J&M PRESERVATION STUDIO

ENGINEERING 101:

A PRIMER ON BASIC STRUCTURAL ENGINEERING TERMS, CONCEPTS, AND ISSUES AS IT RELATES TO AGING BUILDINGS

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INTRO

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GOALS

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GOALS

- Understand common terms of art
- Learn how to hire the right engineer
- Learn engineering assessment procedures
- Understanding the approach to analyze existing structures
- Learning common repairs to avoid demolition and/or removal of historic fabric
- Review of a case study that showcases procedures, design, and implementation
- Earn AIA 1.5 LU

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PROCEDURES

- Identify the issues
- Find the right Engineer
- Develop the scope of work
- Understand the deliverables
- Observations & site evaluation
- Analysis

PROCEDURES

- IDENTIFY THE ISSUES

  ~ What are your concerns for the building/site?

  ~ How long has this issue been present?

  ~ Has there been an event that caused the issue?

  ~ Has any attempt at repair been made?

  ~ Do you understand the cause and effects of the issue?

Procedures

- Finding the right Engineer

~ Inquire with fellow historic site operators

~ Are your building/site issues something the Engineer has experience with?

~ Are they familiar with the Secretary of the Interior's Standards as it applies to historic buildings?

~ Review credentials and references

~ Review the Engineer's approach to the issue and the scope of work proposed.

~ Are there access issues for gathering information? Is the issue readily visible or will it require equipment or selective demolition. If so, who is the responsible party?

~ Are there hazardous materials on-site?

~What are the deliverables from the Engineer?

~ Fee and Contract Terms

~ Availability / Schedule / Deadlines

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Procedures

- Scope of Work Development

~ Pre-proposal site visit (pro bono)

~ Provide as much info. as possible! If you don't have this in time for the initial meeting, try to get it in hand prior to having the engineer begin their assessment

- past reports
- any drawings of the building/site
- general history & significance of the building/site
- photos of the issues (past and present)
- your understanding of potential issue
- goals & expectations for the building/site
- existing and proposed use changes
- funding sources/requirements
- schedule/deadlines

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Procedures

❖ Deliverables

~ Assessment Report with recommendations
~ Opinion of Probable Cost (Cost estimate)
aka Order of Magnitude Cost Estimate
~ <u>Schematic Documents</u>
~ <u>Construction & Permit Documents</u>
~ <u>Bidding</u>
~ <u>Contract Administration</u>
~ Meetings with the client, board, interested parties?
~ Do the deliverables proposed match what may be required of grantors or funding sources?

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Procedures

❖ Design Phase Definitions

~ Schematic Design
To illustrate the concepts of the existing conditions, design or repairs, noting the scale, form and relationship to existing conditions.

~ Design Development
To illustrate the design or repairs, noting all materials, systems, coordination between items, and product lifespans (warranties if applicable). Outline specifications of all materials and contracting requirements is developed.

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Procedures

- Design Phase Definitions

~ Construction/Permitting Documents

To provide a set of drawings and specifications for the contractor price and build the project. This set of documents will also be used to obtain building permits within the designated jurisdiction.

~ Bidding

To assist the owner in obtaining and comparing contractor bids for the project. Design professional shall provide invitations to bid, bidding requirements, outline experience requirements and facilitate fair and equal bidding amongst the contractors. Final selection of the contractor is always made by the owner. The design professional shall prepare the construction contract.

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Procedures

- Design Phase Definitions

~ Contract Administration (CA)

Provided at the owner's discretion, but is highly recommended. The professional will observe the work to help the contractor with conformance with the construction contract. The design professional will provide answers to contractor questions or issues that may arise during construction. The professional will also review the contractor's applications for payment to determine the appropriate billing schedules.

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Procedures

❖ Observations & Evaluation

~ Provide the engineer any information you may have for the building/site if you haven't already done so.

~ Review the goals and expectations for the project together.

~ Current and proposed use and occupancy must be understood.

~ Engineer will observe, measure, photograph, create field sketches, and any other sampling/testing that may be necessary in order to analyze the issue.

~ Testing may include, borings, moisture meter, plaster sounding, resistograph drilling, load testing, etc.

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Analysis

❖ Structural Analysis

- Identify structural component
- Determine which standards apply
- Determine which building codes apply
- Classification of work
- Determine material properties
- Determine minimum design loads and combinations
- Determine load capacity
- Determine if components are code compliant

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Analysis

❖ Structural Components & Systems

- Flexural Members: Beams, joists, girders, rafters
- Axial Members: Columns, pilasters, ties, struts
- Diaphragms: Slabs, walls, floors
- Frames: Truss (formed by a group of members arranged in the shape of triangles)
- Connections: Bolts, rivets, welds, anchors, dowels, pins, etc.

Analysis

❖ Standards

- Research on how structures respond to specific weather and geological hazards determines the building *standards* that specify the loads that structures must be able to withstand.
- Standards have no legal standing on their own.
- These minimum design loads are periodically updated by:
  - American society of Civil Engineering (ASCE),
  - American Society of Testing Materials (ASTM),
  - American National Standards Institute (ANSI), and similar professional organizations.

ANALYSIS

❖ STANDARDS

❖ Design Specifications to aid engineers:

- ASCE Minimum Design Loads for Buildings & Other Structures (ASCE 7)
- American Institute of Steel Construction (AISC)
- National Design Specification for Wood Construction (NDS)
- Building Code Requirements for Structural Concrete (ACI 318)
- Building Code Requirements for Masonry Structures (ACI 530)
- American Association of State Highway and Transportation Officials (AASHTO)
- And many more…

ANALYSIS

❖ BUILDING CODE

- Building *codes* are written by regional and/or local authorities—which use the standards determined by the professional organizations as guidelines.
- The US has never had one national building code. There have been as many as 5,000 separate codes have been in use in the country at a time.
- 1915: Building Officials and Code Administration (BOCA) was formed
- 1927: Uniform Building Code (UBC), the first set of model codes to be published – attributed to Herbert Hoover's efforts.
- 1950: National Building Code (NBC) was published as a single compilation.

ANALYSIS

❖ BUILDING CODE

- Over the past roughly 75 years, 3 sets of model building codes came to be widely accepted as the basis for most of the local codes now in use:
    - Uniform Building Code (UBC)
    - Standard Building Code (SBC)
    - National Building Code (NBC)
- In 1994, the International Code Council (ICC) was formed to develop a single, national, and comprehensive set of building codes.

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ICC INTERNATIONAL CODE COUNCIL People Helping People Build a Safer World™

ANALYSIS

INTERNATIONAL CODE COUNCIL

- International Building Code (IBC)
- International Residential Code (IRC)
- International Existing Building Code (IEBC)

- International Energy Conservation Code
- International Fire Code
- International Fuel Gas Code
- International Green Construction Code
- International Mechanical Code
- ICC Performance Code
- International Plumbing Code
- International Private Sewage Disposal Code
- International Property Maintenance Code
- International Swimming Pool and Spa Code
- International Wildland Urban Interface Code
- International Zoning Code

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Analysis

❖ IBC Existing Structures

Ch 34: Additions, alterations or repairs to any building or structure shall conform with the requirements of the code for <u>new</u> construction. An addition or alteration shall not increase the force in any structural element by more than 5%, unless the member will still be in compliance with the code for new construction, and shall not decrease its strength below the new construction code level. Strengthening of deficient members must conform to the code for new construction.

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Analysis

IBC Chapter 34 or IEBC?

- At the discretion of the designer
- IEBC provides flexibility to permit the use of alternative approaches to achieve compliance with minimum requirements
- Bottom line: DO NOT REDUCE SAFETY

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ANALYSIS

CLASSIFICATION OF WORK PER IEBC

Repairs
Alterations
Change of Occupancy
Additions
Historic Structures
Relocated Structures

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ANALYSIS

DEFINITIONS

- Repairs: Restoration to good or sound condition of any part of an existing building for the purpose of its maintenance.
- Alterations: Any construction or renovation to an existing structure other than a repair or addition. Classified as Level 1, 2, or 3.

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ANALYSIS

❖ ALTERATIONS

A Level 1 alteration is similar to a repair except that newer materials, elements, equipment or fixtures are installed that provide the same purpose of the previous items.

A Level 2 alteration includes the reconfiguration of space, the addition or elimination of doors or windows, extension of any system, or the installation of any equipment. Level 2 alterations must comply with the requirements for Level 1 alterations.

A Level 3 alteration is where the work area exceeds 50% of the total building area. The work area, by IEBC definition, includes all reconfigured spaces. Level 3 alterations must comply with the requirements for Levels 1 & 2.

ANALYSIS

❖ MORE DEFINITIONS

Change of Occupancy: IEBC 305.1 Building must comply with IBC for division or group of NEW occupancy.

Additions: An extension or increase in floor area, number of stories, or height of a building or structure.

Historic Structures: Buildings located on local, state, or national registries.

Relocated Structures: Structures moved shall comply with the provisions of IBC for NEW structures.

ANALYSIS

NO SUCH THING AS "GRANDFATHERED IN"

- IBC Ch 34: Where repairs are made to structural elements of an existing building and uncovered structural elements are found to be unsound or otherwise structurally deficient, such elements shall be made to conform to the requirements for new structures.
- As soon as you touch it, bring it up to code!

ANALYSIS

❖ DETERMINE MATERIAL PROPERTIES

- Obtain original documentation
- Age, environment, and history of structure
- Proprietary structural systems
- Configuration and surface texture may differentiate between cast iron, wrought iron, steel
- Grade and species of lumber
- Material sampling & testing, load testing

Analysis

❖ Determine Minimum Design Loads

- Forces or other actions that result from the weight of all building materials, occupants and their possessions, environmental effects, differential movement, and restrained dimensional changes.
- Magnitudes of loads consist of dead, live, soil, wind, snow, rain, flood, and earthquake.

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Analysis

Dead Loads

- Dead, soil, and hydrostatic loads based on weight of material of construction. These loads are permanently attached to structure.
- Includes walls, floors, roofs, ceilings, stairways, partitions, finishes, cladding, fixed service equipment, weight of cranes.

Live Loads

- Determine live loads based on maximum loads expected by the intended use or occupancy. LL vary in magnitude and position with time.
- Typical LL as per ASCE-7 Table 4-1:
  - Lobbies of assembly areas, 1st floor of office & retail, restaurants, public rooms, stairways, fire escapes, roof gardens: 100 psf
  - Residential, classrooms: 40 psf
  - Attics with storage: 20 psf, Attics without storage: 10 psf
  - Roofs: 20 psf

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ANALYSIS

FLOOD LOADS

- Applies to building in areas prone to flooding as defined on a flood hazard map
- Provisions for erosion and scour

SNOW LOADS

- Ground snow loads used to determine design snow loads for roofs established by statistical analysis of snowfall across the country.
- Philadelphia: 25 psf

ANALYSIS

WIND LOADS

- Buildings, including the Main Wind-Force Resisting System and all components & cladding shall be designed and constructed to resist wind loads based on basic wind speeds.
- Philadelphia: 90 mph

EARTHQUAKE LOADS

- Seismic ground motion values
- Mapped acceleration parameters
- Site soil properties
- Philadelphia is in Moderate-Low region

Analysis

Rain Loads

- Each portion of roof shall be designed to sustain the load of all rainwater that will accumulate on it if the primary drainage system is blocked plus the uniform load caused by water that rises above the inlet of the secondary drainage system at its design flow.

Ice Loads

- Ice load shall be determined using the weight of glaze ice formed on all exposed surfaces of structural members.

Analysis

❖ Design Philosophies

- Allowable Stress Design (ASD): The designer ensures that the stresses developed in a structure due to service loads do not exceed the elastic limit. This limit is usually determined by ensuring that stresses remain within the limits through the use of factors of safety.

- Load & Resistance Factor Design (LRFD): load factors are applied and a member is selected that will have enough strength to resist the factored loads. Theoretical strength of a member is reduced by the application of a resistance factor. The load and resistance factors are determined using statistics and a pre-selected probability of failure.

ANALYSIS

❖ DESIGN PHILOSOPHIES

- Wood, steel, and other materials are still frequently designed using ASD, although LRFD is more commonly taught in the USA university system.
- ASD is more conservative in designs with a live to dead load ratio of 3 or lower. With a higher ratio, LRFD is more conservative.

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ANALYSIS

LOAD COMBINATIONS

Strength Design: *Structures shall be designed so that their design strength equals or exceeds the effects of the factored loads of the following combinations:*

1. 1.4D
2. 1.2D + 1.6L + 0.5(Lr or S or R)
3. 1.2D + 1.6(Lr or S or R) + (L or S or R)
4. 1.2D + 1.0W + L + 0.5(Lr or S or R)
5. 1.2D + 1.0E + L + 0.2S
6. 0.9D + 1.0W
7. 0.9D + 1.0E

Allowable Stress Design: *Consider the combination that produced the most unfavorable effect in the building:*

1. D
2. D + L
3. D + (Lr or S or R)
4. D + 0.75L + 0.75(Lr or S or R)
5. D + (0.6W or 0.7E)

6a. D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)
6b. D + 0.75L + 0.75(0.7e) + 0.75 S
7. 0.6D + 0.6W
8. 0.6D + 0.7E

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ANALYSIS

FUNDAMENTAL PRINCIPLES

- NEWTON'S LAWS OF INERTIA & MOTION

1. A body will exist in a state of rest or in a state of uniform motion in a straight line unless it is forced to change that state by forces imposed on it.
2. The rate of change of momentum of a body is equal to the next applied force.
3. For every action there is an equal and opposite reaction.

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ANALYSIS

FUNDAMENTAL PRINCIPLES

- NEWTON'S LAWS OF INERTIA & MOTION

$$\Sigma F = ma$$

ΣF = summation of all the forces

m = mass

a =acceleration

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Analysis

❖ Equation of Equilibrium

$\Sigma F = 0$

Our buildings are NOT moving!

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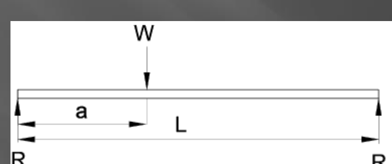
Analysis

Determine Load Path

- Trace the external loads through the structure
- Calculate tributary areas for load computation
- Draw free body diagram for individual structural members
- Determine support conditions: fixed, free, cantilever
- Compute reactions



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ANALYSIS

❖ DETERMINE LOAD CAPACITY

- Typically, analysis of existing framing is computed by hand because it is rare to have a model of the entire building electronically and expensive to prepare.
- Computational spreadsheets are often utilized to assist with the analysis.
- Computer software may be used to analyze framing, but many assumptions must be made if the existing structure is not known.

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ANALYSIS

❖ COMPUTER SOFTWARE ANALYSIS PROGRAMS

- Microsoft Excel
- Enercalc
- RAM Structural System
- Web Structural
- RISA
- Retain Pro
- Woodworks
- NCMA Masonry

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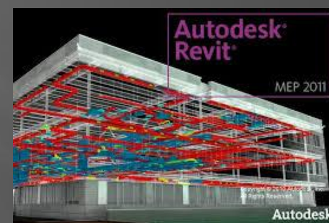
Analysis

❖ Computer Software Programs



- Drafting:
  - Autodesk AutoCAD
  - VectorWorks
- Building Information Modeling (BIM):
  - Autodesk Revit
  - ArchiCAD

BIM is often not utilized for existing buildings due to the complexity of gathering all the relevant information.

Analysis

Code Compliant

- ❖ Determine deficiency:
  - Are members sized properly?
  - Are the connections sufficient?
  - Is there material deterioration?
- ❖ Engineer will recommend a course of action to stabilize the deficiency

COMMON REPAIRS

WOOD
STEEL
MASONRY
CONCRETE

Understand the cause before making the repair!

DETERMINE CAUSE OF DETERIORATION

- Weathering, freeze/thaw cycles
- Moisture infiltration (from roof leak, flooding, building systems, etc.)
- Settlement from poor preparation of site (compaction methods)
- Bacteria, insect infestation
- Storm runoff, soil erosion
- Fire
- Material incompatibility (metal corrosion)
- Imposed alterations, demolition

Common Repairs

Wood

- Causes of Failures:
  - ~ Rot from water infiltration
  - ~ Rot from infestation (termites, borers, squirrels)
  - ~ Overloading and/or undersized
  - ~ Improper bearing (lintels, headers, beams, posts, etc.)
  - ~ Failed or inadequate connections
  - ~ Utility installation compromise capacity

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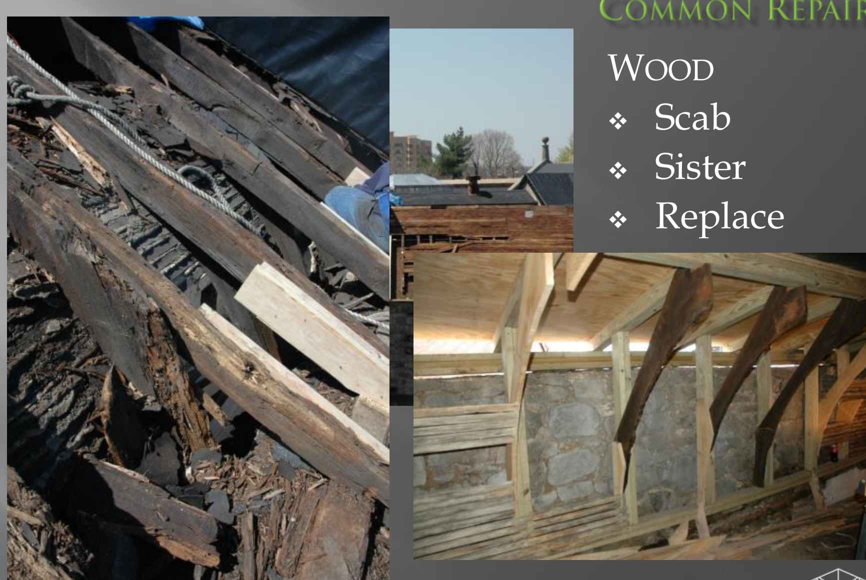
Common Repairs



Wood

- Scab
- Sister
- Replace

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Common Repairs

Wood

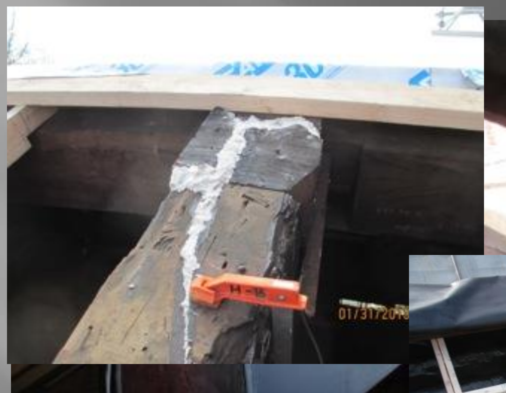
- Dutchman
- New connectors

Common Repairs

Wood

- Improve bearing
- Increase loading capacity

Common Repairs



Wood
- Reconstitute member by repairing checks, cracks, rot

*Note:
Rot must be treated before it can be repaired!

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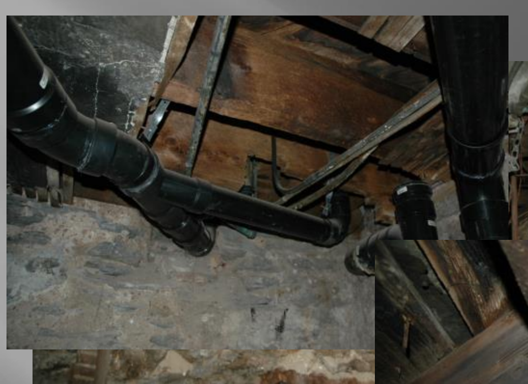
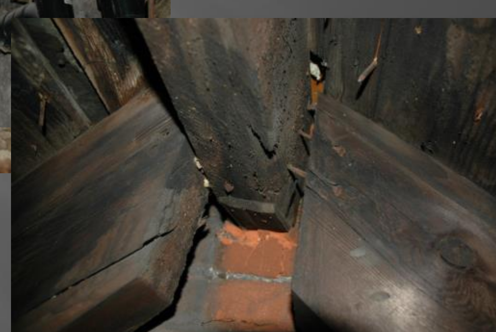
Common Repairs



Wood
- It can be repaired!



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Common Repairs

Wood

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Common Repairs

Steel

Failure Mechanisms:

~ Corrosion

~ Overloading and/or undersized

~ Instability

~ Creep (prolonged exposure to stress @ high temps)

~ Fatigue (repeated cycling of load)

~ Brittle fracture (usually associated with flaws or defects in the material where bulk stresses concentrate)

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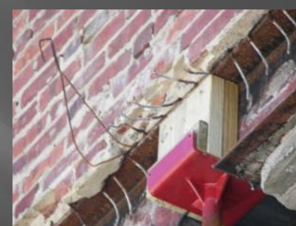
Common Repairs

Steel

- Reinforce



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Common Repairs

Steel

- Add new members

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Common Repairs

Steel

- Add new members

Common Repairs

Steel

- Add new members

Common Repairs

Steel

- Coatings

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Common Repairs

Concrete

- Cause of Failures:
  - ~ Corrosion of steel reinforcement
  - ~ Freeze/thaw cycles
  - ~ Sulfate attack
  - ~ Surface delamination

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Common Repairs

Concrete

- Shorten the span


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Common Repairs

Concrete

- Install reinforcement



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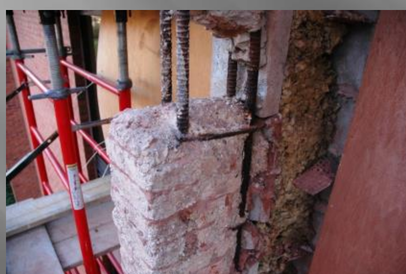
Common Repairs

Concrete

- Substitution



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Common Repairs

Concrete

- Reconstruction

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Common Repairs

Masonry

- Cause of Failures:
  - ~ Freeze/thaw cycles
  - ~ Loss of connection between wythes
  - ~ Incompatible mortar
  - ~ Overloading
- Effects of Failures:
  - ~ Cracking
  - ~ Spalling
  - ~ Overturning

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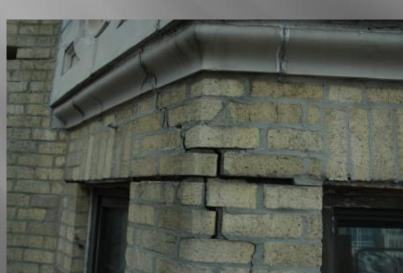
Common Repairs

Masonry

- Repoint



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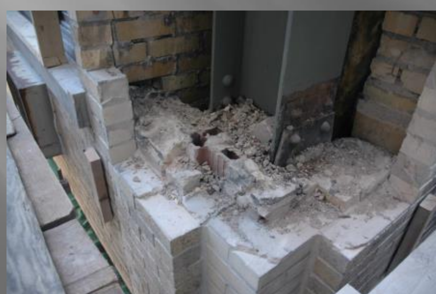
Common Repairs

Masonry

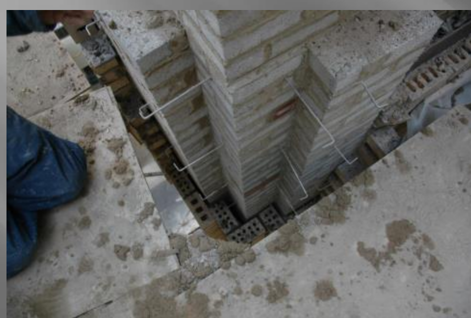
- Reconstruct



Common Repairs

Masonry

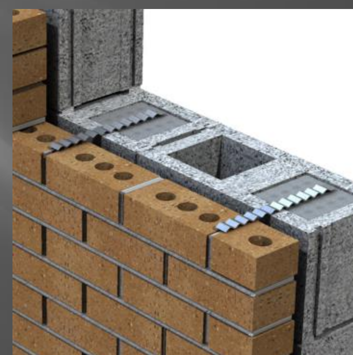
- Reinforce



Common Repairs

Masonry

- Hardware reinforcement



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Common Repairs

Masonry

- Reinforce

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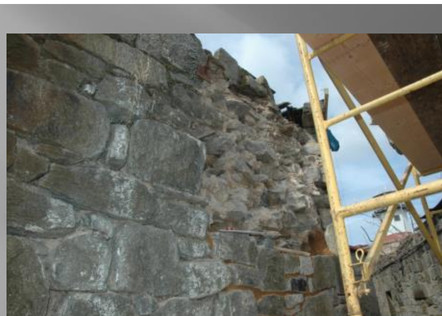
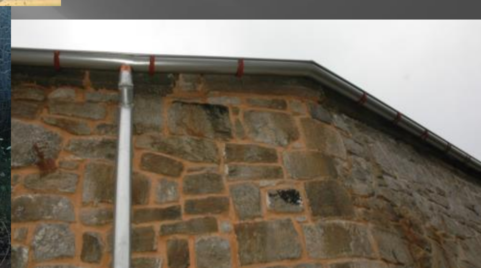
Common Repairs

Masonry

- Reinforce





Common Repairs

Masonry

- Rebuild

Common Repairs

Masonry
- Substitution

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CASE STUDY

St. Peter's Church
Philadelphia, PA

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St. Peter's

Building History

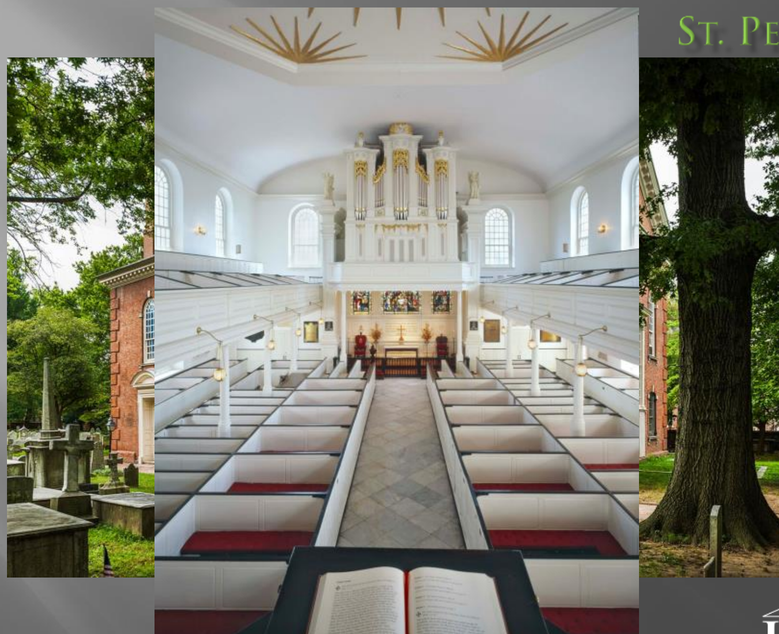
- Peter's Episcopal Church is a National Historic Landmark
- The church first opened its doors in 1761, and served as a place of worship for many of the United States' Founding Fathers.
- Designed and built by Scottish architect/builder Robert Smith, who also designed Carpenter's Hall and the tower of Christ Church.
- Organ is a E.M. Skinner, Opus 862, is housed in the historic 1764 Philip Feyring case.

St. Peter's

Timeline

- Fall/Winter 2010: Reported concern with roof swale and plaster ceiling.
- Early Winter 2011: Report provided noting recommendation of structural analysis needed for roof trusses, replacement of metal roofing, and repairs to wood cornice.
- Summer 2011: Cornice failures reported, temp. netting installed.
- Spring 2012: Structural assessment report submitted and Engineer reported necessary closure of church due to dangerous conditions. Vestry closed the church the next day.
- Summer 2012-Fall 2012: Design-build project initiated to repair dangerous conditions of roof trusses.
- Christmas 2012: Church reopened for services.
- Spring 2013: Project completed.

St. Peter's



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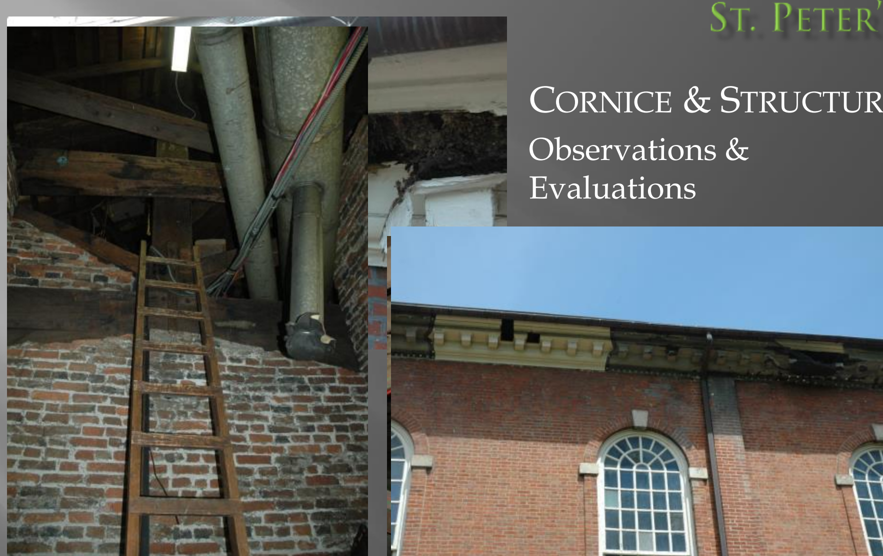
St. Peter's

Cornice & Structure

Observations & Evaluations



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St. Peter's

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Pathology
~ Testing
~ Grading

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St. Peter's Church Roof Structure Assessment - Structural Analysis

Subject: Gravity Load Analysis for Interior Roof Truss
Date: October 16, 2012
Analysis performed by: Melanie Kasper Rodbart, PE

Adjustment Factors as per Table 4D - Design Values for Visually Graded Timbers (5" x 5" and larger)

No.	Member Name	Species	Grade	F_t	F_c	Timber Member	H	V	Tensile Resultant Force, T	Compressive Resultant Force, C	Ft Allowable Tensile Force	F'c Allowable Axial Force Capacity	Status
				psi	psi	in x in	lbs	lbs	lbs	lbs	lbs	lbs	
1	Major Diagonal (Lower)	Sweet Gum	No. 2	325	375	9 x 11 1/2	36,563	18,630		**41,036**		**42,397**	*GOOD*
2	Major Diagonal (Mid)	Sweet Gum	No. 2	325	375	9 x 11 1/2	26,265	13,383		**29,478**		**42,943**	*GOOD*
3	Major Diagonal (Upper)	Sweet Gum	No. 2	325	375	9 x 11 1/2	22,583	11,505		**25,345**		**43,675**	*GOOD*
4	Scissor Chord	Sweet Gum	No. 2	325	375	8 1/4 x 12	36,563	7,107	**37,247**		**37,001**		*NOT GOOD*
5	Horizontal	Sweet Gum	No. 2	325	375	9 1/4 x 14	10,298	-		**10,298**		**51,374**	*GOOD*
6	Interior Diagonal	Red Oak	No. 2	375	825	8 5/8 x 6 5/8	3,682	2,487		**4,443**		**42,574**	*GOOD*
7	King Post	Red Oak	Select Structural	375	825	8 1/8 x 13 1/4	-	19,186	**19,186**		**36,831**		*GOOD*

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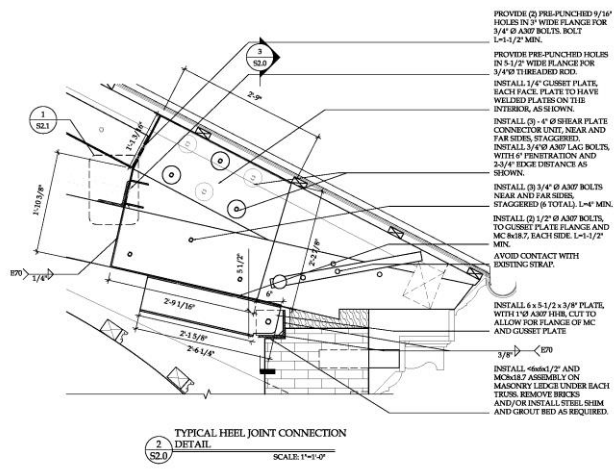

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NORTH TRUSS CONDITIONS						
ID#	Width	Condition (6'-0" from Eave)	Pathology Notes	Grading Issues	Required Repairs	Required Installation Details
** All truss ends beyond strap are considered deficient due to decay. All members considered No. 2 unless otherwise noted. King post is select structural.						
T8	8-1/2"	Severe tunnel rot, extends into both diagonal and scissor chords, between 16-36". Large check running length of scissor chord, from steel strap connection.	Advanced decay in top-major diagonal and scissor 33" above strap. At 48" drillings provided some resistance. Some deflection in major diagonal. Horizontal chord has a 1:2 to 1:4 slope of grain, therefore member is less than a No.2.	Horizontal	Remove rotted material by raking out and vacuuming top-major diagonal and scissor chords. Fill decay pockets with epoxy. Remove lower purlins sections not associated with cornice on gable.	All details per S2.0 and S2.1., except 8/S2.1: King Post to Major Diagonal No upper purlin sister required per 6/S2.1
T7	8-1/2"	Major checks on the west side. East side of diagonal chord is split for at least 7'-0"	Top-major diagonal is considered a No. 2. Mid-purlin has decay along bottom edge, but probably installed with this defect.		Remove any rotted material at heel joints. Remove lower purlin.	All details per S2.0 and S2.1., except 8/S2.1: King Post to Major Diagonal No upper purlin sister required per 6/S2.1
T6	8-1/2"	Severe rot along top of diagonal chord with some material loss. Major check on diagonal chord along west side but is not an indicator of failure. East side shows evidence of charring. Minor rot along scissor chord. Truss members appear displaced to the west, but require additional field verifications. Approx. 3'-6" from the eave, the interior spacing with the adjacent rafter is wider at the eave.	Top-major diagonal and scissor are considered a No. 2. Horizontal chord has a 1:3.5 slope of grain, therefore member is less than a No2.	Horizontal	Remove any rotted material at heel joints. Remove lower purlin. All reinforcement details to be installed to maintain existing displacement/ deflections. Do not attempt to move truss members.	All details per S2.0 and S2.1., except 8/S2.1: King Post to Major Diagonal No upper purlin sister required per 6/S2.1
T5	8-1/2"	Scissor crushed at notch on east side. Diagonal chord has moderate rot and a major check on the west side. Diagonal also has checks and crushing on the south side of the purlin.	Top-major diagonal has 8-12" of superficial decay above strap. Some 1:2 and 1:4 localized grain deviation toward the heel joint.	Scissor @ heel joint	Remove any rotted material at heel joints. Remove lower purlin.	All details per S2.0 and S2.1., except 8/S2.1: King Post to Major Diagonal No upper purlin sister required per 6/S2.1
T4	8-1/4"	Minor checks along east side of scissor. Diagonal truss is visibly displaced to the west. Moderate surface rot at the heel from the back of the strap to the end.	Top-major diagonal chord has a 1:4 slope of grain; therefore member is less than a No2. No further comments.	Major diagonal	Remove any rotted material at heel joints. Remove lower purlin.	All details per S2.0 and S2.1., except 8/S2.1: King Post to Major Diagonal No upper purlin sister required per 6/S2.1
T3	8-1/2"	Tails of both chords rotted and material loss. Major check along west side of diagonal. Check along east side of diagonal is minor at eave, but increases in severity toward the south. Multiple checks present on the east side of the scissor chord.	Top-major diagonal chord has slope of grain 1:5, therefore member is less than a No.2. Localized grain deviation on scissor.	Major diagonal	Remove any rotted material at heel joints. Remove lower purlin.	All details per S2.0 and S2.1., except 8/S2.1: King Post to Major Diagonal No upper purlin sister required per 6/S2.1
T2	8-1/4"	Material loss and rot along diagonal chord at tail. Major check in scissor chord, just north of purlin. Moderate rot of scissor chord tail. Major check on east side of diagonal, and minor check on west side. Moderate check in scissor on east side.	Top-major diagonal chord has a slope of grain of 1:4, therefore member is less than a No.2. Nothing additional noted on scissor chord.	Major diagonal	Remove any rotted material at heel joints. Remove lower purlin.	All details per S2.0 and S2.1., except 8/S2.1: King Post to Major Diagonal No upper purlin sister required per 6/S2.1
T1	8-1/2"	Material loss and severe rot on diagonal and scissor chords at tail. Multiple checks on east side of both chords. Two major checks on east side of diagonal chord, starting 6'-0" from tail. Major checks on east side of scissor.	Top-major diagonal chord has a large pocket of decay at the connection to the king post and is pulling away from the king. Slope of grain is less than 1:6, therefore member is less than a No.2. Nothing additional noted on scissor chord.		Remove rotted material by raking out and vacuuming. Fill decay pockets in major diagonal near king post with epoxy. Remove lower purlins sections not associated with cornice on gable.	All details per S2.0 and S2.1., including 8/S2.1: King Post to Major Diagonal No upper purlin sister required per 6/S2.1. All details per S2.2

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Installation
~ Steel reinforcements
~ Sisters
~ Scabs
~ Epoxy treatments

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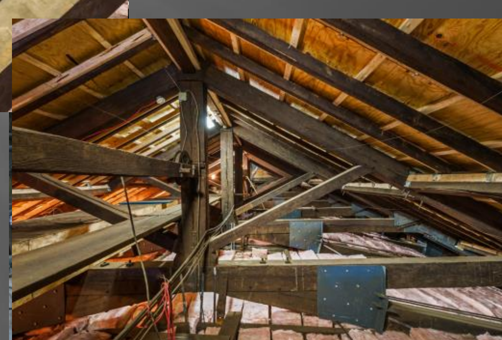

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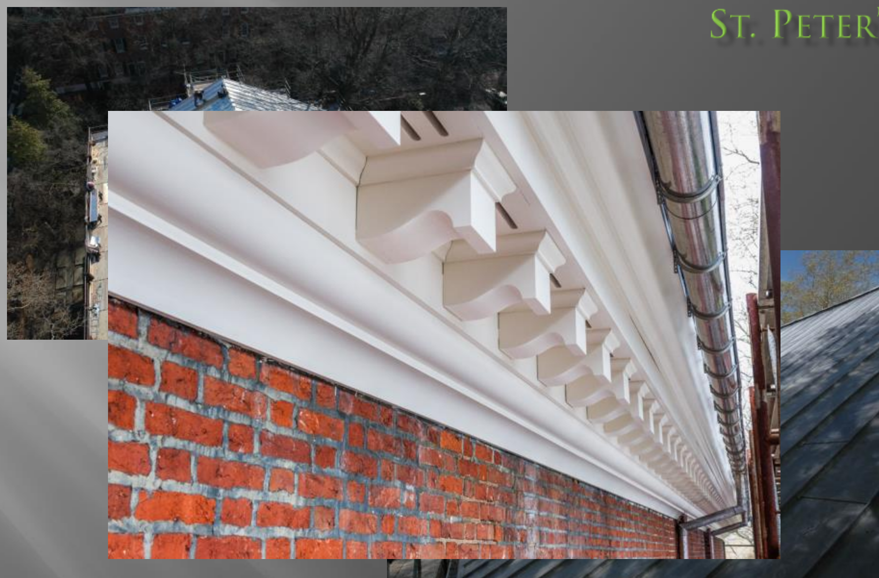

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Tower Roof

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Conclusion

CONCLUSION

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Conclusion

- Lessons Learned

~ Identify the appropriate engineer for the project

~ Provide as much information as possible to your Engineer

~ Have a joint understanding of the goals and expectations

~ Understand the issues and the root causes

~ Understand your project deliverables

~ Understand the options available to avoid demolition

~ Know that within the Engineer's Code of Ethics is the responsibility of ensuring the health, safety, and welfare of the public for their projects. This is a big responsibility so it is important that all involved understand the process.

Thank you!