May 18, 2022

Mansoor Mahmood, Ph.D., P.Eng., Director
Building and Development Branch
Ministry of Municipal Affairs and Housing

Delivered via email to mansoor.mahmood@ontario.ca

Dear Mr. Mahmood:

RE: Increased Structural Resiliency for Part 9 Buildings

I am writing to you to provide information for your consideration with respect to how buildings categorized within Part 9 of the Ontario Building Code can be built to increase their resiliency to high wind events. As you know, there was an EF2 tornado event in the City of Barrie in July of 2021. This resulted in 71 unsafe orders and 7 demolition permits issued. Fortunately, this event created no fatalities, but the damage was devastating. The value of damage to the affected homes was about 100 million dollars.

The tornado provided an opportunity to see the weaknesses in how houses are currently built. The tornado dismantled the homes to varying degrees. What was left provides insight into how things can improve. Over the last 9 months, I have researched information about tornados, looked at the specific damage in Barrie, reviewed the current Code provisions and met with industry experts to determine if and how such devastation could be reduced or possibly eliminated.

The results of that work suggest that it is quite likely that most of the structural damage, which occurred because of the EF2 tornado, can be significantly reduced or eliminated. Paying attention to specific construction details would significantly reduce repair costs, disruption to life and potential loss of life for affected homeowners.

Clearly there is a cost associated with improving the construction to provide more resilience for these buildings. A cost benefit analysis has not been done at this point, but there are organizations (ICLR and others) who are interested in looking at this work.

Included is some background information which supports re-thinking how these buildings can be constructed. The attached report presents key discussion points in identifying how Part 9 buildings can become more resilient to high wind events. Also included are specific Code changes that could implement what is being suggested.

I offer this information as a starting point for your consideration. I would be happy to meet with your team at the Ministry to explore these options in more detail.

Sincerely,

Michael J. Janotta, P. Eng., CBCO
Chief Building Official

Cc: B. Araniyasundaran, General Manager of IGM, City of Barrie
City of Barrie, Council Members

Attachment

IMPROVING THE STRUCTURAL RESILIENCY OF PART 9 BUILDINGS IN HIGH WIND EVENTS

Presented to: Ministry of Municipal Affairs and Housing
Province of Ontario

Michael Janotta, P.Eng., CBCO
Chief Building Official
City of Barrie
May 18, 2022

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1.0 Background Information:

On July 15, 2021, an EF2 tornado event occurred in the City of Barrie. This event resulted in 71 unsafe orders issued on occupied stick frame residential units. These occupants were displaced for extended periods of time until detailed assessments of the damage could be completed, houses could be temporarily shored or repaired on an emergency basis and building permits for permanent repair work were issued such that houses could once again be occupied. Seven demolition permits were issued as a result of the destruction and to date not all building occupants have been able to return to their homes. Fortunately, this event created no fatalities, but the damage to homes and disruption to life was very significant. The value of damage to the affected homes was about 100 million dollars.

The tornado provided an opportunity to see the weaknesses in how houses are currently built. The tornado dismantled the homes to varying degrees. What was left provides insight into how things can improve. Since that time, the City of Barrie has researched information about tornados, assessed the specific damage in Barrie, reviewed the current Code provisions and met with industry experts in various fields to determine if and how such devastation could be reduced or possibly eliminated.

The results of this work suggest that it is possible to eliminate or significantly reduce most of the structural damage which occurred as a result of the EF2 tornado. This would necessitate some upgrading of existing construction standards in the Ontario Building Code (OBC). The changes required are not as significant as one might think. Specifically, paying attention to connection details would significantly reduce repair costs, disruption to life and potential loss of life for homeowners affected by such events.

I would like to thank the following organizations for their contributions to this document.

- The Canadian Wood Council
- Simpson Strong Tie
- The University of Western Ontario
- The Institute for Catastrophic Loss Reduction

2.0 Wind Loads and the Ontario Building Code:

Wind loads are specified in the OBC in the MMAH Supplementary Standard SB -1. Hourly wind pressures are expressed in kPa for one in ten (1/10), and one in fifty (1/50) year return periods. Structural designs for buildings required to be designed to Part 4 of the OBC are designed to resist the 1/50-year loads for strength design. This means there is a 2% chance these loads will be exceeded in any given year.

EF2 tornados create equivalent (1/50) design wind loads of approximately 1.0 kPa. This generally represents a wind load 2 to 2.5 times the wind design load specified in the OBC for most of southern Ontario. Tornados occur far more frequently than once in every 50 years. In fact, in 2021 there were 60 reported tornadoes in Ontario. Over the last four years, on average, there have been 44 tornados per year in Ontario, most of which have occurred in southern Ontario. The frequency and magnitude of exceedance of the 1/50-year wind loads specified in the OBC, suggests that the design loads in the OBC may not be representative of the loads that occur numerous times each year. This leaves buildings vulnerable to significant damage resulting in significant economic loss and human suffering.

Other jurisdictions such as the United States have far higher wind loads that are specified for regions that are known to be subject to high winds. The methodology used to determine these loads is different than in Canada. In Canada, wind loads are based on winds occurring over a very broad area (synoptic scale storms), whereas in the United States the winds loads are based on both synoptic scale storms and thunderstorms which produce higher localized effects. This results in significantly higher wind design values and more robust construction standards.

Within the current framework of the OBC, not all buildings are required to be designed for wind loads. Buildings falling within the scope of Part 9 of the OBC, which includes almost all houses and other stick frame residential construction, are not required to be designed to resist any wind loads provided they comply with the prescriptive requirements and limitations within Part 9.

The prescriptive requirements in Part 9 are based on past performance. Historically, these provisions have worked reasonably well for gravity loads. In the past, typical construction techniques developed sufficient capacity and redundancy to resist lateral loads. There have been significant changes to construction techniques and typical house designs since the creation of these prescriptive provisions. They may not be as appropriate as they once were in resisting the loads these buildings are subject to. This becomes evident when reviewing damage from high wind events.

Given that buildings specifically engineered to resist wind loads specified in Part 4, may represent construction that is not designed to resist loads from high wind events, suggests that those buildings in Part 9 which meet a lesser standard are even more vulnerable to damage from high wind events.

What remains is a discussion if the high wind events which are becoming more prevalent represent a standard that the OBC should adapt to. It becomes difficult to continue to rely on past performance as a rational for acceptance when there is increasing frequency of failure.

3.0 A Continuous Load Path:

Part 9 buildings have historically demonstrated reasonable structural capacity mostly due to redundancies in structural systems and significant unquantified resistance from sheathing and cladding on exterior walls and roofs. Roofs have a tremendous system effect in distributing lateral and vertical loads to any part of the structure that might have capacity to resist it. Historically, Part 9 has been deemed structurally successful by the absence of failures. When failure (or lack there of) is used as the criteria for acceptance, structures are permitted to significantly redistribute loads, not necessarily as intended, in order to prevent failure. This relies heavily on redundancies in load resisting systems.

As failure events, due to high wind events, become more common and redundancies in structural systems become less common, the assumptions Part 9 is based on may not be as appropriate as they once were. In particular, the loss of exterior sheathing on many wood buildings and the movement towards larger open spaces in many houses has removed many of the redundancies that previously existed.

As loads approach failure loads in these redundant support mechanisms, observing failure modes and weak links becomes more important in ensuring houses perform as they are expected to. The concept of providing an intentional continuous load path, rather than some unintentional resistance due to redundancies which may or may not exist in every house, eventually becomes necessary as wind loads increase in magnitude and frequency.

In assessing damage from high wind events, a very common failure is the roof to wall connection. Current OBC provisions provide only nominal resistance to uplift loads imposed on the structure during high wind events at this connection. This interface becomes a critical joint, but the load path needs to continue below this to ensure other connections between the roof and the foundation wall do not fail. There are eight joints to assess in this load path to ensure loads can be transferred to the foundation wall. The capacity of most of these connections is nominal and unintentional with respect to load transfer.

The existing OBC provisions only need minor adjusting in order to provide an intentional continuous load path. It is the details of the connections that need to be addresses in order to provide increased resistance. Exterior sheathing in particular, if placed and connected in a specific manner can address all the gaps or weak links and create the necessary continuous load path. This approach forms the basis of the Code change proposals presented in this document.

4.0 Structural Resilience vs. Energy Efficiency:

As building designs move towards a net zero carbon footprint, there have been tremendous improvements in building practices and technology towards building highly energy efficient buildings. Ontario has been a leader in this field as there have been many significant changes to the OBC towards this end. One significant change in meeting this goal, is the use of continuous outboard (exterior) insulation. There is no doubt that this practice builds a far superior product with respect to energy efficiency.

There is also no doubt that this practice seriously compromises the structural integrity and redundancy that previously existed in stick frame construction where outboard insulation replaces structural sheathing on the exterior of walls. Buildings ideally should be designed with consideration given to resiliency, energy efficiency and sustainability. Well designed buildings achieve a compromise between potentially opposing objectives. Providing energy efficiency cannot take precedence over structural resiliency. While requiring exterior sheathing may reduce the amount of outboard insulation that can fit on the (same width of) foundation wall, the benefits of doing so need to be considered as part of an overall assessment of the entire structure's performance.

5.0 Modifying the Wood Frame for Increased Resilience

There are several steps that can be taken to improve how small buildings (particularly wood frame buildings) can be modified to provide significantly increased resistance to high wind events. Within the framework of the existing OBC, there is opportunity to provide more robust requirements to ensure that buildings act in a more predictable and acceptable manner when subject to high winds. Those options are discussed below with specific OBC change proposals included in section 6 of this Report.

Continuous Load Path:

Providing more clarity that all buildings should provide a continuous load path to the foundation to resist all loads they are subject to may seem intuitive. This is certainly part of the functional statements in the OBC which relate to structural sufficiency. Part 9 of the OBC does not explicitly say this and including new provisions to that effect in Part 9, along with prescription solutions for achieving that, will result in buildings that perform much better in high wind events. There are three sentences proposed in a new clause 9.4.1.2. which provide clarity on this and how it can be achieved.

Uplift Loads on Roofs:

Currently Part 9 of the OBC does not require buildings to be designed to resist any wind load. Only roof elements exceeding certain span lengths are required to be designed to Part 4, and practically this is uncommon. The reality is that these buildings are subject to wind loads and uplift pressures, but this is not being considered in their design. The frequency and magnitude of high wind events warrants that these structures be designed to resist higher loads.

Rather than changing the environmental loads in the OBC, which would be a huge undertaking, the OBC can specify uplift loads that are known to occur in high wind events. If buildings are designed to resist these loads, most if not all of the structural damage seen from high wind events can be eliminated. These loads are specified in the proposed OBC changes (9.4.2.5) and would apply to buildings greater than $20m^2$ in area.

Sheathing Placement and connections:

Exterior wall sheathing has the ability provide the continuous load path required to resist uplift loads provided it is placed in a specific configuration and nailed in a way that transfers loads across the weak links in the wood frame. The new proposed clauses 9.23.2.1(2) to 9.23.2.4. (inclusive) and 9.23.3.6, 9.23.3.7 provide a prescriptive solution within Part 9 to meet the continuous load path requirement. This would not preclude the use of other methods shown to comply with the requirement for a continuous load path.

It is recognized that placing and nailing sheathing in this way is different than most current construction practices. It does represent a slightly more labour-intensive method of construction, but likely still represents the most cost-effective way of meeting this requirement.

Anchorage Requirements:

The current provisions in the OBC for anchorage are very general. These provisions can be clarified to provide more specificity in anchorage requirements, which will result in better outcomes.

Anchor bolts are more effective if they are placed near corners of buildings, are attached to the foundation with larger washers and are placed away from the edge of the wall with sufficient embedment. These changes which are specified in a modified clause 9.23.6.1.(2) and (3). They are prescriptive requirements which can easily be enforced and are rather intuitive.

The current requirements in 9.23.6.2. require posts and columns to be anchored, but there is no specific resistance requirement associated with the anchorage. Roof overhangs and canopies are particularly vulnerable in high wind events and requiring anchorage of a specific resistance will result in far better performance of these building elements. The OBC change proposal includes specific loading based on applicable supported areas.

Bracing and Lateral Support of Walls:

The existing provisions within 9.23.10.2 of the OBC, do not distinguish between interior or exterior walls and allow nominal lateral bracing to stabilize walls in lieu of sheathing. Lateral bracing provides little resistance to any uplift loads applied to walls and does not create an intentional continuous load path to anchor walls. The nominal connections currently in the OBC fail to transfer uplift loads to the foundation in high wind events.

The OBC change proposal treats interior and exterior walls differently and requires all exterior walls to be sheathed.

6.0 Specific OBC Changes:

Specific OBC changes which support the previous discussion are provided in this section. Changes have been presented in the context and order as things currently exist in the OBC.

Black text represents current OBC requirements and green text are proposed modified or new requirements. The changes are presented under the broad categories presented in this paper.

6.1 - CONTINUOUS LOAD PATH

Section 9.4. Structural Requirements
9.4.1. Structural Design Requirements and Application Limitations
9.4.1.1. General

(1) Subject to the application limitations defined elsewhere in this Part, structural members and their connections shall,

(a) conform to requirements provided elsewhere in this Part,

(b) be designed according to good engineering practice such as provided in the CWC, "Engineering Guide for Wood Frame Construction," or

(c) be designed according to Part 4 using the loads and deflection and vibration limits specified in,

(i) this Part, or

(ii) Part 4.

(2) Where floor framing is designed in accordance with Clause (1)(b) or (c) and where supporting wall framing and fastenings, or footings, are designed according to Clause (1)(a), the specified *live load* on the floor according to Table 4.1.5.3. shall not exceed 2.4 kPa.

(3) Location-specific information for structural design, including snow and wind loads and seismic spectral response accelerations, shall be determined according to MMAH Supplementary Standard SB-1, "Climatic and Seismic Data".

9.4.1.2 Continuous Load Path: (NEW)

1. Structures shall provide a continuous load path such that all vertical and lateral loads are transferred into the foundation wall.
2. For wood frame construction described in 9.23.1.1, construction in accordance with articles 9.23.2.1, 9.23.2.2, 9.23.2.3, 9.23.3.6 and 9.23.3.7 shall be deemed to comply with sentence (1).
3. Reactions from any element designed to Part 4 must be transferred to the foundation of the building through a continuous load path.

6.2 - UPLIFT LOADS ON ROOFS

9.4.2. Specified Loads

9.4.2.1. Application

(1) This Subsection applies to light-frame construction whose wall, floor and roof planes are generally comprised of frames of small repetitive structural members, and where,

(a) the roof and wall planes are clad, sheathed or braced on at least one side,

(b) the small repetitive structural members are spaced not more than 610 mm o.c.,

(c) the clear span of any structural member does not exceed 12.20 m,

(d) the maximum deflection of the structural roof members conforms to Article 9.4.3.1.,

(e) the maximum total roof area, notwithstanding any separation of adjoining *buildings* by *firewalls*, is 4 550 m2, and

(f) for flat roofs, there are no significant obstructions on the roof, such as parapet walls, spaced closer than the distance calculated by,

Do 10(Ho – 0.8 Ss / γ

where,

Do = minimum distance between obstructions, m,

Ho = height of the obstruction above the roof, m,

Ss = ground snow load, kPa, and

γ = unit weight of snow, kN/m3.

9.4.2.2. Specified Snow Loads

9.4.2.3. Platforms Subject to Snow and Occupancy Loads

9.4.2.4. Attics and Roof Spaces

9.4.2.5 Wind Uplift Loads From roofs (NEW)

Except for single story buildings not exceeding 20m^2 in area, roof framing members supported by walls, beams or lintels shall be connected to their supporting member to resist a factored uplift of

i) 2.5 kN where roof framing is at 406 mm o.c.

ii) 3.7 kN where roof framing is at 610 mm o.c., or

iii) 6.0 kN/m for spacing of elements other than specified above

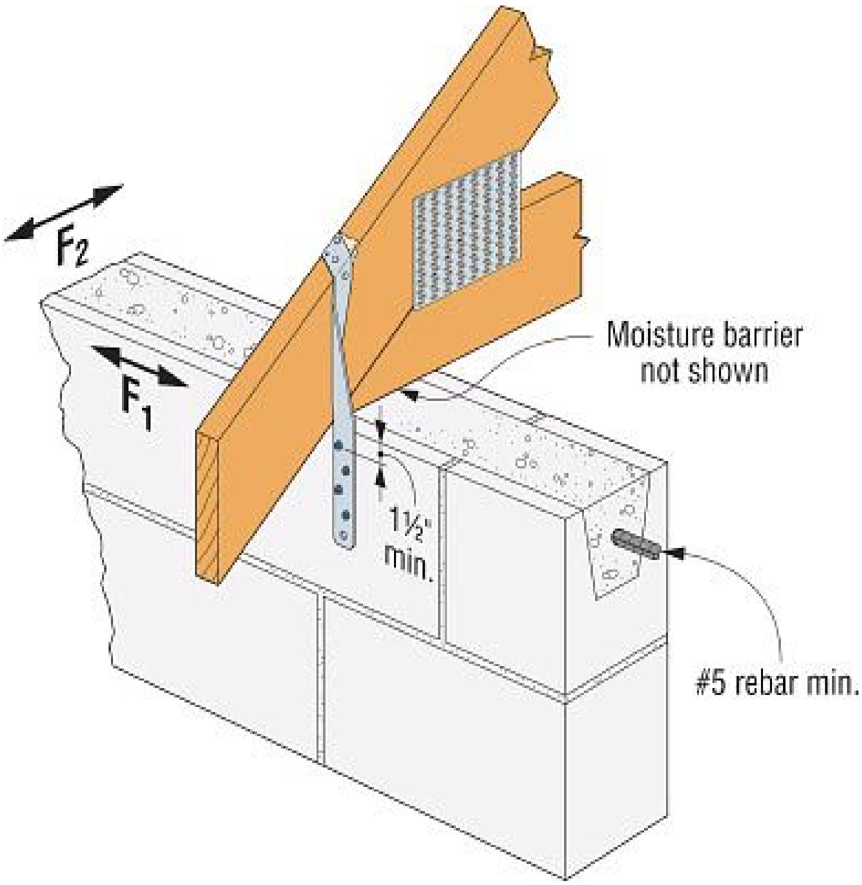
(See appendix for typical connector options for wood frame and other walls. Example pictures included below).

Appendix Information:

Connection Options for Wood Frame Walls:
Hurricane Strap

Truss Screw

Connection Options for Concrete/ICF/Masonry Walls:



6.3 - PLACEMENT OF SHEATHING

Section 9.23. Wood Frame Construction
9.23.1. Application

9.23.2. General
9.23.2.1. Strength and Rigidity
(1) All members shall be so framed, anchored, fastened, tied, and braced to provide the necessary strength and rigidity.

9.23.2.1. (2) (NEW)

All exterior walls which support roof loads shall be sheathed with 11mm (min.) thick OSB or plywood and provide a continuous load path described in 9.4.1.2.

9.23.2.2. Lapping of sheathing to provide a Continuous Load Path. (NEW) *(Existing provisions get bumped down)*

Sheathing shall be lapped over framing members as follows:

1. On the top floor, where wall panels support the roof, sheathing shall be lapped over both top plates as a minimum. (Lapping over raised heel trusses where available is recommended.)
2. Except as provided in 9.23.2.4, on middle floors, where wood framing is provided above and below a floor level, sheathing shall be lapped to extend 75 mm (minimum) over the top and bottom side of each rim board, and
3. On bottom floors, where the wood frame bears on the foundation wall, sheathing shall be lapped to fully cover the sill plate(s) anchored to the foundation wall.

(See Appendix for additional information – provide a drawing)

9.23.2.3. Termination of Sheathing Panels: (NEW)

Where sheathing is not continuous over the height of a wall panel, gaps in sheathing must be at the mid height of the stud, if possible, but not closer than 1000mm from the end of the stud.

9.23.2.4 Straps in Lieu of Sheathing Lapped over Rim Board: (NEW)

On middle floors, where sheathing is not lapped over the rim board, metal straps placed on the inside or outside of the wall may be used to provide a continuous load path. Metal straps shall be

- 914 mm long x 0.87 mm thick (min.)
- Grade 275 steel if 32mm wide, or Grade 230 steel if 38mm wide.
- attached with 9 – 3.88mm x 64 mm nails above and below the rim board
- Be spaced at 1200 mm (max.) o.c.

(See appendix for additional information).

Appendix 9.23.2.4. – Metal Straps in Lieu of sheathing over Rim Board.

6.4 - FASTENERS FOR SHEATHING IN A CONTINUOUS LOAD PATH

9.23.3. Fasteners

9.23.3.6 Location of nails for sheathing providing a Continuous Load Path: (NEW)

1. Wall panels immediately below the roof framing shall have the specified nailing in 9.23.3.7 in both top plates.
2. Wall panels on middle floors shall have the specified nailing in 9.23.3.7 in one wall plate above and below the rim board and centered within the top and bottom 75mm of the rim board.
3. Wall panels on bottom floors shall have the specified nailing in 9.23.3.7. in the bottom sill plate and within the rim board.
4. Wall panels on all floors shall have the specified nailing in 9.23.3.7. in all studs.

9.23.3.7 Nailing of Sheathing providing a continuous load path: (NEW)

1. Nails shall be minimum 64mm in length and a minimum 3.25 mm in diameter.
2. Unless specified otherwise, nails shall be spaced at 150 mm o.c.
3. Nails in a single top or bottom wall plates shall be spaced at 100 mm o.c.
4. Nails into rim boards shall be spaced at 100 mm o.c.

REMOVE 9.23.3.4.(2) ENTIRELY:

~~**(2)** Where the bottom wall plate or sole plate of an exterior wall is not nailed to joists or blocking in conformance with~~
~~Table 9.23.3.4., the exterior wall may be fastened to the floor framing by,~~
~~(a) having plywood, OSB or waferboard sheathing extend down over floor framing and fastened to the floor framing by~~
~~nails or staples conforming to Article 9.23.3.5., or~~
~~(b) tying the wall framing to the floor framing by 50 mm wide galvanized-metal strips,~~
~~(i) not less than 0.41 mm in thickness,~~
~~(ii) spaced not more than 1.2 m apart, and~~
~~(iii) fastened at each end with at least two 63 mm nails.~~

REMOVE FASTENING FOR SHEATHING FROM TABLE 9.23.3.5 (Replaced by 9.23.3.7)

9.23.3.5. Fastening for Sheathing or Subflooring

(1) Except as required by Sentence (5), fastening of ~~sheathing and~~ subflooring shall conform to Table 9.23.3.5.

6.5 - ANCHORAGE REQUIREMENTS:

9.23.6. Anchorage

9.23.6.1. Anchorage of Building Frames

(1) *Building* frames shall be anchored to the *foundation* unless a structural analysis of wind and earth pressures shows anchorage is not required.

(2) Except as provided in Article 9.23.6.3., anchorage shall be provided by embedding the ends of the first-floor joists in concrete or fastening the sill plate to the *foundation* with not less than 12.7 mm diam anchor bolts spaced not more than 2.4m o.c.

9.23.6.1(2) (MODIFIED)

(2) Except as provided in Article 9.23.6.3., anchorage shall be provided by embedding the ends of the first-floor joists in concrete or fastening the sill plate to the *foundation* with not less than 12.7 mm diam anchor bolts spaced not more than 2.4m o.c. Where anchor bolts are used there shall be at least 2 bolts in each straight wall section exceeding 1000 mm in length and bolts must be located within 500 mm of the end of the wall.

(3) Anchor bolts referred to in Sentence (2) shall be fastened to the sill plate with nuts and washers and shall be embedded not less than 100 mm in the *foundation* and so designed that they may be tightened without withdrawing them from the *foundation*.

9.23.6.1.(3) (MODIFIED)

(3) Anchor bolts referred to in Sentence (2) shall be:

i) embedded not less than 100mm into the foundation wall;
ii) be hooked a minimum of 38mm with the hook facing the middle of the wall;
iii) anchored to the foundation wall with 50mm x 50mm x 3mm washers tightly fastened; and
iv) be located not closer than 44mm (1.75”) from the edge of the foundation wall, measured from the center of the bolt.

9.23.6.2. Anchorage of Columns and Posts (MODIFIED)

(1) Except as provided in Sentences (2) and (3), exterior columns and posts supporting roof structures shall be anchored to resist uplift and lateral movement. Uplift loads shall be in accordance with Table (xxxxxx)

Table xxxxxx
Anchorage for Columns and Posts Supporting Roof Structures

Maximum Centre to Centre spacing m (ft.) Column Supports	Maximum Centre to Centre spacing m (ft.) Roof Span	Tributary Area, m2	Factored uplift Load, kN
1.8 (6)	1.8 (6)	1.6	4.1
1.8 (6)	2.4 (8)	2.2	5.4
2.4 (8)	2.4 (8)	2.9	7.2
2.4 (8)	3.05 (10)	3.66	9.15
3.05 (10)	3.05 (10)	4.7	11.6
3.05 (10)	3.66 (12)	5.6	14.0
3.66 (12)	3.66 (12)	6.7	16.7

Loads are based on a factored uplift of 2.5 kPa. Linear interpolation is permitted for other support spacings or tributary areas.

6.6 - WALL STUDS : BRACING AND LATERAL SUPPORT:

Modify Existing 9.23.10.2. to have separate requirements for interior and exterior load bearing walls. (Most of existing provisions are deleted).

9.23.10.2. Bracing and Lateral Support

9.23.10.2.(1) Interior load bearing walls shall:

(a) have an interior finish conforming to the requirements of Section 9.29, or
(b) have blocking or strapping fastened to the studs at mid height to prevent sideways buckling**.**

~~**(1)** Except as provided in Sentence (2), each exterior wall in each *storey* shall be braced with at least one diagonal brace~~
~~conforming to Sentence (3).~~
~~**(2)** Bracing is not required where the walls,~~
~~(a) have an interior finish conforming to the requirements of Section 9.29., or~~
~~(b) where the walls are,~~
~~(i) clad with panel-type siding,~~
~~(ii) diagonally sheathed with lumber, or~~
~~(iii) sheathed with plywood, OSB, waferboard, gypsum or fibreboard sheathing.~~
~~**(3)** Where bracing is required, it shall,~~
~~(a) consist of not less than 19 mm by 89 mm wood members,~~
~~(b) be applied to the studs at an angle of approximately 45° to the horizontal, and~~
~~(c) extend the full height of the wall on each *storey*.~~
~~**(4)** Bracing described in Sentence (3) shall be nailed to each stud and wall plate by at least two 63 mm nails.~~
~~**(5)** Where *loadbearing* interior walls are not finished in accordance with Sentence (2), blocking or strapping shall be~~
~~fastened to the studs at mid-height to prevent sideways buckling~~

9.23.10.2.(2) Exterior load bearing walls shall comply with 9.23.2.1. (2)