generally affected when wind speeds increase by 5%, 10% and 15%, with only ridge beam fixings for heavy roofs showing no changes at all. Typically, less than half of the entries in the fixing tables are affected, but this ranges from 13% of the entries up to 73%.

The practical effect of the above changes on most designs is likely to be negligible as the maximum spans for specific timber sizes may not be reached.

Where the maximum span is reached, then substitution with a higher strength grade of timber or the next timber size up will achieve the required performance.

Most timber-framed buildings have built-in structural redundancy. For example, one lintel size for the whole building, one stud depth for the whole building chosen for the most adverse situation, additional walls not considered for bracing, and so on. This is likely to continue whether or not formal standards are raised as a result of climate change effects. So, the degree of resilience of the whole building is probably higher than it appears. However, wind loading does cause failure in the weakest link, and can be catastrophic with consequential damage, for example in loss of a roof.

Table 5.1 Effects of increasing wind speed by 5%, 10% and 15% on NZS 3604 designs

	5% increase in wind speed	10% increase in wind speed	15% increase in wind speed
Studs			
increases in standard timber size	21 size increases 144 entries in total	61 size increases 144 entries in total	80 size increases 144 entries in total
Lintels supporting a roof			
span reductions	up to 0.2 m 60% of table (light roof only)	up to 0.4 m 80% of table (light roof only)	up to 0.5 m 100% of table (light roof only)
Lintels supporting a roof and wall			
span reductions	up to 0.2 m 10% of table (light roof and light wall only)	up to 0.3 m 20% of table (light roof and light wall only)	up to 0.4 m 40% of table (light roof only)
Lintels supporting a roof, wall and floor			
span reductions	no change	no change	no change
Lintels supporting a wall and floor			
span reductions	no change	no change	no change
Lintel fixings			
light roof & no uplift fixings	spans reduced for Low to High wind zones	spans reduced for Low to High wind zones	spans reduced for Low to High wind zones
light roof & uplift fixing required	spans reduced in all wind zones	spans reduced in all wind zones	spans reduced in all wind zones
heavy roof & no uplift fixings	spans reduced for Low to Very High wind zones	spans reduced for Low to Very High wind zones	spans reduced for Low to Very High wind zones
heavy roof & uplift fixing required	spans reduced in all wind zones	spans reduced in all wind zones	spans reduced in all wind zones
Sill trimmers			
increases in standard timber size	2.4m and 3.0m spans increase one timber size	2.4m and 3.0m spans increase one timber size	2.4m and 3.0m spans increase one timber size
Rafters			
span reductions	up to 7% 6 changes to table	up to 9% 24 changes to table	up to 19% 32 changes to table
Ridge beams - spans			
span reductions: light roof	up to 0.2 m 47% of table	up to 0.4 m 69% of table	up to 0.5 m 84% of table
span reductions: heavy roof	no reductions	up to 0.2 m 3% of table	up to 0.2 m 3% of table

Table 5.1 continued

	5% increase in wind speed	10% increase in wind speed	15% increase in wind speed
Ridge beams - fixings			
fixings: light roof	22% of table entries increase no SED	38% of table entries increase one instance of SED	47% of table entries increase one instance of SED
fixings: heavy roof	no increase no SED	38% of table entries increase no SED	59% of table entries increase no SED
Verandah beams - spans			
span reductions: light roof	up to 0.2 m 98% of table	up to 0.4 m 100% of table	up to 0.5 m 100% of table
span reductions: heavy roof	no reductions	no reductions	up to 0.2 m 27% of table
Verandah beams - fixings			
fixings: light roof	14% of table entries increase	27% of table entries increase	25% of table entries increase
fixings: heavy roof	21% of table entries increase	50% of table entries increase	71% of table entries increase
Verandah beams subject to 2kPa snow loads - spans			
span reductions: light roof	up to 0.2 m 85% of table	up to 0.4 m 100% of table	up to 0.5 m 100% of table
span reductions: heavy roof	no reductions	no reductions	up to 0.2 m 15% of table
Verandah beams subject to 2kPa snow loads - fixings			
fixings: light roof	14% of table entries increase	27% of table entries increase	39% of table entries increase
fixings: heavy roof	23% of table entries increase	48% of table entries increase	73% of table entries increase
Purlins on their flat			
span reductions:	up to 15% 60% of table	up to 23% 73% of table	up to 31% 80% of table
Purlins on their edge			
span reductions:	up to 6% 25% of table	up to 12% 44% of table	up to 15% 63% of table
fixings	13% of table entries increase	31% of table entries increase, with 13% changed to SED	50% of table entries increase, with 26% changed to SED

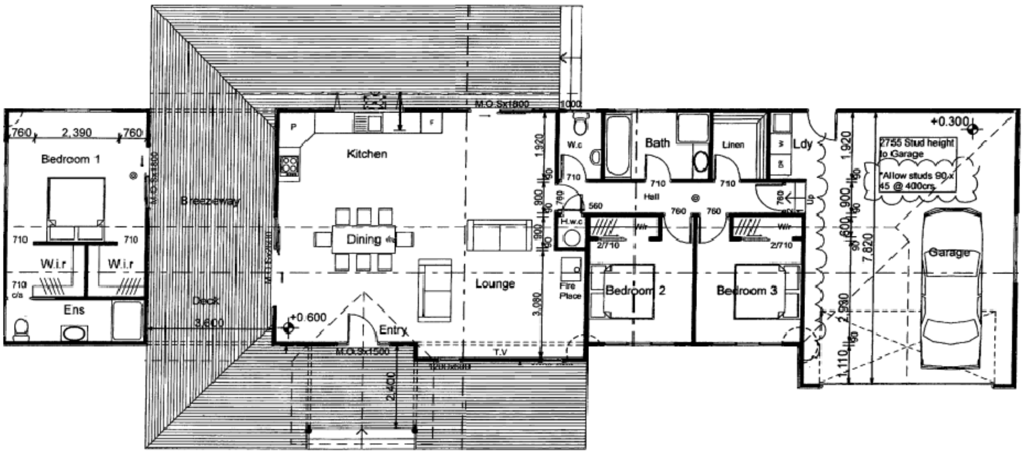
6 Case study of timber-framing changes and costs

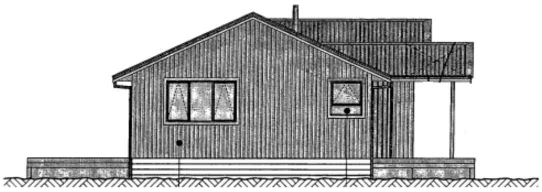
To illustrate the effect of increasing wind speeds on building designs and more accurately estimate the costs, an analysis of the framing requirements for three typical house plans was carried out by MiTek. Their report is provided in Appendix A.

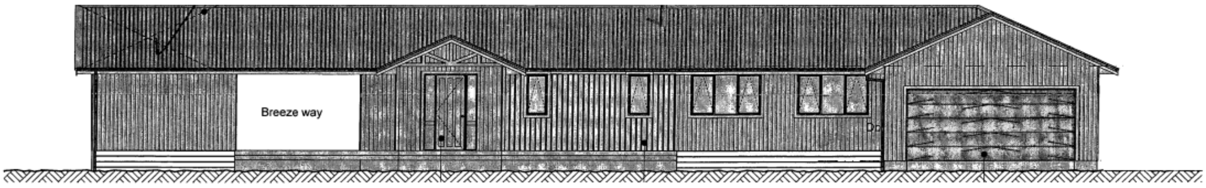
6.1 The houses

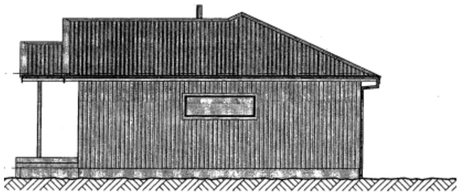
Three house designs have been analysed, as shown below.

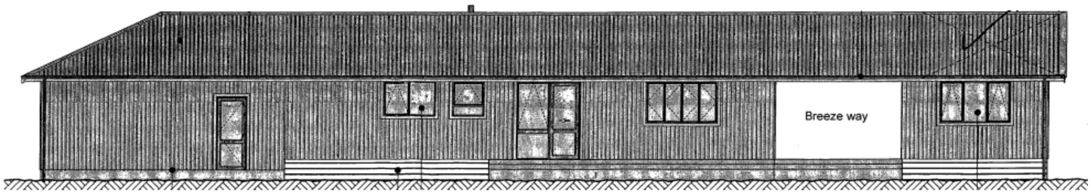
House A: total area = 180 m^2 (plans reproduced with permission of Native Bird Drafting Ltd)



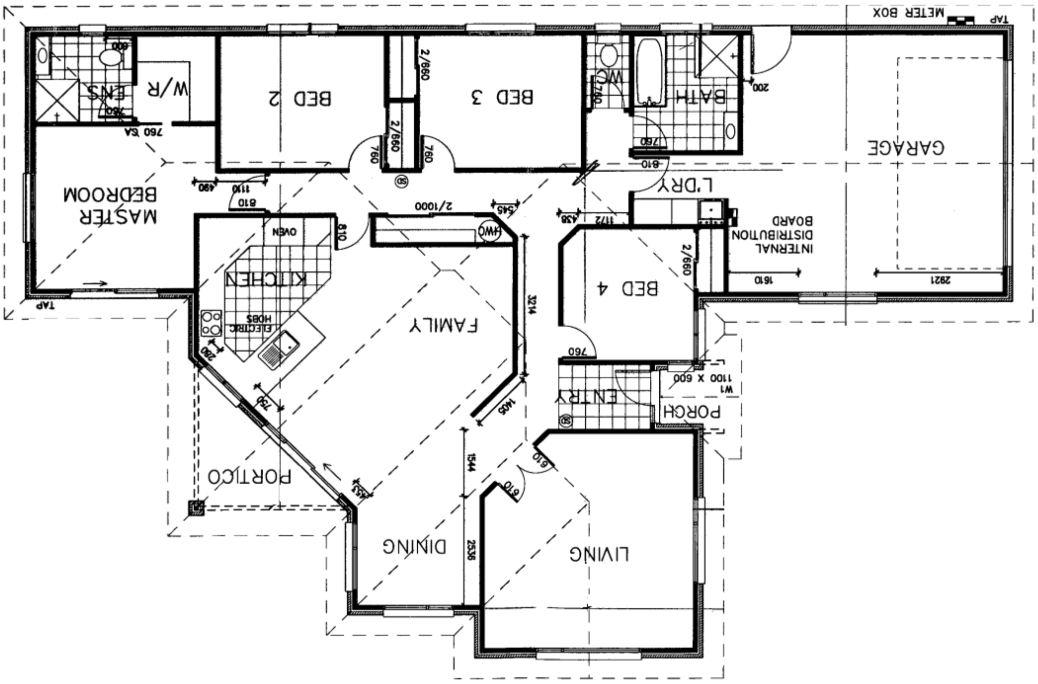


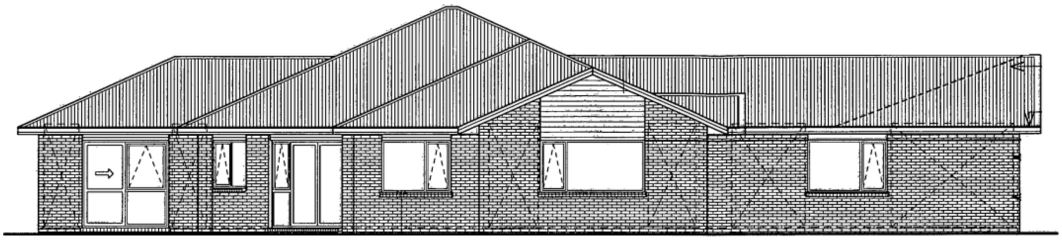


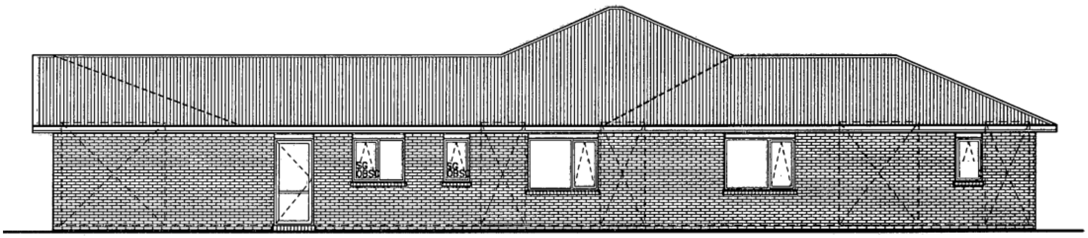


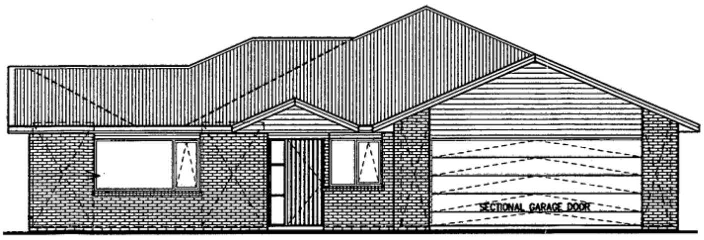


House B: total area = 220 m^2 (plans reproduced with permission of Drafting Waikato)

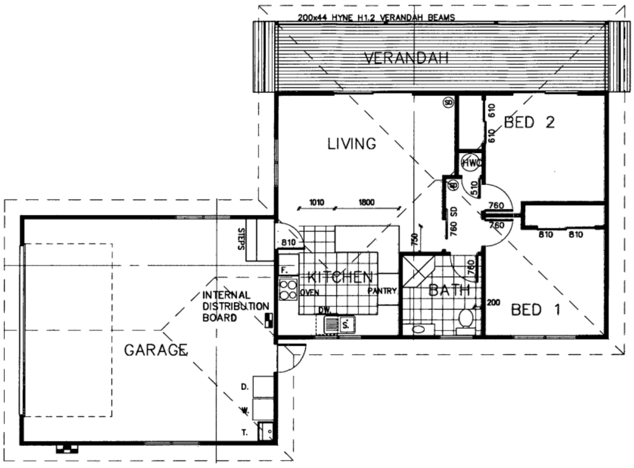


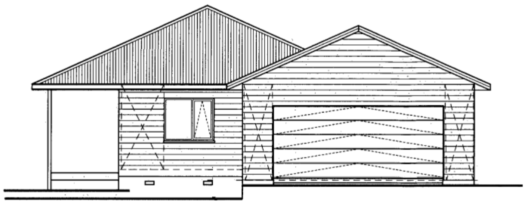


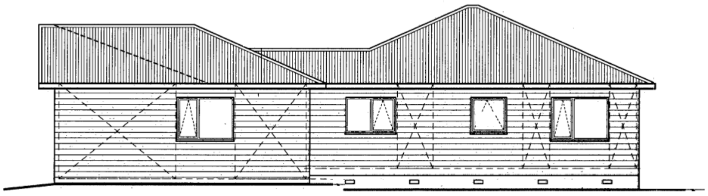


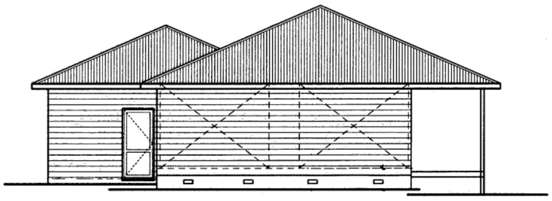


House C: total area = 110 m^2 (plans reproduced with permission of Drafting Waikato)









6.2 The analysis

A structural analysis was undertaken to determine the required wall and roof framing for the following design wind speeds.

- 32m/s (Low),
- 44m/s (High),
- 55m/s (Extra High), and
- 63 m/s (Specific Engineering Design = Extra High + 15%)

The walls were designed using NZS 3604, and roof trusses were specifically designed using MiTek's proprietary software. The quantity of timber and uplift fixings required for different wind speeds was determined, and these quantities were then used to cost the impact of increasing wind speeds on the design.

6.3 Results

The cost of increasing the design wind speed on timber framing is shown in Table 6.1, by comparing the costs from one wind zone to the next wind zone. The relative increase in the wind speed from one wind zone to the next is between 15% and 38%, which is greater than projected effects of climate change of up to 10%. Therefore, these results are likely to provide an upper bound of possible cost increases of timber framing due to climate change. The cost increases listed in Table 6.1 are between 0.1% to 0.4% of the average cost to building a house (assuming an average cost of $2736/m^2 to build a house).

Wind zone	Low 32 m/s		High wind 44 m/s		Extra High 55 m/s		SED 63 m/s	
	Quantity (m^3)	Cost ($)	Quantity (m^3)	Cost ($)	Quantity (m^3)	Cost ($)	Quantity (m^3)	Cost ($)
House A								
Roof Truss	4.16	$4,801	4.5	$5,290	5.03	$6,249	5.15	$7,191
Wall Frame	7.9	$8,063	7.9	$8,063	8.35	$8,517	8.35	$8,517
Uplift Fixing	NA	$77	NA	$149	NA	$170	NA	$329
Total	12.06	$12,941	12.4	$13,502	13.38	$14,936	13.5	$16,037
Increase in wind speed from lower wind zone				38%		25%		15%
Increase in cost from lower wind zone (House floor area = 180m^2)				$561 ($3/m^2)		$1,434 ($8/m^2)		$1,101 ($6/m^2)
House B								
Roof Truss	6.62	$7,686	6.82	$8,236	7.55	$9,690	7.3	$10,506
Wall Frame	9.07	$9,253	9.07	$9,253	9.77	$9,963	9.77	$9,963
Uplift Fixing	NA	$186	NA	$326	NA	$646	NA	$802
Total	15.7	$17,125	16	$17,815	17.6	$20,299	17.8	$21,271
Increase in wind speed from lower wind zone				38%		25%		15%
Increase in cost from lower wind zone (House floor area = 220m^2)				$690 ($3/m^2)		$2,484 ($11/m^2)		$972 ($4/m^2)
House C								
Roof Truss	3.45	$3,517	3.68	$4,329	4.3	$5,247	3.72	$5,701
Wall Frame	4.77	$4,863	4.77	$4,863	5.06	$5,162	5.06	$5,162
Uplift Fixing	NA	$106	NA	$134	NA	$280	NA	$408
Total	8.22	$8,486	8.45	$9,326	9.4	$10,689	9.27	$11,271
Increase in wind speed from lower wind zone				38%		25%		15%
Increase in cost from lower wind zone (House floor area = 110m^2)				$840 ($4/m^2)		$1,363 ($6/m^2)		$582 ($3/m^2)

7 NZS 4223.4 analysis

An analysis of NZS 4223.4 has been done to establish the sensitivity of glass sizing determined in accordance with NZS 4223.4 to changes in the design wind pressure that could be expected to occur with climate change. Because climate change estimates of future wind speeds are variable, the analysis has not used wind speeds from a specific climate change scenario, but has instead determined the effects of a few different wind speeds that are believed to be within the range of likely future changes.

NZS 4223.4 provides plots of the maximum span of a glass pane as a function of the design pressure, for different aspect ratios of the glass pane. The Standard provides these design curves for a wide range of glass pane thicknesses and for different types of glass. Figure 6.1 shows the design curves for monolithic annealed 6mm thick glass.

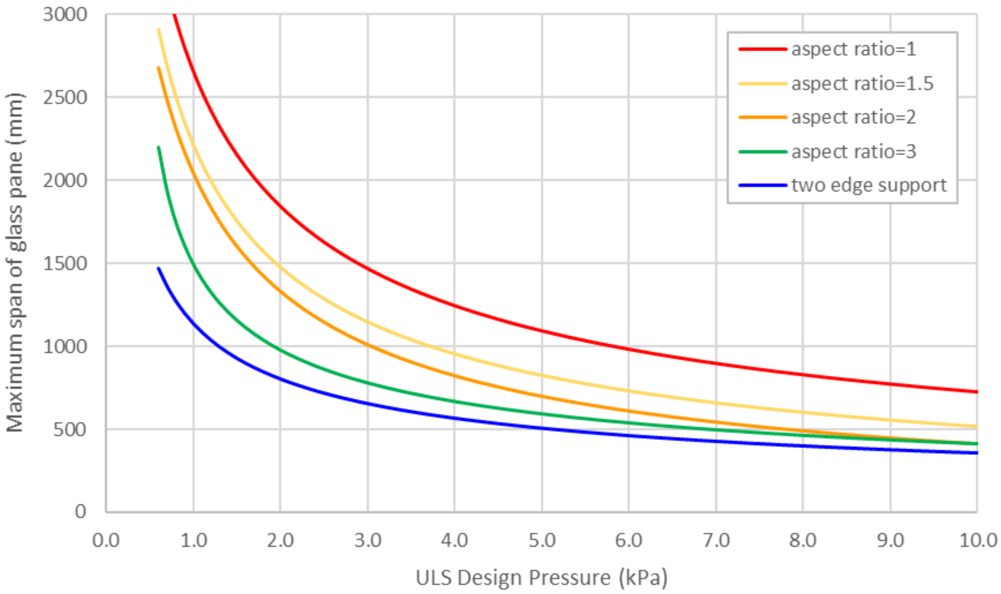


Figure 7.1 Maximum span for monolithic 6mm annealed glass

7.1 Assumptions

The analysis of NZS 4223.4 has investigated the effect of increasing wind speeds by 5%, 10% and 15% uniformly across New Zealand, which corresponds to increasing the design pressures by 10%, 21% and 32% respectively.

Design pressures below 0.6 kPa are not calculated because the wind climate throughout New Zealand generally exceeds this value. Serviceability limits on the slenderness of a glass pane (i.e., thickness / span) also limit the span that can practically be used.

The effects of increasing wind pressure have only been calculated for monolithic annealed glass. This is because other types of glass specified in NZS 4223.4 (for example, toughened and heat strengthened glass) are affected by wind in the same way as annealed glass, but have different pane thickness depending on their relative strength.

The effects of snow loads have been ignored in the analysis because there are very few scenarios where snow loads will dominate wind loading. Only sloped overhead glazing (for example, skylights) in snow zones must be designed for snow loads, in addition to wind loads. However, the proportion of glazing that is used in buildings that must be designed for snow is small, and where the glazing design is governed by snow loads, there will obviously be no effect on the limiting glass span as wind speeds increase.

7.2 Span reduction

The design curves in NZS 4223.4 have been recalculated for design pressures corresponding to an increase in wind speed of 5%, 10% and 15%. These recalculated curves were then used to determine the reduction in the maximum span compared to the design curves in NZS 4223.4. The results of this analysis for monolithic annealed 6mm thick glass are shown in Figure 7.2. The maximum span of a glass pane is observed to scale approximately linearly with the pane thickness, so the span reductions plotted for the 6mm thick glass are representative of the span reductions for other glass thicknesses, which are not shown in this report.

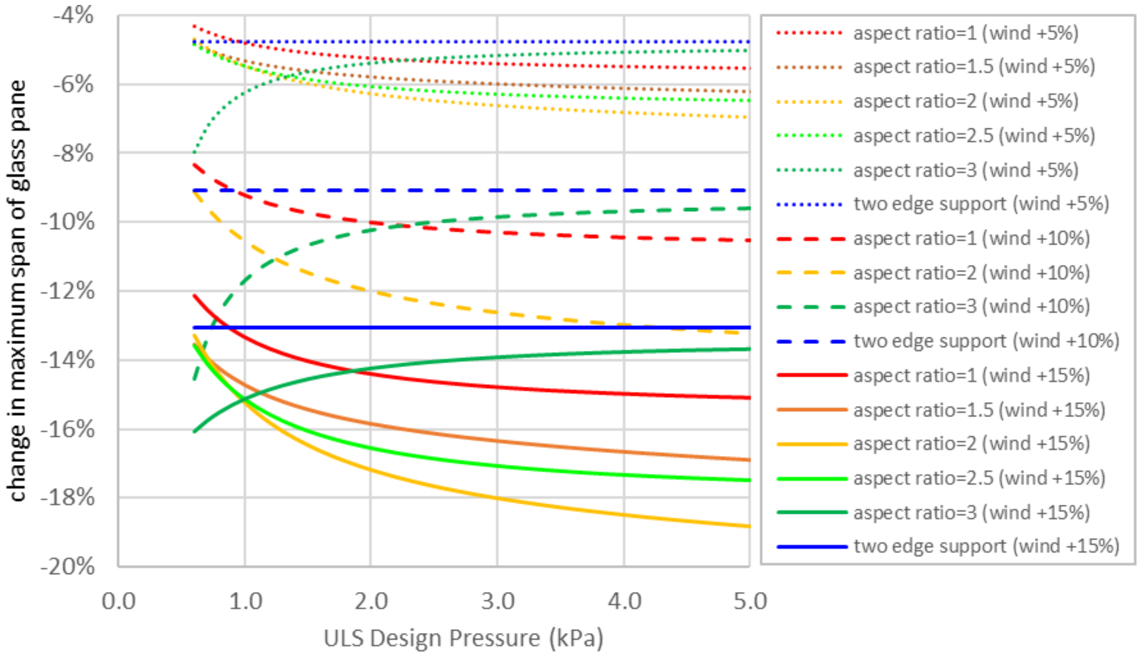


Figure 7.2 Span reduction for 5%, 10% and 15% increases in design wind speed

Figure 7.2 shows the spans of glass panes reduce by between 5% and 7% when the design speed increases by 5%, they reduce by between 9% and 13% when the design speed increases by 10%, and they reduce by between 13% and 19% when the design speed increases by 15%. The reduction in span is characterised by a non-linear relationship between the change in span and the design pressure and aspect ratio, which results in the maximum reductions in span occurring for panes with an aspect ratio of 2.

7.3 Impact on design

The overall impact on glazing designs of increasing the design wind speeds by 5%, 10% and 15% is expected to be minor, as the greatest reduction in the maximum spans of glass is 19%. Where the reduction in span cannot be tolerated by a design, then the next glass size up can be used to achieve the desired strength and/or deflection limits. Because NZS 4223.4 is used to size specific panes of glass, each design can be relatively well optimised, which also minimises the impact for different aspect ratios, glass thicknesses and glass types.

The practical effect of the above changes on most new designs is likely to be negligible. Glass suppliers can already size glass for specific buildings and can successfully account for different wind zones (and corresponding wind pressures) in their products. Any changes to the current wind zones that might occur could easily be incorporated into NZS 4223.4.

8 NZS 4211 and E2/AS1

Wind zones are an integral part of the performance rating of windows in NZS 4211 and of determining the weathertightness solution in E2/AS1. Therefore, the effects of increasing wind speeds by 5%, 10% and 15% on the wind zones is discussed below, before discussing the impacts on NZS 4211 and E2/AS1.

8.1 Wind zones

The wind zones defined in NZS 3604, and used in the other Standards, are listed in Table 8.1. The maximum ultimate limit state design speed and the corresponding maximum design pressure for each wind zone are also shown in the table. When wind speeds and pressures exceed the maximum limit for the extra high (EH) zone the site is rated as specific engineering design (SED). This means the design solutions in the Standards and Acceptable Solutions cannot be used and a bespoke design must be done by an engineer or specialist designer, which adds considerably to the compliance costs.

The ultimate limit state wind speeds corresponding to the 105%, 110% and 115% of the current speeds have been shaded in Table 8.1 to show how the wind zones would change if wind speeds increased by 5%, 10% and 15%. This shows that most sites would increase by one zone (for example, medium to high, or high to very high). Only if wind speeds increase by 15% would the wind zones increase by more than one zone, and then only the very high zone (VH) would become a specific engineering design (SED).

Table 8.1 Effects of increasing wind speed by 5%, 10% and 15% on wind zones

			Percentage increase in wind speed		
			5%	10%	15%
Wind zone		Ultimate limit state wind speed (m/s)			
L	Low	32	33.6	35.2	36.8
M	Medium	37	38.9	40.7	42.6
H	High	44	46.2	48.4	50.6
VH	Very High	50	52.5	55.0	57.5
EH	Extra High	55	57.8	60.5	63.3
		Ultimate limit state design pressure (kPa)			
L	Low	0.61	0.68	0.74	0.81
M	Medium	0.82	0.91	0.99	1.09
H	High	1.16	1.28	1.41	1.54
VH	Very High	1.50	1.65	1.82	1.98
EH	Extra High	1.82	2.00	2.20	2.40

An increase of one wind zone is unlikely to have a significant effect on the design of a building, unless the wind zone becomes SED. Specific engineering design can have a large effect on projects because specialist designers are needed to carry out the design, whereas all other wind zones have non-specific design solutions available in the Standards.

Wind speeds also increase with height above the ground and so higher wind speeds are already accommodated by designers of buildings above 8m high, which is the height used to define the wind speeds and the wind zones in NZS 3604. For example, a window or glass in a building 16m high would have design wind speeds 8% to 10% higher than those used for NZS 3604, depending on the ground roughness that is assumed (i.e., Terrain Category 2 or 3). This increase in speed with building height is similar to the increases considered for climate change, which suggests that such changes can, and are, routinely accommodated in designs.

8.2 Distribution of wind zones

The number of buildings in each wind zone has been estimated using BRANZ Maps to compare the wind zone and number of properties within each grid of the BRANZ Maps data. The results of this analysis are shown in Figure 8.1.

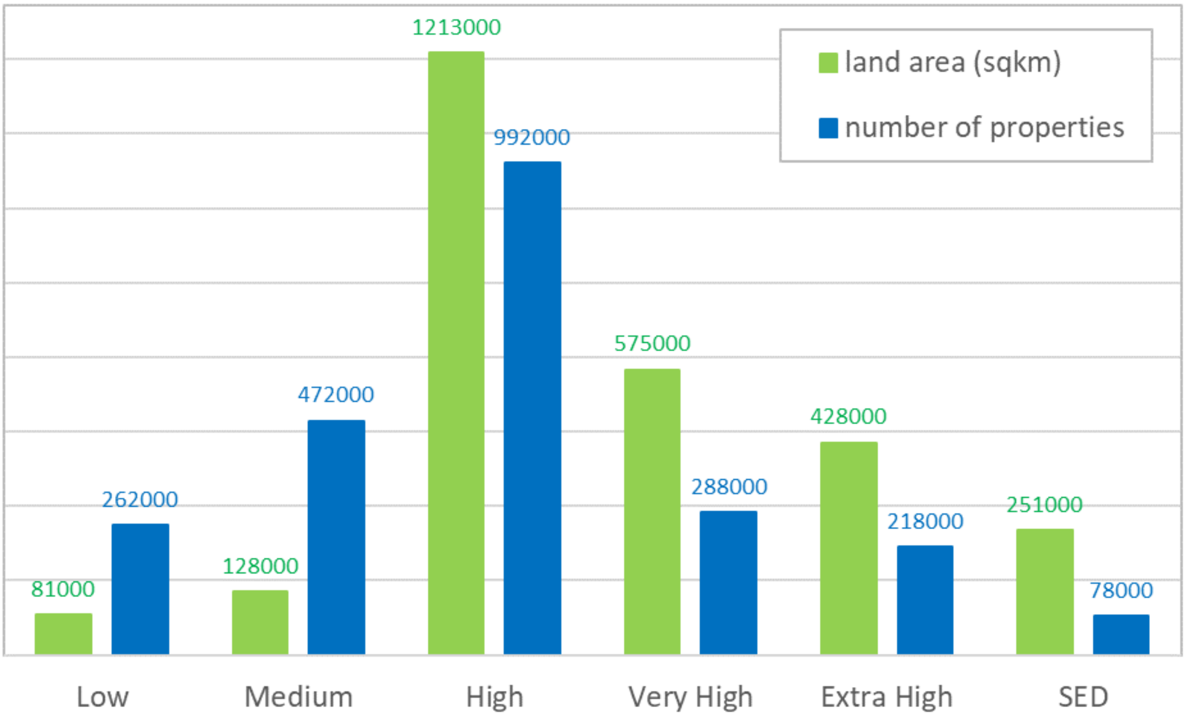


Figure 8.1 Estimated number of properties and land area in each wind zone

Figure 8.1 shows the distribution of land area within the wind zones is weighted more to the higher wind zones compared to the distribution of properties, which are weighted toward the lower wind zones. The majority of properties are located in medium and high wind zones (63% of the total properties) while the majority of the land area lies in the high and very high wind zones (or 67% of the total land area). In the windiest land area, 9.4% of the total land area, is rated as SED, while only 3.4% of the properties are rated SED. Extra high wind zones occur over 16% of the land area, but 9.4% of the properties.

The difference in weighting of the zones as regards land area compared to number of properties is not surprising given the wind zone calculations produce lower wind speeds on flatter terrain and in areas with a high density of houses. The mountainous terrain that makes up much of the backcountry has higher design wind speeds than flat land, and is undeveloped. Conversely, flatter land has lower design speeds and is generally easier to develop. In urban areas, the sheltering effects of surrounding buildings further reduces the calculated design wind speeds.

8.3 Impact on design

The empirical nature of NZS 4211 and E2/AS1 makes it difficult to detail the specific impact that wind speed increases will have on a design. As outlined in section 8.1, the general effect of increasing the design wind speeds by 5% - 15% will be an increase of one zone of the wind zone rating. Increasing the wind zone by one zone is unlikely to impact designs significantly, except when the wind zone becomes SED - at which point considerably more design effort is required.

NZS 4211

Using NZS 4211, window systems are tested to the maximum level of wind actions (and corresponding wind zone) they can withstand. Generally, suppliers develop windows that are rated for the highest wind zone, EH. This simplifies the range of windows that are needed and ensures their windows can be used for most projects. Therefore, the majority of windows can be used in any wind zone and changes in zone do not affect the design. When SED is required for window design, then specialist design is needed and standard window designs may need further strengthening or stiffening to meet higher demands, or the window may need to be substituted with an alternative product. Building code compliance will generally become more difficult when a design deviates from the Standard or Acceptable Solution.

E2/AS1

In E2/AS1 the risk score is used to determine the weathertightness solution that can be used, and ranges from a minimum of 0 (minimum risk) to a maximum of 28 (highest risk). Risk scores are banded into subsets of 0 – 6, 7 – 12, 13 – 20, 20+ and weathertightness solutions specified for each band with increasing stringency as the risk increases. The risk score is dependent on a number of factors that are individually scored and that contribute to the overall risk score.

Wind has a risk score between 0 and 2 depending on the wind zone. Buildings in a very high or extra high wind zone get a score of 2, high wind zones are scored 1, and medium and low wind zones are scored 0. Changing the wind zone by one zone will increase the overall risk score by 0 or 1, depending on the wind zone. Increasing the risk score of 1 will have no effect on the design unless it is at the very limit of the band of risk scores for a particular weathertight solution.

For the majority of buildings, it is unlikely that changing the design wind speeds by 5%, 10% or 15% will have a significant effect on weathertightness design using E2/AS1.

However, if a wind zone becomes SED as a result, then E2/AS1 can no longer be used, and specific design will be needed. This would require a specialist designer and will generally make building code compliance more complex, the work more expensive, and building consents more difficult to obtain. Based on the analysis in section 8.2, approximately 9% of new buildings would be affected in this way with an increase from VH to SED.

9 Conclusions

1. The impacts of increased wind speeds due to climate change on the designs of light timber-framed buildings are unlikely to be significant, based on current climate change projections. Modelling of the most severe climate change scenario indicates wind speeds increase by up to 10% in parts of New Zealand. Compared to this 10% change, wind speed increases of 5%, 10% and 15% have been shown to have minimal impact on design solutions from NZS 3604, NZS 4223.4, NZS 4211, and E2/AS1.

2. Only minor changes in the dimensions and/or sizes of building members and components are needed to resist the higher wind loads from a 15% increase in the design wind speed. The costs associated with these minor changes are minimal, in the order of 0.1% of the total cost . Some components are conservatively designed for use in all wind zones, so increasing wind speeds will generally have no effect. However, costs are likely to increase if wind zone limits in the Standards are exceeded, which would then require specific engineering design (SED). In these circumstances, the additional costs of SED arise from specialist design input and more onerous building consent processes. Approximately 3.4% of existing properties are estimated to be zoned as SED.

3. The methodology for analysing non-specific design standards has worked well for standards with an analytical basis, such as NZS 3604 and NZS 4223.4. Incremental changes in wind speeds could, in theory, be assessed for any projected change in the wind climate. However, design methods that incorporate empirically developed parameters and solutions require a comparative analysis to assess the impact of changes in climate. For example, the effects of changes in wind speed on the weathertightness of buildings was assessed by comparing the design solutions associated with different wind zones.

4. A benefit of using a sensitivity analysis rather than a single projection is that as climate data is updated or amended, the analysis remains valid and can be easily applied to the most recent projections. The results will not be tied to a particular set of modelling assumptions or emissions targets. Sensitivity analysis also allows a risk-based approach to managing climate adaption, where only large changes in the building, rather than large changes in the design inputs, need attention.

5. Generally, buildings that are built to non-specific design Standards, such as NZS 3604, are expected to have more conservativism built in than specifically designed buildings. This is due to the prescriptive nature of non-specific design standards, which cover a wider range of building shapes and sites. The need for specialist designers (for example, a structural engineer) who would otherwise optimise the design for the specific site is therefore eliminated. An analysis of the adaptation needed for buildings that are specifically designed will be more complex and difficult than for the non-specific designs illustrated in this research. Common design concepts and construction details would need to be identified in order to draw more general conclusions about climate impacts on construction overall. However, because a specifically designed building is optimised for the specific conditions it is exposed to, then climate change impacts could reasonably be expected to relate more directly to the extent of changes in the climate.

6. This research has only looked at the impact of changes to the wind climate. The IPCC (2021) identifies a number of future climatic changes for New Zealand, including projections of:
   - increases in the mean temperatures and extreme heat (high confidence)
   - decreases in cold spells and frosts (high confidence)
   - increases in mean precipitation in the south and west of New Zealand and a decrease in the north and east (medium confidence)

- increase in river floods (medium confidence)
- increase in fire weather (medium confidence)
- decrease in snow (medium confidence)
- increase in relative sea level (high confidence)
- increase in coastal flooding (high confidence)
- increase in coastal erosion (high confidence)

These climate parameters all affect the performance of New Zealand buildings to a greater or lesser degree, depending on their location in New Zealand. They all warrant consideration regarding the adaptation of buildings to climate change.

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Appendix A – Case study of design and cost implications

CLIMATE CHANGE AND TRUSS DESIGN

MITEK REPORT 00323265

SEPTEMBER 2022

Prepared by: Chenhao Xu, Design Engineer

Checked by: In Ling Ng, Engineering Manager NZ

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PO Box 58-014 Botany 2163
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NZBN 9429040670560

MITEKNZ.CO.NZ

Test House

Job case number: 00323265

Job Scope

The scope of work comprises an analysis of the three typical buildings – 2 x houses and 1 x smaller ancillary building.

Assume sites are in Auckland / Waikato wind zone

Analyse each building for 4 x wind speeds:

32m/s - (Low)

44m/s - (High),

55m/s - (Extra High)

63 m/s - (SED, Extra High + 15%)

Job Requirements:

Provide quantity of timber in roof trusses and wall framing;

Provide cost of roof trusses and wall frames;

Provide cost of uplift fixings.

Assumptions:

Wall Panel:

1. Studs spacing according to NZS3604-2011 Table8.2.
2. Nogs spacing 800mm crs.
3. Lintel size according to the plans or NZS3604 Table8.9.
   No specific design for Lintel and Lintel fixing according to wind zone changes.
4. Trim studs & sills according to NZS3604.

Price:

Timber cost

\$1020 per m^3 – MSG timber H1.2

\$2100 per m^3 – LVL Hychord H1.2

Test House A

House Basics

Loading:

Roof = Coloursteel roofing, Purlins @ 900mm crs

Ceiling = standard ceiling restrains @ 600mm crs

IL = 2, design life = 50yr

Roof Layout:

Single storey

Roof Pitch = 25°

Truss overhang = 450mm

Ceiling Height = 2455mm&Slope/2755mm

Wall:

Wall height 2455mm including double top plate.

All studs to be 90x45 SG8 H1.2

External & Load bearing wall:

32m/s – 600mm crs

44m/s – 600mm crs

55m/s – 400mm crs

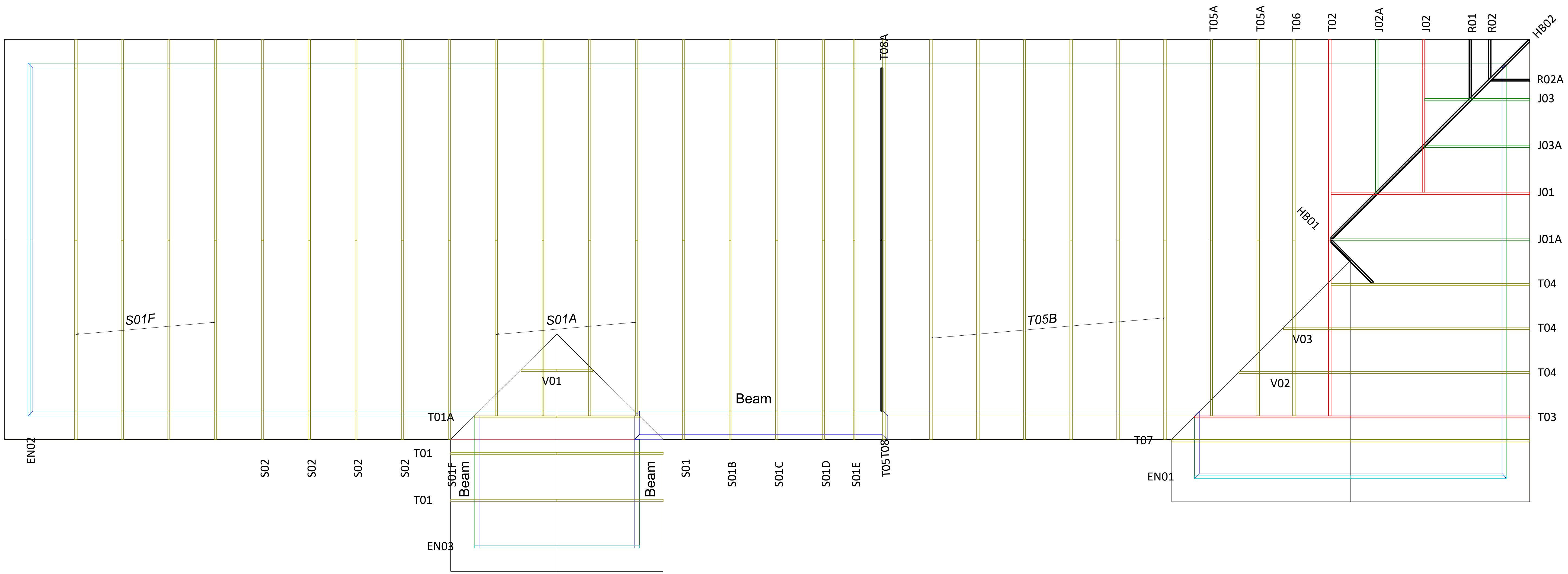
63 m/s - (Extra High + 15%) – 400mm crs

Non-Load bearing wall:

Studs @ 600mm crs

Nogs:

Nogs @ 800mm crs all the time.



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Project

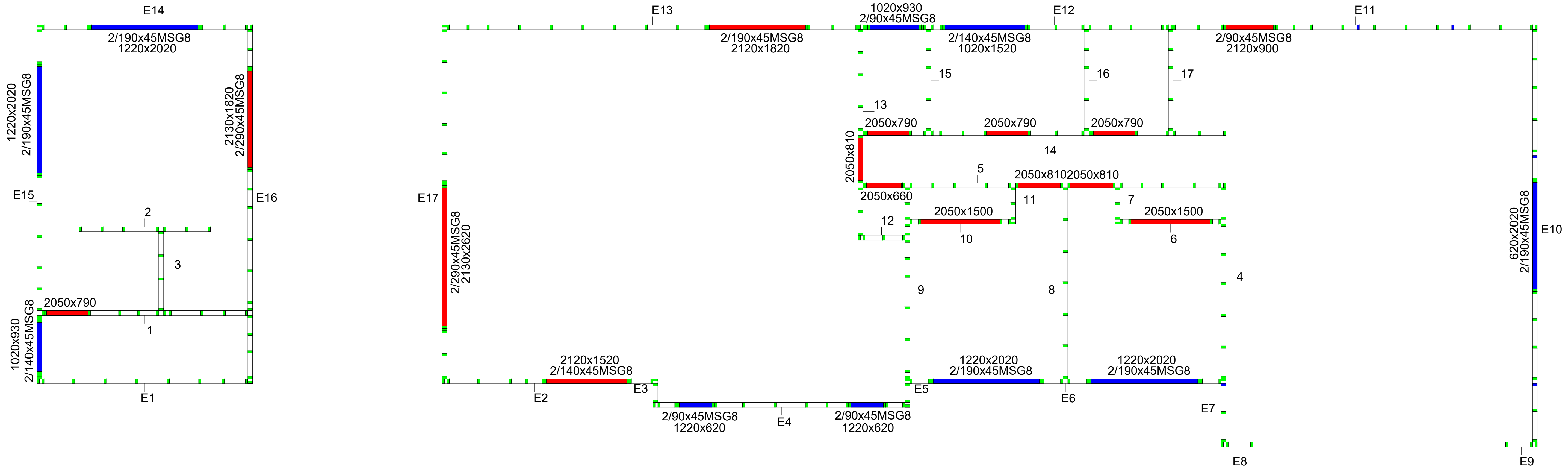
TEST HOUSE A

Roof Truss

Job Details
Roof Pitch: 25°
Roof Live Load: 0.25 kPa
Truss Centres: 900 mm
TC Restrains: 900 mm
BC Restrains: 600 mm

Designed by: C.X.
Drawn by: C.X.
Checked by:
Date:

Scale:
Job No: 00323265
Drawing No:
Rev.:



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TEST HOUSE A

Title

Wall Panel

Designed by: C.X.
Drawn by: C.X.
Checked by:
Date:

Scale:
Job No: 00323265
Drawing No:
Rev.:

Table 1. Quantity and Price variation according to changing in wind speed for **House A.**

House A	Low 32 m/s		High wind 44 m/s		Extra High 55 m/s		SED 63 m/s	
	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	m^3	$	m^3	$	m^3	$	m^3	$
Roof Truss	4.16	$4801	4.5	$5290	5.03	$6249	5.15	$7191
Wall Frame	7.9	$8063	7.9	$8063	8.35	$8517	8.35	$8517
Uplift Fixing	NA	$77	NA	$149	NA	$170	NA	$329
Total	12.06	$12941	12.4	$13502	13.38	$14936	13.5	$16037

Test House B

House Basics

Loading:

Roof = Coloursteel roofing, Purlins @ 900mm crs

Ceiling = standard ceiling restrains @ 450mm crs

IL = 2, design life = 50yr

Roof Layout:

Single storey

Roof Pitch = 25°

Truss overhang = 600mm

Ceiling Height = 2455mm

Internal LBW for truss according to plan

Wall:

Wall height 2455mm including doble top plate.

All studs to be 90x45 SG8 H1.2

External & Load bearing wall:

32m/s – 600mm crs

44m/s – 600mm crs

55m/s – 400mm crs

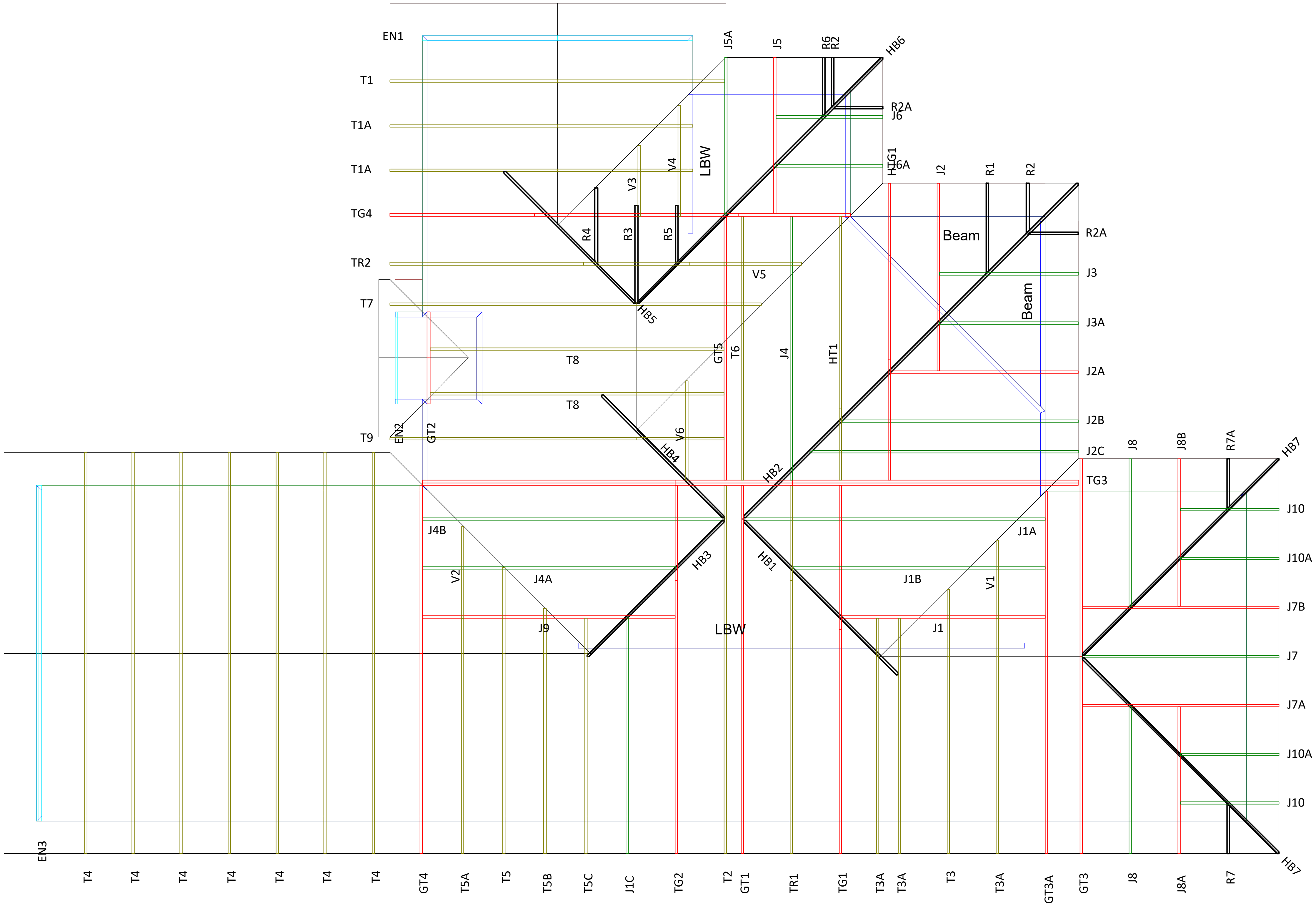
63 m/s - (Extra High + 15%) – 400mm crs

Non-Load bearing wall:

Studs @ 600mm crs

Nogs:

Nogs @ 800mm crs all the time.



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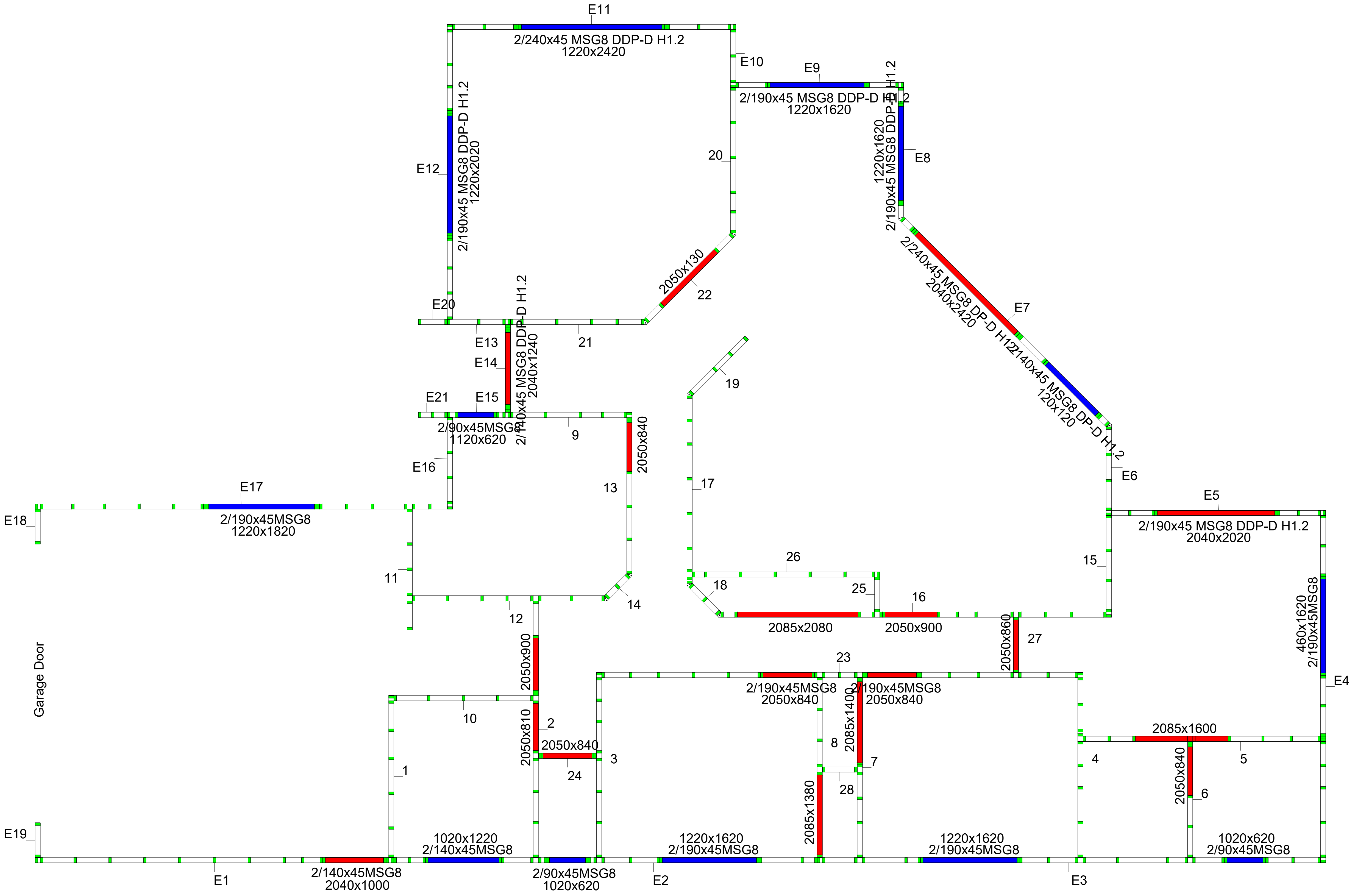
TEST HOUSE B

Roof Truss

Job Details
Roof Pitch: 25°
Roof Live Load: 0.25 kPa
Truss Centres: 900 mm
TC Restrains: 900 mm
BC Restrains: 450 mm

Designed by: C.X.
Drawn by: C.X.
Checked by:
Date:

Scale:
Job No: 00323265
Drawing No:
Rev.:



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TEST HOUSE B

Title

Wall Panel

Designed by: C.X.
Drawn by: C.X.
Checked by:
Date:

Scale:
Job No: 00323265
Drawing No:
Rev.:

Table 2. Quantity and Price variation according to changing in wind speed for **House B.**

House B	Low 32 m/s		High wind 44 m/s		Extra High 55 m/s		SED 63 m/s	
	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	m^3	$	m^3	$	m^3	$	m^3	$
Roof Truss	6.62	$7686	6.82	$8236	7.55	$9690	7.3	$10506
Wall Frame	9.07	$9253	9.07	$9253	9.77	$9963	9.77	$9963
Uplift Fixing	NA	$186	NA	$326	NA	$646	NA	$802
Total	15.7	$17125	16.0	$17815	17.6	$20299	17.8	$21271

Test House C

House Basics

Loading:

Roof = Coloursteel roofing, Purlins @ 900mm crs

Ceiling = standard ceiling restrains @ 450mm crs

IL = 2, design life = 50yr

Roof Layout:

Single storey

Roof Pitch = 25°

Truss overhang = 450mm

Ceiling Height = 2455mm

Wall:

Wall height 2455mm including doble top plate.

All studs to be 90x45 SG8 H1.2

External & Load bearing wall:

32m/s – 600mm crs

44m/s – 600mm crs

55m/s – 400mm crs

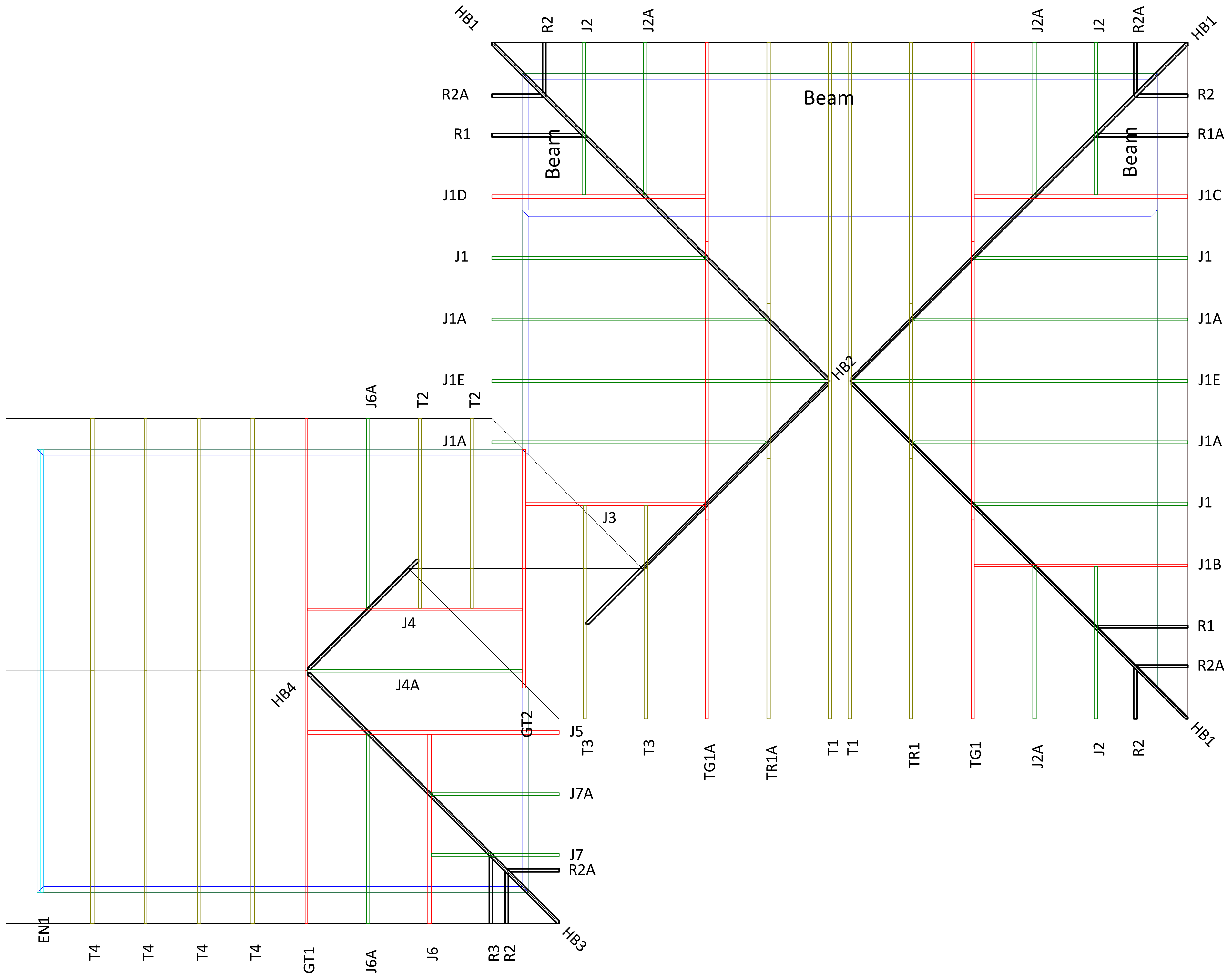
63 m/s - (Extra High + 15%) – 400mm crs

Non-Load bearing wall:

Studs @ 600mm crs

Nogs:

Nogs @ 800mm crs all the time.



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Project

TEST HOUSE C

Roof Truss

Job Details
Roof Pitch: 25°
Roof Live Load: 0.25 kPa
Truss Centres: 900 mm
TC Restrains: 900 mm
BC Restrains: 450 mm

Designed by: C.X.

Drawn by: C.X.

Checked by:

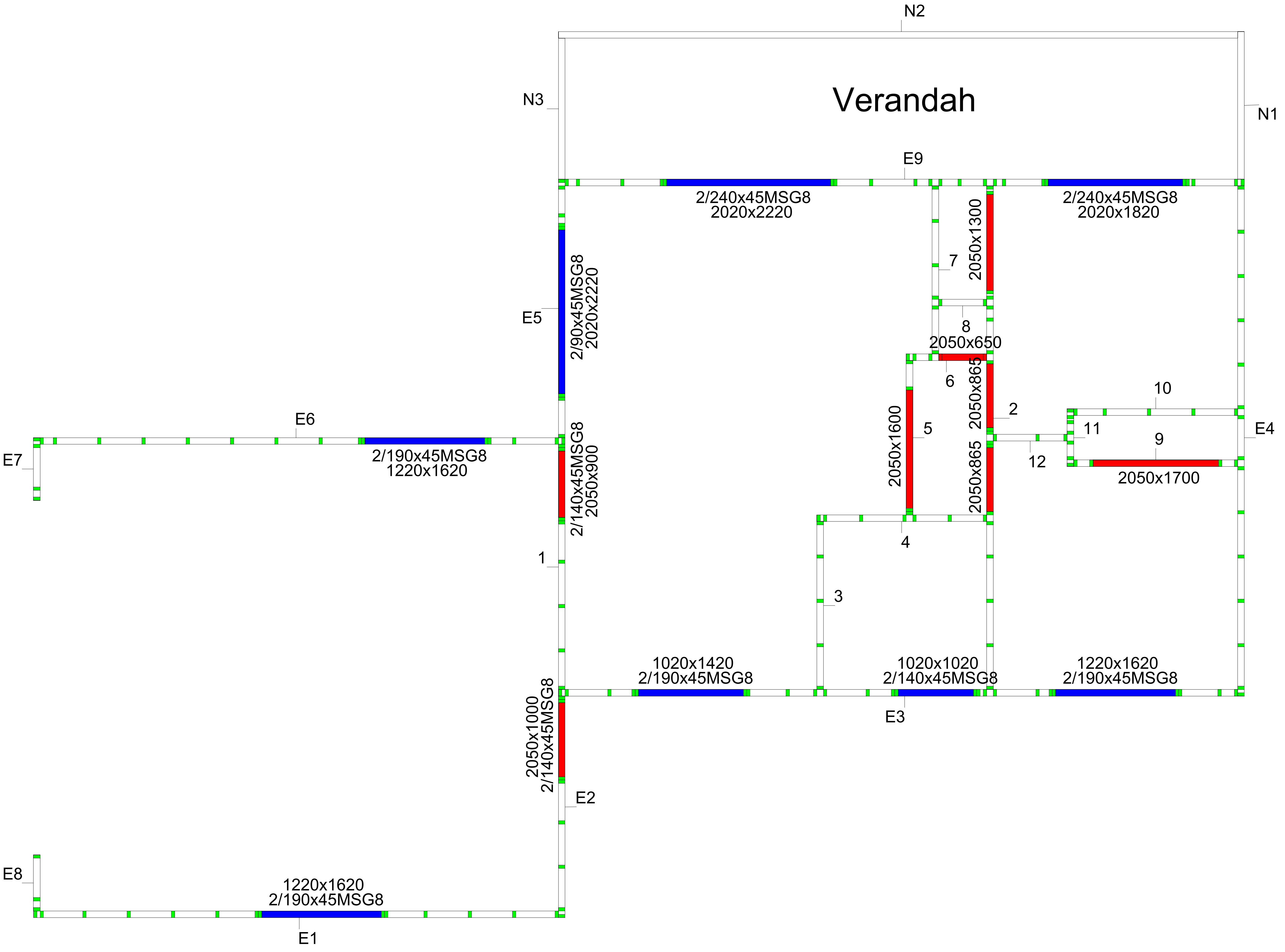
Date:

Scale:

Job No: 00323265

Drawing No:

Rev.:



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Project

TEST HOUSE C

Title

Wall Panel

Designed by: C.X.
Drawn by: C.X.
Checked by:
Date:

Scale:
Job No: 00323265
Drawing No:
Rev.:

Table 3. Quantity and Price variation according to changing in wind speed for **House C.**

House C	Low 32 m/s		High wind 44 m/s		Extra High 55 m/s		SED 63 m/s	
	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	m^3	$	m^3	$	m^3	$	m^3	$
Roof Truss	3.45	$3517	3.68	$4329	4.3	$5247	3.72	$5701
Wall Frame	4.77	$4863	4.77	$4863	5.06	$5162	5.06	$5162
Uplift Fixing	NA	$106	NA	$134	NA	$280	NA	$408
Total	8.22	$8486	8.45	$9326	9.4	$10689	9.27	$11271

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