Major changes in CSA O86-2014 to address mid-rise construction

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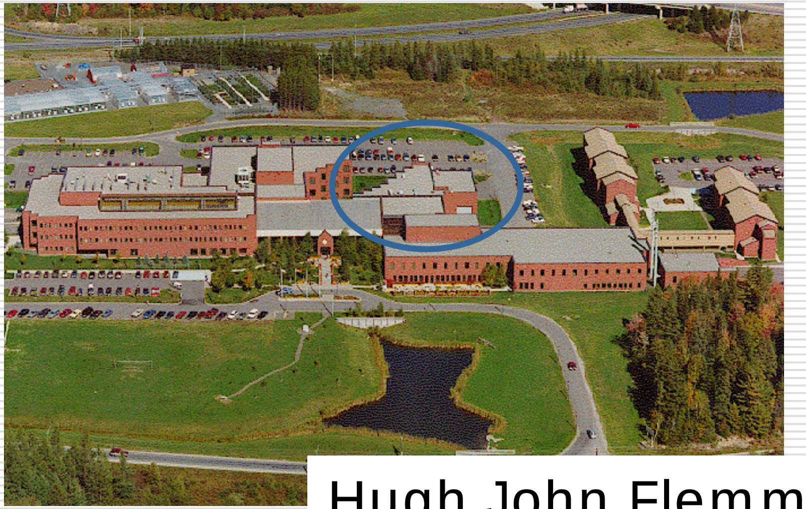
Atlantic WoodWORKS! Wood Design Seminar
December 3rd, 2014
Charlottetown, PEI

Wood Science & Technology Centre

A world-renowned and nationally recognized research centre on engineered wood products and building systems



Hugh John Flemming Forestry Centre

Products R&D and testing

Floor

Wall

Joist hanger & wood I-joist

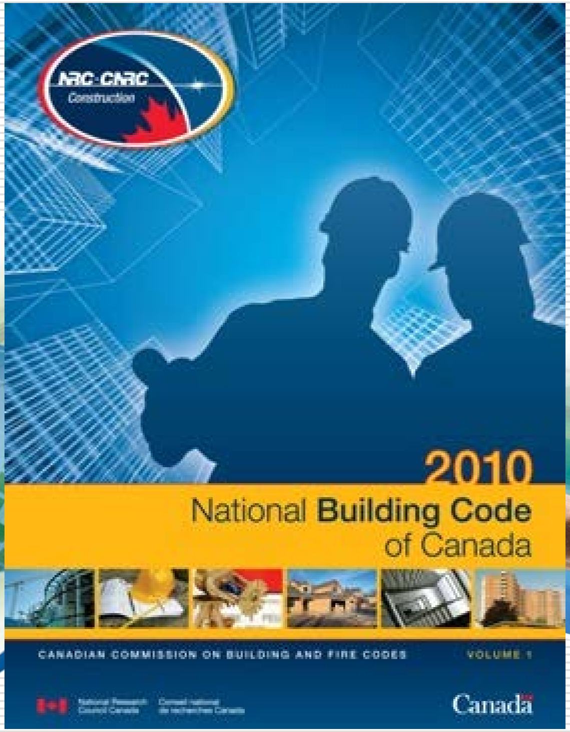
Steel-web beam

Research to support building codes and standards

CSA Group

O86-14

Engineering design in wood



NRC·CNRC Construction

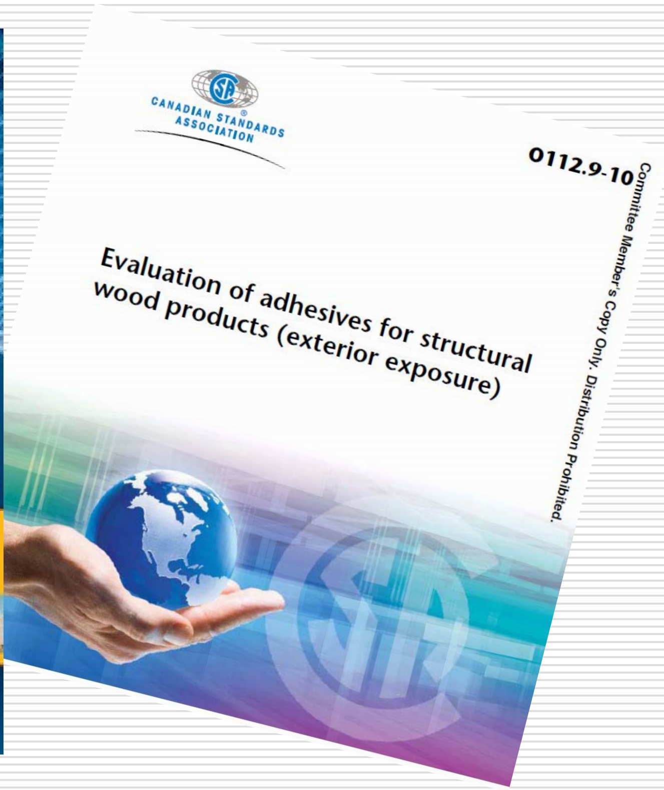
2010

National Building Code of Canada

CANADIAN COMMISSION ON BUILDING AND FIRE CODES

VOLUME 1

Canada



CANADIAN STANDARDS ASSOCIATION

O112.9-10

Evaluation of adhesives for structural wood products (exterior exposure)

Committee Member's Copy Only. Distribution Prohibited.

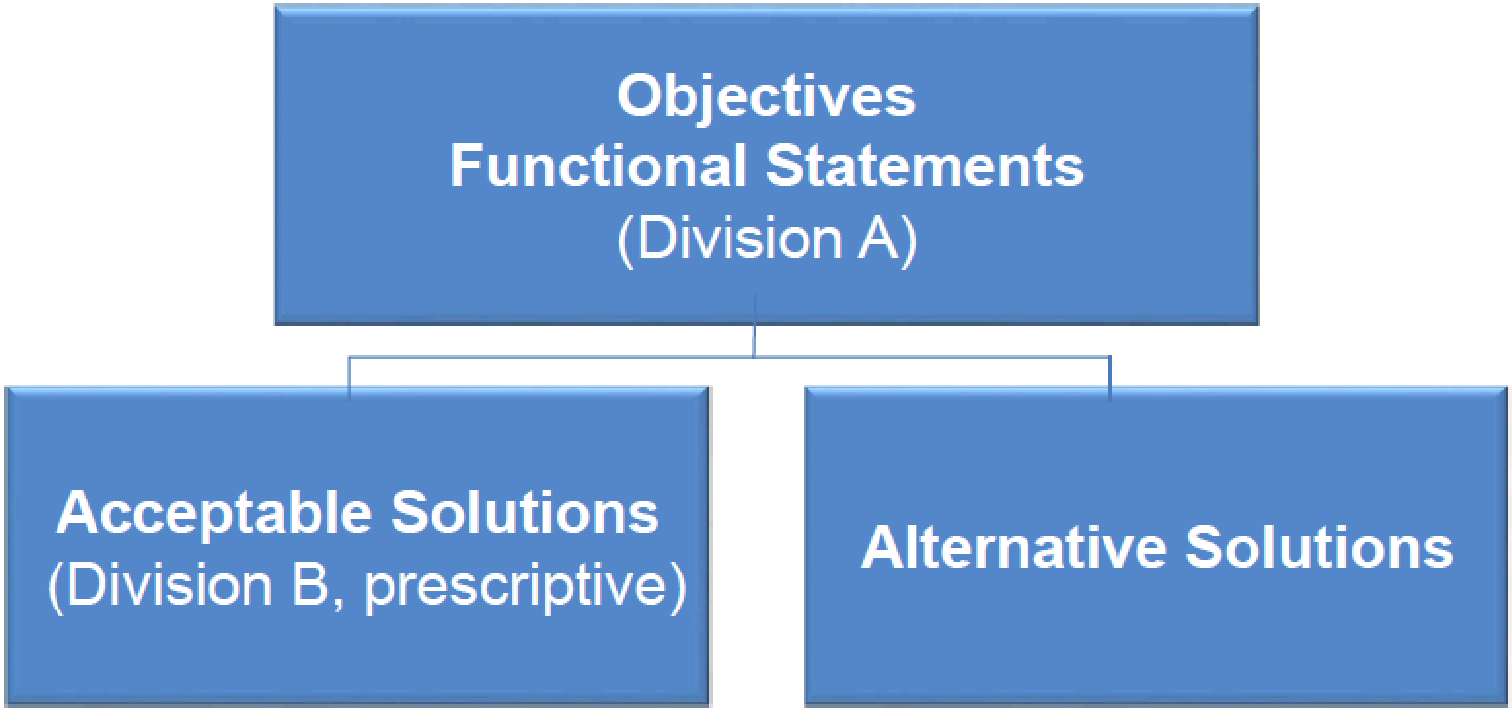
NRC·CNRC

NRC • CONSTRUCTION

Evaluation Report
CCMC 13500-R

MASTERFORMAT:	06 73 14.01
Issued:	2012-07-31
Re-evaluation due:	2015-07-31

National Building Code of Canada



Objectives
Functional Statements
(Division A)

Acceptable Solutions
(Division B, prescriptive)

Alternative Solutions

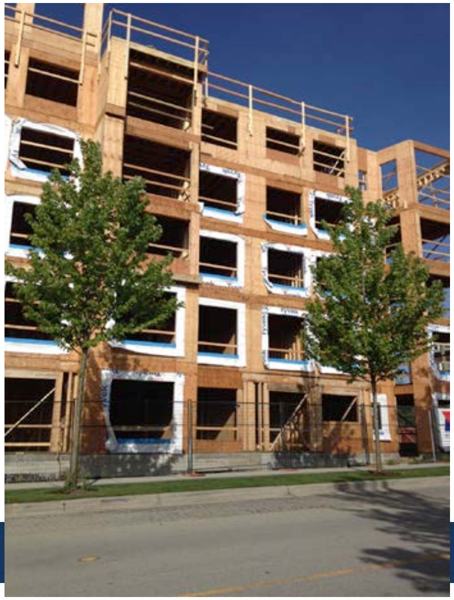
burden of proof

Proposed changes on combustible construction pending final approval in March 2015

Proposed Changes in NBCC

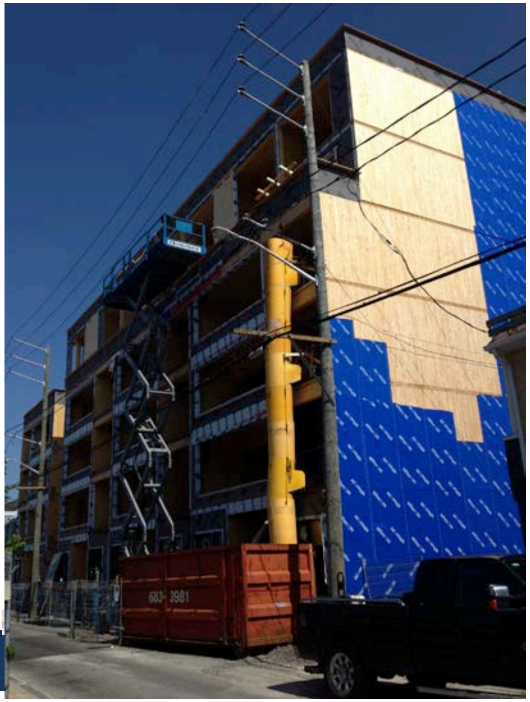
Building size limits for mid-rise combustible construction:

- Upto 6 storey of residential and business occupancies
- Mixed use occupancies on lower storeys



Light wood

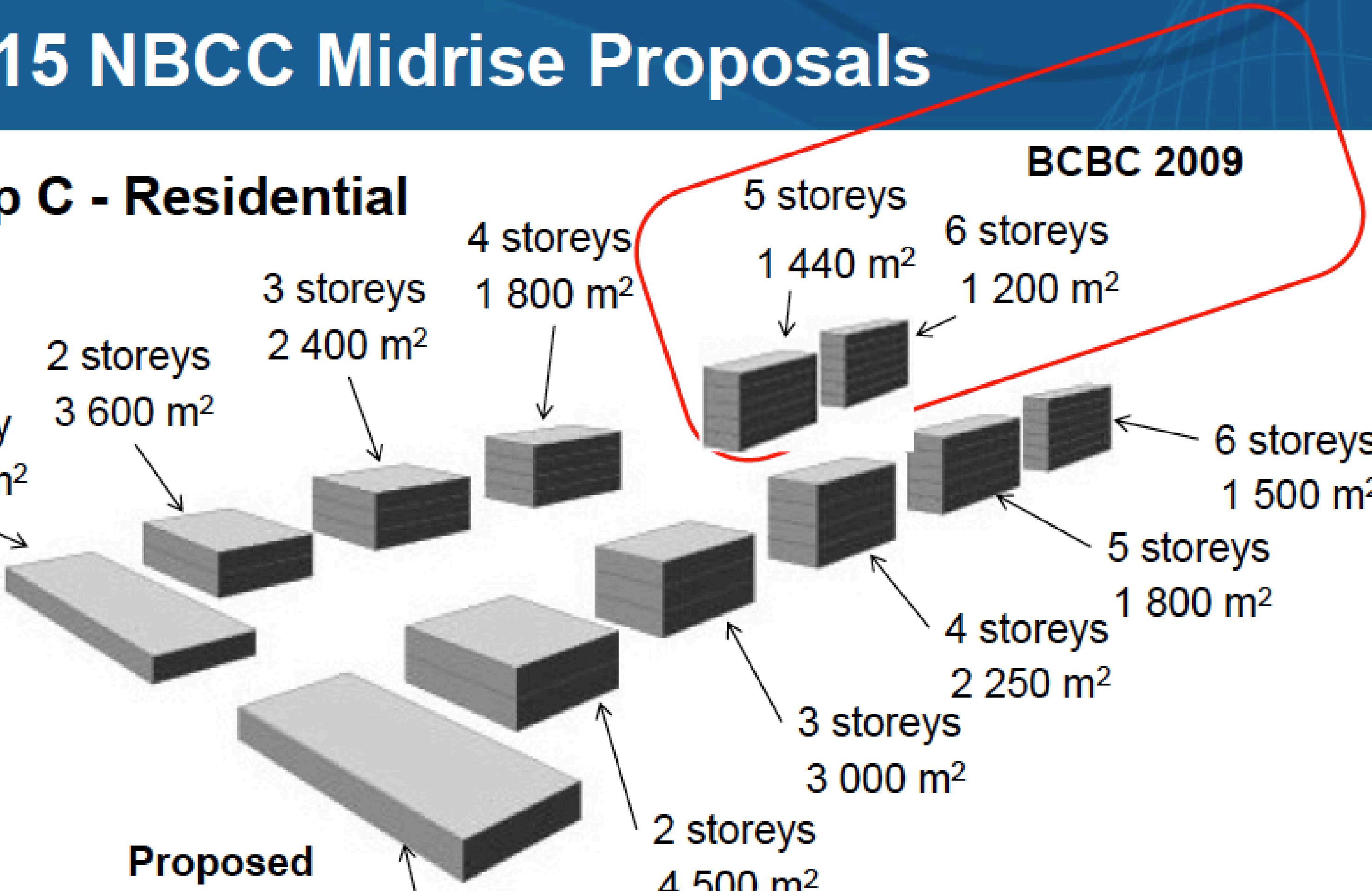
Post & Beam



Cross laminated timber (CLT)

2015 NBCC Midrise Proposals

Group C - Residential



BCBC 2009

5 storeys
1 440 m^2

6 storeys
1 200 m^2

1 storey
7 200 m^2

2 storeys
3 600 m^2

3 storeys
2 400 m^2

4 storeys
1 800 m^2

Proposed NBCC 2015

1 storey
9 000 m^2

2 storeys
4 500 m^2

3 storeys
3 000 m^2

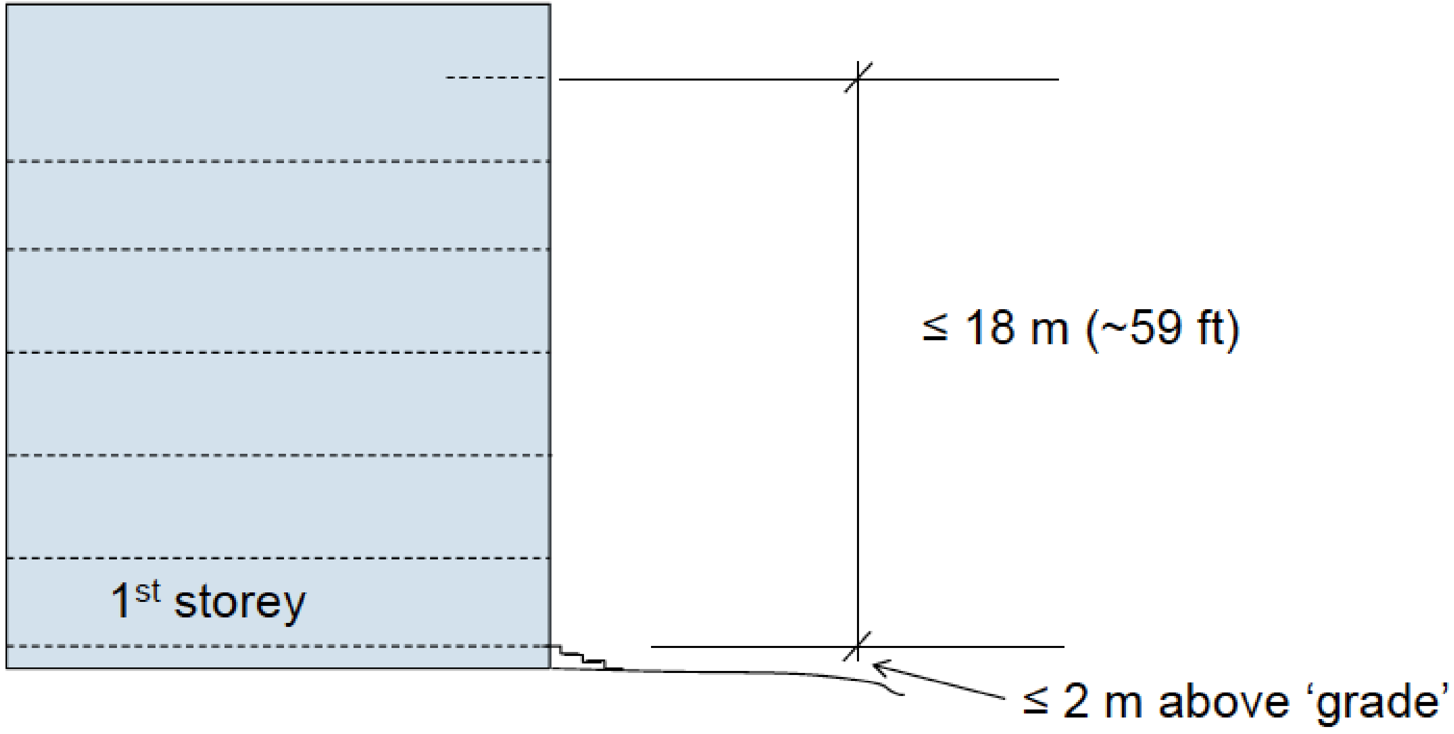
4 storeys
2 250 m^2

5 storeys
1 800 m^2

6 storeys
1 500 m^2

2015 NBCC Midrise Proposals

Height Limit: 18 m from floor of 1st storey to floor of uppermost floor level



2015 NBCC Midrise Proposals

- NFPA 13R → NFPA 13 → …
  - Sprinkler protection in concealed spaces
  - Sprinkler protection on balconies

2013

NFPA 13
Standard for the
Installation of
Sprinkler Systems

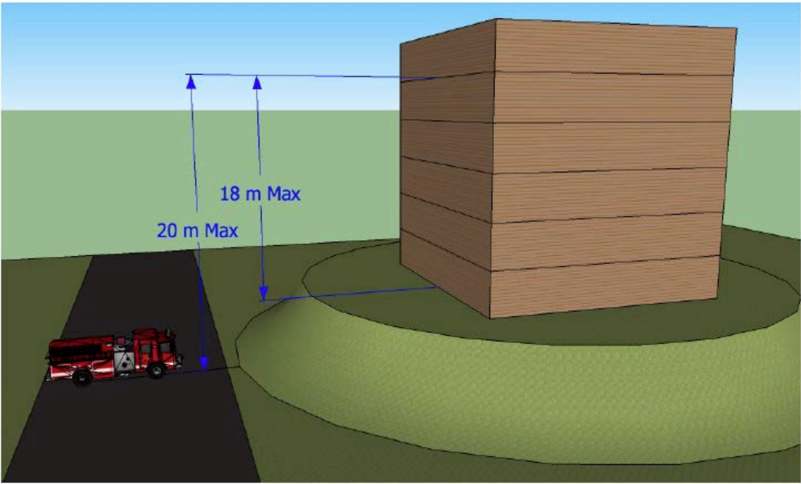
13

NFPA

2015 NBCC Midrise Proposals

Firefighting Access:

- 25% of the perimeter of the building is required to be within 15 m of a street or access route
- Street or access route to have elevation not more than 2 m below the floor of the 1st storey



2015 NFCC Midrise Proposals

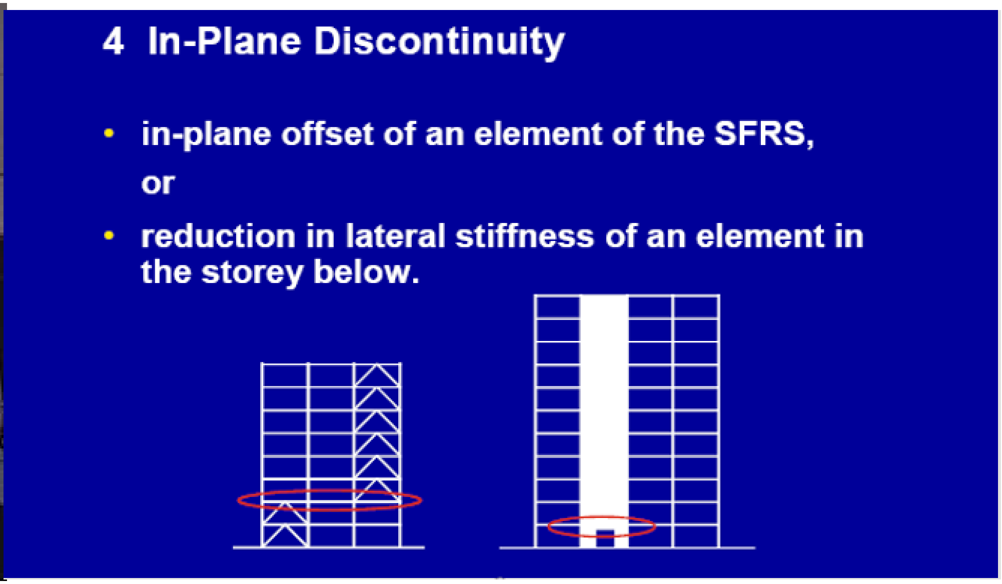
Fire Safety at Construction and Demolition Sites (National Fire Code of Canada):

- Fencing, boarding or barricades
- Required water supply
- Unobstructed clearance around hydrants
- Site identification
- Construction access stairway
- Smoking area requirements (where permitted)
- Minimum clearance: waste containers, roofing kettles, exposed combustibles to exits/means of egress

2015 NBCC Midrise Proposals

Earthquake Design:

- Reduced risk of soft-storey by prohibiting Type 4 and 5 irregularity in shear wall
- Increased seismic design load if natural period is calculated by mechanics method (20%)



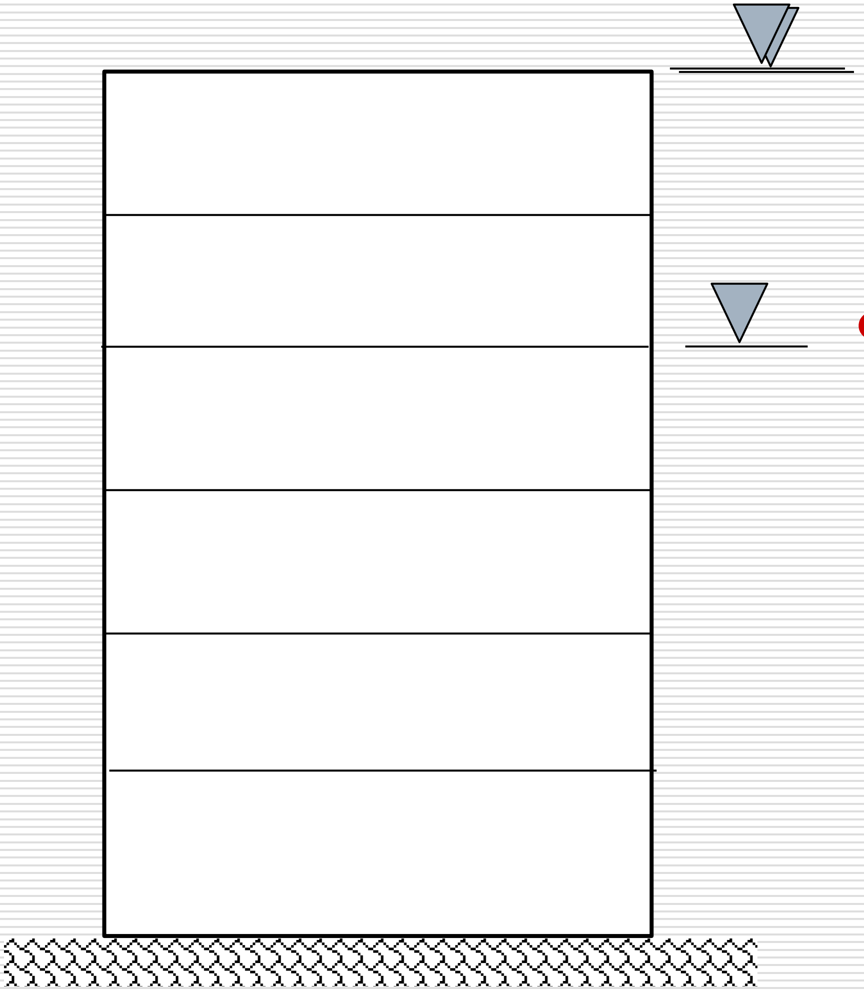
4 In-Plane Discontinuity

- in-plane offset of an element of the SFRS,

  or

- reduction in lateral stiffness of an element in the storey below.

We will be back to pre-1953 NBCC



- 6 storey or ≈ 21m
proposed 2015

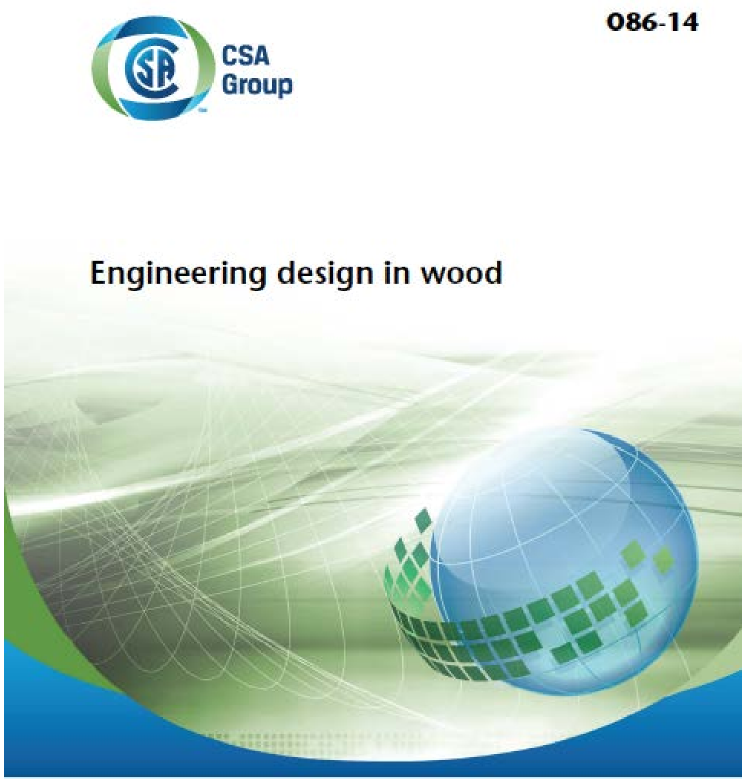
- 75 ft
1941

- 4 storeys 1953

2015 NBCC Midrise Proposals

Structural Design:

- Additional provisions in 2014 edition of CSA O86

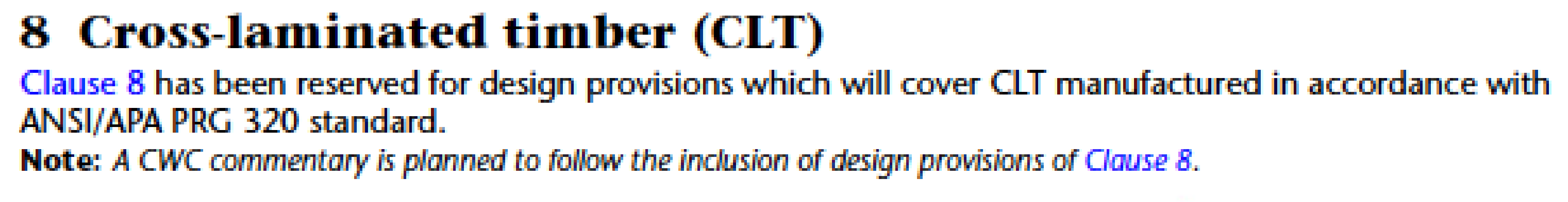


CSA Group

O86-14

Engineering design in wood

1. Placeholder for future design provisions for CLT (2016?)



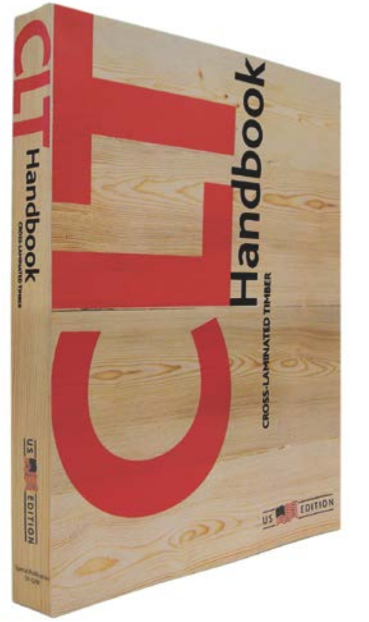
8 Cross-laminated timber (CLT)

Clause 8 has been reserved for design provisions which will cover CLT manufactured in accordance with ANSI/APA PRG 320 standard.

Note: *A CWC commentary is planned to follow the inclusion of design provisions of Clause 8.*

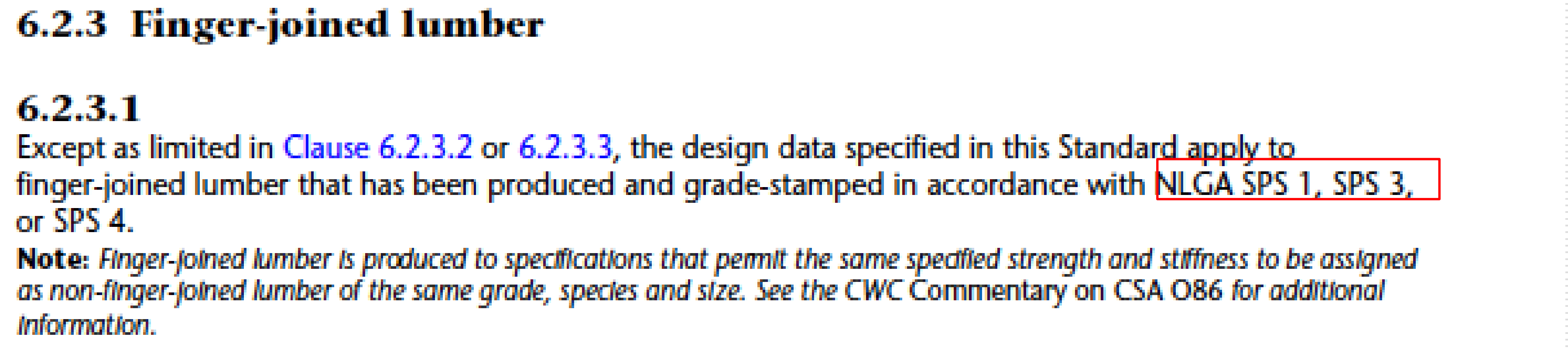
CLT

10-storey CLT building, Melbourne



Guidance document

2. Finger-jointed lumber grades



6.2.3 Finger-joined lumber

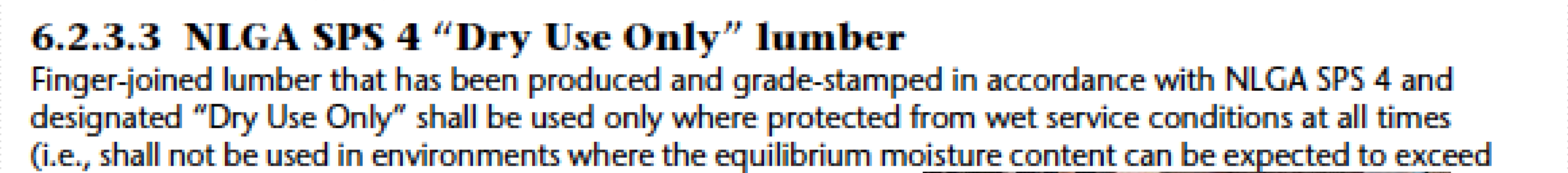
6.2.3.1

Except as limited in Clause 6.2.3.2 or 6.2.3.3, the design data specified in this Standard apply to finger-joined lumber that has been produced and grade-stamped in accordance with NLGA SPS 1, SPS 3, or SPS 4.

Note: *Finger-joined lumber is produced to specifications that permit the same specified strength and stiffness to be assigned as non-finger-joined lumber of the same grade, species and size. See the CWC Commentary on CSA O86 for additional information.*

New provision permitting use of FJ MSR lumber

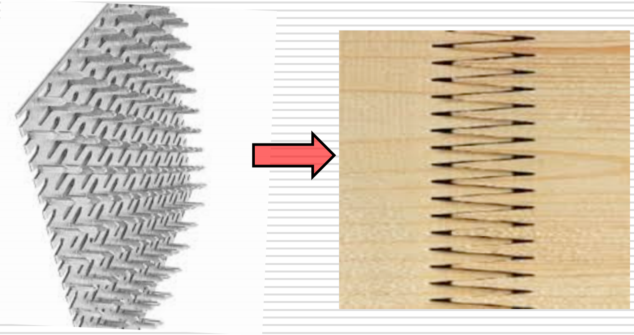
- SPS4 ‘Fingerjoined Machine Graded Lumber (FJ-MGL)’

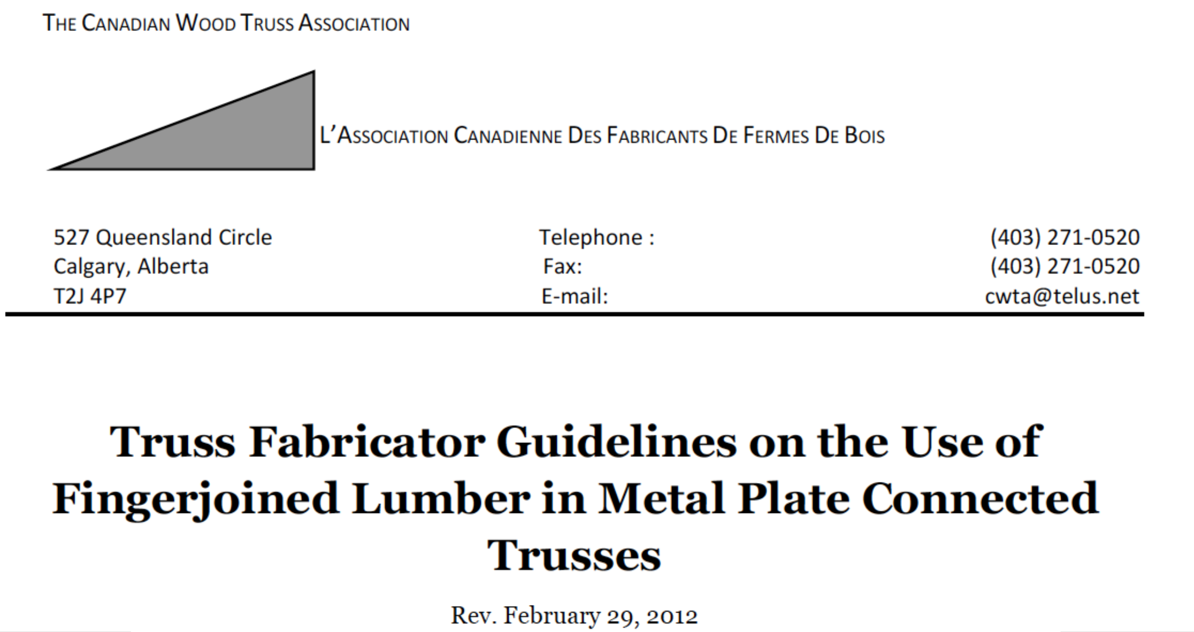


6.2.3.3 NLGA SPS 4 “Dry Use Only” lumber

Finger-joined lumber that has been produced and grade-stamped in accordance with NLGA SPS 4 and designated “Dry Use Only” shall be used only where protected from wet service conditions at all times (i.e., shall not be used in environments where the equilibrium moisture content can be expected to exceed 19%).

Special fabrication considerations for trusses





The Canadian Wood Truss Association

L'Association Canadienne Des Fabricants De Fermes De Bois

527 Queensland Circle
Calgary, Alberta
T2J 4P7

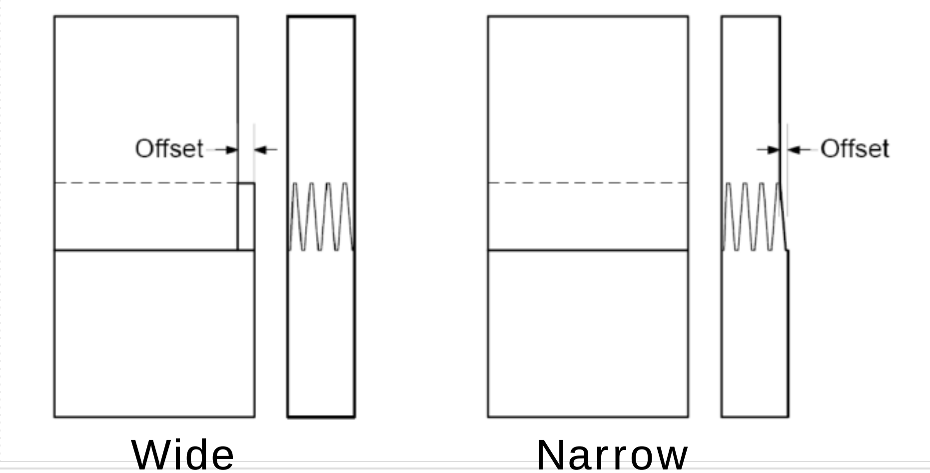
Telephone : (403) 271-0520
Fax: (403) 271-0520
E-mail: cwta@telus.net

Truss Fabricator Guidelines on the Use of Fingerjoined Lumber in Metal Plate Connected Trusses

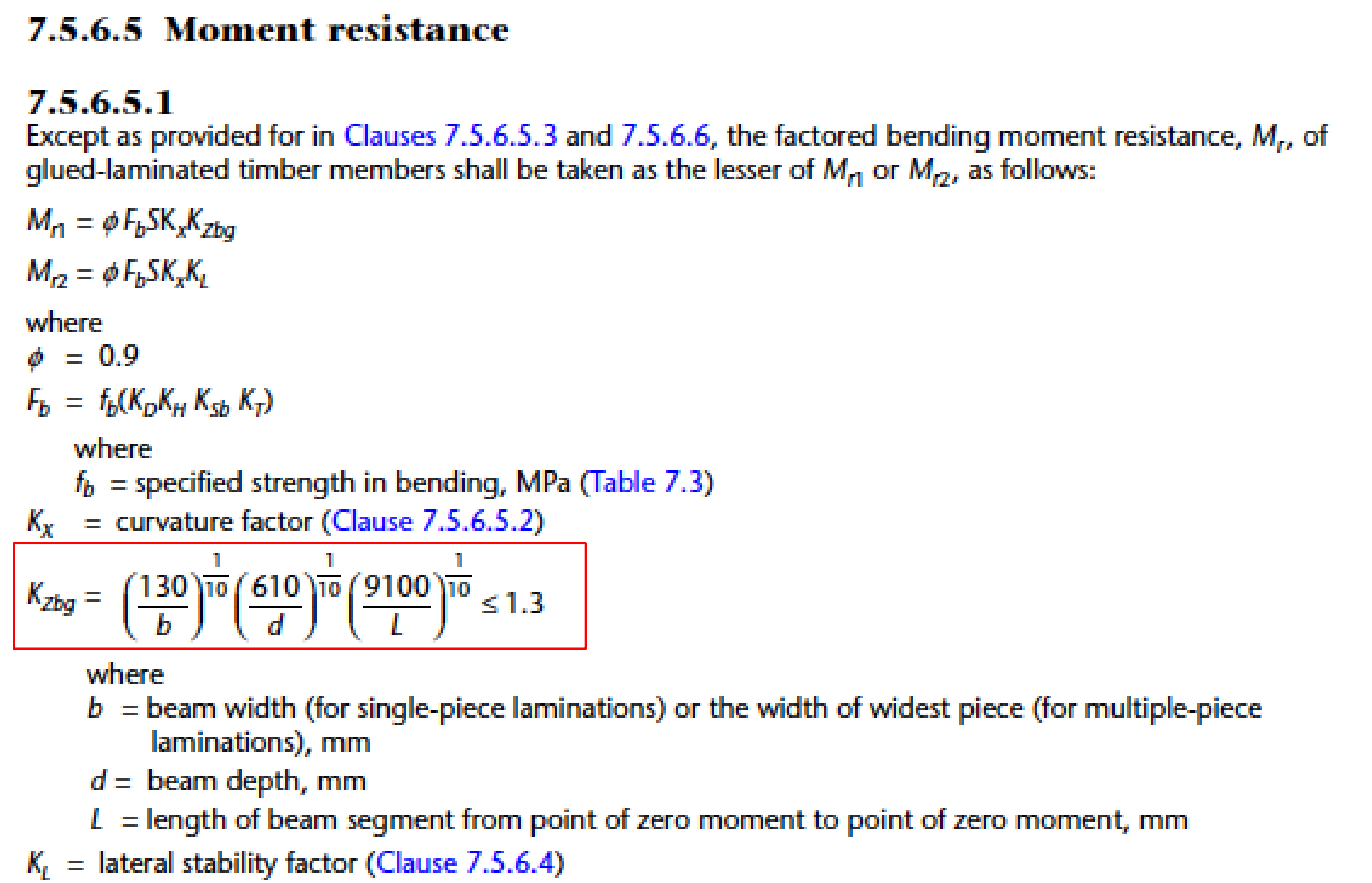
Rev. February 29, 2012

Fingerjoined lumber specifications do not require planing after joining

- Offset < 1/16"



3. Size factor for glulam beams



7.5.6.5 Moment resistance

7.5.6.5.1

Except as provided for in Clauses 7.5.6.5.3 and 7.5.6.6, the factored bending moment resistance, M_r, of glued-laminated timber members shall be taken as the lesser of M_{r1} or M_{r2}, as follows:

$$M_{r1} = \phi F_b S K_x K_{Zbg}$$

$$M_{r2} = \phi F_b S K_x K_L$$

where

ϕ = 0.9

F_b = $f_b(K_D K_H K_{Sb} K_T)$

where

f_b = specified strength in bending, MPa (Table 7.3)

K_X = curvature factor (Clause 7.5.6.5.2)

$$\boxed{K_{Zbg} = \left(\frac{130}{b}\right)^{\frac{1}{10}}\left(\frac{610}{d}\right)^{\frac{1}{10}}\left(\frac{9100}{L}\right)^{\frac{1}{10}} \leq 1.3}$$

where

b = beam width (for single-piece laminations) or the width of widest piece (for multiple-piece laminations), mm

d = beam depth, mm

L = length of beam segment from point of zero moment to point of zero moment, mm

K_L = lateral stability factor (Clause 7.5.6.4)

Issue with O86-09 requirement

$$K_{Zbg} = 1.03(BL)^{-0.18} \le 1.0$$

where

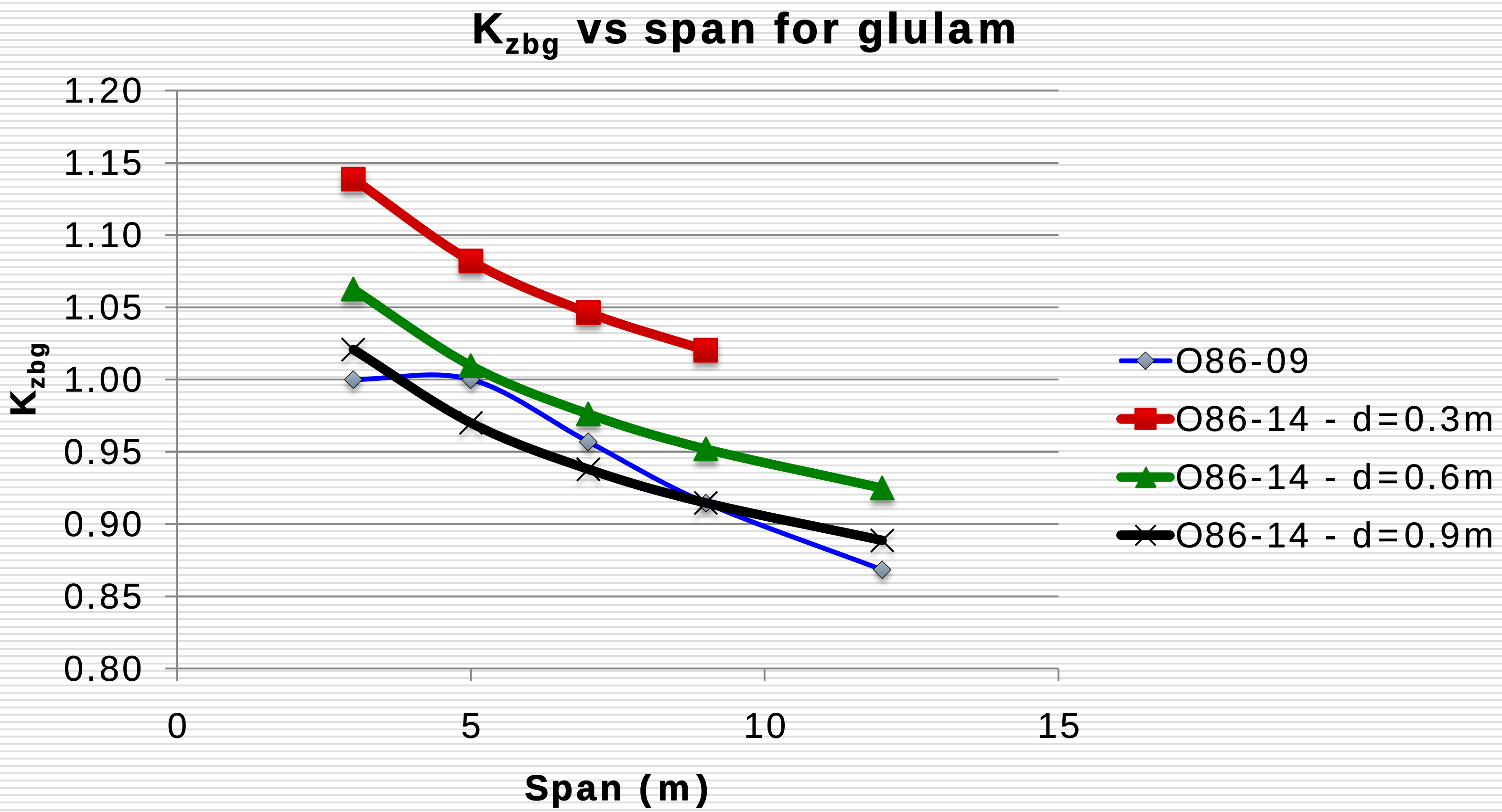
B = beam width (for single-piece laminations) or the width of widest piece (for multiple-piece laminations), m

L = length of beam segment from point of zero moment to point of zero moment, m

- Large reduction in capacity for large beams
- Out of date – not in line with national and international design standards

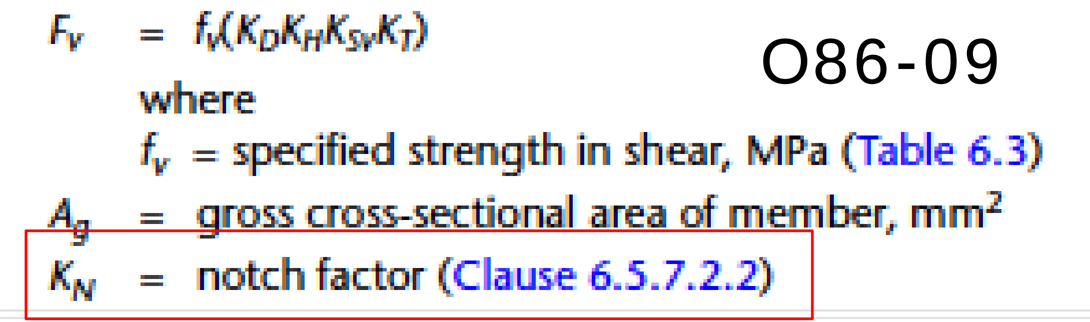
Large testing program at UBC, including 3ft deep beams @50ft span

Impact of change on bending moment capacity



- Allows increase for shallow beams
- Addresses the large reduction for large beams

4. Shear resistance of glulam with an end notch



$F_v = f_v(K_D K_H K_{Sv} K_T)$

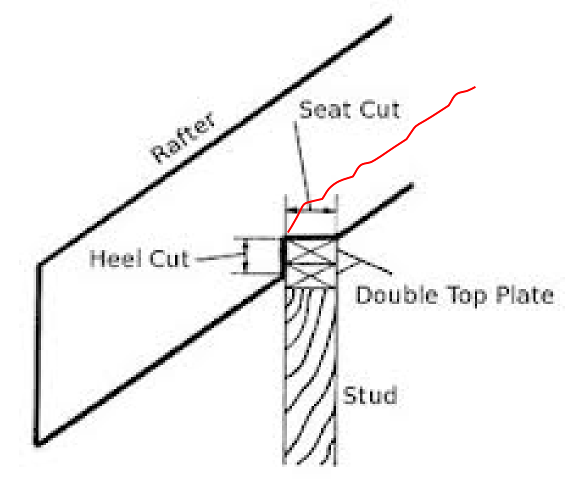
where

f_v = specified strength in shear, MPa (Table 6.3)

A_g = gross cross-sectional area of member, mm^2

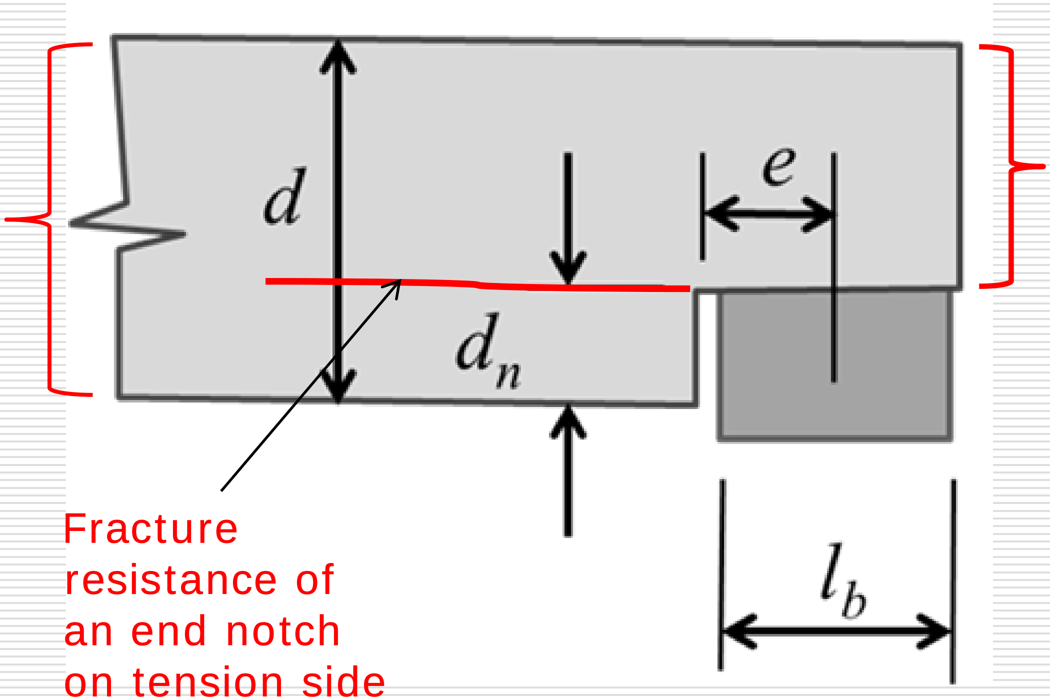
K_N = notch factor (Clause 6.5.7.2.2)

O86-09



Glulam with an end notch

- O86-2014 harmonizes design provisions for notched sawn lumber and glulam members



Shear of unnotched section

Shear of compression side of a notched section

Fracture resistance of an end notch on tension side

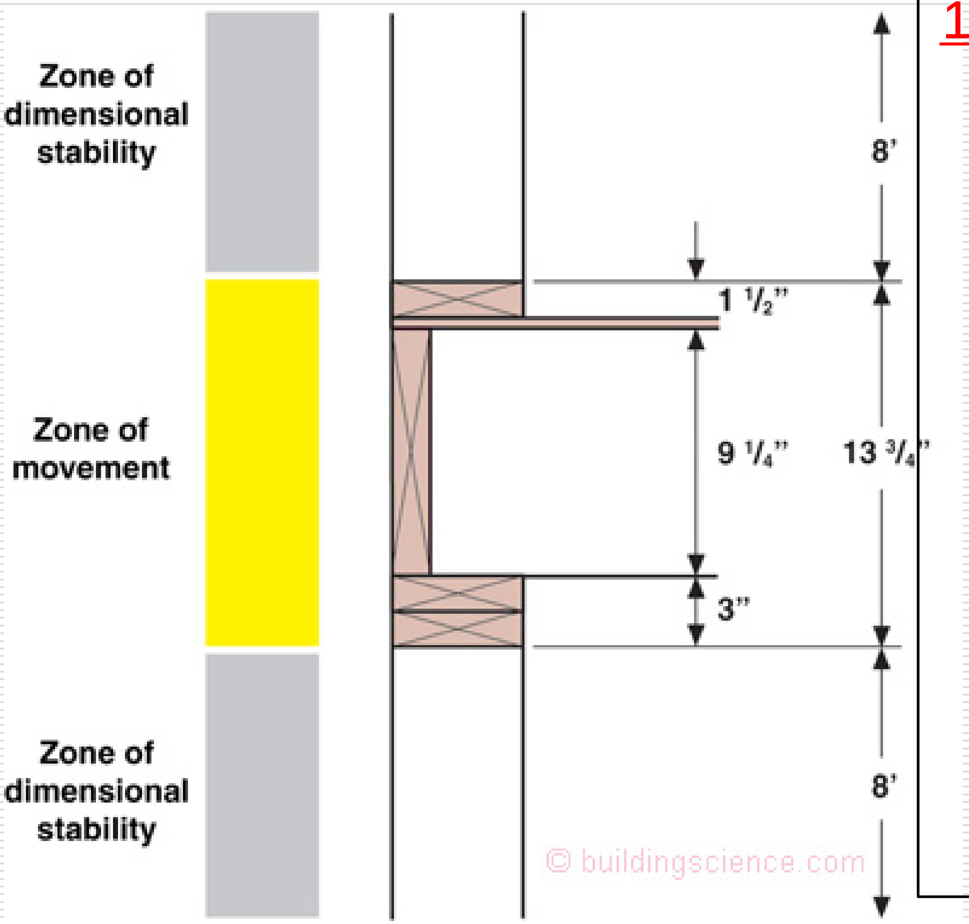
5. Building movement due to shrinkage and swelling

Parallel to grain

Perpendicular to grain

- Shrinkage coefficient is 40 times

Parallel to grain



Shrinkage from 19% to 10% MC

0.048 inch

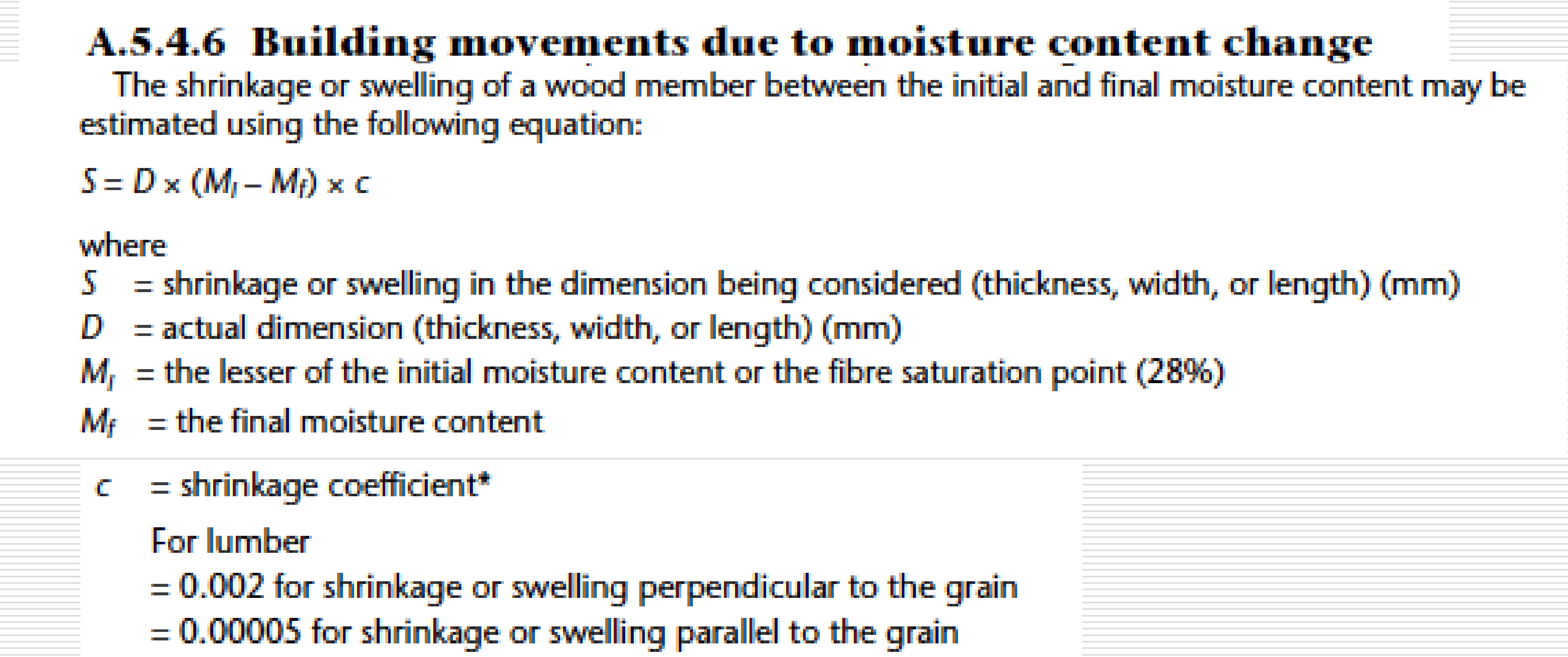
0.1 inch

0.048 inch

In extreme situation (25% to 5% MC), total shrinkage ≈ 4 inches for 6-storey building

Source :

Method of calculating shrinkage and swelling – Appendix note



A.5.4.6 Building movements due to moisture content change

The shrinkage or swelling of a wood member between the initial and final moisture content may be estimated using the following equation:

$$S = D \times (M_I - M_f) \times c$$

where

S = shrinkage or swelling in the dimension being considered (thickness, width, or length) (mm)

D = actual dimension (thickness, width, or length) (mm)

M_I = the lesser of the initial moisture content or the fibre saturation point (28%)

M_f = the final moisture content

c = shrinkage coefficient*

For lumber

= 0.002 for shrinkage or swelling perpendicular to the grain

= 0.00005 for shrinkage or swelling parallel to the grain

Example:

S = 13.75 x (25%-5%) x 0.002 = 0.55 inch

(350mm) (14mm)

6. *Mechanics method for calculation capacities for shear wall and diaphragm*

- O86-09 – Shear wall and diaphragm design strengths are given in tabular format for discrete nail size, nail spacing and sheathing thickness

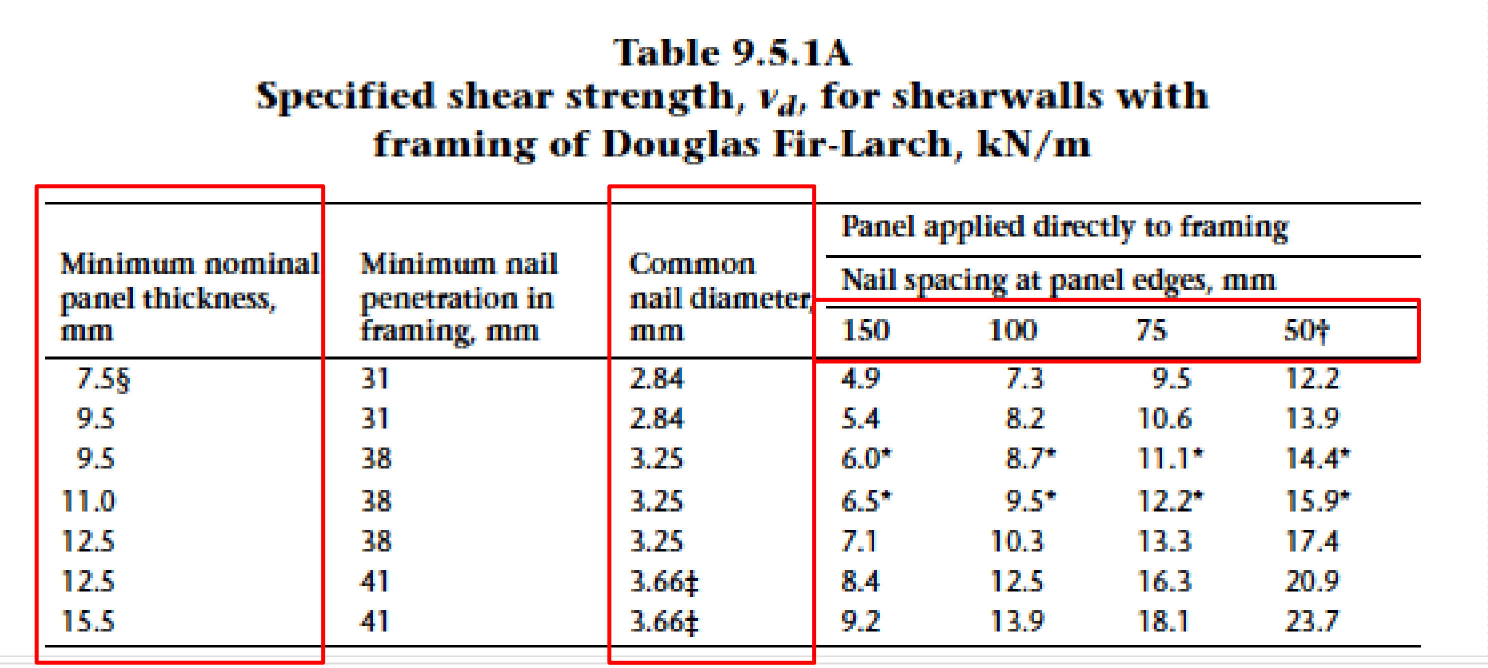
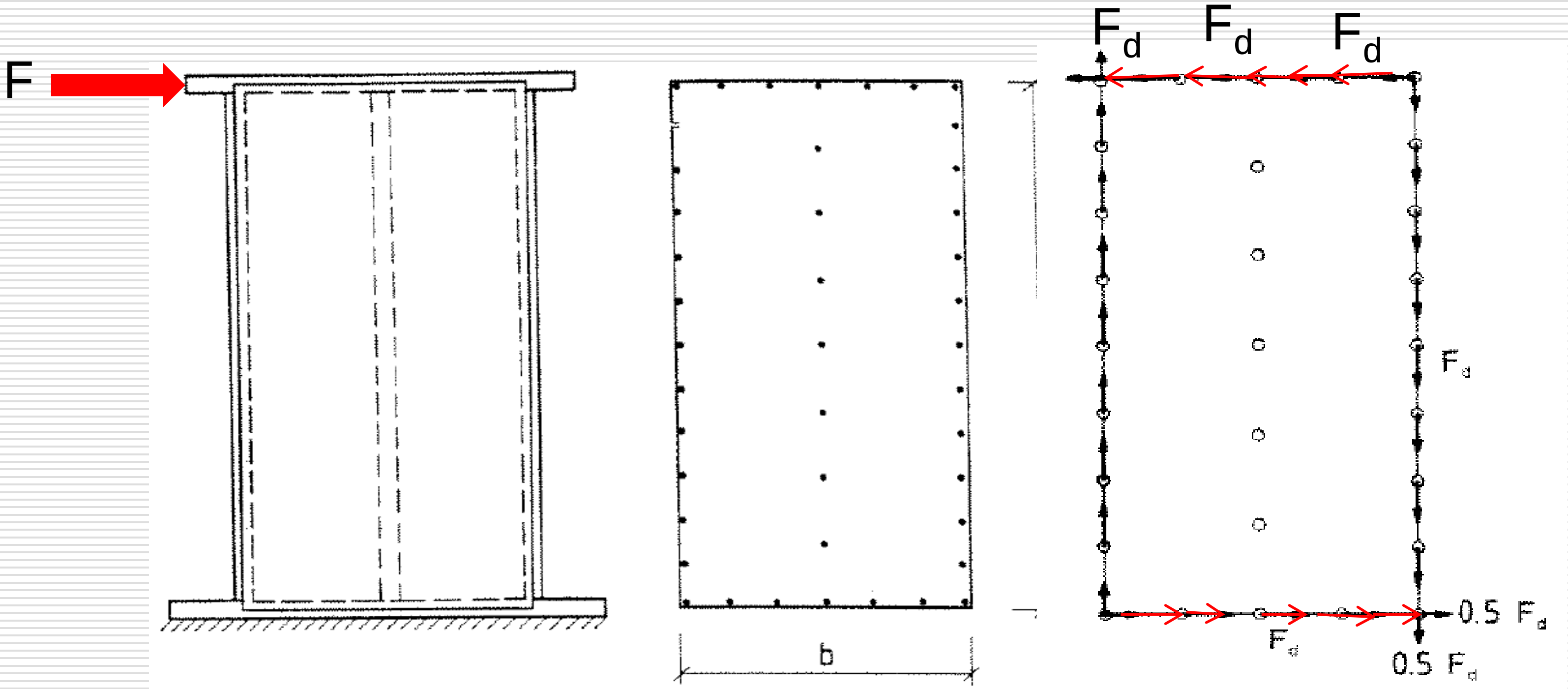


Table 9.5.1A
Specified shear strength, v_d, for shearwalls with framing of Douglas Fir-Larch, kN/m

Minimum nominal panel thickness, mm	Minimum nail penetration in framing, mm	Common nail diameter, mm	Panel applied directly to framing Nail spacing at panel edges, mm 150	 100	 75	 50†
7.5§	31	2.84	4.9	7.3	9.5	12.2
9.5	31	2.84	5.4	8.2	10.6	13.9
9.5	38	3.25	6.0*	8.7*	11.1*	14.4*
11.0	38	3.25	6.5*	9.5*	12.2*	15.9*
12.5	38	3.25	7.1	10.3	13.3	17.4
12.5	41	3.66‡	8.4	12.5	16.3	20.9
15.5	41	3.66‡	9.2	13.9	18.1	23.7

- Strengths were developed by testing

Research background



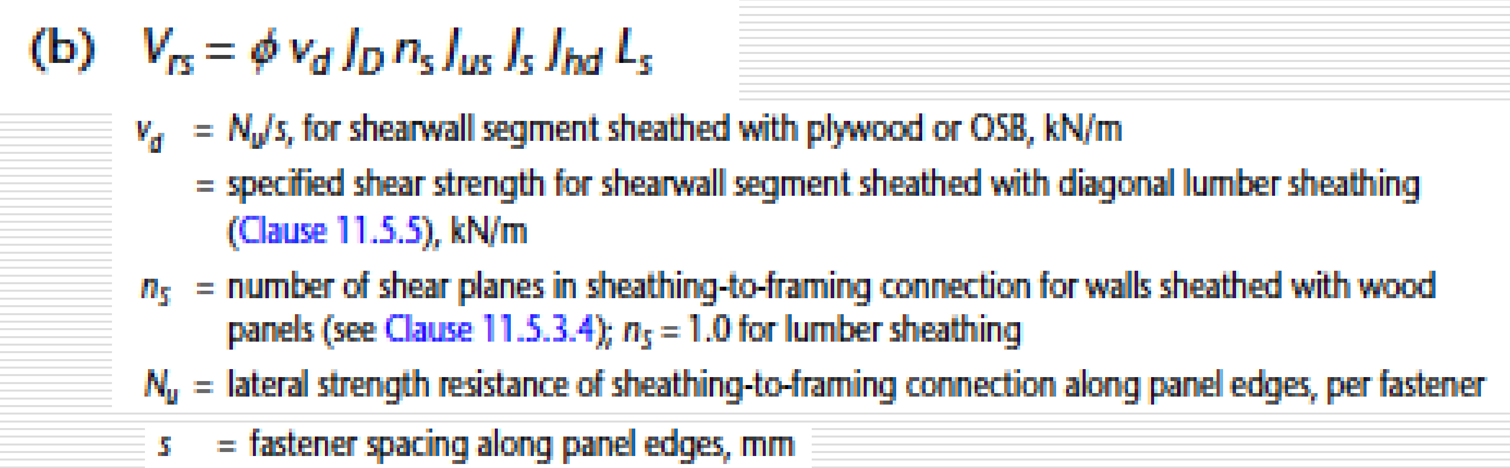
- $F \approx n \times F_d$

where n = no of fasteners along panel edges, F_d = single nail joint capacity

- Other national design standards already adopted this approach e.g. EC5, NZ, Australia

Check both fastening and panel buckling strength

- Check fastening



(b) $V_{rs} = \phi\, v_d\, J_D\, n_s\, J_{us}\, J_s\, J_{hd}\, L_s$

v_d = N_u/s, for shearwall segment sheathed with plywood or OSB, kN/m

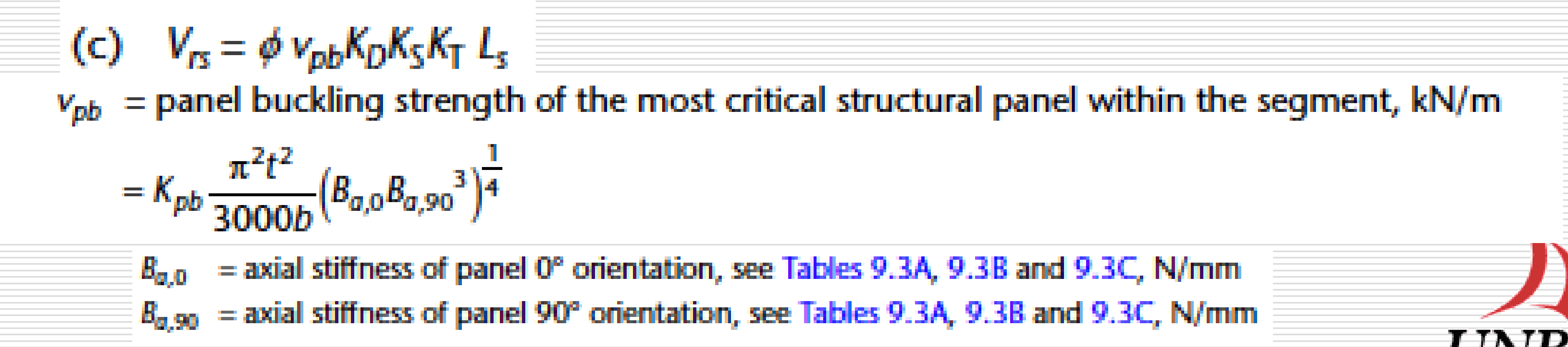
= specified shear strength for shearwall segment sheathed with diagonal lumber sheathing (Clause 11.5.5), kN/m

n_s = number of shear planes in sheathing-to-framing connection for walls sheathed with wood panels (see Clause 11.5.3.4); $n_s = 1.0$ for lumber sheathing

N_u = lateral strength resistance of sheathing-to-framing connection along panel edges, per fastener

s = fastener spacing along panel edges, mm

- Check sheathing panel buckling (for thin sheathing)



(c) $V_{rs} = \phi\, v_{pb} K_D K_S K_T\, L_s$

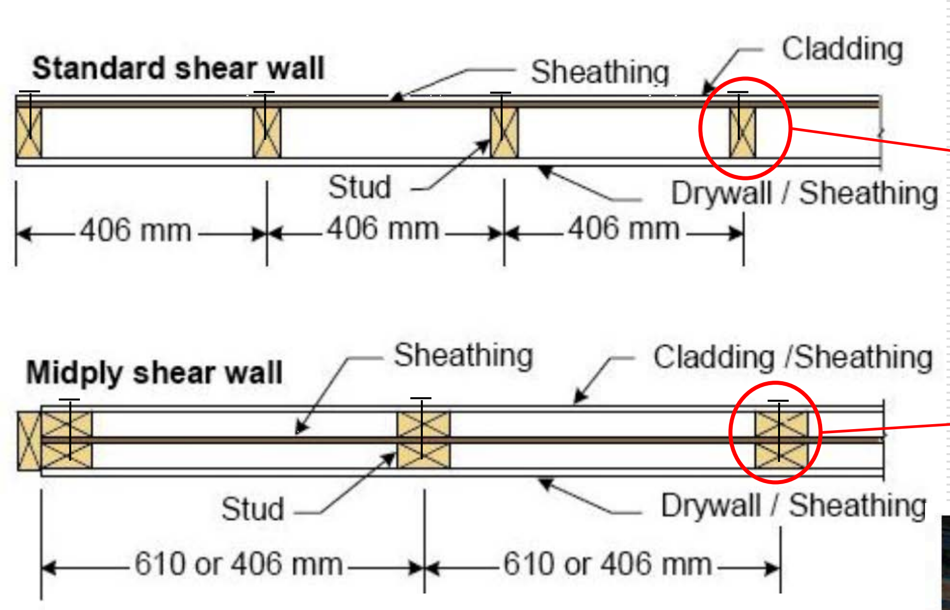
v_{pb} = panel buckling strength of the most critical structural panel within the segment, kN/m

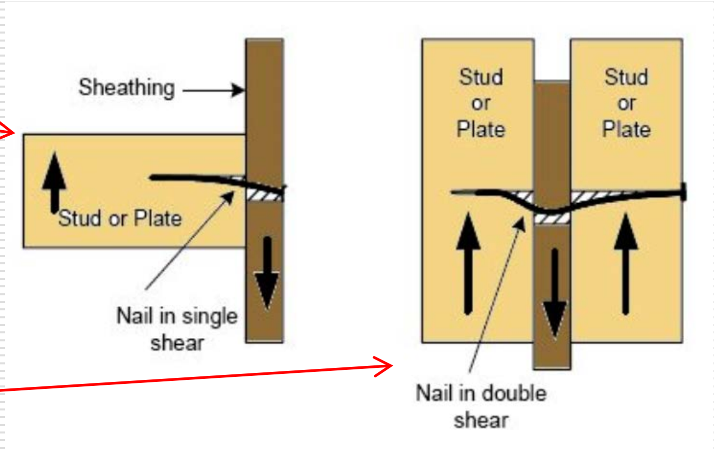
$$= K_{pb} \frac{\pi^2 t^2}{3000b} \left(B_{a,0} B_{a,90}{}^{3}\right)^{\frac{1}{4}}$$

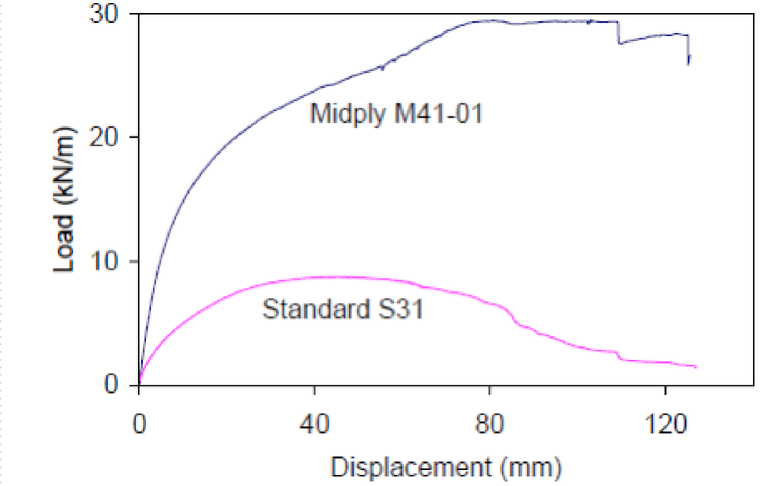
$B_{a,0}$ = axial stiffness of panel 0° orientation, see Tables 9.3A, 9.3B and 9.3C, N/mm

$B_{a,90}$ = axial stiffness of panel 90° orientation, see Tables 9.3A, 9.3B and 9.3C, N/mm

Mid-ply shear wall

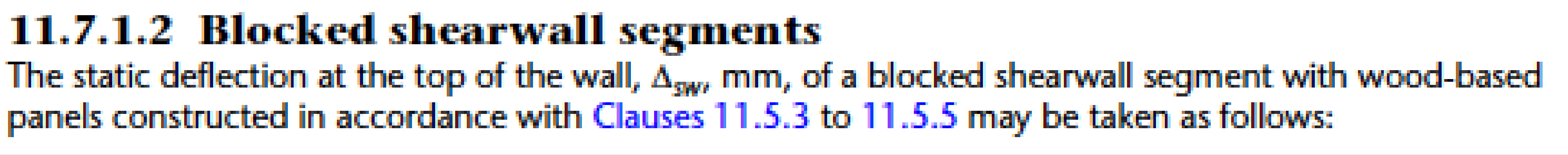






7. Deflection in mid-rise buildings (6 storeys)

- Deflection of a single shear wall



11.7.1.2 Blocked shearwall segments

The static deflection at the top of the wall, Δ_{sw}, mm, of a blocked shearwall segment with wood-based panels constructed in accordance with Clauses 11.5.3 to 11.5.5 may be taken as follows:

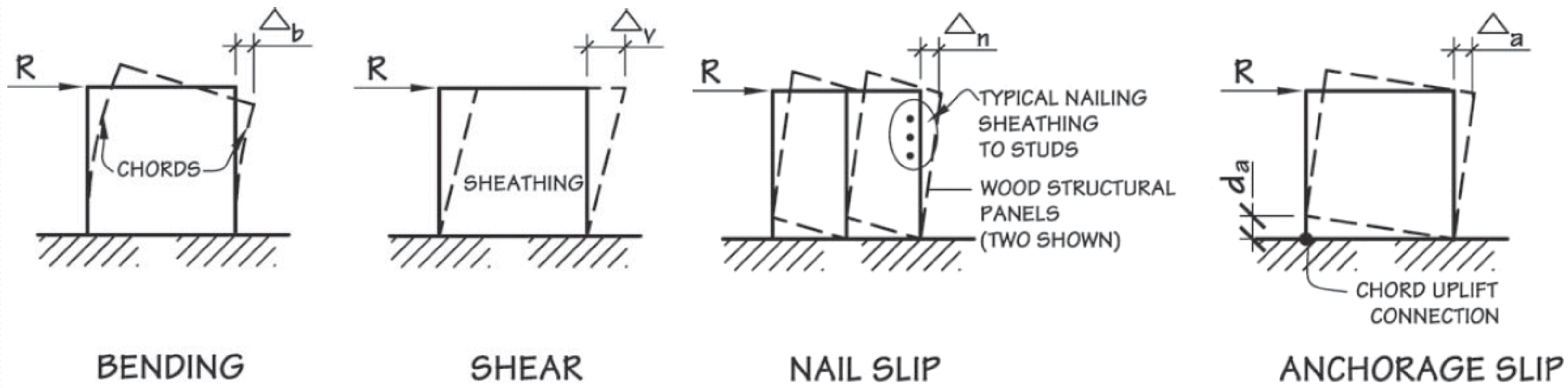
$$\Delta_{sw} = \frac{2vH_s^3}{3EAL_s} + \frac{vH_s}{B_v} + 0.0025H_s e_n + \frac{H_s}{L_s} d_a$$

Stud bending

Panel shear

Nail slip

Hold-down uplift



O86-14 Annex A

Rotation at lower storeys affects total deflection at an upper storey

A.11.7.1 Deflection of shearwalls in multi-store

(a) Deflection of blocked shearwall segments

The interstorey drift at the *i*-th level, mm, may be taken as follows:

$$\Delta_i^{storey} = \Delta_{b,i}^{storey} + \Delta_{s,i}^{storey} + \Delta_{n,i}^{storey} + \Delta_{hd,i}^{storey}$$

Stud bending

Sheathing panel

Fastener slip

Hold-down uplift

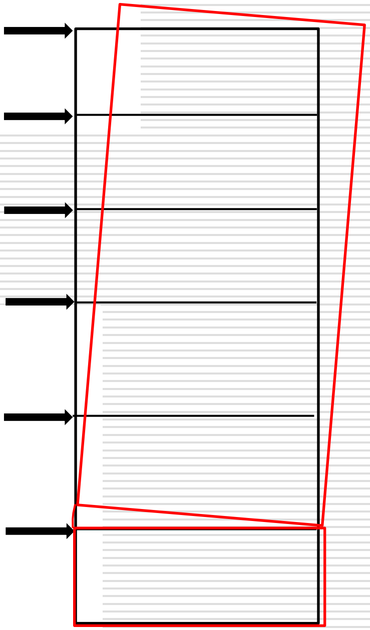
And the total deflection at the *i*-th level, mm, may be taken as follows:

$$\Delta_i^{total} = \Delta_{b,i}^{total} + \Delta_{s,i}^{total} + \Delta_{n,i}^{total} + \Delta_{hd,i}^{total}$$

where

Δ_i^{storey} = interstorey drift at the *i*-th storey

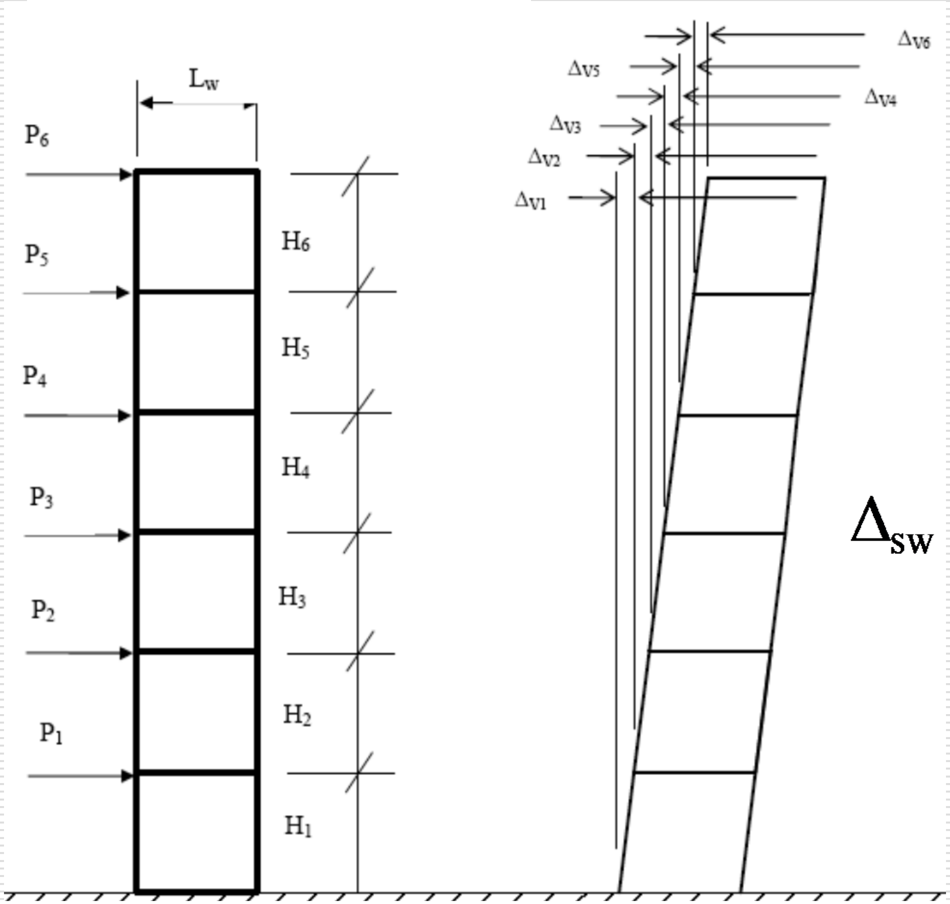
Δ_i^{total} = total deflection at the *i*-th storey



Stacked shear wall panels

Multi-storey effect

- Total deflection at an upper storey due to shear in panels and fastener slip is a simple summation of interstorey deflection



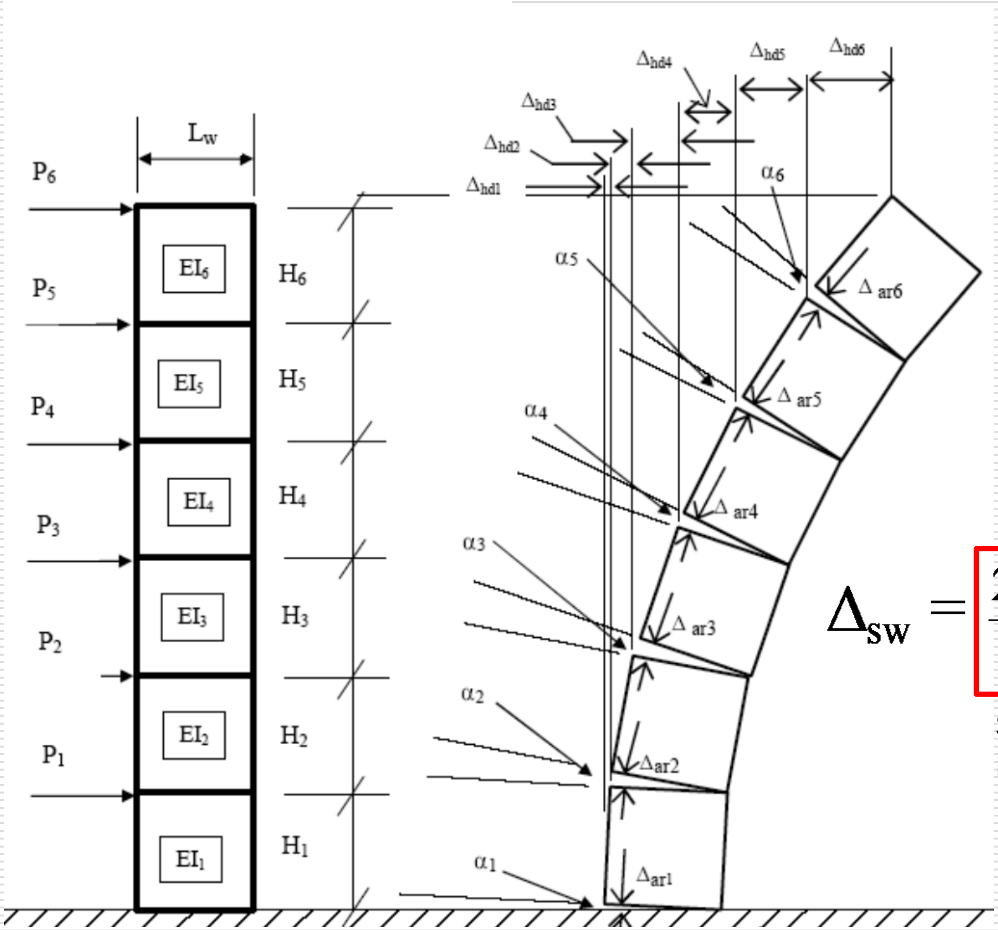
$$\Delta_{sw} = \frac{2vH_s^3}{3EAL_s} + \boxed{\frac{vH_s}{B_v}} + \boxed{0.0025H_s e_n} + \frac{H_s}{L_s} d_a$$

Sheathing panel

Fastener slip

Multi-storey effect

- For bending deflection and deflection due to hold-down slip, the rotation of wall panels needs to be considered



$$\Delta_{sw} = \boxed{\frac{2vH_s^3}{3EAL_s}} + \frac{vH_s}{B_v} + 0.0025H_s e_n + \boxed{\frac{H_s}{L_s} d_a}$$

Stud bending

Hold-down uplift

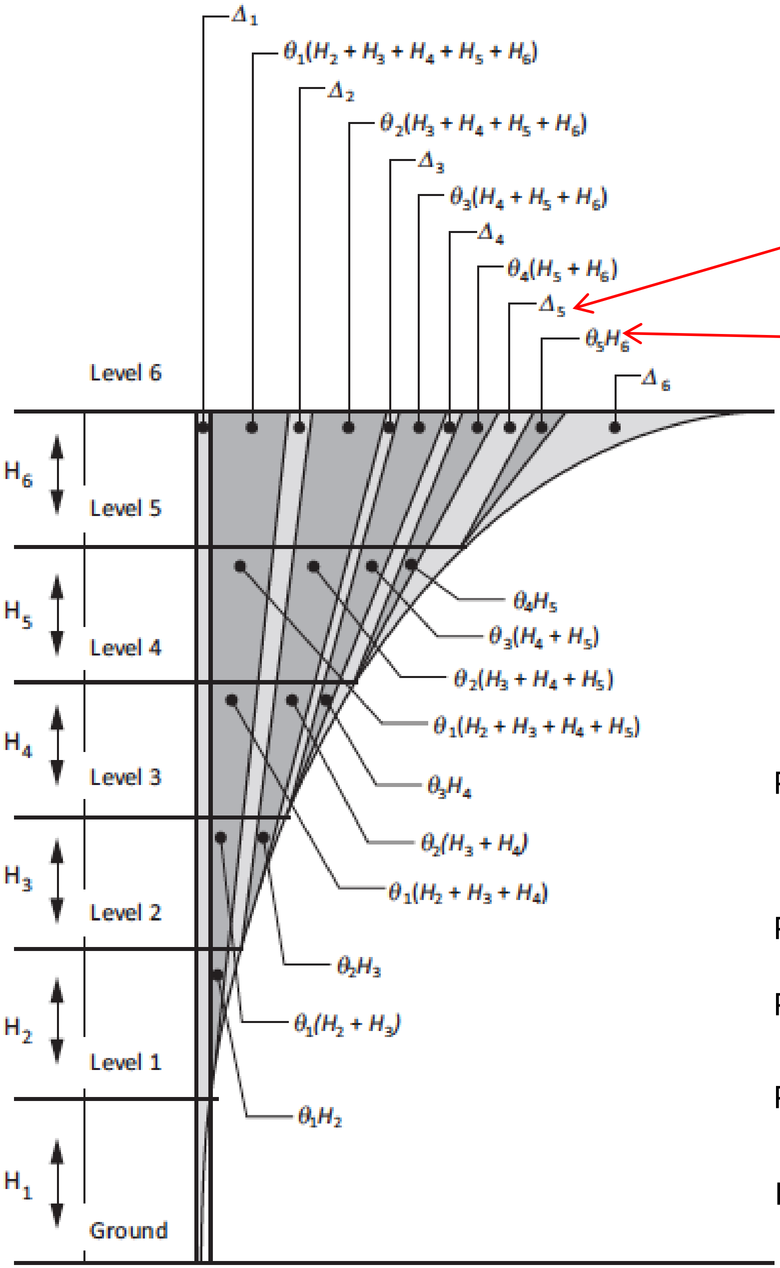


Figure A.11.7.1C
Deflection due to bending

$$\Delta_{b,i} = \frac{M_{i+1}H_i^{\,2}}{2(EI)_i} + \frac{V_i H_i^{\,3}}{3(EI)_i}$$

$$\theta_i = \frac{M_{i+1}H_i}{(EI)_i} + \frac{V_i H_i^{\,2}}{2(EI)_i}$$

M_i = overturning moment

V_i = shear force in shear wall

$(EI)_i$ = bending stiffness of boundary member

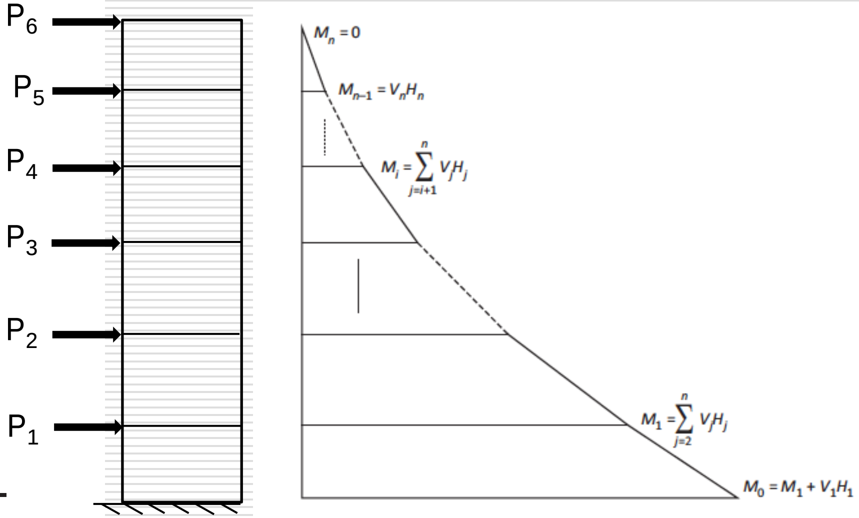
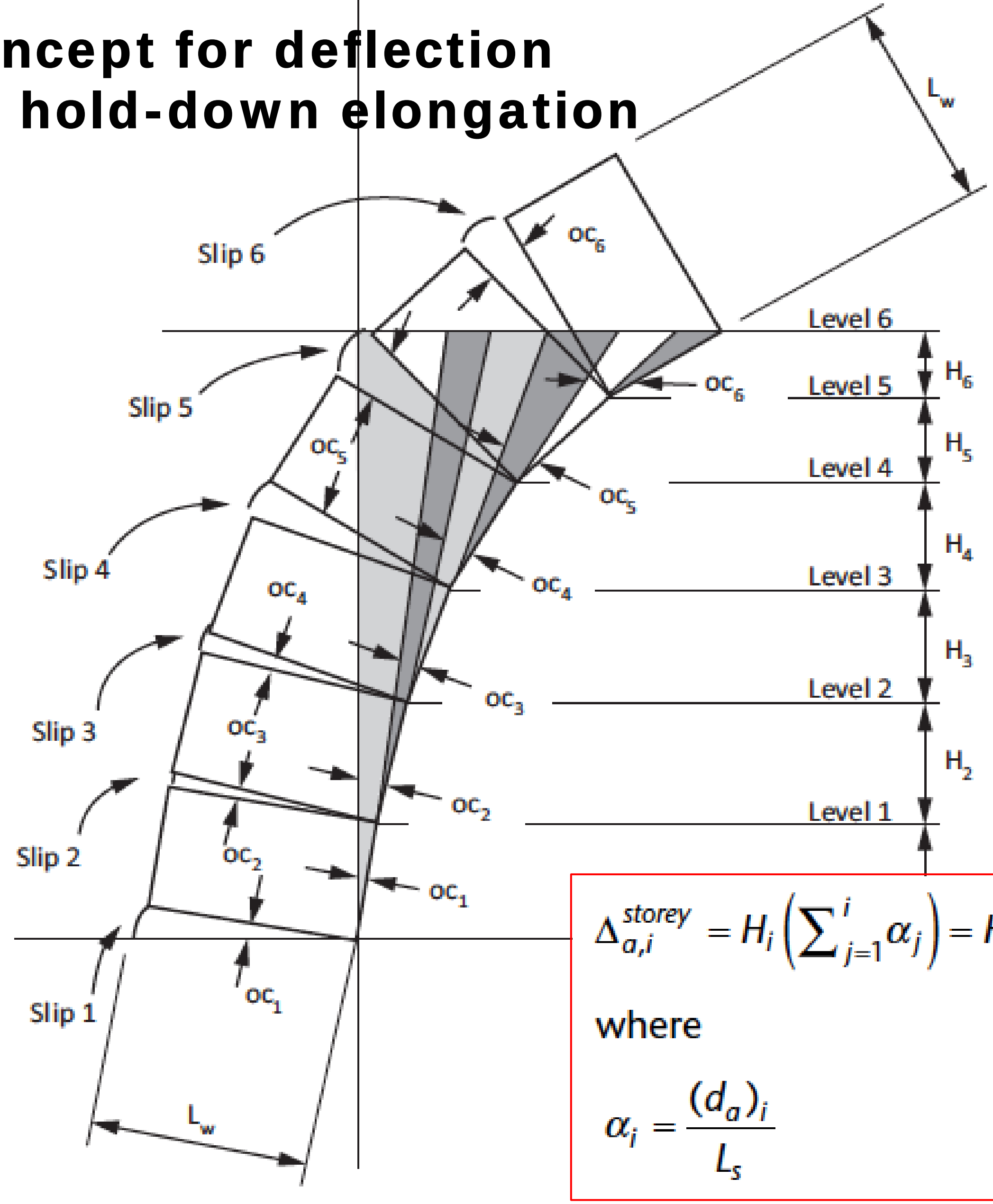


Figure A.11.7.1B
Moment diagram

Similar concept for deflection caused by hold-down elongation



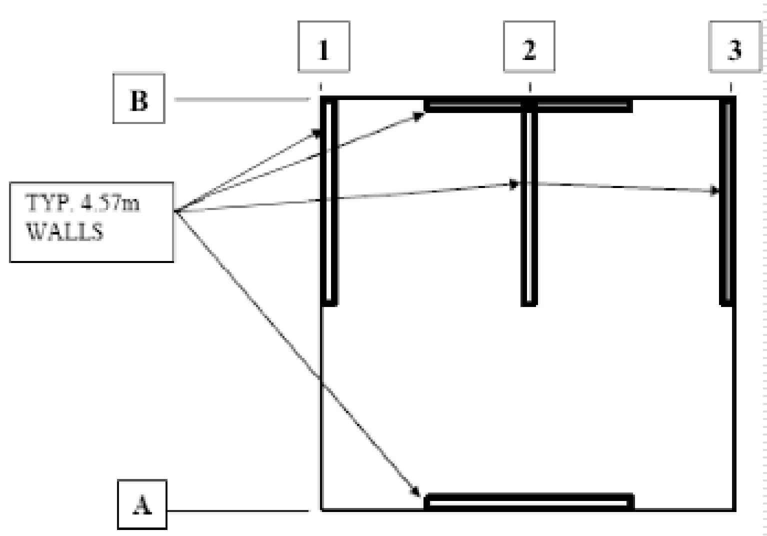
$$\Delta_{a,i}^{storey} = H_i\left(\sum_{j=1}^{i}\alpha_j\right) = H_i\alpha_i + H_i\left(\sum_{j=1}^{i-1}\alpha_j\right)$$

where

$$\alpha_i = \frac{(d_a)_i}{L_s}$$

Figure A.11.7.1E
Deflection due to vertical elongation of the wall anchorage system

Impact of change



Building data

Size : 9.14m x 9.14m

Storey height : 3m

Location: Vancouver

Table 4: **Drift comparison**

3 6.54

Impact can be significant (≈ 50% more)

6. Fire resistance of large cross-section timber members

Light framing – faster burn-through

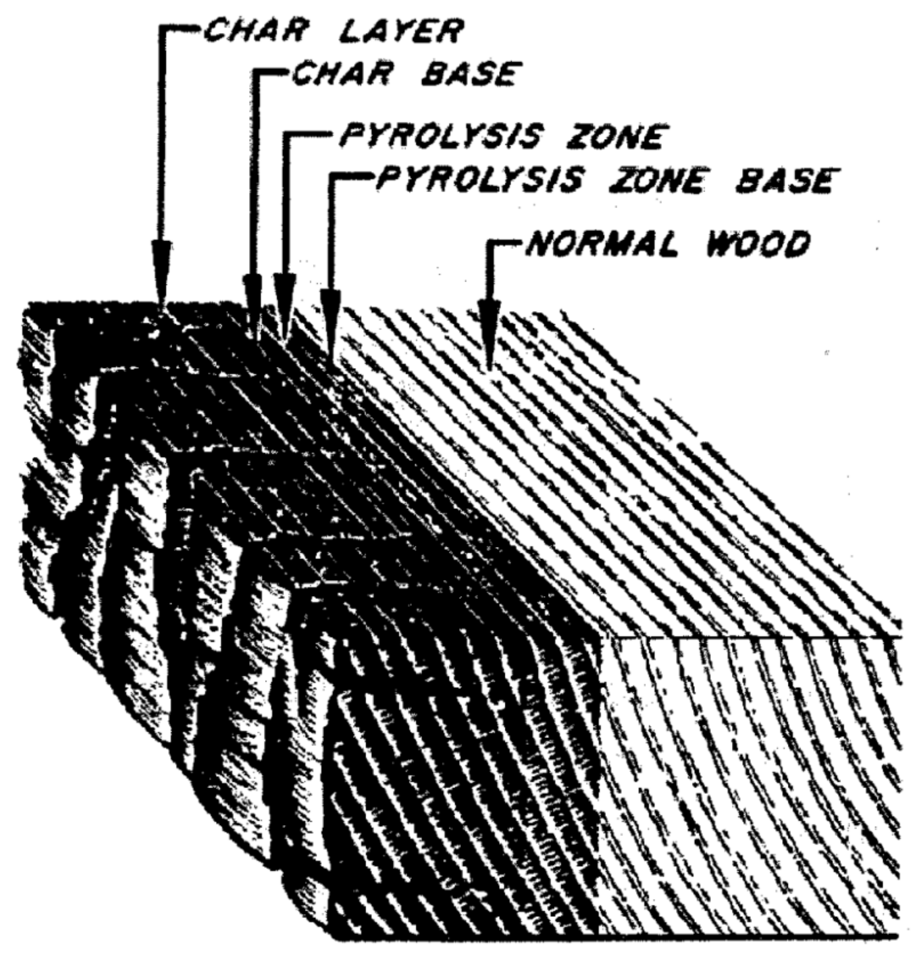
Massive timber – slower or no burn-through

Heavy timber retains structural integrity during fire

2x6 nail-laminated

Response of wood to Fire

- Although wood burns at about 220° C, it has the natural ability to form a protective layer on the surface that slows down burning



Source : FPInnovations.

Fire Resistance Test – CLT floor

Source : FPInnovations.

Scope of Annex B

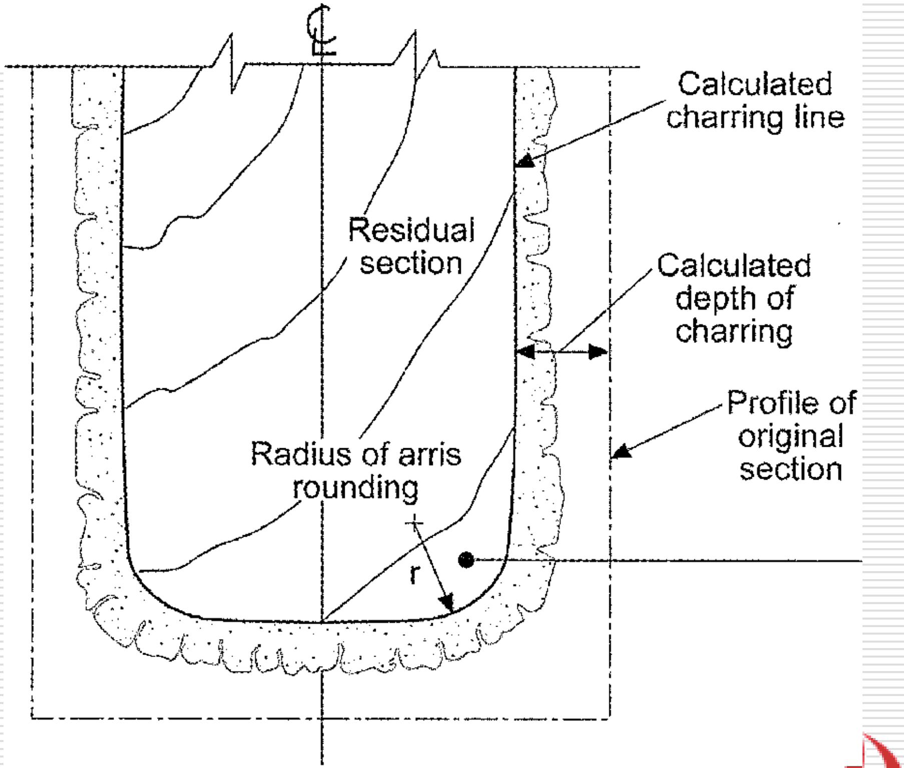
- FRR of a building assembly is traditionally evaluated by testing to CAN/ULC-S101' Standard methods of fire endurance tests of building construction and materials'
- Annex B provides an engineering approach to predict FRR of wood elements exposed to the standard test, CAN/ULC-S101

New Annex B – Charring method

Annex B (informative)

Fire resistance of large cross-section wood elements

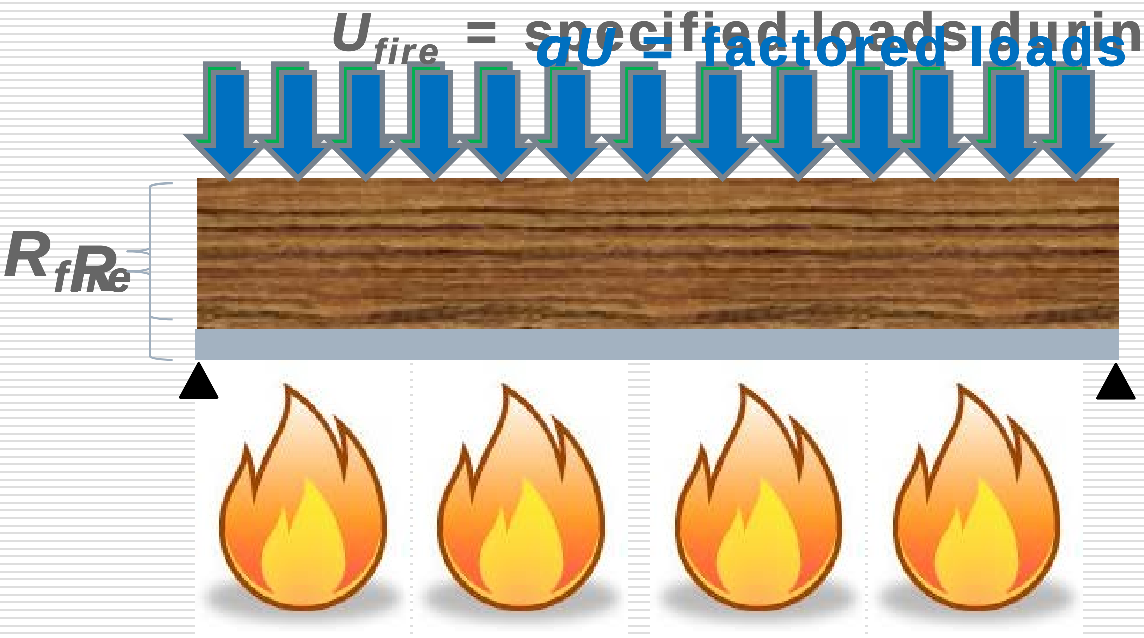
- Fire performance of heavy timber member can be easily calculated since charring rate of wood is fairly constant ≈ 0.7mm/min



Structural design for Fire

$$U_{fire} \leq \Phi_f R_{fire} \tag{1}$$

where U_{fire} = the design action from the applied load at the time of the fire; (Unfactored)
Φ_{fire} = the strength reduction factor for the timber material; and (=1)
R_{fire} = the nominal load capacity at the time of the fire, accounting for charring of wood members (mean strength)

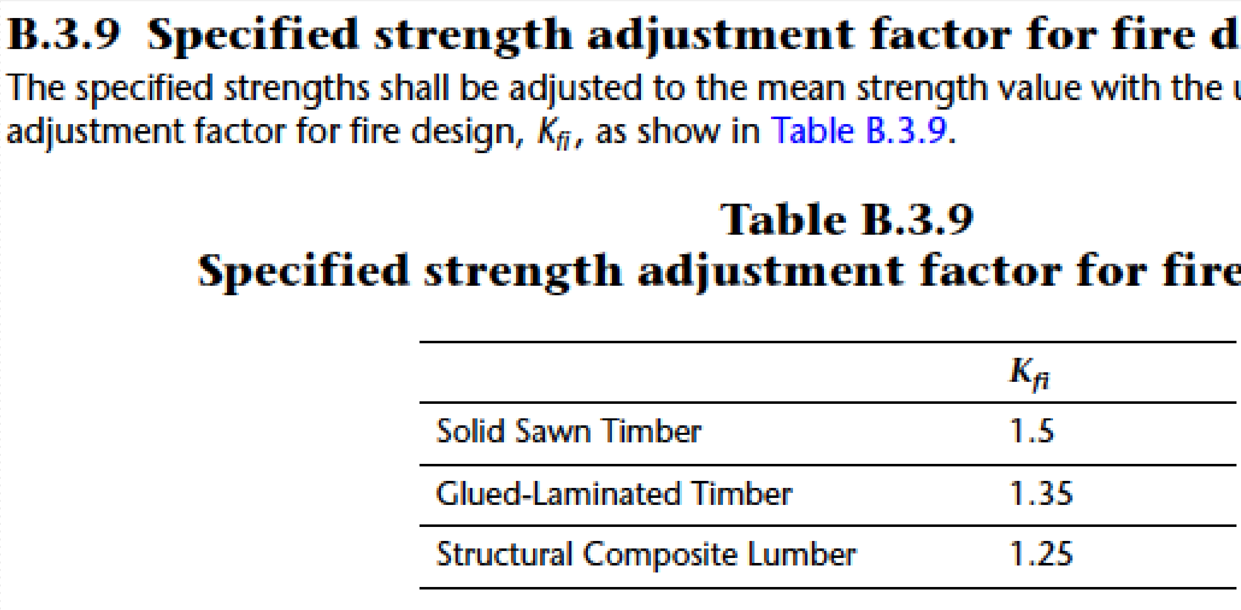


$\alpha U \leq \phi R$

Source:GHL Consultants

Scope of new Annex B

- Materials covered: sawn timber, glulam and Structural composite lumber (SCL)

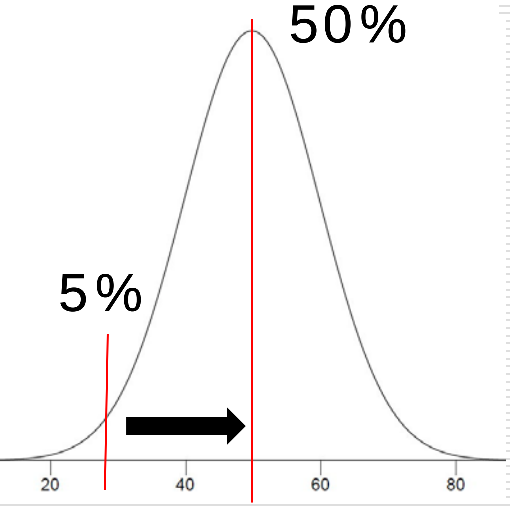


B.3.9 Specified strength adjustment factor for fire design, K_{fi}

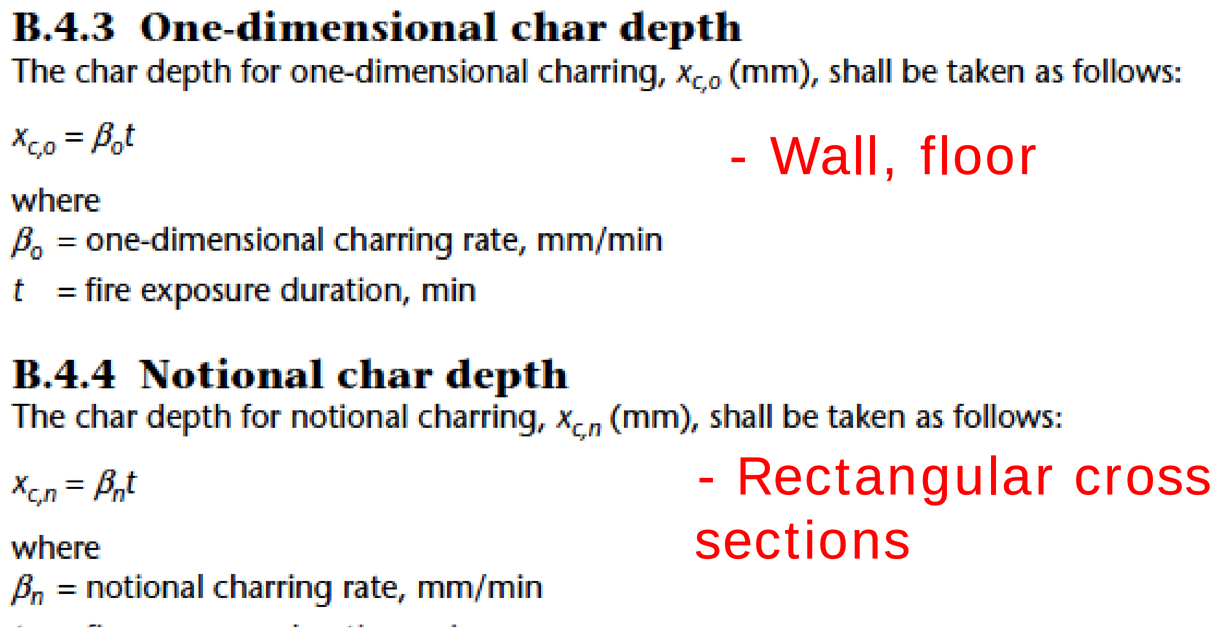
The specified strengths shall be adjusted to the mean strength value with the use of the specified strength adjustment factor for fire design, K_{fi}, as show in Table B.3.9.

Table B.3.9
Specified strength adjustment factor for fire design, K_{fi}

	K_{fi}
Solid Sawn Timber	1.5
Glued-Laminated Timber	1.35
Structural Composite Lumber	1.25



Charring rates for various materials



B.4.3 One-dimensional char depth

The char depth for one-dimensional charring, $x_{c,o}$ (mm), shall be taken as follows:

$x_{c,o} = \beta_o t$

- Wall, floor

where

β_o = one-dimensional charring rate, mm/min

t = fire exposure duration, min

B.4.4 Notional char depth

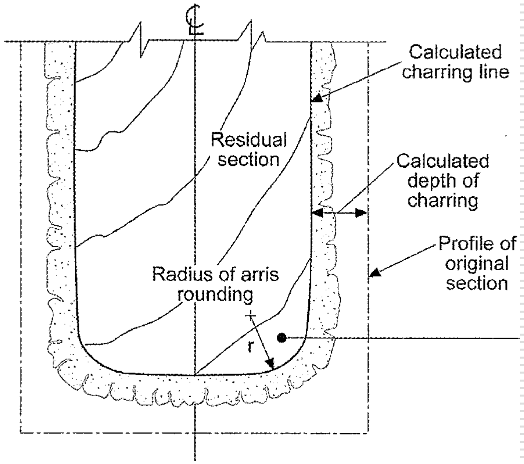
The char depth for notional charring, $x_{c,n}$ (mm), shall be taken as follows:

$x_{c,n} = \beta_n t$

- Rectangular cross sections

where

β_n = notional charring rate, mm/min



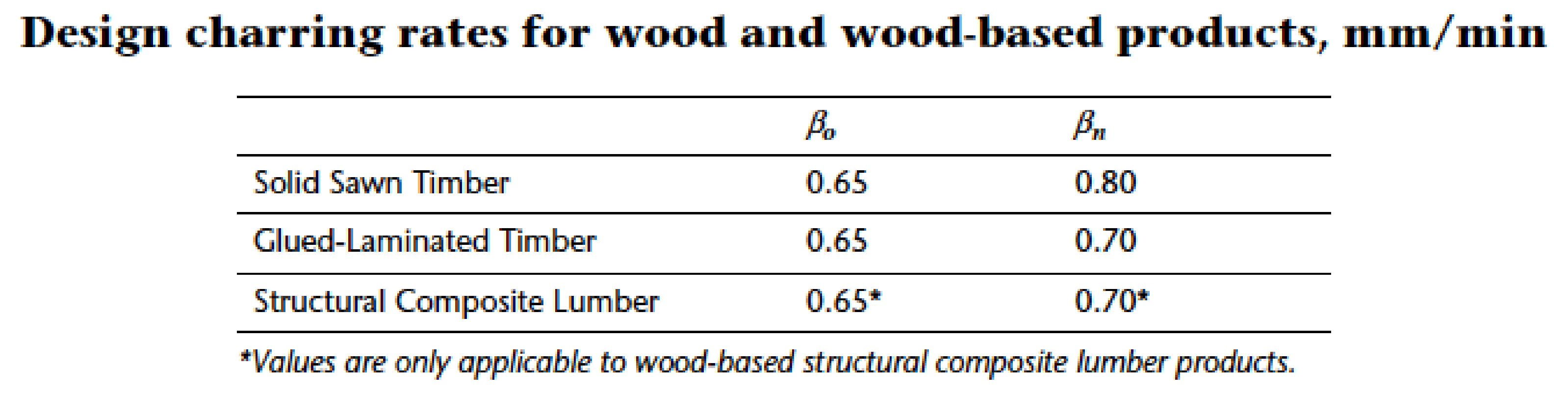
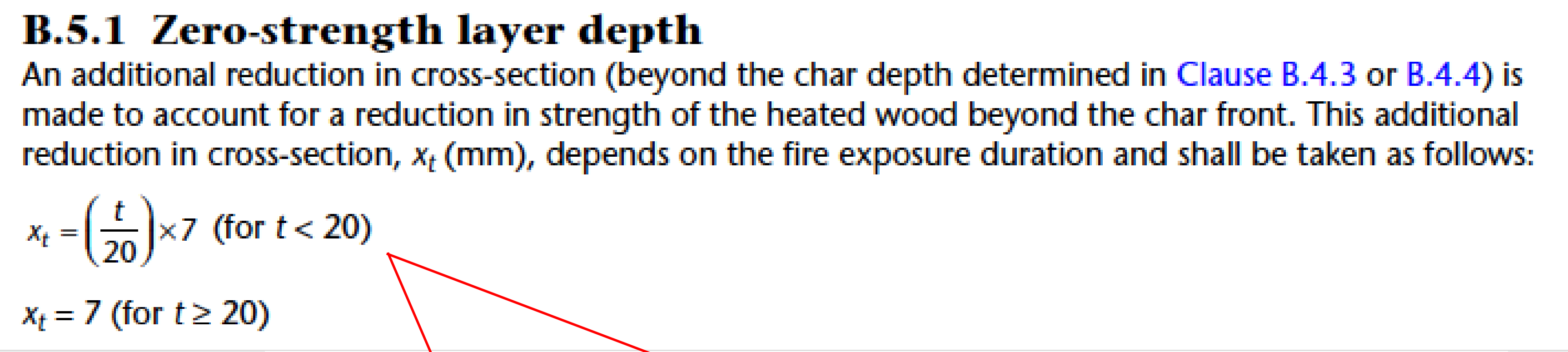


Table B.4.2
Design charring rates for wood and wood-based products, mm/min

	β_o	β_n
Solid Sawn Timber	0.65	0.80
Glued-Laminated Timber	0.65	0.70
Structural Composite Lumber	0.65*	0.70*

**Values are only applicable to wood-based structural composite lumber products.*

Heated layer – assumed zero strength

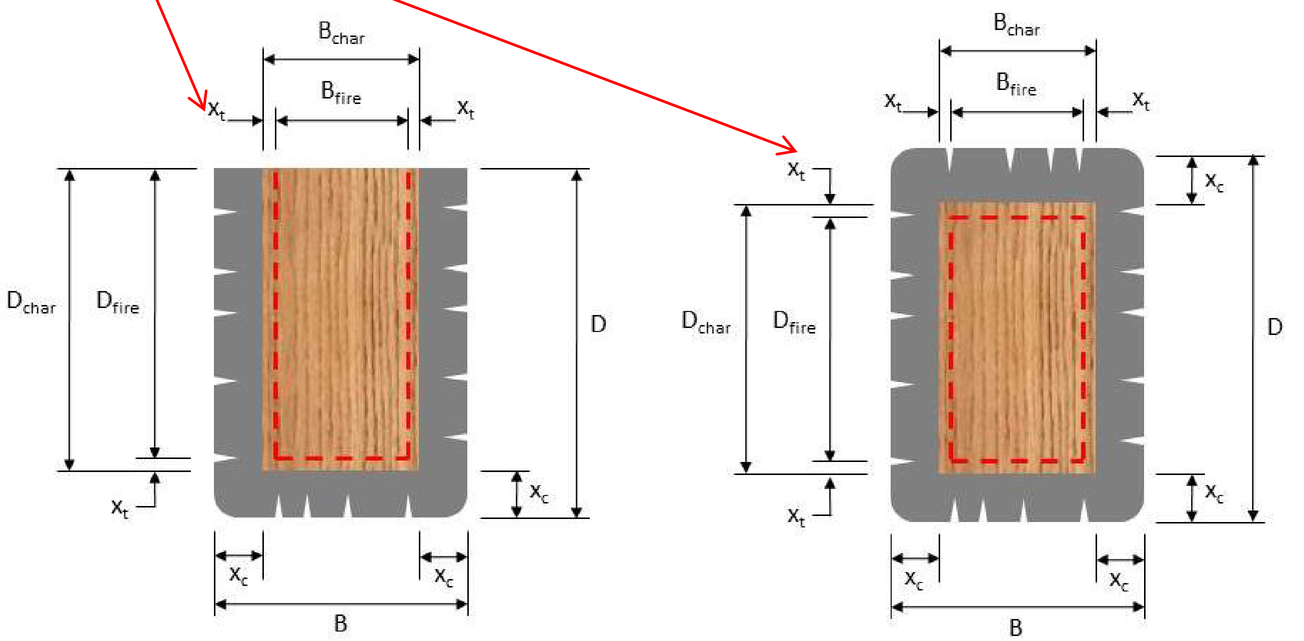


B.5.1 Zero-strength layer depth

An additional reduction in cross-section (beyond the char depth determined in Clause B.4.3 or B.4.4) is made to account for a reduction in strength of the heated wood beyond the char front. This additional reduction in cross-section, x_t (mm), depends on the fire exposure duration and shall be taken as follows:

$$x_t = \left(\frac{t}{20}\right) \times 7 \quad (\text{for } t < 20)$$

$$x_t = 7 \quad (\text{for } t \geq 20)$$



Source : FPInnovations

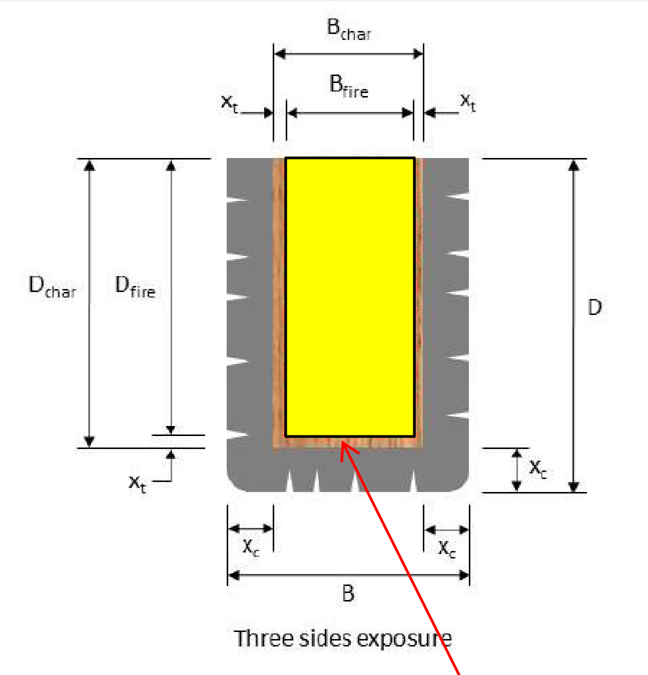
Three sides exposure

Four sides exposure

Example – bending resistance of glulam

1. Assume a fire resistance rating (t in min)

2. Calculate the char depth around the member



Three sides exposure

3. Calculate the zero strength layers and effective residual cross section, S_{res}

Example – bending resistance of glulam

4. Calculate the moment resistance of the residual cross section, $F_{b,fi}\ S_{res}$

$$\boxed{F_{b,fi} = f_b \bullet K_{fi} \bullet K_D \bullet K_H \bullet K_{Sb} \bullet K_T}$$

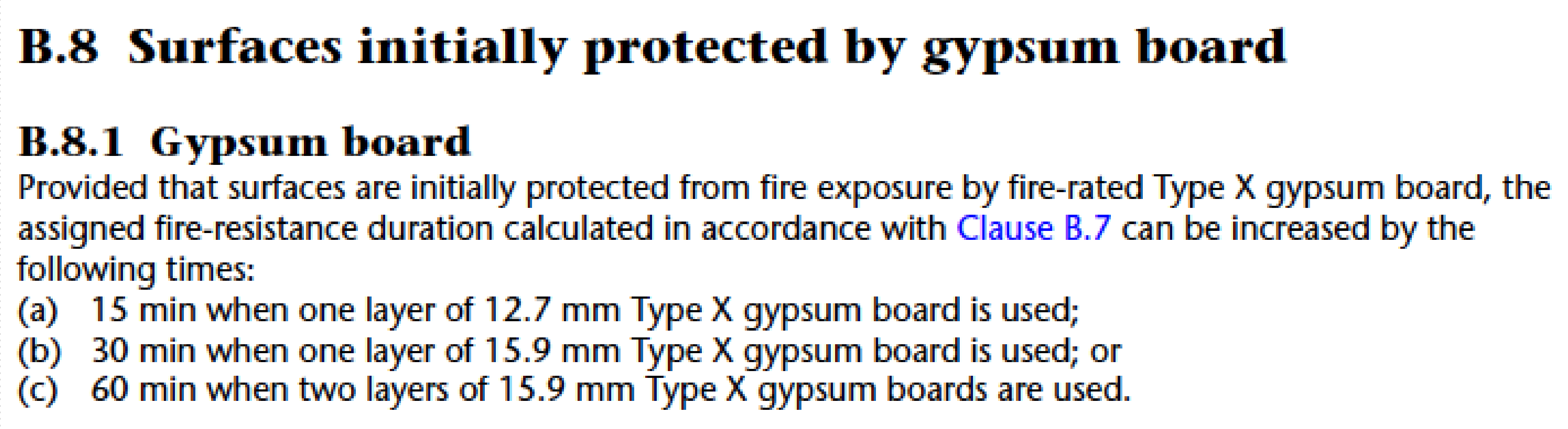
where K_{fi} =factor to convert from 5th percentile to median strength (1.35 for glulam)

5. Calculate the load effect using unfactored load

$$\boxed{\text{Design load effect} = 1.0D + 1.0L}$$

6. If Design load effect > $F_{b,fi}$, revise time t and recalculate until resistance > load effect

Contribution of gypsum board



B.8 Surfaces initially protected by gypsum board

B.8.1 Gypsum board

Provided that surfaces are initially protected from fire exposure by fire-rated Type X gypsum board, the assigned fire-resistance duration calculated in accordance with Clause B.7 can be increased by the following times:

(a) 15 min when one layer of 12.7 mm Type X gypsum board is used;
(b) 30 min when one layer of 15.9 mm Type X gypsum board is used; or
(c) 60 min when two layers of 15.9 mm Type X gypsum boards are used.

Gypsum Board Members	Fire Resistance Rating
One layer of 12.7mm (½ in) GWB	15min
One layer of 15.9mm (⅝ in) GWB	30min
Two layers of 12.7mm (½ in) GWB	40min
Two layers of 15.9mm (⅝ in) GWB	60min
Three layers of 15.9mm (⅝ in) GWB	90min
Four layers of 15.9mm (⅝ in) GWB	120min

Mid- to high-rise wood buildings around the world

7-storey, Växjö, Sweden (2008)

9-storey, London (2009)

10-storey, Melbourne (2012)

Mid- to high-rise wood buildings around the world

14-storey, Bergen, Norway (2014-15)

https://www.youtube.com/watch?feature=player_detailpage&v=e5XsqauBCX4

ARCHITECTURE

PROPOSED 18-STOREY UBC WOODEN TOWER TO BE TALLEST OF ITS KIND IN THE WORLD

BY KENNETH CHAN | 3:14 PM PST, TUE SEPTEMBER 30, 2014 | SPEAK UP

2.8K SHAR

Thank you

Email contact :
yhc@unb.ca