

Condition Evaluation of Existing Structures

ASCE Web Seminar

Presented by Alexander Newman, P.E.



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1

Introduction

□ **We Will Cover the Following Topics**

- Investigating existing conditions: Challenges and protocols
- Concrete
- Steel
- Masonry
- Wood
- Conclusion, Q&A



2

Selected References for Further Study

- SEI/ASCE 11-99, *Guideline for Structural Condition Assessment of Existing Buildings*
- SEI/ASCE 30-00, *Guideline for Condition Assessment of the Building Envelope*
- A. Newman, *Structural Renovation of Buildings*, McGraw-Hill, 2001
- 2-day ASCE seminar *Structural Condition Assessment of Existing Structures*
- Other sources mentioned on slides



3

Investigating Existing Conditions

- **Why Investigate?**
 - Establish fitness for intended or existing use
 - Typically because of planned renovations or pre-purchase
 - Sometimes because of deterioration of framing, structural damage or failure
 - Post-disaster evaluation
 - Typical need: Determine deficiencies that require upgrade



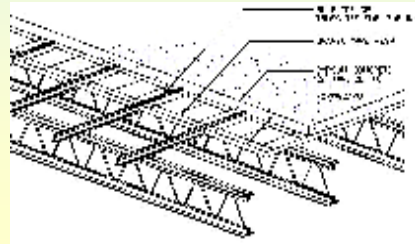
4

FEMA

Investigating Existing Conditions

□ **Some Challenges**

- **Lack of access to structure**
 - Physical entry
 - Framing covered with finishes
- **Working with archaic/proprietary systems**
- **Lack of budgets**
- **Degree of damage uncertain**



5

Investigating Existing Conditions

□ **Guidance for Assessing Building Condition**

- **SEI/ASCE 11-99, *Guideline for Structural Condition Assessment of Existing Buildings***
- **SEI/ASCE 30-00, *Guideline for Condition Assessment of the Building Envelope***



6

Investigating Existing Conditions

□ **Assessing Building Condition, Cont'd**

- **ASTM E2018-01, *Standard Guide for Property Condition Assessments: Baseline Proper Condition Assessment Process***
 - Suggests min. scope of work and report format.
 - Assumes visual inspection.
 - Add'l work extra (entering confined spaces, removing finishes, moving furn.)
 - Appendix: ADA accessibility survey.



7

Investigating Existing Conditions

□ **Other Sources**

- **S & P's *Structured Finance Rating Real Estate Finance: Property Condition Assessment Criteria* (structural part)**
Detailed protocol for inspection and report for different types of buildings (office, retail...) with examples



8

Investigating Existing Conditions

□ **Field Investigation**

- **The first walk-through**
- **Exploratory demolition**
 - **Extent depends on age and condition**
 - **A dangerous exercise (beams bearing on finishes; damage to tension rods...)**
- **Detailed assessment**



9

Investigating Existing Conditions

□ **Office Analysis for Condition Assessment**

- **Looking for design information... some sources:**
 - **Client**
 - **The building department**
 - **Architect, contractors, suppliers**
 - **Old publications**

Some detective work may be needed...



10

Investigating Existing Conditions

□ Office Analysis, Cont'd

- Analyzing existing framing
 - Try simple methods first
 - Look at the system: load path, connections, diaphragms
 - Using more accurate analysis methods than original vs. actual damage to members.

□ Detailed Assessment

- Second walk-through, etc.



11

Investigating Existing Conditions

□ Suggested Report Format per ASCE 11

- Executive summary (optional)
- Introduction
- Description of the structure
- Performance criteria (e.g., desired design loads)
- Description of assessment and evaluation processes
- Findings and conclusions
- Recommendations

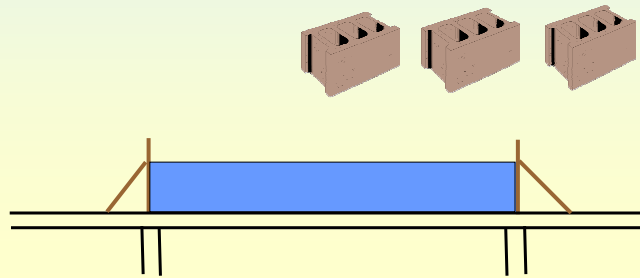


12

Investigating Existing Conditions

□ Load Testing: Per Governing or Trade Code

- When to use it
 - For proprietary structures, no drawings, deteriorated framing, theoretical overstress
- Use procedure in trade code (e.g., ACI 318), or use IBC when trade code is silent
- What kind of load?
 - Uniform
 - Concentrated



13

Investigating Existing Conditions

□ Load Testing Per AISC Spec. '05 App. 5, Sec. 5.4

- Tested strength: $1.2D + 1.6L$ (can use L_r , S , R in lieu of L), but use more severe load combinations when code requires
- After service load is reached and inelastic behavior begins, monitor deformations
 - Keep max. test load for 1 hr; deformations should increase $\leq 10\%$
 - Also record deformations 24 hrs after test load is removed [but no limit on permanent set is given]

14

Investigating Existing Conditions

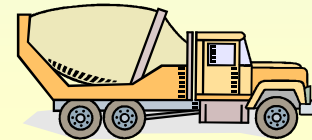
□ Load Test per Older (pre-2008) ACI 318 Editions

- Test load: $0.85(1.4D + 1.7L)$

where D includes dead load already in place.

Test OK if deflection does not exceed $L^2/20,000h$

where L is span and h , thickness.



15

Investigating Existing Conditions

□ Load Test per ACI 318-08*

- Test load the larger of:

1. $1.15D + 1.5L + 0.4(L_r \text{ or } S \text{ or } R)$

2. $1.15D + 0.9L + 1.5(L_r \text{ or } S \text{ or } R)$

3. $1.3D$

where D includes dead already load in place.

- Test OK if max. deflection does not exceed $L^2/20,000h$, where L is span and h , thickness and residual deflection is \leq of $1/4$ max.
- Test may be repeated as described.

16

*See ACI 318-08 Sec. 20.3 for more info.

Investigating Existing Conditions

□ **In-Situ Load Test per IBC-03, -06**

- IBC-03, -06, for gravity-load elements: (IBC-06 Para. 1713.3.2)
 - Gradually apply twice the “unfactored design load”
 - Keep in place 24 hrs
 - Test OK if design load deflection is within limit*, and within 24 hrs after load removal 75% of max deflection is recovered, and no evidence of failure during or after test

17

* IBC-06 Table 1604.3

Investigating Existing Conditions

□ **In-Situ Load Test per IBC-09 Para. 1715.3.1**

- IBC-09 follows procedure above (uses 2 x “superimposed design load”)
- Then adds another loading cycle to 2.5 x “superimposed design load,” or to destruction, or beyond deflection limits*
- Allowable superimposed design load is the lesser of:
 1. Load that produces deflection limit*
 2. Failure load divided by 2.5
 3. Max. load divided by 2.5



18

* IBC-09 Table 1604.3 (same in -06)

Concrete

□ Properties of Early Concrete

- 1910 NACU spec.: 2000 psi, 1:2:4 mix (cement:sand:coarse), water not limited
- 1918: Duff Abrams introduced w/c ratio
- Check for voids and segregation in pre-1950 concrete

More info:

ASCE webinar Deterioration and Repair of Concrete

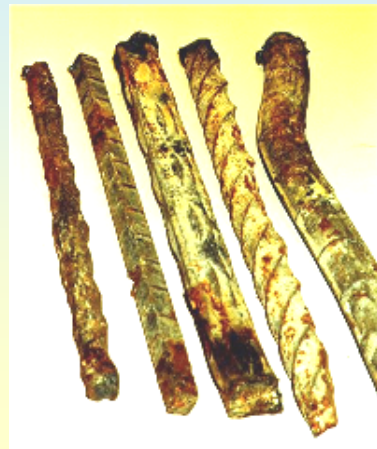


19

Concrete

□ Properties of Early Reinforcement

- F_y of plain and deformed bars:
 - A15 billet steel (1911-1966): structural grade (“soft”) 33 ksi, intermediate 40 ksi, hard 50 ksi.
 - A16 rail steel plain, deformed, hot-twisted (1911-1966): 50 ksi.
 - Cold-twisted bars: 55 ksi.



20

Concrete

□ **Concrete: Performing a Condition Survey**

- **ACI 201.1R-08, *Guide for Conducting a Visual Inspection of Concrete in Service* (revised title)**
 - Includes a lengthy checklist and many color illustrations of various concrete defects
- **ACI 224.1R-07, *Causes, Evaluation, and Repair of Cracks in Concrete Structures***
- **ACI 364.1R-07, *Guide for Evaluation of Concrete Structures Before Rehabilitation***
- **U.S. Army EM 1110-2-2002, *Evaluation and Repair of Concrete Structures*, 1995**

21

Concrete

□ **Visual Survey Can Find...**

- **Sagging**
- **Cracking**
- **Spalling**
- **Creep**
- **Efflorescence**

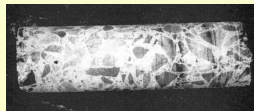


22

Concrete

□ **Strength Determination: Destructive Testing**

- Determination of concrete strength: Taking cores (ASTM C42) for compression testing (ASTM C39)...min. of 3
- Petrographic examination (ASTM C295)
 - Proportions, air %, presence of reactive aggregates
- Tension test of rebars (ASTM E8) (12" lg)

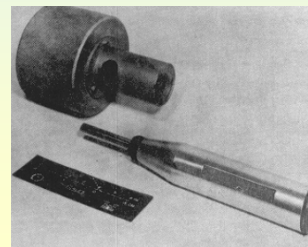


23

Concrete

□ **Strength Determination: Nondestructive Testing**

- Windsor probe (ASTM C803): A gun drives probe; depth of penetration $\sim f'_c$
- Rebound hammer (ASTM C805): Strikes surface, rebound distance is converted to f'_c



Rebound hammer: EM1110-2-2002

24

Concrete

□ Finding Rebars

- Pachometers, cover meters, rebar locators
 - Generate magnetic field
 - Rebars affect magnetic field and are detected
 - Either size (if cover known) or cover, not both
- X-ray and gamma-ray radiography
 - Emissions help locate rebars
 - Gamma-rays can find concrete voids, determine bar size
 - Not effective for concrete > 12" thick, \$\$, health hazard



25

Concrete

□ Causes of Concrete Deterioration

- Environmental damage
 - Chemical attack
 - Rebar corrosion
 - Carbonation
- Internal chemical distress



26

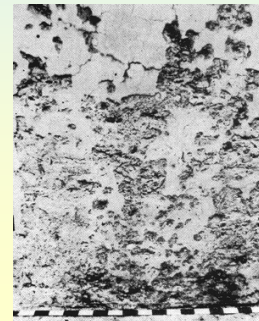
Concrete

□ Cracks and Surface Damage

- Cracks
- Scaling
- Popouts



27 Popout
EM11110-2-2002

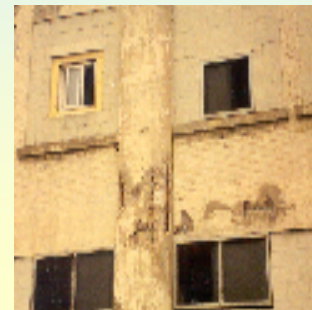


Medium scaling
EM11110-2-2002

Concrete

□ Detecting Concrete Deterioration

- Façade: carbonation, salt-water spray or mist
- Interior structure: chlorides or other chemicals
 - Sources of chlorides: Deicing salts, admixtures (esp. CaCl_2), unwashed beach sand, fumes, acid etching Interior structure



28

Concrete

□ Carbonation of Façade

- Carbon dioxide CO_2 reacts with $\text{Ca}(\text{OH})_2$ and forms Ca carbonate $\text{CaCO}_3 + \text{H}_2\text{O}$, reduces pH to 8-9.
- Similar reaction between sulfur dioxide and cement
- Slow process, rarely $> 1/8$ to $1/4$ " in 30 yrs, but faster in industrial buildings with CO_2 emission
- Cracked concrete, corners most vulnerable.

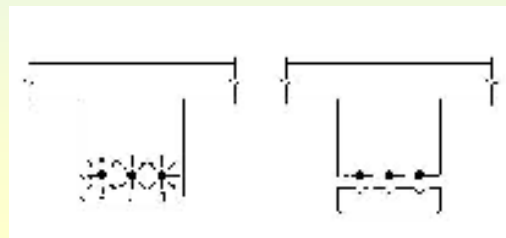


29

Concrete

□ Assessing Corrosion Activity

- Visual clues: Cracking, rust stains
- May be too late if chloride attack starts at top and *bottom* bars are rusted
- Can find depth of carbonation by using 1% phenolphthalein solution to a core. Concrete section will be pink except for carbonated areas (gray).



30

Concrete

□ **Assessing Corrosion Activity, Cont'd**

- **Rapid soluble-chloride test**
 - Trimmed ends of cores ground up
 - Find acid-soluble chlorides as % wt of concrete
- **Chloride thresholds:**
 - Min. 1.2 lb/yd³ to initiate,
 - 3 lb/yd³ to accelerate,
 - 7 lb/yd³ - major loss of steel.
- 700 ppm = 2.6 lb/yd³ = 0.07% by weight
- **Construct chloride distribution through thickness**



31

Concrete

□ **Nondestructive Testing for Assessing Corrosion**

- **Half-cell potential (ASTM C876)**
 - Finds electric potential of rebars by portable equipment at grid points
 - Copper/copper sulfate half-cell is connected to voltmeter and rebar
 - Corrosion probable if > 0.3 or 0.35V (less for exterior concrete).

32

Concrete

□ Detecting Delamination

- Chain drag: Hollow sound indicates delamination
- Hammer strike
- Impact-echo: Sim. principle, but steel ball is tapped against concrete; stress waves reflect internal flaws, recorded, frequency content analyzed
- GPR: Radar emits electromagnetic impulses, reflected by voids. Results influenced by moisture % and rebars.
- Pulse velocity: Ultrasonic waves generated by sonoscope
- Infrared thermography: Infrared radiation applied to one side of object; voids distort the flow, are detected



33

Steel

□ The Easiest Material to Evaluate?

- Condition evaluation starts with finding construction date
- If uncovered, relatively easy to measure and identify
- Corrosion can be readily observed

More info:

- 2-day ASCE seminar *Steel-Framed Buildings: Practical Issues in Design and Renovation*
- ASCE webinar *Renovation of Steel-Framed Buildings*



34

Steel

□ **Allowable Stresses in Early Steel, Cont'd**

ASCE 41 for pre-1900 steel: Lower-bound $F_y = 24$ ksi, $F_u = 36$ ksi

See AISC Design Guide No. 15 for an expanded table

See ASCE 41 and FEMA 356 for L.B and expected strength tables

TABLE 3.2 Typical Design Values for Structural Steel Used in Buildings

Period	ASTM Specification	F_u (tensile strength), ksi	F_y (minimum yield point), ksi	F_b (maximum bending stress), ksi
1900–1908	A9 (medium)	60–70	50% of F_u	16
1909–1923	A9 (structural)	55–65	50% of F_u	16
1923–1931	A9 (structural)	55–65	50% of F_u but at least 30	18
1932	A140-32T	60–72	50% of F_u but at least 33	18
1933	A9 (structural)	55–65	50% of F_u but at least 30	18
1934–1936	A9 (structural)	60–72	50% of F_u but at least 33	18
1936–1960	A7 (structural)	60–72	50% of F_u but at least 33	20
	A9 (structural)			
1960–1963	A7 (or A36)	60–72 (58)	50% of F_u but at least 33 (36)	22
1963–present	A36	58	36	24
1970s–present	A572, Gr. 50	65	50	33

SOURCE: References 11, 17, and 26.

Steel



□ **Early Steel Fasteners: Rivets**

- First to be used; hot vs. cold-formed; clamping effects for hot rivets debatable...bearing or friction?
- Sizes: $\frac{1}{2}$ " to $1\frac{1}{2}$ "; most common $\frac{3}{4}$ " and $\frac{7}{8}$ " with button head.
- Identifying size: Per AISCM 5th ed. (1961)...
 - Driven head dia. = $1.5D + \frac{1}{8}$ " ($1\frac{1}{4}$ " for $\frac{3}{4}$ ", $1\frac{7}{16}$ " for $\frac{7}{8}$ ")
 - Manuf. head = $1.5D + \frac{1}{32}$ " ($1\frac{5}{32}$ " for $\frac{3}{4}$ ", $1\frac{11}{32}$ " for $\frac{7}{8}$ ")

□ Rivets, Cont'd

- Determine allow. rivet values from current AISC spec. as for high-strength bolts.
- 1923 AISC spec. allow. values: 10 ksi shear or hand-driven, 13.5 ksi for power-driven, no tension stress given.
- 1949 AISC spec. allow. values: 15 ksi shear, 20 ksi tension



37

TABLE 3.3 Typical Design Values for Rivet Steel Used In Buildings in 1900–1950

Period	ASTM Specification	Tensile strength, ksi	Minimum yield point
1900–1908	A9	50–60	50% of tensile strength
1909–1913	A9	48–58	50% of tensile strength
1914–1923	A9	46–56	50% of tensile strength
1924–1931	A9	46–56	50% of tensile strength, but at least 25 ksi
1932–1949	A141	52–62	50% of tensile strength, but at least 28 ksi

□ Bolts

- First “unfinished” bolts: weak and loose; revisited in 1930s because of rivet noise, fire, \$
- Common (rough, unfinished, unturned, ordinary) bolts: square nuts, similar to hand rivets

TABLE 3.4 Some Typical Shear Values for Fasteners Used in Buildings in the 1950s and 1960s

Fastener	Allowable shear, ksi	³ / ₄ -in diameter	⁷ / ₈ -in diameter
Power-driven rivets and turned bolts in reamed holes	15	6.63	9.02
Unfinished bolts	10	4.42	6.01
High-strength A325 bolts: friction and bearing type, threads included in shear plane	15	6.63	9.02
bearing type, threads excluded from shear plane	22	9.72	13.23

NOTES:

1. Bearing value of connected members may control—check by current AISC Specification.
2. Values indicated are for single shear; values for double shear are twice those shown.

SOURCE: Reference 23.

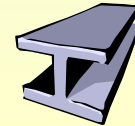
38



Steel

□ **Steel Material Testing**

- **ASTM A 370: tensile, bend, impact, hardness properties**
- **Can test in situ materials with smaller specimens, but scale down dimensions proportionally**
- **AISC Spec. App. 5 suggests destructive testing needs**
Requires determination of an appropriate ASTM standard and using F_y allowed by it, not just measured strength*
- **FEMA 356 requires testing of F_y , F_u , carbon equivalent of both base and connection material if design drawings with ASTM Spec. are not available**



³⁹ *S. Zoruba, AISC, Answer in Steel Interchange, MSC, Nov. 2006

Steel

□ **Common Destructive Tests of Steel**

- **Tension (ASTM E8): Most common; finds F_y , F_u , E**
- **Compression (ASTM E9): Finds F_y , F_c , E**
- **Chemical (ASTM E30): Finds chemical composition, incl. carbon content**
- **Bend (ASTM E190, E290): Specimen bent into U shape with certain inside radius, outside checked for cracks (measures ductility of metal and welds)**
- **Fatigue (ASTM E466, E606): Repetitive stretching, twisting, or bending**



40

Steel

❑ Other Destructive Tests

- Charpy, Izod, drop-weight impact (ASTM E23, E208, A673): A specimen notched in std way is fractured by impact of dropped weight (measures brittle-fracture potential and toughness)

❑ Nondestructive: Hole Drilling Test (ASTM E837)

- Finds existing stress in steel
- A hole of std size drilled in flange, 3 strain gages attached around hole. The stresses around the hole are relaxed, measured by gages. From those, principal surface stresses are found.

41

Masonry

❑ Definition

❑ Existing Masonry Materials

- Stone
- Brick



Old City Hall, Richmond, VA, 1894



More info:

- 2-day ASCE seminar *Design, Construction, and Renovation of Masonry Structures*

- ASCE webinar *Renovation of Masonry Facade*



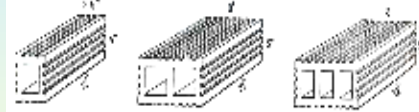
Independence Hall

42

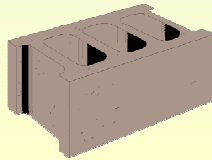
Masonry

□ Existing Masonry Materials, Cont'd

- Adobe
- Tile, Terra Cotta
- CMU



U.S. Bureau of Naval Personnel



43



Masonry

□ Masonry Items to Evaluate

- Presence of reinforcement
- Condition of units and mortar
- Loadbearing capacity for gravity loads
- LFRS



44

Masonry

□ **Field Investigation of Masonry**

- Exterior survey

□ **Exploratory Demolition**

- The need
- Extent depends on age, condition and type of construction (new exposed CMU vs. plastered brick)



45

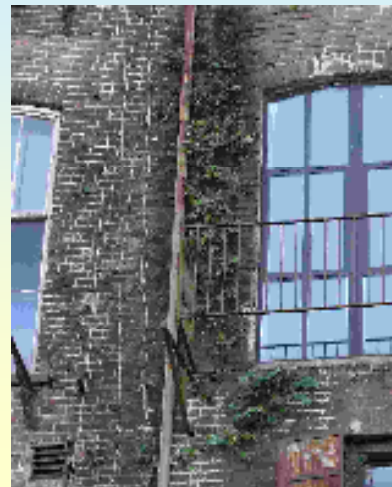
Masonry

□ **Condition Evaluation of Masonry Units, Mortar**

- Deterioration could be caused by:

- Weathering, freeze-thaw
- Leakage or water damage
- Lateral loads
- Improperly made previous renovations

(examples follow...)



46

Factors Walk, Savannah

Masonry

□ Examples:

- Weathering
- Freeze-thaw damage



47



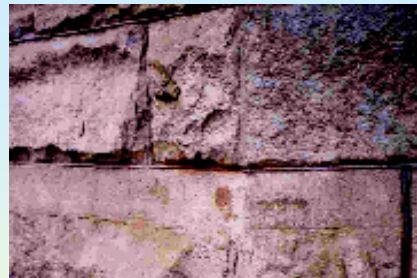
Masonry

□ Examples:

- Brownstone delamination



48



Masonry

□ **Examples:**

- **Cracked terra cotta**



49

Masonry

□ **Example:**

- **Interior leakage**



50

Masonry

□ Example:

- Damage from lateral loads



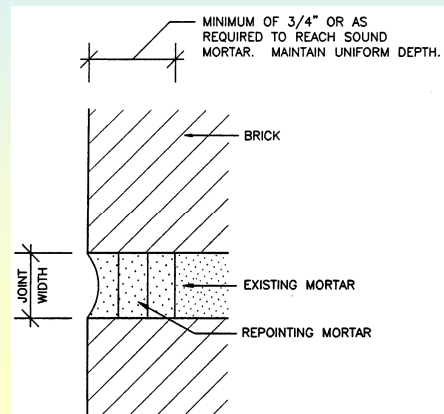
51

Northridge 1994, FEMA

Masonry

□ Example:

- Improperly made previous renovations



52

Masonry

❑ **Problems Caused by Differential Movement**

- **Masonry/structure**
- **Within masonry**
- **Settlement**

❑ **Example: Movement Between Masonry and Structure**



53

Masonry

❑ **Example: Movement within Masonry**



54

Masonry

□ **Determination of Masonry Strength**

- Destructive vs. nondestructive: (+)s and (-)s

□ **Destructive Tests**

- Take prisms from both intact and deteriorated areas, from different types or ages of masonry.
- Determine compressive strength, *E*, freeze-thaw resistance.
- Also, full-scale load tests.

55

Masonry

□ **Nondestructive Tests**

Experts: Atkinson-Noland & Associates, Boulder, CO
1-800-735-3629

56

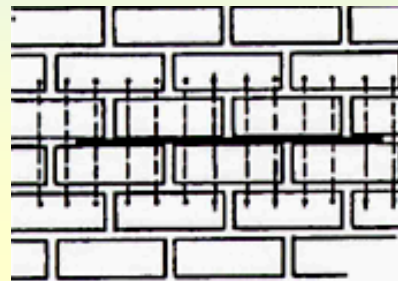
		NONDESTRUCTIVE TESTING TECHNIQUES							
		Schmidt Hammer	Single Flatjack	Double Flatjack	In-Plane Shear	Modified Shear Test	Ultrasonic Pulse	Mechanical Pulse	Magnetic Method
MATERIAL PROPERTIES	Compressive Strength (Direct)		●						
	Compressive Strength (Indirect)	●					○	○	
	Deformability		●						
	Joint Shear Strength				○	●			
	Coulomb Shear Relationship					●			
CONDITION	Voids Between Wythes						●	●	
	Cracks in Outer Wythes						○	○	○
	In-Situ Stress		●						
	Material Uniformity	●					●	●	○
	Location of Reinforcement							●	

- Useful for evaluation
- Useful, but may require additional information regarding loading conditions and crack distributions

Masonry

□ ***In Situ* Compressive Stress Test (Single Flatjack)**

- Attach dial gage points above & below tested bed joint
- Remove bed joint (units slide down, the amount is measured)
- Insert a flatjack, pressurize until gage readings restored
- Estimates stress within 10-15%.



57

US Army TM 5-809-3

Masonry

□ ***In Situ* Deformability Stress Test (Double Flatjack)**

- 2 flatjacks 4-6 courses apart, pressurize in stages equally
 - Measures amount of compression & deformation. Make stress-strain curves, $E = \text{stress/strain}$
 - Cont. until stress-strain curve flattens. If continue to failure, test becomes
- 8 *In situ* determination of f'_m

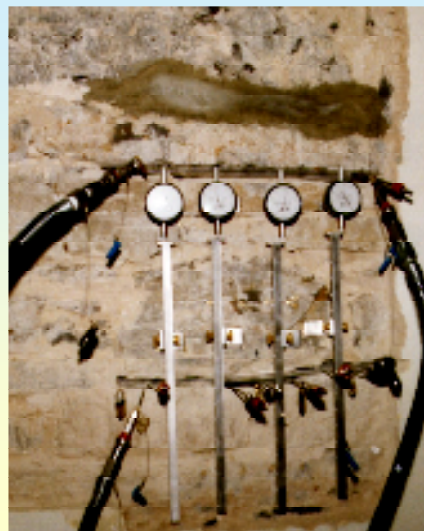
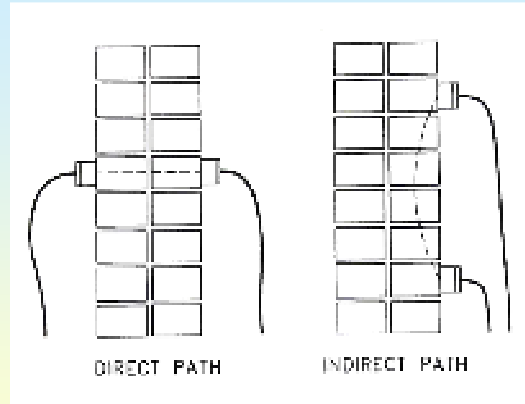


Photo: David Woodham

Masonry

□ **Ultrasonic Pulse**

- **Ultrasonic: high freq. (50 kHz) -- smaller wavelength -- shorter distance.**
- **Most use for uniform concrete**



Typical ultrasonic test configuration w/
2 transducers (transmitter & receiver)

59

TM 5-809-3

Masonry

□ **Borescope**

- **Check embedded items, voids, flashing**
- **Includes a light source**
- **View through eye piece or monitor.**

Collar-joint investigation
using fiber-optic borescope



60

Photo: David Woodham

Masonry

- **Condition Evaluation of Masonry LFRS**
- **Is Unreinforced Masonry (URM) Present?**
 - FEMA 547: “One of the most hazardous building types.”
 - Allowed even in today’s codes, depending on SDC (A & B)
 - Rigid walls, flexible diaphragms



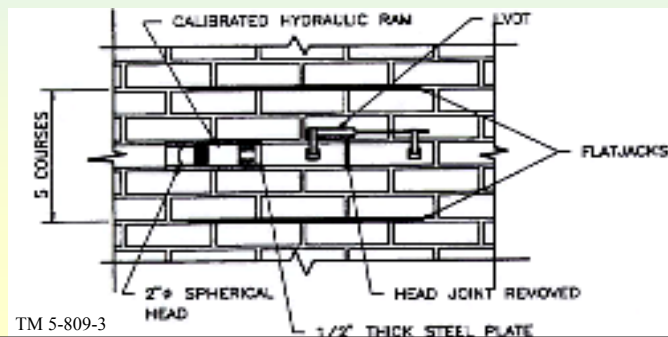
61

Masonry

□ Modified *In Situ* Shear Mortar Test

- More accurate than Coulomb: quantifies contrib. of P and collar joint.
- Vert. stress measured by 1-flatjack test, then controlled by 2 flatjacks.
- Conduct on same jt for several levels of vert. stress => find friction L .
- More complex. Best used after uniformity found by Schmidt Hammer.
- Contribution of collar joint can be measured separately

More info:
ASTM C 1531-02, *Standard Test Methods for In Situ Measurement of Masonry Mortar Joint Shear Strength Index*

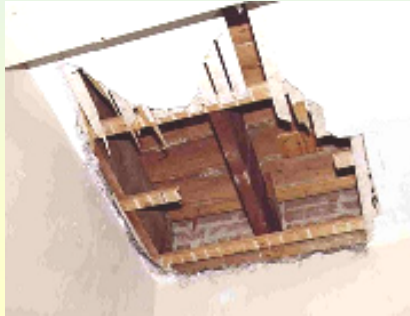


TM 5-809-3

62

Wood

- ❑ **Field Investigation: Challenges**
- ❑ **Expect to see...**
 - **Variable workmanship, lack of standards**



63

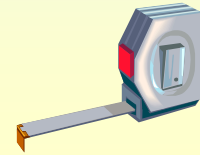
Wood

- ❑ **Determining Properties of Existing Wood**
 - **By testing, visual evaluation, reasonable assumptions**
 - **By allowable code value**
 - (E.g., 2006 IEBC table A1-D allows for existing Douglas Fir wood the allowable stresses same as for current values of D.F. No. 1)
 - **Engage a wood lab to test**
 - **In no budget, assume reasonable properties for first check**
 - **Check for approximate grade (e.g., structural grade req's knots to be tight, < defined size, no knot clusters)**
 - **Become familiar with grading rules... remained fairly constant**

64

□ Properties of Existing Wood, Cont'd

- Try Center for Wood Anatomy Research for questions regarding wood identification
<http://www2.fpl.fs.fed.us/TechSheets/techmenu.html>
 - This web site also mentions sources of wood ID kits and provides properties for various species
 - Specimens 1 X 3 X 6 inches are recommended for ID
- A source on East Coast:
Wood Advisory Services, Inc.
PO Box 1322, Millbrook, NY 12545
<http://www.woodadvisory.com>



65

□ Properties of Existing Wood, Cont'd

- A lab can perform on-site visual grading considering existing defects per ASTM D245, *Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber*
- Once graded, use today's reference stress values?
- Nondestructive evaluation follows later...



66

Wood Advisory Services, Inc.

Wood

□ **Establishing Properties by Testing Specimens**

- Example: Finding F_c , F_b , E of wood piles
- Specimens are wrapped to preserve their moisture content



67

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Wood

□ **Establishing Properties by Testing Specimens**

- Example, Cont'd: Cutting pile sections to fabricate 1x1" small clear test specimens for flexure (16" long) and compression for test per ASTM D143

Fabricated test specimens wrapped in plastic to preserve their "wet" condition prior to testing

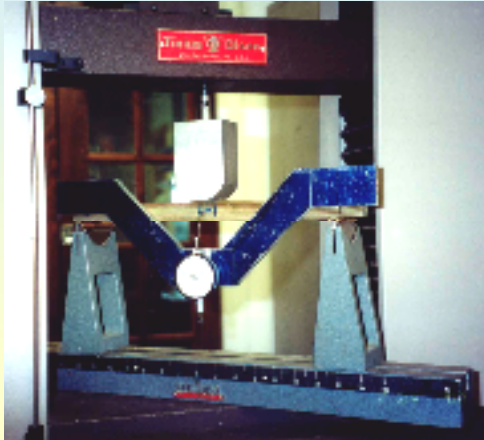


68

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□ Testing Specimens, Cont'd

- Example, Cont'd: ASTM D143 bending and compression tests



69



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□ Identifying Wood Deterioration

- Multiple mechanisms for degrading wood: biotic (living) and physical agents.

□ Wood Deterioration by Biotic Agents

- Require right moisture, O₂, T
- *Insects* (invite woodpeckers for more damage)
- *Fungi* (primitive plants) need wet environment, typ. work slowly.



70

Wood

□ **Insect Damage**

- *Insects* either eat wood (termites) or nest in it (ants, who can even attack PT wood). Also, powder-post beetles, marine borers...

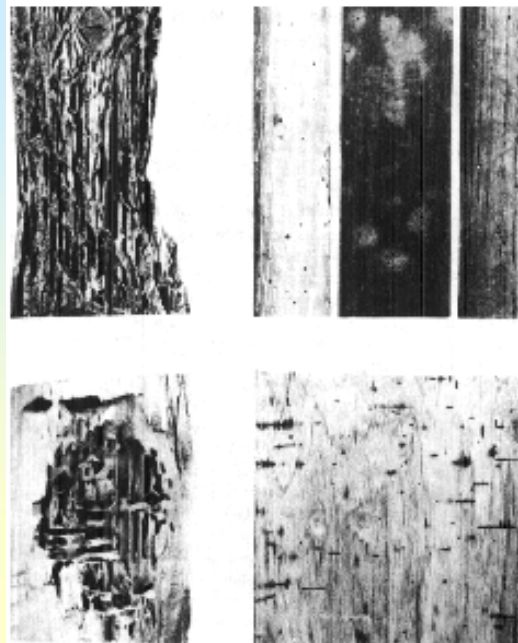


71

Wood

□ **Identifying Insect Damage**

- **Termite:** Feeding galleries // grain, contain soil, frass
- **Powder-post beetle:** wood not discolored, emergence holes, filled w/ 'flour'
- **Carpenter ant:** nesting galleries perp. to grain, free of residue
- **Beetle attack in green wood:** feeding galleries free of residue, wood darkly stained



72

NAVFAC MO-111.1

Wood

□ **Wood Rot: Incipient Stage**

- **Hard to detect. Some change of color and maybe odor.**
 - **Visible clues (soft, punky, crumbly wood) and change in weight at advanced stages.**
 - **A 5-10% weight loss may mean a 50-70% reduction in F_b and 60-70% in E .**



73

Wood

□ **Exterior Methods**

- **Probing (penetrate less than 1/2" in SW, 1/4" in HW)**
- **Pick test**



74

Wood

□ Interior Methods

- Confirm findings of exterior
 - Hammer sounding. (Dull or hollow sounds ~ decay.)
 - Moisture meters. (Moisture > 20 –25% helps decay)



75

Wood

□ Interior Methods, Cont'd

- Coring, take pencil cores with increment borer
- Microscope lab check for fungi hyphae (cut 5-10 micron sections)

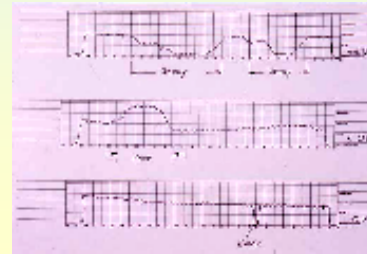


76

□ Interior Methods, Cont'd

Wood

- Using hand drill to feel resistance, or
- Cordless resistance drill -- uses 12" long needle; another needle makes EKG-like graph



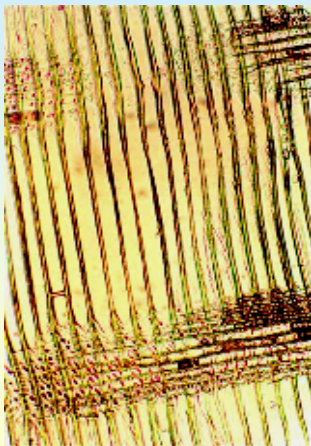
77

Pictures: Wood Advisory Services, Inc.

□ Interior Methods, Cont'd

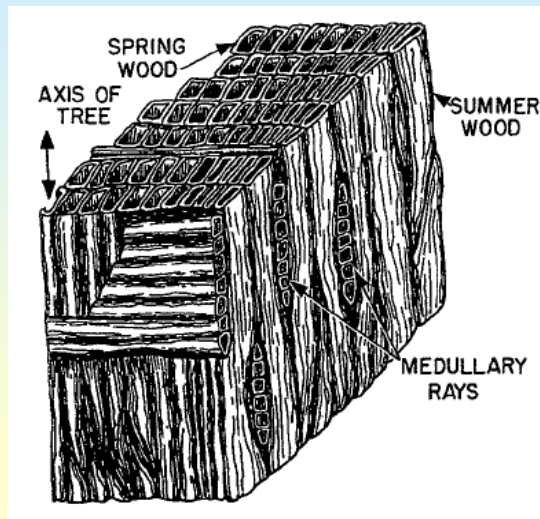
Wood

- Microscopic evaluation (side view, mag ~ X400)



Good cellular structure:
78 regular and ray cells

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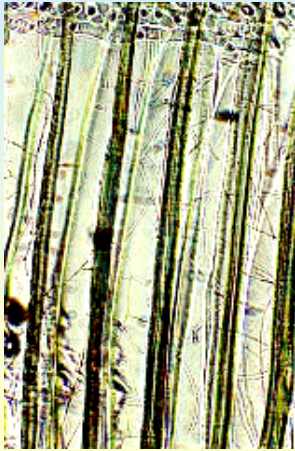


US Bureau of Naval Personnel

Wood

□ Interior Methods, Cont'd

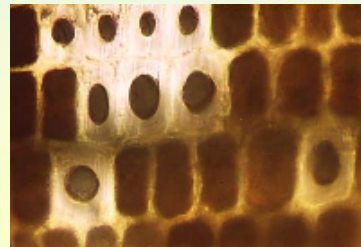
- Microscopic evaluation
(side view & cross-sect., mag ~ X400)



⁷⁹ Incipient rot (root-like);
ray cells in section on top



Normal regular and ray cells.
Spring growth at left, summer
at right.



Soft rot cell damage

Wood Advisory Services, Inc.



Q & A

Alexander Newman, PE

anewman@exponent.com

