Introduction to Masonry Construction and Design Standards

1:00 PM – 2:00 PM
David Stubbs

Lecture Outline

1. Historic Masonry (5)
2. Modern Loadbearing Masonry (15)
3. Masonry Material Standards (20)
4. Masonry Construction Standard (10)
5. Masonry Design Standard (10)
Historic Masonry in Canada

- Masonry was building of material of choice for early Canadian settlements
- Toronto Fire of 1904
- Institutional and historic buildings

The Arrival of Concrete

- Reinforced Concrete
- Capacity Design
- Brutalism and Utilitarianism
Cavity Walls and Reinforced Masonry

- Focus on Rain Screen Cavity Wall Design
- More Restrictive Codes Require Reinforcement
- Advances from Other Materials

Modern Loadbearing Masonry in Canada
Cavity Walls (Veneer Walls)

Brick Veneer

- 1st line of defence
- High strength (80+ MPa)
- Tight pore space
- Low/negligible maintenance
- Modular
Air Space

- 2nd Line of defence
- Capillary break for moisture ingress
- Accommodates construction tolerances
- Permits differential movements and deflections
- Facilitates as pressure equalization
- Serves as drainage plane

Air Space - Drainage

- Flashing
- Weep holes and Vents
  - 800 mm
  - May use cover
- Mortar dropping net (optional)
Air – Vapour Barrier

- 3rd line of defence
- Continuous air barrier is key to building envelope
- Properly tied into flashing to permit drainage
- Proper lapping and treatment at openings and junctions

Insulation

- Continuous insulation
- Minimizes thermal bridging of slabs
- Size of cavity adjusted for insulation requirements
Concrete Masonry Unit Wall

- Loadbearing system
  - Gravity loads
  - Out-of-plane (weak axis) face loads such as wind
  - In-plane (strong axis) loads such as earthquake

Loadbearing Mid-rise Masonry

- Preferred structural system
  - Concrete block loadbearing walls
  - Pre-cast hollowcore concrete floor slabs

- Limitations
  - Over 12 stories can be difficult with commercially available units
  - Long spans and open concept areas are better achieved with structural steel or concrete
  - Availability of materials, skilled labour, knowledgeable engineers and experienced contractors
  - Weather, timing and management

- Benefits
  - Very quick and cost effective
  - Structure and building envelope completed with one trade
Important Aspects of Masonry Construction

• Available materials
• Able workforce
• General Contractor and Mason Contractor
• Knowledgeable Modern Design

Masonry Material Standards

• CSA A82
• CSA A165
• CSA A179
• CSA A370
CSA A82

- Fired Clay and Shale Bricks
  - Freeze-thaw
  - Durability
  - Finish
  - Texture
  - Colour
  - Compressive Strength
  - Absorption
  - Efflorescence
  - Size
  - Distortion
  - Out-of-Square

**Metric Modular Brick**
Grade and Type of Brick

**Grade (Freeze-Thaw Durability)**
- Interior Grade
- Exterior Grade

**Type (Tolerances and Aesthetics)**
- Type X
- Type S
- Type A

Other Brick Properties

- Initial Rate of Absorption (IRA)
- Efflorescence
- Finish, Texture and Colour
### CSA A165

- Concrete Block and Brick
  - Classification of Concrete Block
    - 4 Facet
    - Solid Content, Compressive Strength, Density and Moisture Content
  - Classification of Concrete Brick
    - Type of Brick
      - Solid and Hollow
    - Grade of Brick
      - Compressive Strength, Density and Moisture Content

### Concrete Block

- Loadbearing and Non-Loadbearing
- 4-Facet System
- Engineered Masonry
Concrete Brick

- **Type**
- **Solid**  
  - >75% Solid  
  - Loadbearing
- **Hollow**  
  - >50% Solid  
  - Non-Loadbearing

**Concrete Brick**

190 X 90 X 57 MM

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### Table 1
Physical properties
(See Classes 5, 7, 9.2, and 10.3)

<table>
<thead>
<tr>
<th>Property</th>
<th>Grade I</th>
<th>Grade II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum specified compressive strength, MPa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid units*</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>Hollow units*</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Maximum water absorption, % by mass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density over 2000 kg/m³</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Density from 1700 to 2000 kg/m³</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Density less than 1700 kg/m³</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Maximum moisture content, % of total absorption$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear shrinkage less than 0.03%</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Linear shrinkage from 0.03 to 0.045%</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Linear shrinkage greater than 0.045%</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>
Prefaced Concrete Masonry Units

- Resin or Glazed Tile Facing
- Freeze-thaw Durability
- Thermal Shock

CSA A179

- Mortar
  - Proportion versus Property Specification
  - Compressive Strength, Tensile Bond Strength, Water Resistance
- Grout
  - Proportion versus Property Specification
  - Compressive Strength, Slump
Mortar

- Type S
  - Below Grade and Structural
- Type N
  - Non-Structural and Low Compressive Strength

<table>
<thead>
<tr>
<th>Location</th>
<th>Building segment</th>
<th>Recommended mortar type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior above grade*</td>
<td>Loadbearing walls requiring high compressive strength</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>Loadbearing walls requiring low compressive strength</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Non-loadbearing walls</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Part of walls and masonry subject to high vibration levels such as chimneys and freestanding boundary walls</td>
<td>S*</td>
</tr>
<tr>
<td>Exterior at or below grade*</td>
<td>Foundation walls, retaining walls, masonry, sewers, pavements, walls, and patios</td>
<td>S*</td>
</tr>
<tr>
<td>Interior</td>
<td>Loadbearing walls requiring high compressive strength</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>Loadbearing walls requiring low compressive strength</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Non-loadbearing partitions</td>
<td>N</td>
</tr>
</tbody>
</table>

Grout

- Fine Grout
  - Aggregate < 6.0 mm
  - Void < 50 mm
- Coarse Grout
  - Aggregate < 10.0 mm
  - Void > 50 mm
CSA A370

- Connectors for Masonry
- Ties, Anchors and Fasteners
- Performance-Based Standard
- Prescriptive Connectors

Ties

- Connect 2 wythes of masonry
- Connect masonry veneer to back-up
- Slotted Ties
Non-Compliance

Prescriptive Ties

- Corrugated Strip Ties
- Market flooded with non-compliant ties
Specialty Ties

1. Thermal Bridging
2. Seismic
3. Insulation Positioners

Shear Ties

- Veneer acts in lateral load sharing
Anchors

- Intersections
- Structural Support
- Stone

Fasteners

- Joining or Securing of Ties or Anchors
### Table 5.1
Minimum level of corrosion protection for masonry connectors
(See Clause 5.2.1.)

<table>
<thead>
<tr>
<th>Connector use</th>
<th>Exposure environment**</th>
<th>Type of connector</th>
<th>Minimum level of corrosion protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior masonry</td>
<td>Not subject to moisture</td>
<td>All connectors</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subject to moisture</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Masonry below grade (in contact with the ground)</td>
<td>Protected by waterproofing on the face in contact with the ground</td>
<td>All connectors</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Non-aggressive soils</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Exterior masonry not more than 1.5 m above local grade, **</td>
<td>aDR \leq 7</td>
<td>All connectors</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>aDR &gt; 7</td>
<td>All connectors except anchors</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anchors**</td>
<td></td>
</tr>
<tr>
<td>Exterior masonry more than 1.5 m above local grade</td>
<td>aDR &lt; 2.75</td>
<td>All connectors</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>aDR \geq 2.75</td>
<td>All connectors except anchors</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anchors**</td>
<td></td>
</tr>
</tbody>
</table>
Masonry Construction Standard

- CSA A371

CSA A371

- Masonry Construction for Buildings
  - Hot and Cold Weather
  - Tolerances
  - Bonding
  - Reinforcement Placement
  - Grouting
Construction Tolerances

Table 15
General dimensional tolerances
(See Clauses 6.4.6.1, 6.4.6.3, and Figure 1.)

<table>
<thead>
<tr>
<th>Dimensions, m</th>
<th>Allowable variation, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2.4</td>
<td>±5</td>
</tr>
<tr>
<td>2.4–4.8</td>
<td>±8</td>
</tr>
<tr>
<td>4.8–9.6</td>
<td>±12</td>
</tr>
<tr>
<td>9.6–14.4</td>
<td>±20</td>
</tr>
<tr>
<td>14.4–19.2</td>
<td>±30</td>
</tr>
<tr>
<td>19.2–57.6</td>
<td>±50</td>
</tr>
</tbody>
</table>

57.6 – as specified by the designer

Notes:
(1) The tolerance on the top surface elevation of suspended slabs shall be ±20 mm, before removal of formwork.
(2) This Standard shall not be used for determining the deflection of slabs on structural steel or precast concrete.
Support of Masonry by Wood

- Not permitted in Part 9
  - Empirical
- Part 4 Structures Designed with the S304
  - Shrinkage and Creep Effects
  - Possible Rotations of Shelf Angle
  - Moisture Protection
### Mortar Joints

- 10 mm Standard
- 6 – 20 mm First Course
  - 0 – 13 mm on shelf angle or lintel (2014)
- Full Bedding
- Face Shell Bedding

### Weather Protection

<table>
<thead>
<tr>
<th>Air temperature, °C</th>
<th>General requirements during construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 4</td>
<td>Sand or mixing water shall be heated to a minimum of 20 °C and a maximum of 70 °C.</td>
</tr>
<tr>
<td>-4 to 0</td>
<td>Sand and mixing water shall be heated to a minimum of 20 °C and a maximum of 70 °C.</td>
</tr>
</tbody>
</table>
| -7 to -4            | (1) Sand and mixing water shall be heated to a minimum of 20 °C and a maximum of 70 °C.  
                     | (2) Source heat shall be provided on both sides of the walls under construction.  
                     | (3) Windbreaks shall be employed when the wind speed exceeds 25 km/h. |
| -7 and below        | (1) Sand and mixing water shall be heated to a minimum of 20 °C and a maximum of 70 °C.  
                     | (2) Enclosures and supplementary heat shall be provided to maintain an air temperature above 0 °C.  
                     | (3) The temperature of the unit when laid shall be not less than 7 °C. |
| -10 to 0            | The mortar shall have a minimum temperature of 4 °C and a maximum temperature of 50 °C. |
| -7 to -6            | (1) The mortar shall have a minimum temperature of 4 °C and a maximum temperature of 50 °C.  
                     | (2) Source heat shall be provided on both sides of the wall under construction.  
                     | (3) Windbreaks shall be employed when the wind speed exceeds 25 km/h. |
| -7 and below        | (1) The mortar shall have a minimum temperature of 4 °C and a maximum temperature of 50 °C.  
                     | (2) Enclosures and supplementary heat shall be provided to maintain an air temperature above 0 °C. |
Reinforcement and Grouting
High versus Low Lift

- Maximum Bar 30M (25M 2014)
- Joint Reinforcement 3.0 - 5.0 mm
- 6 mm clear cover Fine Grout
- 13 mm clear cover Coarse Grout
- Cover requirements
Air Space

- Weep Holes 800 mm
- Air Space Minimum 25 mm ± 13 mm, when A/V Barrier
- Flashing and Dampproofing

Masonry Design Standard

- CSA S304
4. Design Requirements
5. Specified Strengths
6. Analysis
7. Unreinforced Walls and Columns
8. Glass Block
9. Veneer
10. Reinforced Walls and Columns
11. Reinforced Beams
12. Reinforcement Details
13. Prestressed Masonry
14. Prefabricated Masonry
15. Field Control

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A. Dimension Cut Stone
B. Effective Length Factors
C. Determination of Specified Strength
D. Testing of Masonry Prisms
E. Bond Wrench Test
F. Empirical Design