6-Storey Residential Buildings
Combustible Construction

A Regulator's Perspective

City of Richmond, BC Canada

Richmond

Remy mid-rise Project

5388 Cambie Street, Richmond BC

Our first…learning curve

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It’s Allowed by building code

* We view 5 and 6 storey, combustible residential construction as an approved building typology
* Its techniques and required procedures are evolutionary as opposed to revolutionary as compared to 4 storey wood frame structures
* Recognition for 5 and 6-storey combustible Group C buildings was added in an April 2009 amendment under 3.2.2.45 to the 2006 BCBC
* 6-storey combustible Group C is now under 3.2.2.50 of the 2012 BCBC

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Conditions set out in Code

* Maximum combined floor area of 7200 m^2 as per 4 storey wood frame structures
* Maximum height of less than 18m between grade and floor of top storey
* Building has to be sprinklered to NFPA 13 not NFPA 13R
* 1 h FRR for floors (with some exceptions) and mezzanines. Structure to have same FRR as supported assembly
* Sprinklered roof attic spaces
* Concealed combustible spaces not permitted

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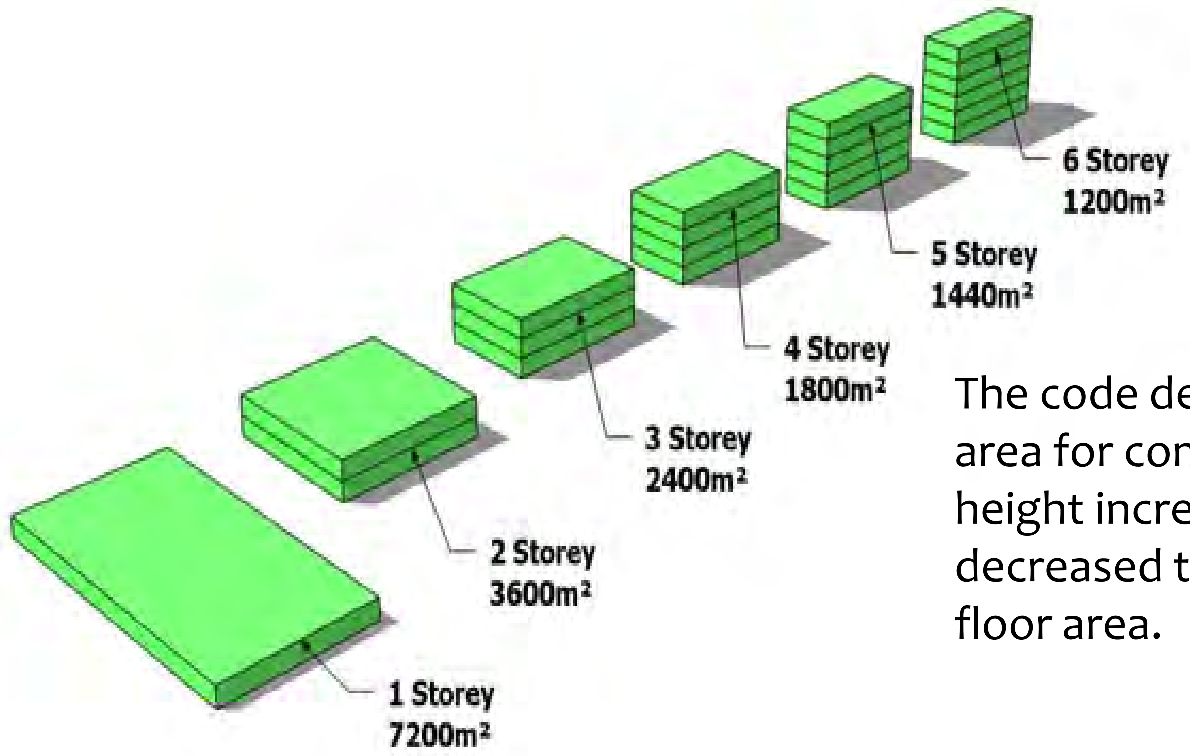
Interaction of Height and Area



The code defines the permissible floor area for combustible construction. As height increases, the building area is decreased to maintain the overall floor area.

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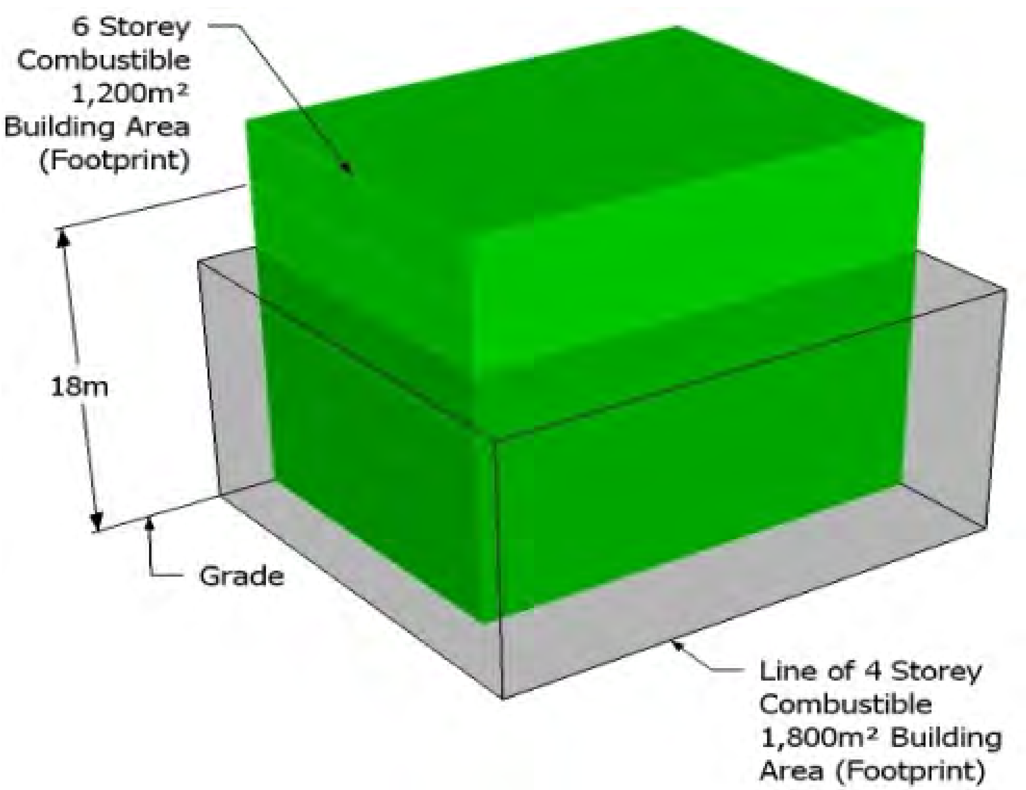
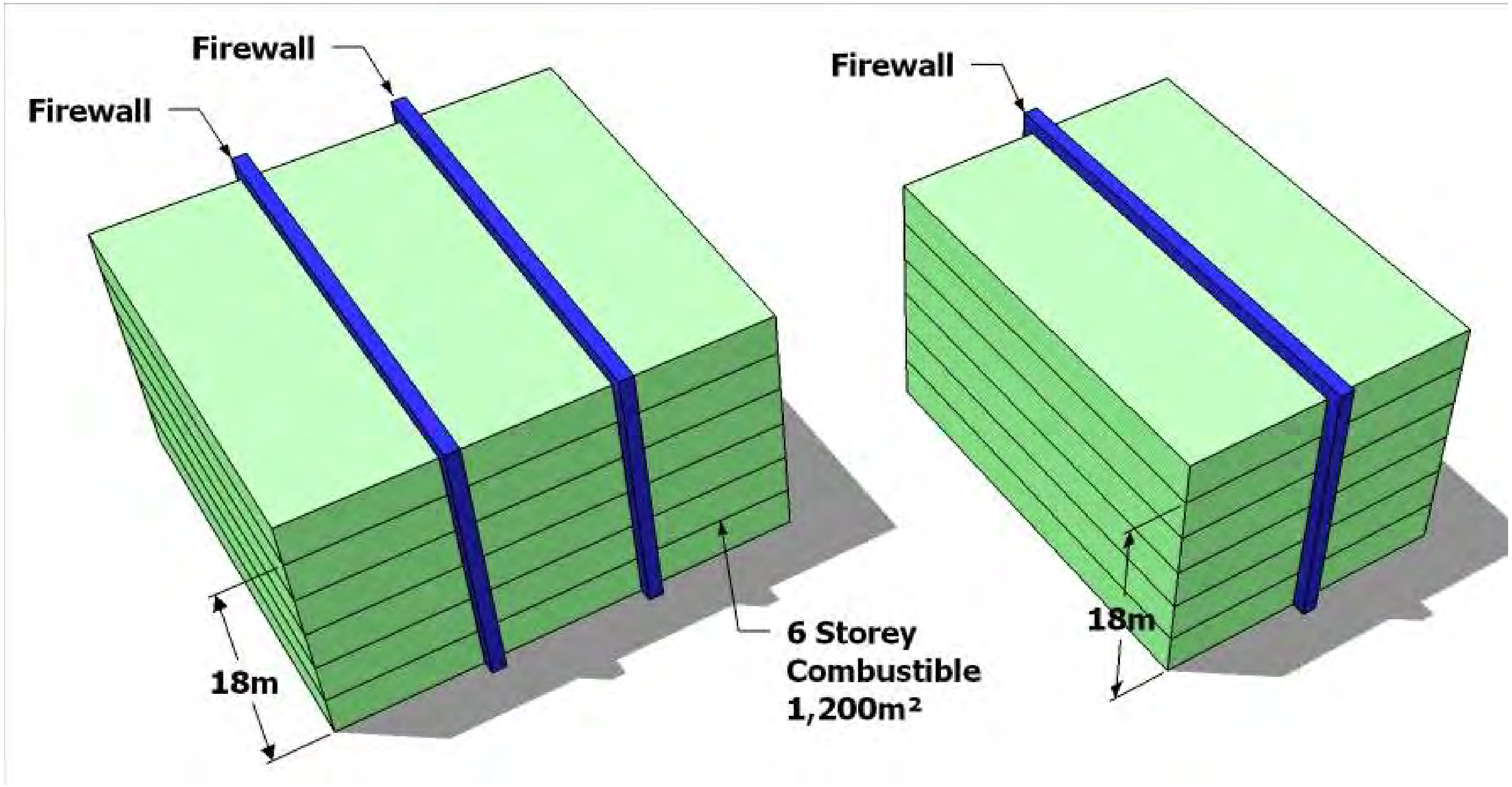
What does this mean?



Provision# 2 – Building Area Sub-Clauses 3.2.2.45.(1)(D)(V) & (VI)

* This code change for building area defines the total permissible building area for each floor of a five and six-storey wood-frame building (1440m² if 5 *storeys* or 1 200 m² if 6 *storeys* in *building height).*

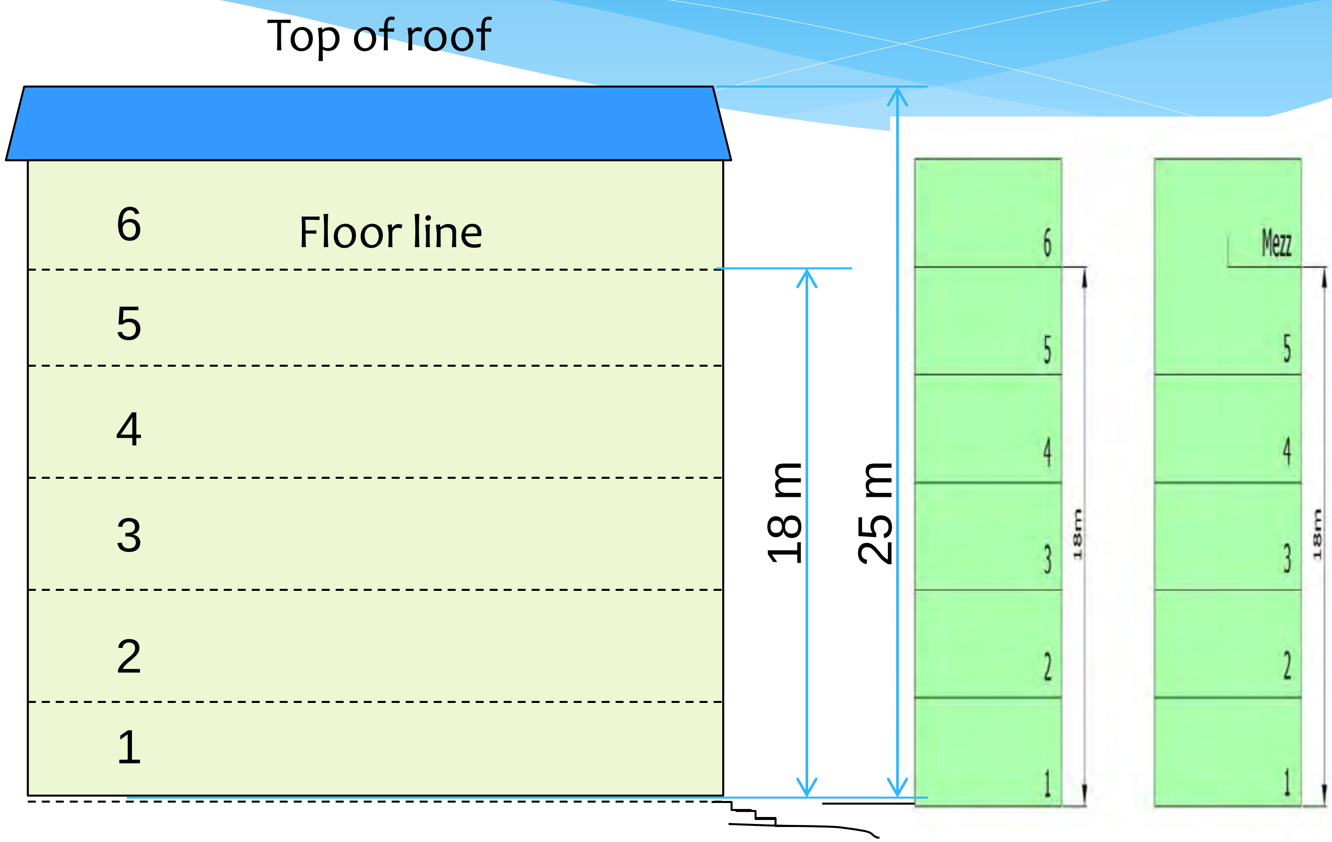
Firewalls allow the density



Height is the thing…

- If height ≤ 25 m, combustible roof construction and roof covering

- If height > 25 m, noncombustible or FRTW roof construction and noncombustible roof covering



Code Conditions, continued…

* Exterior wall assembly to be
  * Protected by non-combustible cladding

    or

    * Protected by fire-retardant-treated wood cladding **or**
  * Have an interior surface protected by a thermal barrier (i.e. Gypsum, lath and plaster, masonry) limiting flame spread to 5m above an opening and maximum heat flux of 35kW/m² at 3.5 m above that opening

More to Consider…

* Overall technical risk of 6-storey combustible is not likely to be greater than 4-storey combustible, based on GHL Stage 3 Report – Technical and Process Risks in 5 and 6 Storey Wood-Frame Buildings of Residential Occupancy
* But there are considerations at the construction site where design, materials and process meet…
* Design and Construction criteria are very much different from 4 storey wood frame buildings

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To be considerate, cont.

* Structural Design Considerations interact with other functions such as energy/insulation and sound attenuation. Careful design and site reports required.
* Wood frame panels are often built offsite in order to minimize moisture absorption addressing requirement to keep wood dry
* Ends of cut wood members typically painted with fire retardant. Fasteners to be compatible with fire retardant paint
* Important to have registered professionals and constructors familiar with the design concepts
* Fire resistance and stopping become even more critical

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Lots going on with these buildings… they are very different from 3 and 4 storey wood frame construction

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Designs tend to be complex

Challenges

* 6-storey structures have higher lateral seismic forces and wind forces compared to 4-storey.
  * Richmond requires the Registered Professional to have a Structural Eng. designation.
* Larger impact from seasonal expansion/contraction of building components
* More rigorous requirements for construction/structural details, especially at interface of different structural materials
* Fire stopping details and use of alternate solutions become critical

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Design Complexity

* There is design complexity that translates to construction techniques and assemblies that require a learning curve for constructors and building inspectors alike
* Inspections generally take longer in order to verify the translation of equivalencies and design complexities on site
* Increased administrative load with verification of field reports, certificates, testing data, installation requirements, and professional reviews
* Generally, proposed designs involve some alternate solutions such as for fire wall design

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Case in point…

Our fearless
building inspector!

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Complexity derives from integration of multiple structural and building systems and their interfaces

* Integration of multiple material systems with the primary wood vertical and lateral structural construction

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And of course there’s a lot of wood

- Corridor and demising walls are shear panel walls

- Close Stud Spacing typical at lower floors

- Abundance of back framing

- Solid Wood built up timber sections within walls

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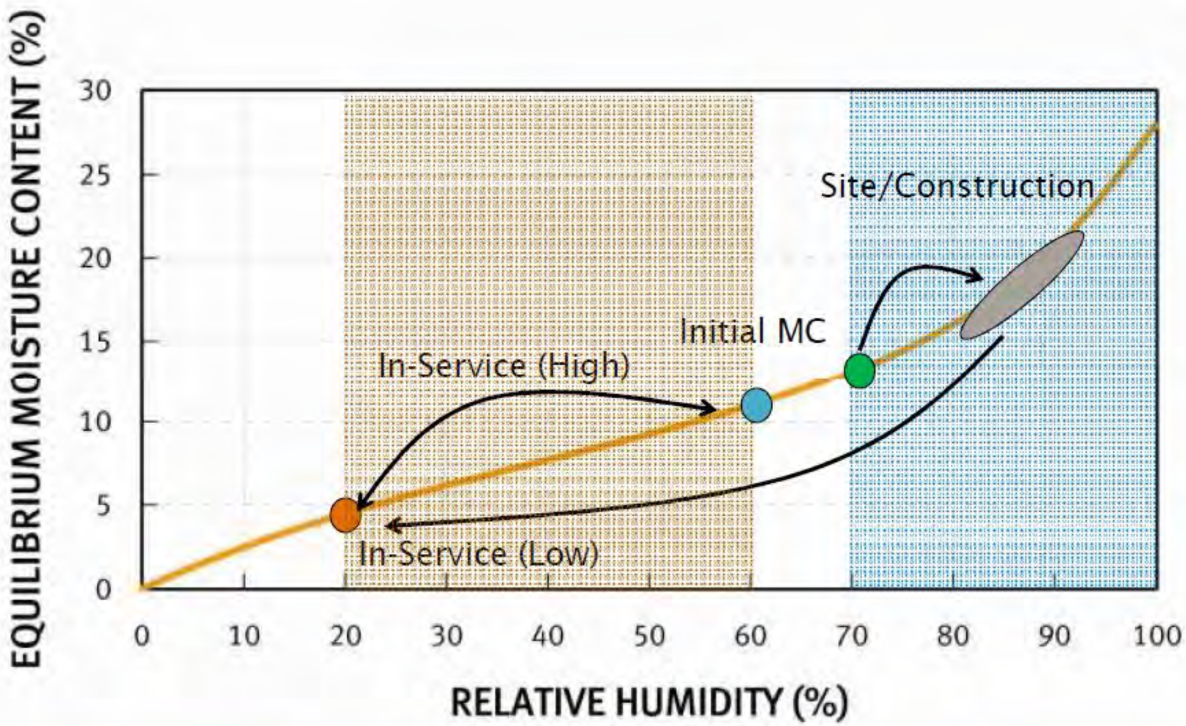
Wood needs to be kept dry



Wood shrinkage is 0.20% to 0.25% in dimension per 1% change in MC

Moisture in wood affects overall shrinkage and installation of wall assembly elements

Most construction efforts keep the wood structure dry

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Structural design addresses both the nature of wood and differential movement

Structural connectors designed allow differential movement between different materials

Interface of materials at building elements addressed with structural discontinuity at some interfaces

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I’ll hit that stud yet…

* Sometimes the best constructor benefits from the observation of a building inspector

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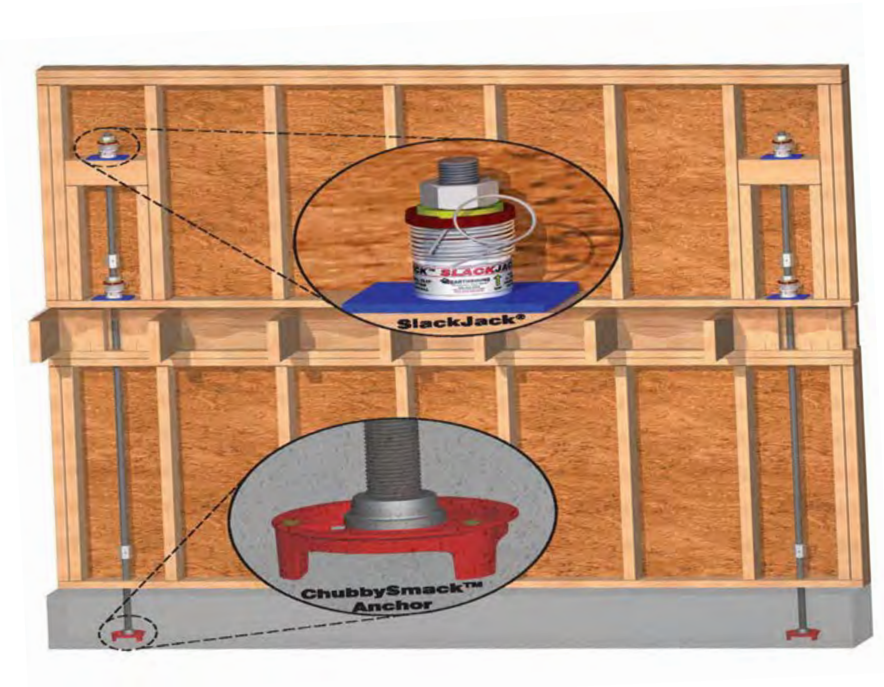
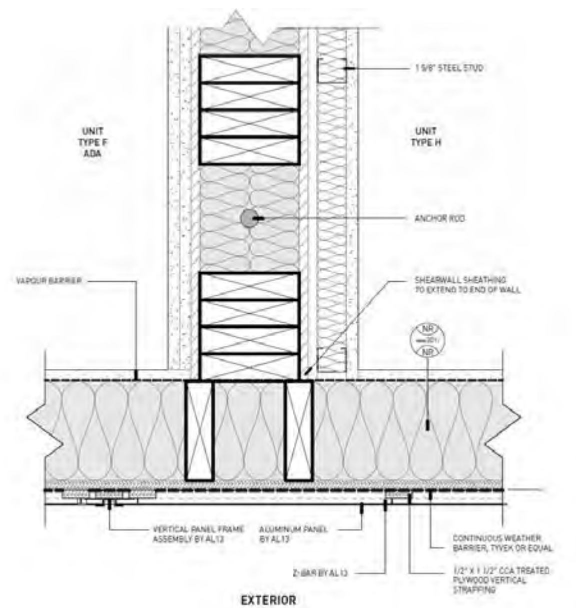
Shear wall hold downs address vertical movement due to shrinkage





Hold downs designed for vertical movement in response to shrinkage

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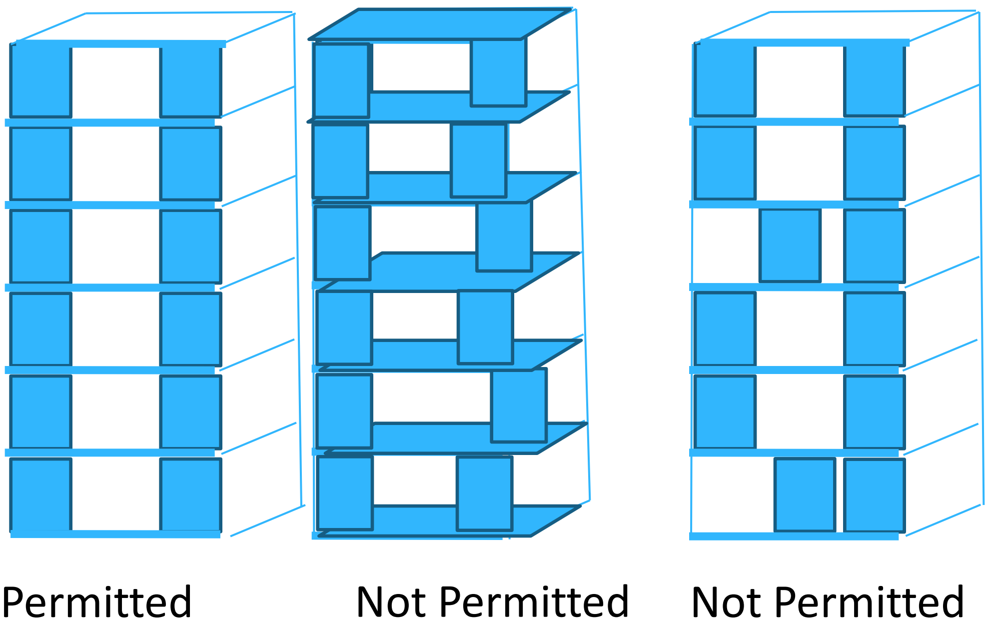
Shear wall design must line up

Provision #4- Shear Walls Sentence 3.2.2.45.(4)

* This code change for shear walls provides direction to the structural engineer on designing and locating shear walls.
* This provision prohibits certain types of irregularity in a shear wall system so that expected responses of this type of structure are maintained at reasonable levels by well-defined lateral-load resisting systems. In-plane discontinuity and out-of-plane offset in a timber shear wall system will not be allowed over the entire height of a mid-rise timber structure.



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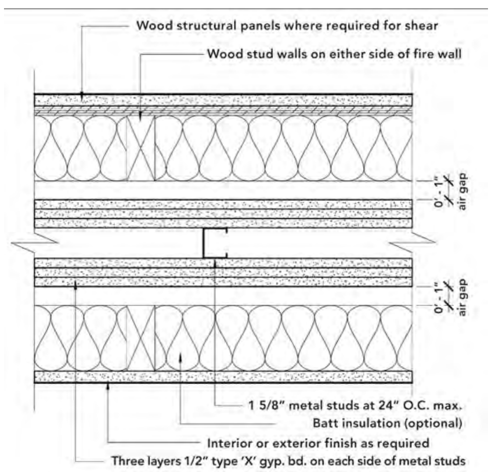
Sometimes new ways of constructing



Fire Wall design using steel stud and multiple layers of type-X gypsum wall board accepted using Alternate Solution

Solid Wood Elevator Shafts, stud construction exterior

Plywood lined interior

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Integration of building systems

More systems

Installed smaller cavity spaces and ceiling spaces

Systems running in non-combustible concealed space above corridor

Cast iron drain pipe sleeve detail

Non structural systems must accommodate the characteristics of wood when amplified by increased stories

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Cavity space is at a premium

Electrical, low voltage, plumbing, and fire resistance systems need to be accommodated within the structural design

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Traditional inspection phase takes multiple visits

- Fire protection elements often are installed after traditional inspection phases
- Inspection of fire resistance and fire stopping elements are often address at separate inspections

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Typical techniques for addressing combustible concealed spaces

Addressing continuity of fire separations

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Fire stopping details are critical

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Non-combustible bulkheads and chases

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What's life without more challenges…

* Differential Material movement has impacts to:
  * Integrity of construction assemblies
  * Interface of different materials (i.e. wood floor assembly against masonry firewall) may result in differential movement
  * Exterior elements such as windows, flashings, sealing, air barrier and cladding systems are designed to anticipate vertical movement
  * rigid non-structural components (i.e. piping, ductwork, conduit, exterior facade) will have to accommodate differential movement of structure and building systems

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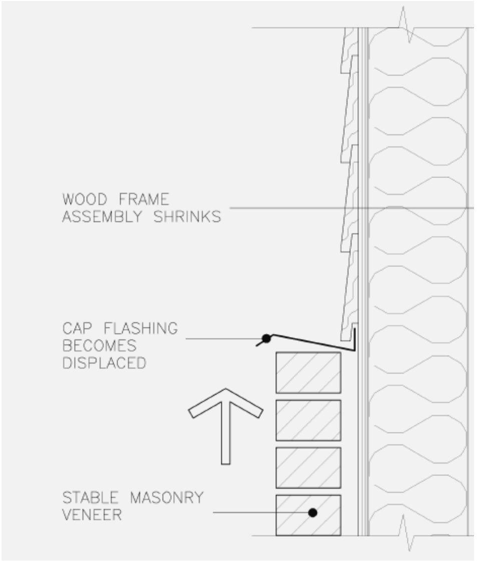
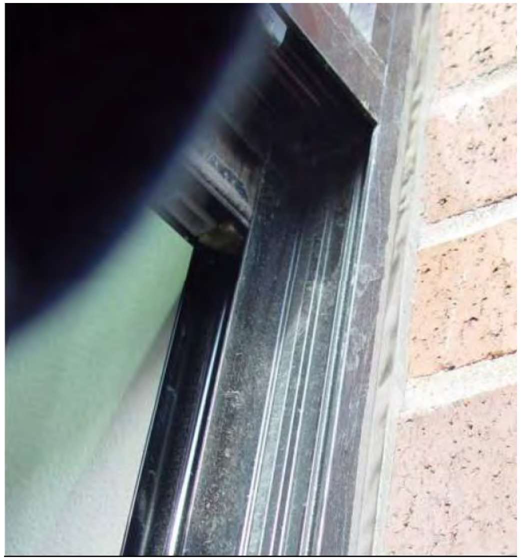
Effect of wood's shrinkage is to produce differential movement at building envelope

* Cladding materials typically have differential vertical movement in relation to the wood structure





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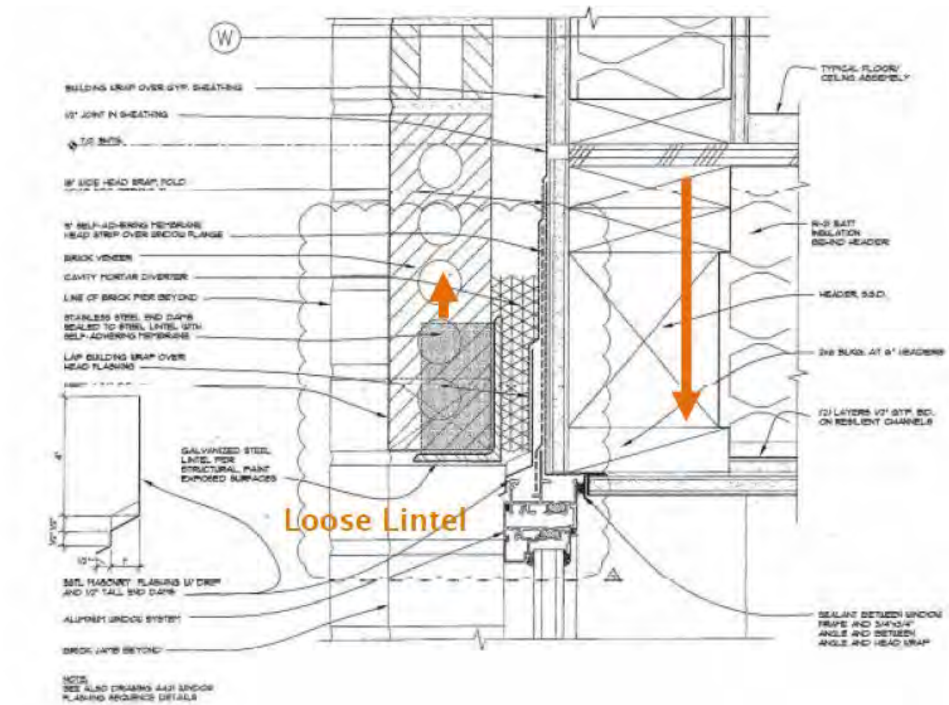
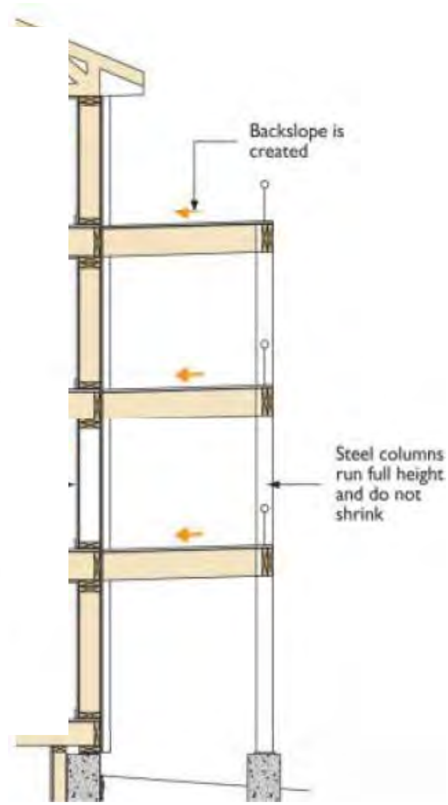
Innovative building envelope design essential

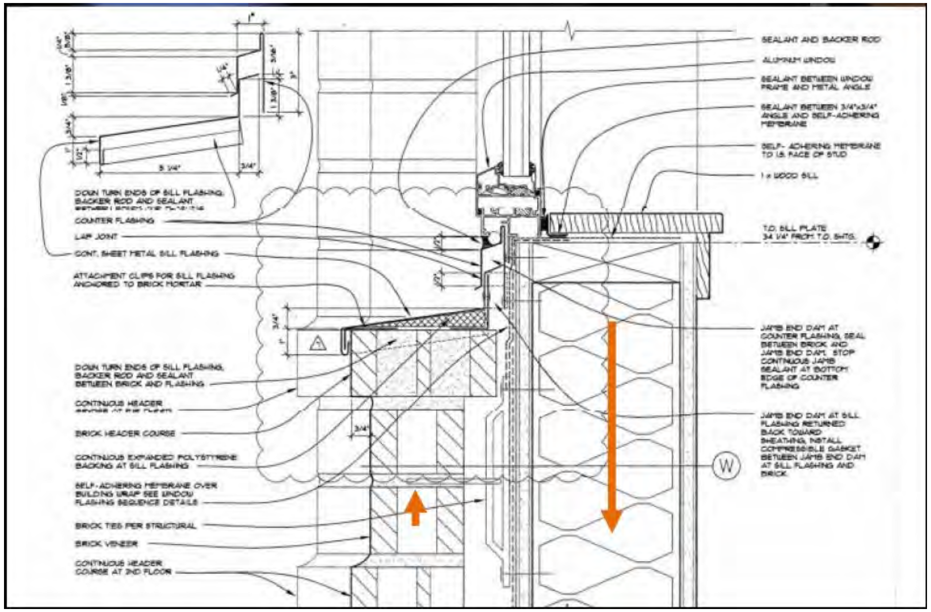




The effect of shrinkage is cumulative and expressed most at uppermost levels

Window head flashing detail that accommodates vertical differential movement

Appropriate detailing



Sill flashing detail to take up differential vertical movement

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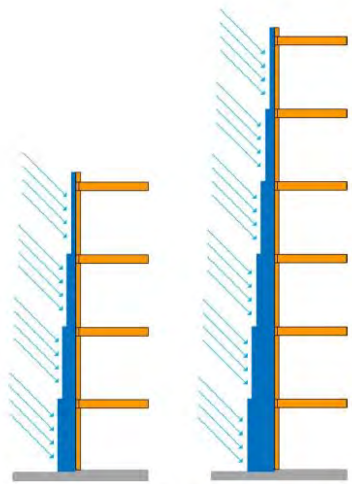
Cladding considerations…when considering shrinkage of structural elements

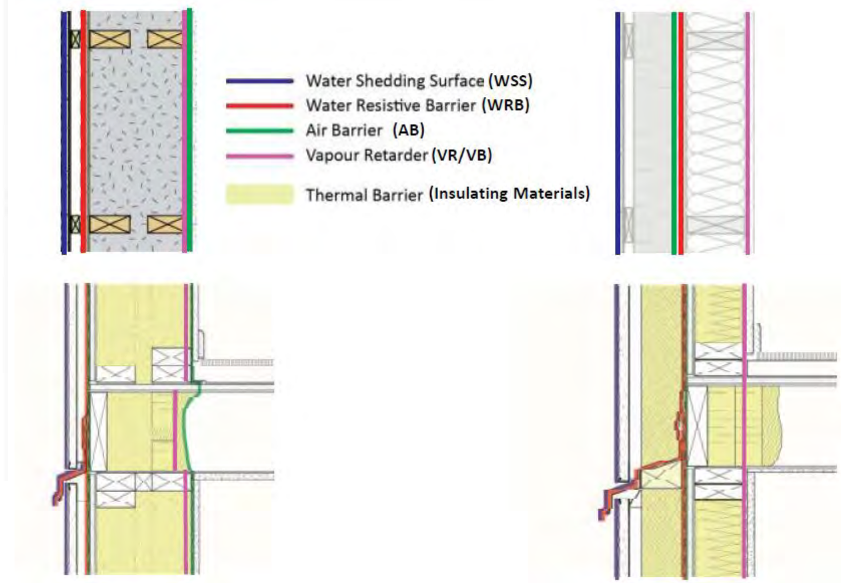
Sitka Apartments

Climatic considerations

- Specified structural and water penetration performance criteria for windows
  - Some low-rise windows may not work as well in mid-rise buildings
- Cumulative runoff
  - Water shedding features become more critical – continuity, drip edges
  - Water penetration control strategy
  - Selection of materials
- Moisture during construction



The height of the building requires that close attention is paid to the management of moisture especially around openings. Air/Moisture barrier design and installation are critical.



Rain screen construction typical

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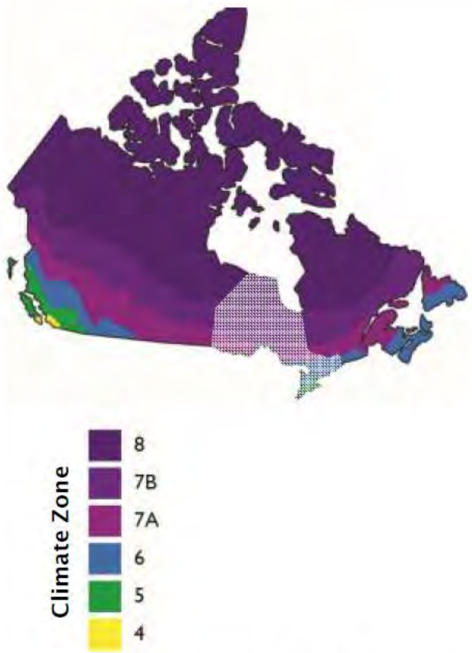
Climatic considerations… Insulation



*7A/7B combined in ASHRAE 90.1

NECB 2011

Climate Zone	Wall: Min. R-value	Roof - Sloped or Flat: Min. R-value
8	31.0	40.0
7A/7B	27.0	35.0
6	23.0	31.0
5	20.4	31.0
4	18.6	25.0

Minimum Effective R-values (IP)

ASHRAE 90.1-2010

Climate Zone	Wall – Wood *Res/Comm* Min. R-value	Roof – Slope, Flat: *Res/Comm* Min. R-value
8	27.8	47.6, 20.8
7A/7B	19.6	37.0, 20.8
6	19.6	37.0, 20.8
5	19.6 Res, *15.6 Comm*	37.0, 20.8
4	*15.6 Res, 11.2 Comm*	37.0, 20.8

Increasing energy efficiency requirements will require measures to address the cold bridging nature of reduced cavity spaces in wood frame exterior walls

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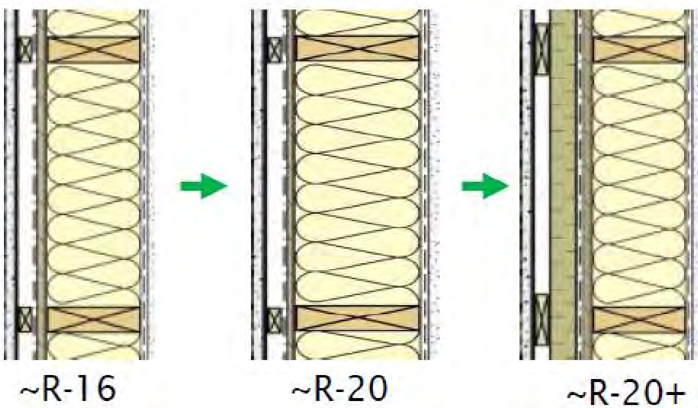
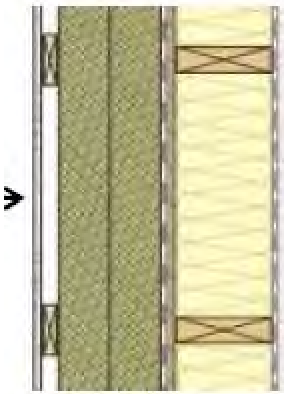
Climatic considerations… Insulation

→ Code shift of prescriptive effective R-value targets to R-20 range (from ~R-16 in previous codes):

- → 2x8 framing (w/ R-28+ batts)
  - › Limited if cavity full of framing, services and tie-downs etc.
- → 2x6 with 1 to 1.5" (R-4+) of exterior insulation





<u>Split Insulation</u>:
R-20 to R-40+ effective

- Constraints: cladding attachment
- Good durability with proper design

Typically over cladding with exterior insulation is required to meet energy efficiency standards

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What does this mean to the plan review and inspections?

* We expect a well coordinated set of construction documents that are compliant with code provisions and integration of building systems
* Alternate Solutions that are practicable on site
* Clear lines of communication between the construction and building inspector in charge
* A higher level of coordination required to address this level of complexity working with combustible materials to achieve the stated fire separations
* High standards for field review from engineers and architects

With larger projects come larger fuel loads…

* There are higher unprotected fuel loads during construction prior to installation of rated assemblies
* In many cases, these are complex buildings with large aggregate floor areas on sites with multiple buildings
* Additional stories add exponentially to the load
* The threat of fire during construction must be carefully managed

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If not…this happens

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What happened at the first Remy Construction

- Fire rated assemblies were not completed at time of fire
- Sprinklers were not yet installed
- Fire likely started from hot works on site
- Burning embers caused spot fires at surrounding houses

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Lessons Learned…

For 6 Story combustible construction, the City of Richmond Requires

* Construction Fire Safety Plan
  * to address storage of materials
  * coordination with fire fighting operations of Fire and Rescue Department
  * Safety of surrounding occupied structures to be addressed, especially on phased developments
  * Fire watch to be implemented with 24 hr. surveillance
  * Construction may not start without Construction Fire Safety Plan approved by the Fire Department

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Lessons Learned…

The Fire Safety Plan includes:

* Standpipes to be operational as each floor is constructed
* Firewalls and doors to be functional as each floor is completed
* Fire compartments exposed to adjacent buildings to be sprinkler-protected during construction
* Strict adherence to safety measures for controlled torching, welding, and all hotworks
* Drywall installation commences at ground floor and moves to upper floors unlike typical process for starting at upper floors and moving downward

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Standpipes to be charged upon completion of every floor

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Moving forward…

* We are seeing the first generation of 6 storey , combustible residential buildings in Richmond
* It has been a learning curve for everyone
* It will continue to be so with evolving techniques learned from monitoring the performance of these first examples and newer technologies
* We are seeing good examples of construction using this typology

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Although the building official is usually right…It's ok to plead your case…we're not as square as you think

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Future systems… Hybrid construction using CLT floors

Cross laminate Timber elements are seen as offering a simpler way of achieving the required fire rating at floors

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Current Example

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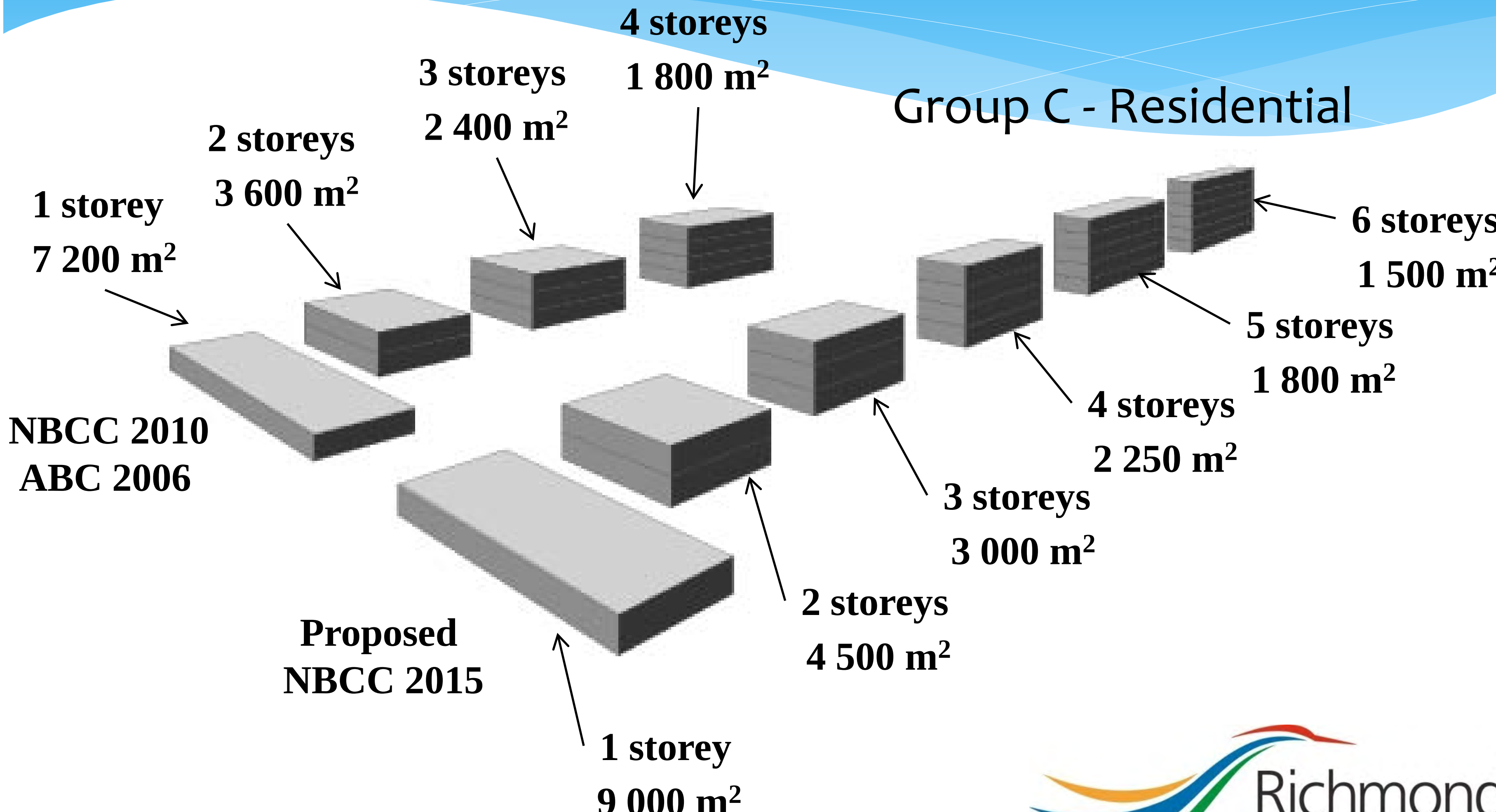
Acceptance for larger floor area

Group C - Residential



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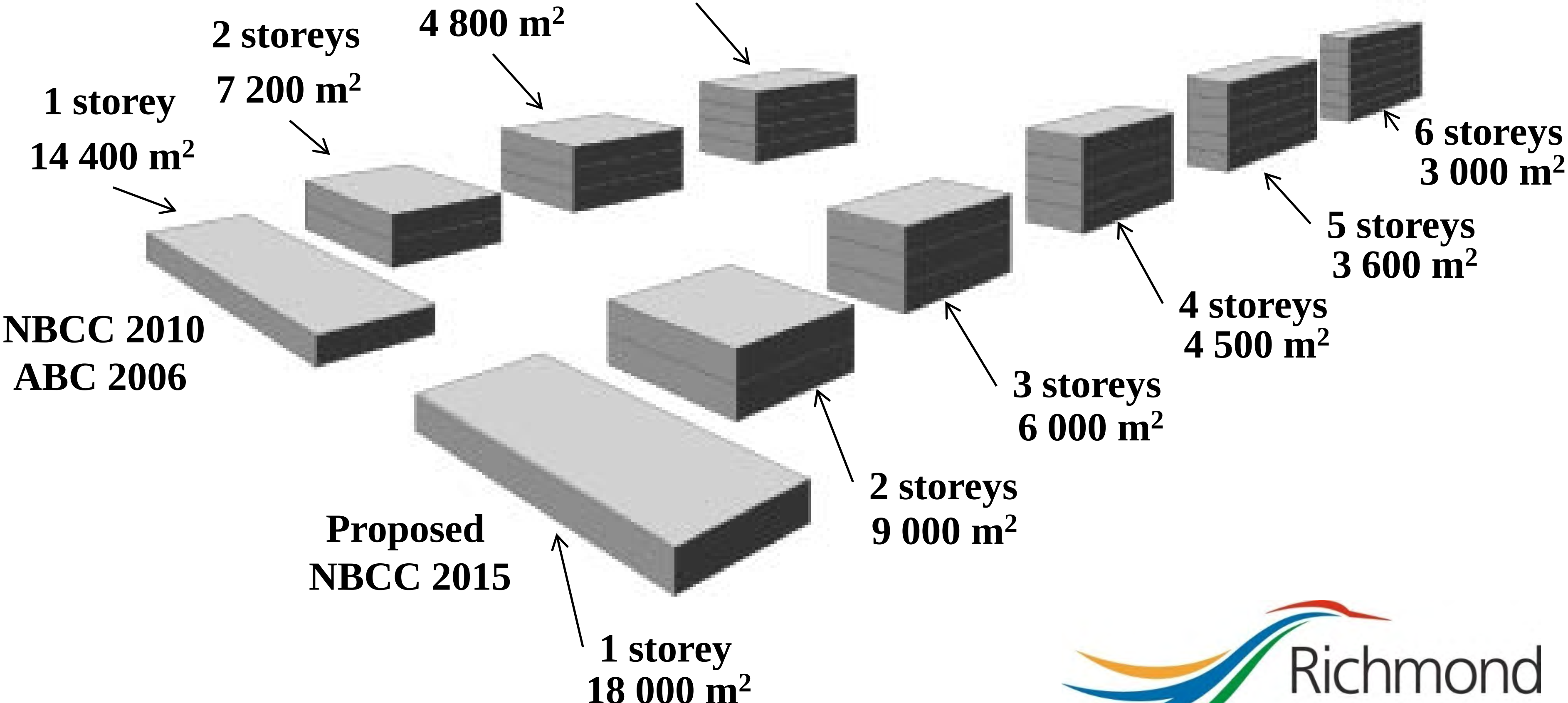
Innovations in building code means new innovation in building typology

- **Group D – Business and Personal Services**



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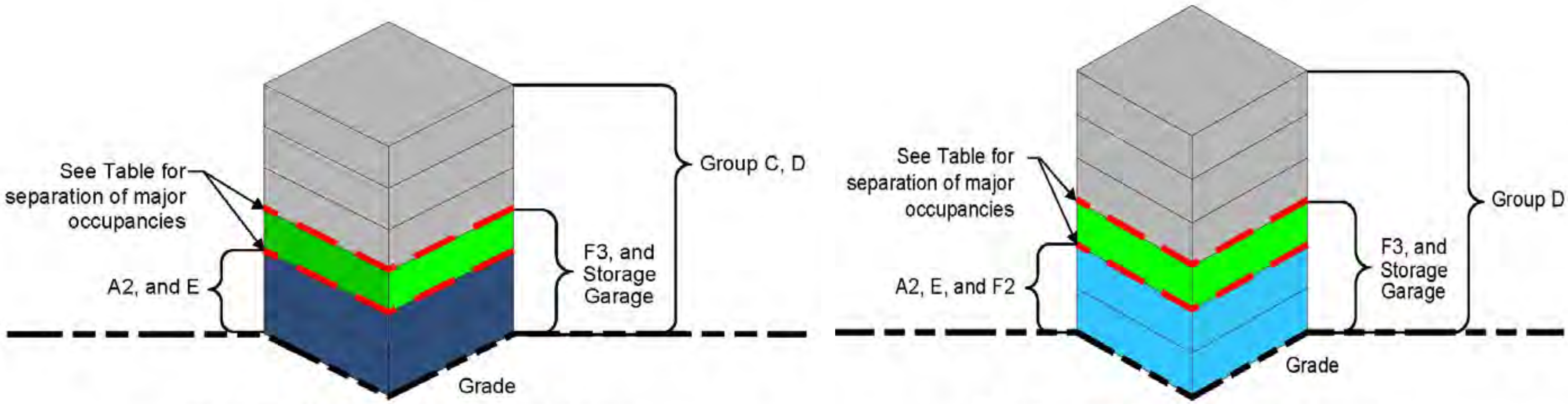
Mixed use applications



3.2.2.50.-2015 Group C, up to 6 Storeys, Sprinklered, Increased Area

3.2.2.57.-2015 Group D, up to 6 Storeys, Sprinklered, Increased Area

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Some built examples

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