• Introduction
• Background
• Two common pitfalls
• Case studies:
  • Miami Dade garage collapse
  • NYC Gap Analysis
• Questions, discussion
Introduction: Jeffrey Garrett, Ph.D., S.E.

- Educated at Iowa State University
- 23-year career in structural design, management
  - Single family residences to 50 story buildings
  - Constructed value nearly $2 billion
- 17-year career in structural forensics
  - Investigated a variety of structures
  - Constructed with a variety of materials
- Member of ASCE, SEAOI, AISC, ACI, ABA
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Forensic engineering

- Name given to the activity of failure investigation
- Implies presentation of findings in litigation

Forensic engineering in construction

- Most cases involve lazy mistakes
- 90% of cases typically settle prior to litigation
- Process is still costly in terms of time & dollars
Failure defined

Failure

- Condition of not meeting an intended objective

Examples of failure

- Serviceability
  - Excessive deflection and/or vibrations
- Durability
- Structural distress
- Partial or total collapse
Sources of failure

- Fundamental conceptual errors
- Design errors, omissions
- Fabrication, manufacturing defects
- Construction defects
- Materials defects
- Operational errors
Sources of construction litigation

- Modifications/change orders: 19.00%
- Contract disputes: 13.20%
- Payment disputes: 10.00%
- Delay claims: 9.70%
- Incomplete specifications: 8.90%
- Termination for default: 8.00%
- Liquidated damages: 6.70%
- Deficient work: 5.40%
- Unforeseen site conditions: 4.80%
- Facility performance: 3.60%
- Overhead: 1.60%
- Errors & omissions: 1.60%
- Owner furnished equipment: 0.90%
- Architect/engineer: 0.70%
- Subcontractor disputes: 0.30%
- Value engineering: 0.30%

Source: US Government Services Administration
Litigation is big business

American Bar Association estimates that:

- Consulting structural engineering firms
  - Almost 50% named in a suit
- Structural engineers
  - 1 in 10 will be personally named
Litigation is big business

Estimates by American Society of Civil Engineers:

• Annual claims against member companies
  • Exceed $5 billion annually
• This figure is based on insurance estimates
  • Underestimates actual amounts
• Most settlements never made public

jlgconsultingllc
Total costs to defend a claim include:
- Non-billable time, lost revenue
- Legal fees, expert fees
- PLUS the amount of any claim settlement

Immeasurable consequences include:
- Damaged reputation
- Ability to market
- Impact to future business

Litigation is big business
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Two key areas that need improvement:

- **Contractual language**
  - The engineer had signed a bad contract
  - Engineers make for bad negotiators
- **Maintain good records**
  - Keep your house in order
Contractual issues

Contract clauses that receive the most attention:

- Scope of Work
- Standard of Care
- Limitation of Liability
- Indemnification

These are the clauses your clients will attempt to modify to their benefit
Contractual issues

Contract clauses that receive the most attention:

- **Scope of Work**
  - Establishes legal obligations
    - This is the work to be performed
  - Sets the standard of care for services rendered
    - Insist that the scope be sufficiently detailed
  - First document to be reviewed in a suit
Contractual issues

Contract clauses that receive the most attention:

• **Standard of Care**
  - “The work will be performed to the highest standard……”
  - Sets an unnecessary high standard
    - Higher than what is normally expected
  - Sets the bar on how you will be judged
Contractual issues

Contract clauses that receive the most attention:

- **Limitation of Liability**
  - Endeavor to limit your liability to the value of the fee or some dollar value
  - Include language that limits your liability to only those actions you have control over
  - However, you cannot limit your liability if litigation was caused by your negligence
Contract clauses that receive the most attention:

- **Indemnification**
  - Include language that indemnifies you from third party law suits
  - You have no control over their actions
  - Include language that requires client to defend you in the event of a third party law suit
Maintain good records

Activities that should be business as usual:

• Files to be maintained indefinitely include:
  • Proposals
  • Contract negotiation notes
    • Scope of work
    • Schedule
  • Draft contracts
  • Executed contracts
Activities that should be business as usual:

- Recommend you maintain project files:
  - The sum of:
    - Time set by Statue of Limitation
    - Time set by Statue of Repose
Activities that should be business as usual:

- **Statute of Limitation:**
  - Bars action after a fixed period of time
  - Regardless of whether damage or injury has been discovered during that period

- **Statute of Repose:**
  - Bars causes of action after a fixed period of time following discovery of an error
Maintain good records

Activities that should be business as usual:

• Maintain the calculation file
  • Will calc’s make sense to a stranger in 10 years?
  • Keep only calc’s that define completed project
• Follow office policy and procedure:
  • Sequentially number, check and initial each sheet
Maintain good records

Activities that should be business as usual:

• Establish a **written retention policy** and follow it
  • No matter how long records are to be retained:
    • Follow the retention policy strictly
  • Avoids any question of impropriety when a project ends up in litigation
    • Produce all documents according to the retention policy
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Front page projects

- I-35W bridge collapse, Minneapolis
- Big Blue crane collapse, Milwaukee
- Tropicana parking garage collapse
- Big Dig roof collapse, Boston
Most projects don’t even make the news

- Structural failure, collapse
- Distress, performance issues
- Design or construction defects
- Materials failures, performance issues
- Standard of care, delays, loss of use & business
Miami Dade College parking garage collapse

- Parking garage under construction
- Precast concrete construction
  - Nearly complete with precast erection
- 5 supported levels
  - Grade, Level 1
  - Roof, Level 6
Miami Dade College parking garage collapse
Miami Dade College parking garage collapse
Miami Dade College parking garage collapse
Miami Dade College parking garage collapse

Dead weight applied to Column B3 at collapse:

- Unfactored \( P = 900 \) kips
  - Unfactored stress in concrete = \( 1.0 \) k.s.i.
  - Not excessive for \( f'c = 9,000 \) p.s.i.
- Attention turned to the crane
  - The crane had bumped Column B1
Miami Dade College parking garage collapse

The “crane accident” theory

• Boom had contacted Column B1
  • Incident had occurred 3 days earlier
• Theory: Structure at point of incipient collapse
• Crane had been inspected for damage
  • Was returned to service
• Contact left paint marks on Column B1
  • No additional damage to column was found
Miami Dade College parking garage collapse

Column B3

- Almost 5-feet of column base was missing
- Reinforcing was splayed out
- Specific shape to the failure surface
Miami Dade College parking garage collapse

Column B3

- Specific shape to the failure surface
Miami Dade College parking garage collapse

Column B3 base
Miami Dade College parking garage collapse

Theory: Failure of Column B3 initiated collapse

- Facts:
  - No grout installed
  - Column rested on 8-inch square shims
  - Stress in column = 1.0 k.s.i.
  - Stress transferred to shims = 14.0 k.s.i.
  - Exceeds design f’c by 5.0 k.s.i.

- Why didn’t the failure occur sooner?
Miami Dade College parking garage collapse

- Tested aggregate, cement, concrete:
  - Aggregate susceptible to creep
  - Found micro-cracking of the concrete
    - Took time to form, coalesce
    - Failure planes perpendicular to major stress
  - Confinement of column base by column ties
- Micro-cracking occurs until failure plane forms
  - Bottom 5-feet of Column B3 disappeared
Miami Dade College parking garage collapse
Miami Dade College parking garage collapse
NYC DOB retained CTLGroup

- Rash of construction accidents
  - Prompted action by the Mayor
- Objective:
  - Perform a GAP analysis of current practice
  - Make recommendations
  - Modify code, if needed
High rise construction observations

• HRCO concrete team:
  • Established data base of site conditions
  • Total sites visited: 181 site observations
• Quality & formwork data based on:
  • Subset of 98 active construction sites
  • Each inspected by P.E.
High rise construction observations

- Site distribution:
  - 49 union sites (50%)
  - 41 non-union sites (42%)
  - 8 unknown affiliation (8%)
High Rise Concrete Overview

- Union
- Non-Union
- Unknown
High-rise Concrete Areas of Interest

1. Formwork Issues
2. General Site Safety
3. Special Inspection and Construction Quality
4. Worker Falls
High-rise Concrete Formwork Issues
High Rise Concrete Overview

High rise concrete formwork issues

- Observed inadequacies:
  - Incomplete design specifications
  - Improper installation and sequencing
  - Damage due to wind
### High Rise Concrete Overview

### High rise concrete formwork issues

<table>
<thead>
<tr>
<th>HRCO Observed Defects</th>
<th>All Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>98</td>
</tr>
<tr>
<td>Number of Critical Formwork Defects</td>
<td>57 (58%)</td>
</tr>
</tbody>
</table>
High rise concrete formwork issues

Critical formwork defects:

- No stamped formwork design (per NYC Code)
- Formwork construction not in conformance to design
- Premature stripping or premature reshore removal
- Insufficient number of reshored floors (per design)
- Insufficient number of shored floors (per design)
High Rise Concrete Overview
High Rise Concrete Overview
High Rise Concrete Overview
Formwork failures due to wind

Leading edge formwork failure:
- Reported winds of 30-40 mph
- 808 Columbus, Manhattan
- June 11, 2008

Leading edge formwork failure:
- Reported winds of 30-40 mph
- 469 West Street, Manhattan
- March 9, 2008
# Historic Wind Incidents

<table>
<thead>
<tr>
<th>Address</th>
<th>Boro.</th>
<th>Incident Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jay Street</td>
<td>Brooklyn</td>
<td>7/24/2006</td>
<td>Wind dislodged several deck panels from formwork on 27th floor.</td>
</tr>
<tr>
<td>Broadway</td>
<td>Manhattan</td>
<td>7/12/2006</td>
<td>Wind dislodged vertical column formwork from upper floor</td>
</tr>
<tr>
<td>Spring St.</td>
<td>Manhattan</td>
<td>12/23/2007</td>
<td>Wind Dislodged Shoring Element from the 39th Floor</td>
</tr>
<tr>
<td>11th Ave</td>
<td>Manhattan</td>
<td>10/22/08</td>
<td>Wind Dislodged (2) 3x4 timber posts from 16th floor. Leading Edge deck lifted</td>
</tr>
</tbody>
</table>
Formwork recommendations

1. Require that essential specification be included on stamped formwork designs
   - Reshoring sequences and schedules
   - Required numbers of reshored floor levels
   - Clear information regarding:
     - Spacing and layout
     - Lumber grade and design strengths
Formwork recommendations

2. Require regular inspection of formwork and reshore installations by formwork designer
   - Structural layout of formwork system
   - Structural integrity, individual members & system
   - General conformance with essential specifications
Formwork recommendations

3. Incorporate national design standards for temporary construction
   • ASCE 37, Temporary Construction
   • ASCE 7, Wind load criteria

4. Require formwork construction to be positively secured against uplift
   • Perimeter decking
   • Provide positive load path to slab
High-rise Concrete General Site Safety
High Rise Concrete Overview

Observed defects, violations
- Debris dangerous to public
- Poor housekeeping practices
- Impediment to emergency egress
- Improper material storage
- Fall protection
  - Missing
  - Inadequate
High-rise concrete general site safety

<table>
<thead>
<tr>
<th></th>
<th>Sample Size</th>
<th>Unprotected Edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Sites</td>
<td>181</td>
<td>78 (43%)</td>
</tr>
</tbody>
</table>

HRCO Observed Fall Hazard Violations
High Rise Concrete Overview

High-rise concrete worker falls
High Rise Concrete Overview
High Rise Concrete Overview

Site safety recommendations

1. Effect a consistent level of knowledge and understanding among DOB inspectors
   - Understand the latest NYC Building Code provisions pertinent to site safety practices
   - Promote inspection consistency
High Rise Concrete Overview

Site safety recommendations

2. Update and publish standard set of DOB inspection protocols
   - Establish thresholds for violations
   - Establish thresholds for Stop Work Orders
High Rise Concrete Overview

Items subject to further study

- Utilize outrigger systems
- Maintain unbroken edge protection
- Provide hoisting platforms
- Utilize cocoon systems
High Rise Concrete Overview

High-rise Concrete Special Inspection and Construction Quality
High Rise Concrete Overview

Special inspection and construction quality

- Observed defects
  - Ineffective special inspection
  - Insufficient level of documentation
  - Improper concrete testing
  - Misplaced reinforcing
  - Poor quality bar fabrication
### High Rise Concrete Overview

**Special inspection and construction quality**

<table>
<thead>
<tr>
<th>Description</th>
<th>All Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Active, Engineer-Inspected Site Observations</td>
<td>90</td>
</tr>
<tr>
<td>Number of Observed Quality Issues</td>
<td>39 (43%)</td>
</tr>
<tr>
<td>Number of Observed <strong>Critical</strong> Quality Issues</td>
<td>20 (22%)</td>
</tr>
</tbody>
</table>

**HRCO-Observed Quality Defect Rate**
High Rise Concrete Overview

Special inspection and construction quality

• Critical construction quality defects
  • Improper placement of shear reinforcement
  • Insufficient numbers of installed shear stirrups
  • Improper column tie installation
  • Improper bar engagement
  • Severe bar congestion
  • Improper column splice configurations
High Rise Concrete Overview

Special inspection and construction quality
High Rise Concrete Overview

Special inspection and construction quality
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High Rise Concrete Overview

Special inspection and construction quality
Special inspection and construction quality

- 67 sets of stirrups required per design
- 47 sets installed
- Shear capacity reduced by ~20%
High Rise Concrete Overview

Special inspection and construction quality

- Two of 6 stirrups legs engaged
- Shear capacity reduced by ~33%
Quality recommendations

- Enforce NYC Special Inspection Rule
- Strengthen outreach to industry regarding Special Inspection qualifications
- All Special Inspectors must hold proper registrations or certifications
<table>
<thead>
<tr>
<th>Special Inspection Category</th>
<th>2008 Code Section</th>
<th>Primary Inspector or Inspection Supervisor</th>
<th>Supplemental Inspector (Alternative 1) - under direct supervision of Inspection Supervisor</th>
<th>Supplemental Inspector (Alternative 2) - under direct supervision of Inspection Supervisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete – Cast-in-place &amp; Precast</td>
<td>BC 1704.4</td>
<td>• PE or RA; and • 1 year relevant experience</td>
<td>• ACI Certification as Concrete Construction Special Inspector (ACI-CCSI) OR • ICC Certification as Concrete Special Inspector (ICC-CSU)</td>
<td>• ACI Certification as an Associate Concrete Construction Special Inspector (ACI-ACCSI)</td>
</tr>
</tbody>
</table>

**Note:** Licensed concrete testing lab to perform sampling and testing of cylinders

**NYC Inspection Rule 26, Eff. June 2008**
High Rise Concrete Overview

Quality recommendations

- Provide inspector training
- Maintain institutional knowledge
- Promote uniform enforcement
- Establish clear non-conformance
High-rise Concrete Worker Falls
High Rise Concrete Overview

Construction worker falls
- Observed defects
  - Insufficient leading edge protection
  - Insufficient interior opening protection
  - Improper or insufficient use of PFAS
  - Workers ignorant of tie-off requirements
Construction worker falls

- Leading causes of construction fatalities in 2006:
  - Falls: 442 out of 1,178 (38%)
  - Electrocutions: 179 (15%)
  - Struck by object: 206 (17%)
  - Caught, trapped: 97 (8%)
High Rise Concrete Overview

High-rise Concrete Worker Falls
High Rise Concrete Overview

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<td>Fall Hazards</td>
<td>43%</td>
</tr>
<tr>
<td>Tie-off Compliance</td>
<td>33%</td>
</tr>
</tbody>
</table>

Construction worker falls

- Fall hazards
  - Unprotected perimeter edges
  - Unprotected interior openings
- Tie-off violations
  - Improper barrier installation
  - Improper use of PFAS
  - Failure to tie-off when required
High Rise Concrete Overview

Construction worker falls

• Reduce fall incidents
  • Site safety line of accountability:
    • Leads to owner (not to CM)
  • Non-compliant workers:
    • Contractor to document remedial actions taken
  • Implement fall hazard awareness campaign
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• Questions, discussion
Discussion, questions

Discussion, questions