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STRUCTURAL ENGINEERING FOR EXISTING STRUCTURES
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Date:	**Thursday, June 23, 2022**
To:	**Attendees of the Masonry Educators Workshop**
From:	**Craig M. Bennett, Jr., PE**
cc:	---
Subject:	**Why We Do What We Do** or **What You Should Know about Historic Masonry**
Number of sheets:	**4**
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Outline
- Why should you study historic masonry?
- General characteristics of historic masonry
- History of masonry
- Deterioration and other issues
- Near collapses
- Successful examples
- Why do we do what we do?

Why should we study historic masonry?
- So as not to repeat the mistakes of the past but to build on the successes
- Because we all are likely be called on to evaluate historic structures

General characteristics of historic masonry
- Clay masonry
- Unreinforced
- Low compressive strength
- Mortar is soft

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- Masonry has near zero tension capacity
- Design is controlled, not by strength, but by stability - read: *The Stone Skeleton*

History
- Early masonry
- Up to 1800 in USA: Materials and bond
- 1800 to 1840: Materials, bond and geometry
- 1840 to 1860s: Materials, bond and geometry
- Late 19th Century masonry
  - Material and uses; Monadnock and the beginning of the end of load bearing brick masonry
- Early 20th century
  - Framed buildings; Brick fireproofing; Hollow clay tile; Terra cotta; Water intrusion
- Mid-twentieth century
  - Brick masonry as a veneer over CMU for structure; Framed structures with brick veneer

Deterioration and Other Issues:
- Clay masonry growth and concrete masonry shrinkage; Loss of mortar; Too hard a mortar relative to brick; Water movement; Freeze-thaw cycles; Very weak clay masonry

Mortars
- Introduction
- Terms
- Ingredients of mortars
- Types of mortars
  - Mason's mortar; Natural cement mortars; Lime putty mortars; White Portland cement - lime mortars; Natural hydraulic lime mortars

Terms
- Mortar is a workable paste used to bind building blocks such as stones, bricks, and concrete masonry units together, fill and seal the irregular gaps between them, and sometimes add decorative colors or patterns in masonry
- Bedding mortars - mortars into which bricks or stones are laid
- "Mortar holds brick apart, not together"
- Pointing and repointing mortar - mortar which forms the boundary between the bedding mortar and the environment
- Stucco and parging mortar - a mortar used to cover brick, sometimes scored to give the appearance of stone

Mortar consists of:
- A binder - cement and/or lime; Fine aggregate - sand; Water

Types of mortars
- Mason's mortars - Gray Portland cement, lime, sand, polymers
- Natural cement mortars - Natural or Roman cement, sand
- Lime putty mortars - Slaked lime, sand
- White Portland cement - lime mortars - White Portland cement, hydrated lime, sand

Natural hydraulic lime mortars - NHL, sand

Mason's mortars
Gray Portland cement, lime, sand, polymers; Generally has no place in historic preservation

Natural cement mortars
Natural or Roman cement, sand; Common in large construction up through 1900; Lighthouses, fortifications, bridges, large buildings; ASTM C 10; Freedom and Rosendale cements today

Lime putty mortars
Slaked lime, sand; ASTM C5; More commonly used for pointing or plaster work, if used at all; Cures by carbonation; Master-of-Plaster

White Portland cement - lime mortars: Made up of ASTM C150 white Portland cement, ASTM C207 Type "S" hydrated lime, and ASTM C144 sand
M, S, N, O, K, L designations; Common for preservation in the 1980 to now
Type M: High-compressive strength mortar, but not very workable (2500 psi). Used for masonry below grade, in contact with earth, retaining walls, sewers and manholes.
Type S: General all-purpose mortar with maximum flexural bond strength (1800 psi). Used in reinforced masonry and new unreinforced masonry where strength is an issue.
Type N: General all-purpose mortar with good bonding capabilities and workability (750 psi). Recommended repointing, severe weather exposure above grade, parapets, chimneys, external walls and masonry veneers.
Type O: Low-strength mortar, used mostly for interior application and restoration (350 psi). Cost effective and used with solid units on the interior, non-weathering applications and as a general repointing mortar for pre-1890 masonry.
Type K: Highest lime content (75 psi).
Type "L": contains no cement

ASTM C270 Designation	White Type I Portland Cement (ASTM C150)	Type S Hydrated Lime (ASTM C207)	Sand (ASTM C144)
M	1	1/4	3 to 3 3/4
S	1	1/2	4 to 4 1/2
N	1	1	5 to 6
O	1	2	8 to 9
K	1	3	10 to 12
"L"	0	1	2 1/4 to 3

Natural hydraulic lime mortars: Made up of NHL and sand; ASTM C1713; NHL 2, 3.5 and 5
NHL 5: "Eminently Hydraulic Lime"; Applications such as building or repairing wall head copings, pointing and parging the water table or foundation.; Used in sea-bearing walls.; (St. Astier)
NHL 3.5: "Moderately Hydraulic Lime"; Applications such as laying or repointing brick.; Can be used to make scratch coats on exterior stucco or interior plaster.; High "free lime" content;(St. Astier)
NHL 2: "Feebly Hydraulic Lime"; Applications such as the consolidation of frail historic masonry.; Highest amount of "free lime."; Use to make very soft pointing mortars.; Similar to lime putty in;

its properties.; Sets with air & water; cures in approximately 4 days.; Cured it is about as hard as a piece of chalkboard chalk.; (St. Astier)

Examples of pointing and bedding

- Fort Washington - Maryland
- The 1851 building housing the Historic Preservation program at the College of Charleston
- A former residence at the College of Charleston

How Historic Buildings Collapse and How They Don't

- The incentive
- Factors common to collapses
- What actually causes collapse
- How do we prevent collapse

Factors common to collapses

- Building is unoccupied; Roof failures and water intrusion; The building is under construction; Failure to recognize or inability to deal with warning signs

What actually causes collapses

- Wall or building collapses; Roof deterioration and subsequent water intrusion; Support settlement and subsequent overload; Deterioration of bedding mortar; Lateral loading (seismic or wind); Serious overload; Construction

How we prevent collapse

- Keep the water out of the building; Occupy the building or mothball it; Do the cyclical maintenance: inspection and repair; Look for the irregularities in the planes of the building; Understand the risks of making multiple changes to the structure

Near Collapses:

- Cathedral of St. Luke and St. Paul; Grace Church Cathedral; 5 College Way; 4 Gadsden St

Successful Examples:

- Drayton Hall (Structure Magazine May 2017); Fort Jefferson (Structure Magazine May 2013)

Why do we do what we do?

- We do this because we are not *owners* of this great heritage… We are *stewards*.
- I take care of these buildings to pass them on to you.
- And you must do the same, so that you can pass them on to my grandchildren.