Material Selection Matters

Dr John Straube, P.Eng.
Principal, RDH Building Science
Professor, School of Architecture
University of Waterloo

Outline

- Materials
- Structural Systems
- Enclosures
- Concrete
- Steel
- Wood
- Trends, Research and Field Experience
SOME MATERIAL SCIENCE

Materials – Basic Review

• Agents of material deterioration
  – Water + Oxygen
  – UV
  – High heat / very cold
  – Fire

• Three primary material categories
  – Metallic
    • Corrosion=oxidation
  – Polymer/organic
    • UV, oxidation, high heat, cold, moisture (natural polymers)
  – Mineral/Ceramic
    • Freeze-thaw, salt
  – Composite: made up of others
Polymers: Carbon bonds

- Polyethylene, PE
- Polypropylene, PP
- Polystyrene, PS
- Polyvinyl chloride, PVC
- Polytetrafluoroethylene, PTFE

Asphalt – a modified natural polymer
e.g. Minerals used to protect polymer from UV

Wood: a natural polymer
Clay Brick: an time-tested mineral-based product

Salt (+water)
THE CHANGING WORLD
New Challenges / Trends

- Faster construction & design cycles
  - All weather construction
- Congested sites
  - i.e., urban & additions
- More high-rise & multi-use
- Better energy performance
  - More on this later…
- Climate change & resiliency
- Design for maintenance & renewal

Building Energy Use

- Growing demand from codes and some customers for lower energy use
- Actual measured performance beginning to play a role- game changer
  - Models vs reality
  - Code compliance vs performance
- Energy use is a SYSTEM and DESIGN issue not a material issue
  - Continuous insulation, air barrier are critical!
Aside: Thermal Mass & Energy

- Thermal mass can improve comfort, resiliency, and save energy
- Mass in exposed ceilings is most valuable
- Exterior walls also helpful- but keep it inside

Aside: Embodied Energy

- Operation / use comprises 80-90% of life-cycle energy of common buildings
- Material choice is a small overall factor
- Energy-efficiency & design-efficiency are 90-95%
- Durable buildings are lower GHG
MATERIALS AND STRUCTURAL SYSTEMS

Different Occupancies / Different Needs

• Residential
  – Compartments: fire, sound, odour
  – Many good internal partitions
    • Concrete / CMU vs framed hollow
• Office
  – Wide open flexible spaces, lots of services
  – Concrete or steel with concrete topping
• Retail
  – Very few partitions
**Past:** the last 50+ yrs

- Wood
  - Low-rise, single-family
  - Some three+ storey multi’s
- Masonry
  - Low- & mid-rise institutional/commercial
- Concrete Frame
  - Mid- & high-rise institutional/commercial/resid.
- Steel Frame
  - Low- to high-rise commercial (some instit.)

**Why?**

- Why were those choice made?
- Usually because the different choices were deemed best for different needs
- High-rise is more expensive than low-rise
  - Higher loads, higher fire resistance, more durability expectations
- None of the material properties has changed
  - Why are choices changing?
  - Labour, energy, performance expectations
**Future** material selection

- Building designers need to change to meet
  - More labor efficient (price)
    - Prefab
  - Higher density means...
    - Taller buildings, people next to each other
    - Fire and sound more important!
  - More energy efficient
    - More insulation, more airtightness, less thermal bridges
  - Building in any weather, fast
    - Prefabrication, less moisture sensitive

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In the old days …

Labour & time expensive
Wood single-family housing

- Low-cost
- Easy to escape in fire
- Sufficient load capacity (if connected)
- Separation for fire/noise by air gap or CMU

Hot-rolled Steel Frame

- Low weather sensitivity
- Fast erection
- Requires significant additional fire protection esp. for taller buildings
- Requires enclosure system (like all frames)
- Requires partition system (like all frames)
Low-rise spec. office building
Additional finish, fire protection and sound isolation needed

Site-cast Concrete Frame

- Integral Fire-proofing
- Shear walls / floor can be excellent fire/sound separating partitions
- Cold-weather sensitive
- Need to have repetition in formwork to be economical
Institutional building
Strong, durable, fire/sound resistant
Flexible floor plan
Cold weather heating...

Concrete Masonry Mid-rise

Investor-owned building
Strong, durable, fire/sound resistant
Fixed compartments
Masonry= labour expensive, weather
Insulated Concrete Forms

Emerging technology
Includes enclosure thermal/air
Less weather/formwork sensitive
Foam needs fire protection/finish

ICF
• High rise practical – manage window widths
Total Precast (MURB)

- Investor owned
- Fast erection, excellent fire sound separation
- Little weather sensitivity

Sandwich Panel

- Fast erection, excellent fire sound separation
- Little weather sensitivity
- Prefab w/windows in factory
Tall Wood Buildings

• Much closer framing
  – Not practical much beyond 6 stories
• Cross-Laminated Timber
  – Can be used for tall building
• Post-and-Beam
  – Can easily be 10 storeys with big enough wood
• Wood-frame infill
  – Any height structurally…

Four+
Six-Storey Mid-Rise Wood Buildings (Framed)

6 storeys is very different . . .

- Price rockets as the amount of wood doubles and triples
- Connections!
Complexity

- Fire and sound separation more challenging with framed assemblies

Challenges with Mechanically Attached Air Barriers & Wind During Construction
CLT- new kind on the block

- New: solid wood strips, cross laminated
- Much stronger, heavier, more fire resistant
- Much more costly

Solid Wood: CLT
High-rise Around the World

We can …

- … but should we?

- Significant complexity to manage
  - Many layers, trades, details
- New challenges to overcome
  - Construction moisture
  - Shrinkage/movement
  - Fire
Construction Moisture

- Taller buildings exposed to more rain and snow
- More concerns re. water storage/damage

Moisture Trapped in Wood

- Don’t use organic (paper) faced insulation in contact with damp wood

- Drying of a wetted roof by natural means through more than one layer of plywood can be very slow
Shrinkage

- Cross-grain wood shrinks
Differential Shrinkage

Out of the Comfort Zone

- Wood frame and masonry or concrete walls (fire walls, stairwells, elevator core)
- Masonry cladding
- Floor and roof penetrations (plumbing, sprinkler pipes, tops of masonry walls)
- Different support structure (balconies with exterior columns)

Windowsill Sliding Flashing to Accommodate Shrinkage
Fire During Construction

• Can you get insurance?
SOME ENCLOSURE ASPECTS

Many ways to enclose …

Building Elements - Envelope

Contractors perspective– PCL Constructors
Ensure continuous water & air barrier, insulation

Highly moisture tolerant and fire resistant system

Detailing penetrations continues to be a focus
Forgiving system
Steel Stud Infill

- Significant on-site & on-wall work
- Most insulation needs to be on exterior
Curtainwall

Prefabricated/Unitized but, modern curtainwalls, window walls are around R-3 to R-4 including spandrels and have lots of hidden sealant

Architectural Precast
Federal Reserve
Minneapolis MN
HOK Architects

FBI HQ
Buffalo, NY

Commercial/Retail
Calgary, AB

Modern Approach
High thermal
Excellent air / water
Durable

Note: Precast concrete is the water and air control layer between joints
Panel connection cast into panel or venting shims, fill with spray foam to control convection of air
Smoke seal (air seal) and firestop
Fill space between slab edge and back or panel with mineral fiber firestop
Line of outer sealant at panel joints as rainscreen and finish
Line of inner sealant at joints: air seal and drainage plane

R-10 to R-30

Precast panel (installed first)
Steel alignment plate completely sealed from interior air by spray foam
Gypsum board
Steel stud
Air-impermeable spray or board insulation
Cast in place anchor

Ensure airflow control continuity from the wall past the slab (including behind any columns)

Structural columns and walls should be held back from slab edge to allow for installation of air and thermal control layers
Don’t do this!

Avoid Air Gap!!

Provide continuous “convection” barrier inside (e.g., sealed gypsum, taped board foam, taped foil-face

Old, problematic design approach
Poor thermal
Poor air control

Wide Range of Aesthetics
Waterloo Region Courthouse
NORR Architects

Complete prefab high-performance enclosure

Structural columns and walls should be held back from slab edge to allow for installation of connections.

R-10 to R-25
Fort McMurray, AB **Integrally Insulated** Wall Panels
Windows Cast-in at Precast Plant

**UBC / Sandwich panel**
Architects KPMB & HCMA
ICF & Cladding

- Many options
- Drained is best but EIFS is practical
- Beware: all openings must be drained!

Window / Balcony Details are Critical! Drain opening.
This is a penetration too!

Beware “stick and peels”
Wood Enclosure Options

2x4 (or 2x6) stud wall

CLT/mass timber

2x4 (or 2x6) stud wall

R-20 to R-30+ Exterior air barrier

Exterior air barrier
Challenges with Mechanically Attached Water Control Layer & Wind

Fully-adhered air & water barriers preferred for higher exposure

Poor/Limited Choices

Low R-value

Higher Moisture Risk

2x6 stud wall 2x8 stud wall

Double-stud wall
Conclusions

• Different materials have different properties
• Different projects have different needs
• We can usually use all materials for all projects, but …
  the best materials will depend on the project!

Contact me at:
live@buildingsciencelabs.com

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