Agenda

- 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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Structural forensic engineering

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

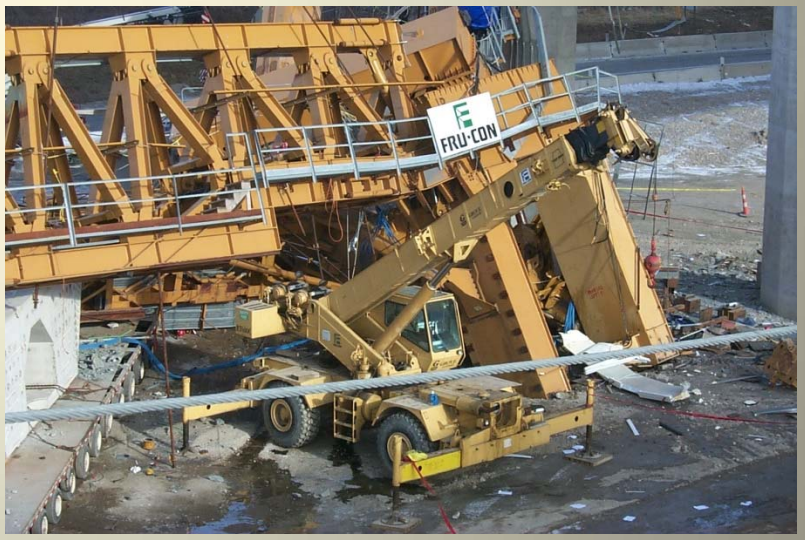
- Condition of not meeting an intended objective

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

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
  - Exceeds $5 billion annually
- This figure is based on insurance estimates
  - Underestimates actual amounts
  - Most settlements never made public

Litigation is big business

- 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

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Risk management

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

Contractual issues

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

Maintain good records

Activities that should be business as usual:

- Recommend you maintain project files:
  - The sum of:
    - Time set by Statue of Limitation

      Plus

    - Time set by Statue of Repose

Maintain good records

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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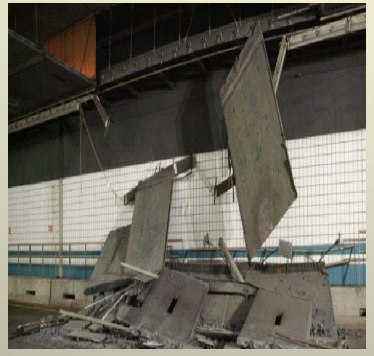
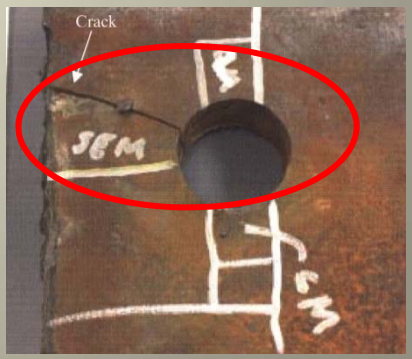
Front page projects

- I–35W bridge collapse, Minneapolis
- Big Blue crane collapse, Milwaukee
- Tropicana parking garage collapse
- Big Dig roof collapse, Boston



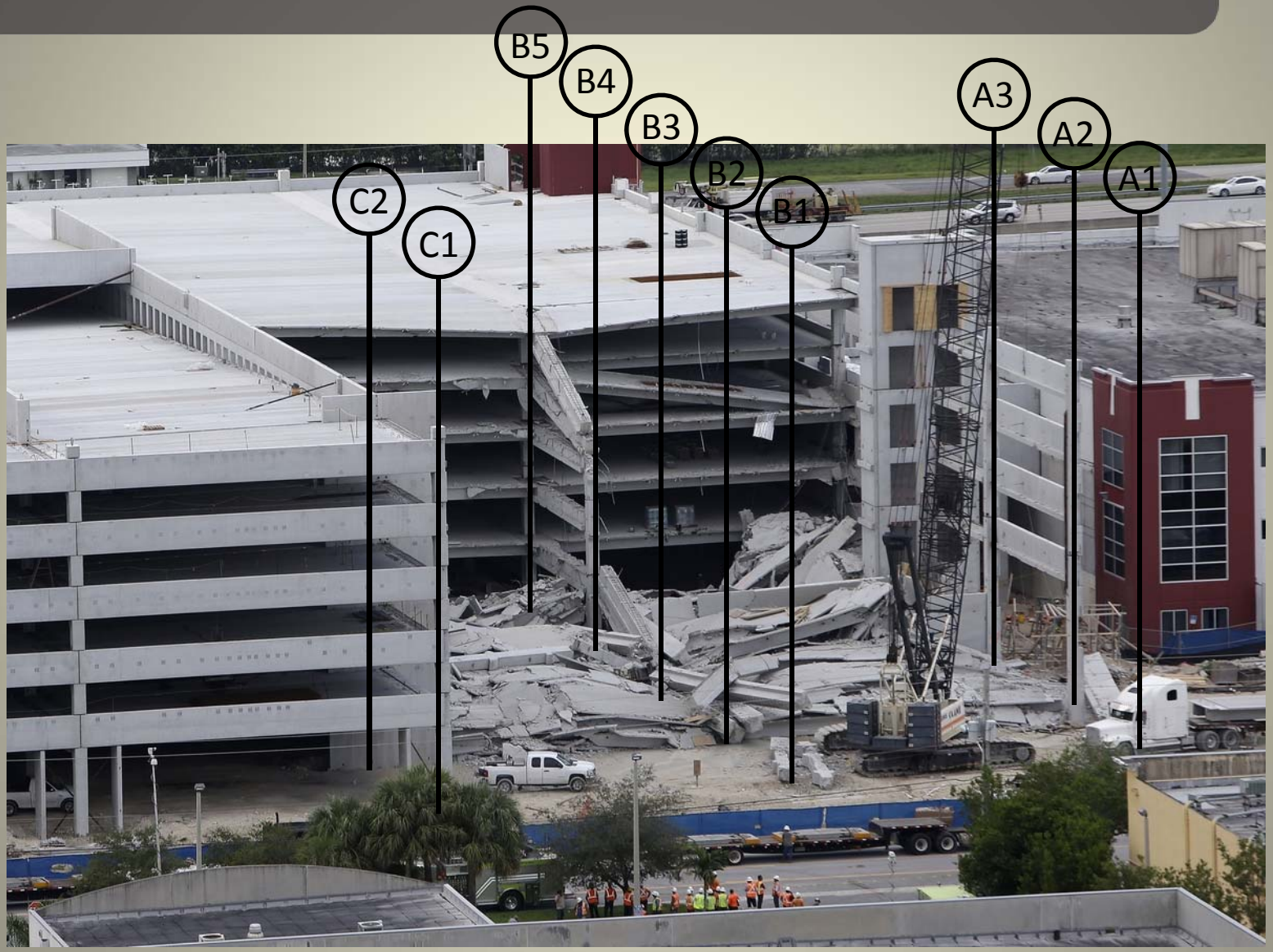
Most projects don't even make the news

- 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

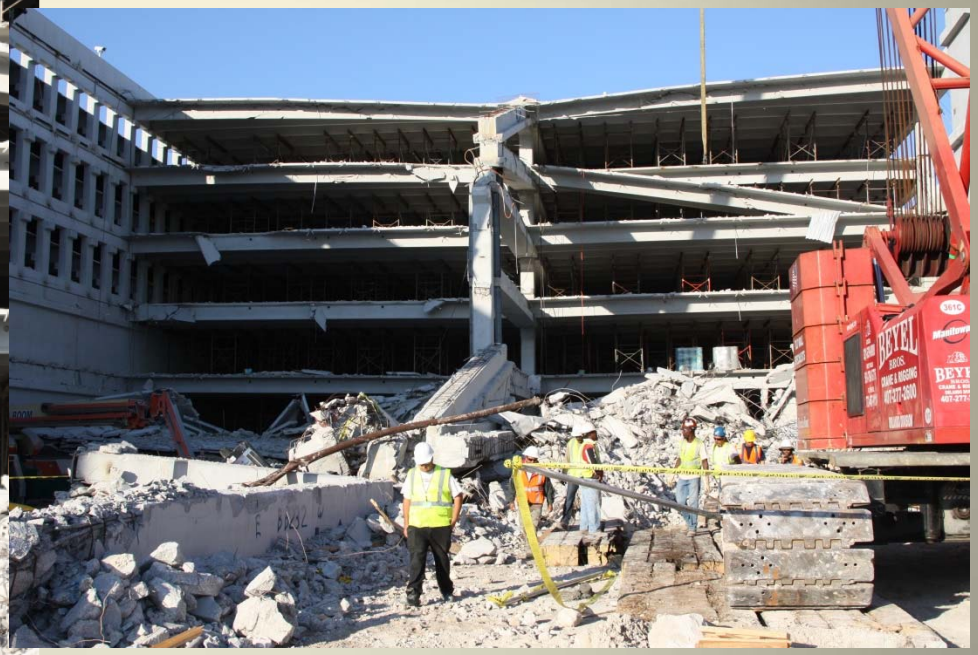
- Parking garage under construction
- Precast concrete construction
  - Nearly complete with precast erection
- 5 supported levels
  - Grade, Level 1
  - Roof, Level 6

Miami Dade College parking garage collapse



Miami Dade College parking garage collapse

Miami Dade College parking garage collapse



jlgconsultingllc

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

High Rise Concrete Overview

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 Concrete Overview

High rise construction observations

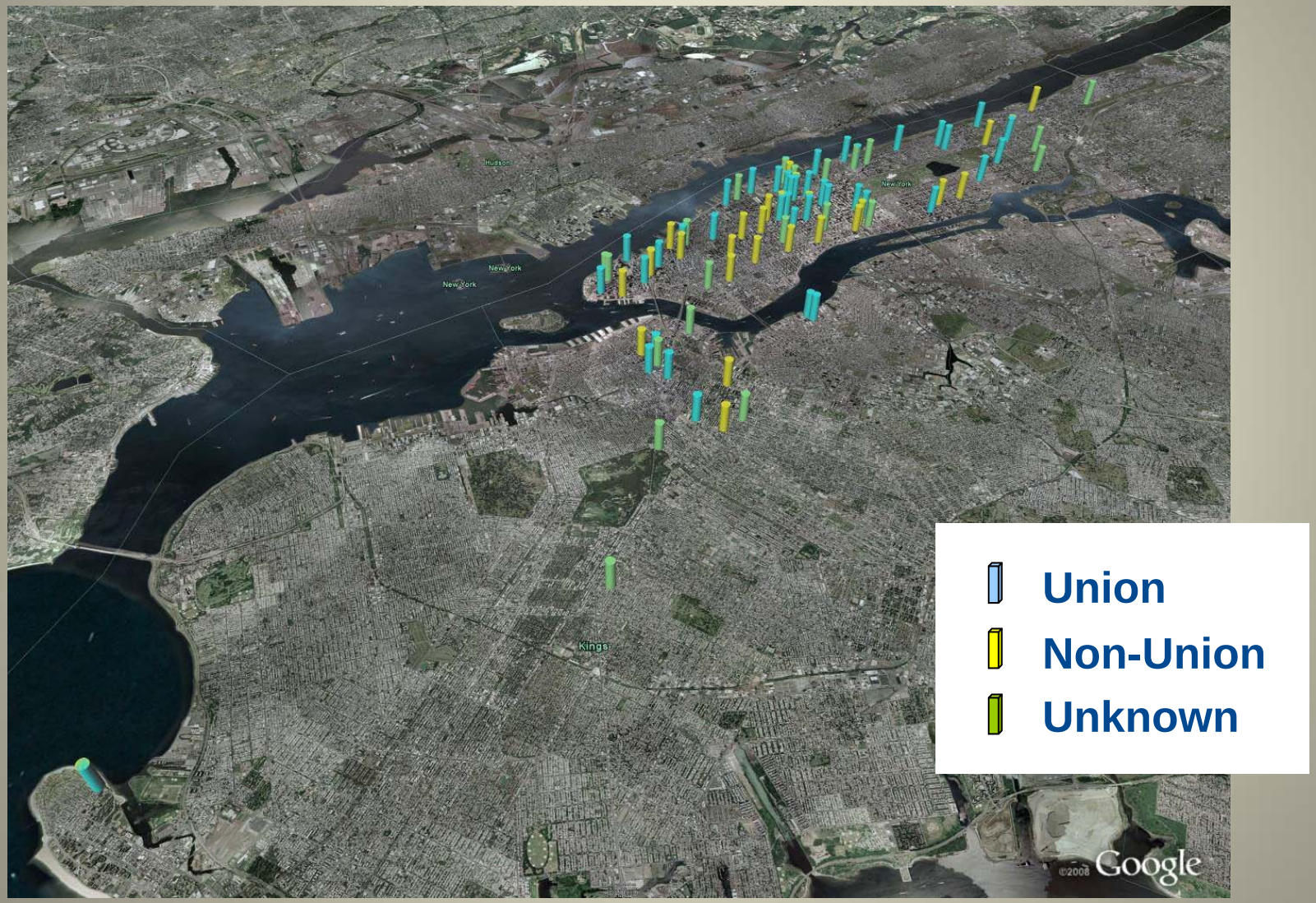
- HRCO concrete team:
  - Established data base of site conditions
  - Total sites visited: 181 site observations
- Quality & formwork data based on:
  - Subset of 98 active construction sites
  - Each inspected by P.E.

High Rise Concrete Overview

High rise construction observations

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

High Rise Concrete Overview



High Rise Concrete Overview

High-rise Concrete Areas of Interest

Formwork Issues

General Site Safety

Special Inspection and Construction Quality

Worker Falls

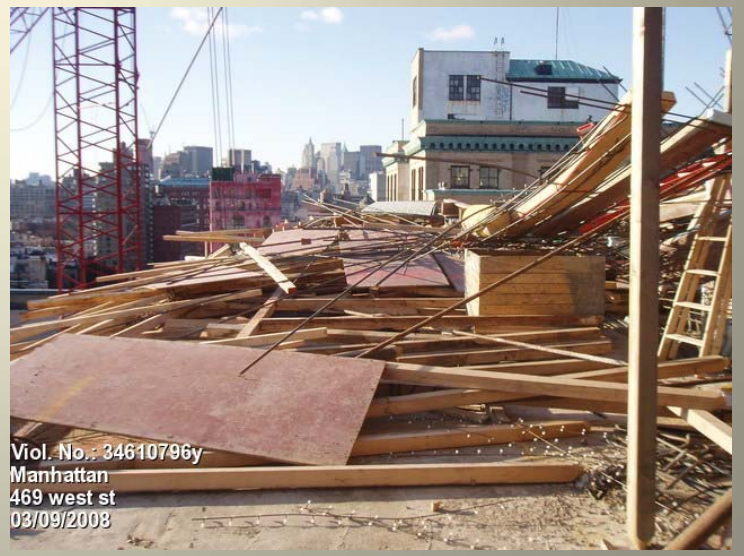
High Rise Concrete Overview

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

HRCO Observed Defects

	All Projects
Sample Size	98
Number of **Critical** Formwork Defects	57 (58%)

High Rise Concrete Overview

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

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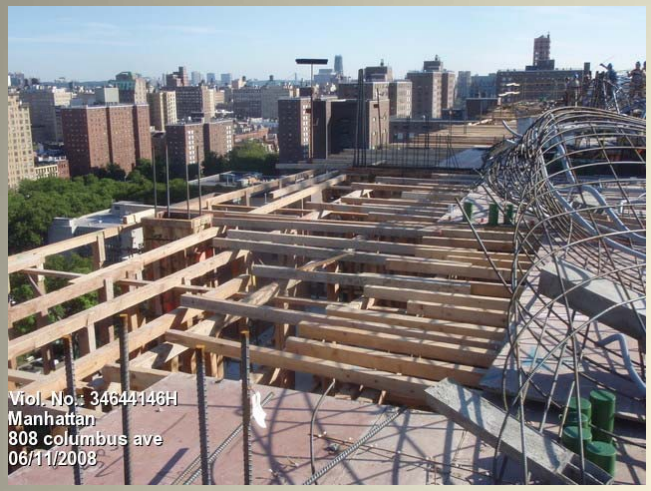
High Rise Concrete Overview



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

High Rise Concrete Overview

Historic Wind Incidents

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

High Rise Concrete Overview

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

High Rise Concrete Overview

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

High Rise Concrete Overview

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 Overview

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 Overview

High-rise concrete general site safety

	Sample Size	Unprotected Edges
All Sites	181	78 (43%)

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

	All Sites
Number of Active, Engineer-Inspected Site Observations	90
Number of Observed Quality Issues	39 (43%)
Number of Observed **Critical** Quality Issues	20 (22%)

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

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Special inspection and construction quality

High Rise Concrete Overview

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%

High Rise Concrete Overview

Quality recommendations

- Enforce NYC Special Inspection Rule
  - Strengthen outreach to industry regarding Special Inspection qualifications
  - All Special Inspectors must hold proper registrations or certifications

Special Inspection Category	2008 Code Section	Qualifications[1,2]		
		Primary Inspector or Inspection Supervisor	Supplemental Inspector (Alternative 1) - under direct supervision of Inspection Supervisor	Supplemental Inspector (Alternative 2) - under direct supervision of Inspection Supervisor
Concrete – Cast-in-place & Precast **Note**: Licensed concrete testing lab to perform sampling and testing of cylinders	BC 1704.4	• PE or RA; and • 1 year relevant experience	• ACI Certification as Concrete Construction Special Inspector (ACI-CCSI) OR • ICC Certification as Concrete Special Inspector (ICC-CSI)	• ACI Certification as an Associate Concrete Construction Special Inspector (ACI-ACCSI) **Note:** ACI-ACCSI only permitted to perform inspection under on-site supervision by PE, RA, ACI-CCSI, or ICC-CSI

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 Overview

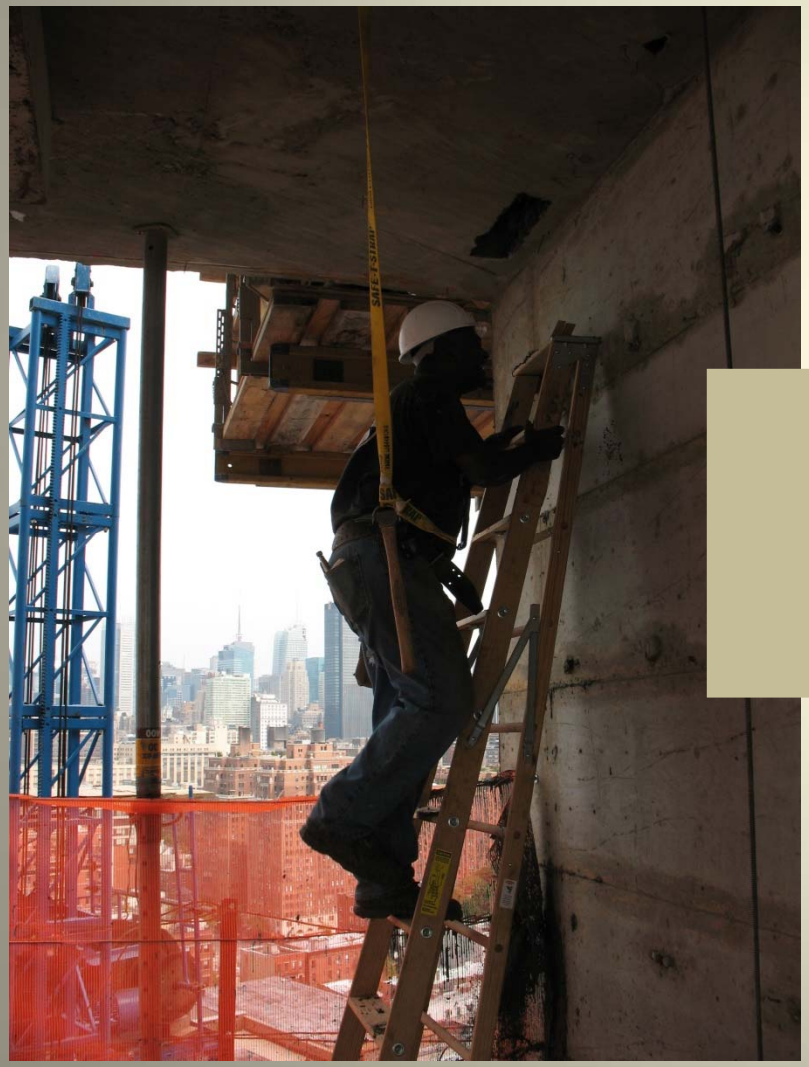
High-rise Concrete Worker Falls

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

High Rise Concrete Overview



High Rise Concrete Overview

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

High-rise Concrete Worker Falls

High Rise Concrete Overview

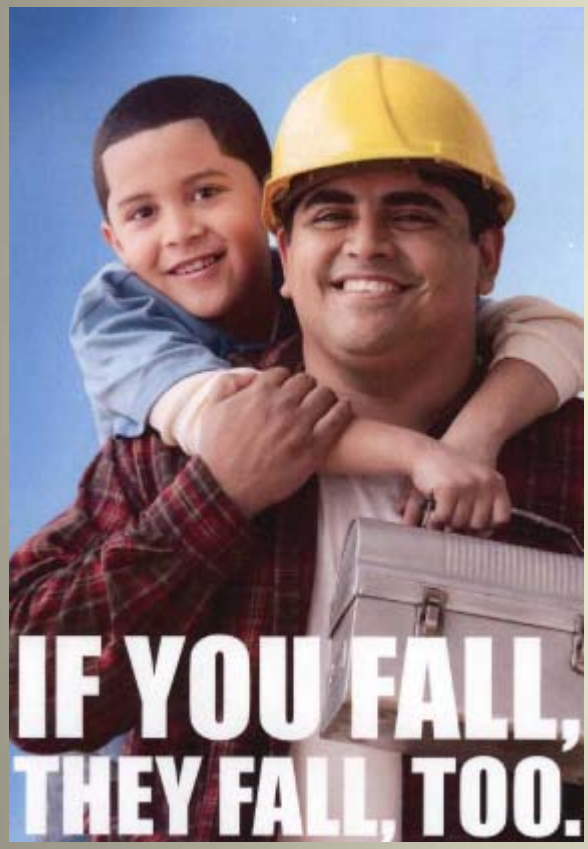
	All Projects
Fall Hazards	43%
Tie-off Compliance	33%

HRCO Observed Violations

Construction worker falls

- Fall hazards
  - Unprotected perimeter edges
  - Unprotected interior openings
  - Improper barrier installation
- Tie-off violations
  - 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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