Engineering Response to Catastrophic Workplace Accidents

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John Osteraas, Ph.D., P.E.
Exponent Failure Analysis Associates

Introduction

Catastrophic Workplace Accidents

- Low probability, high consequence events
- Frequently loss of life or serious injuries
- All normal activities suspended indefinitely
- Post-incident, multi-faceted inquiry

Introduction

Common Causes of Catastrophic Workplace Accidents:

- Failure of cranes and hoisting equipment
- Collapse of scaffolding and formwork
- Collapse of completed or partially completed structure
- Fires & Explosions

Plus others, some beyond imagination

Introduction

Phases of Catastrophic Accident Response

- Emergency Response
- Investigation
- Recovery

Introduction

Rapid response to a catastrophic accident with experienced team is critical to:

- Minimizing injuries and loss of life
  - No new victims
- Ensuring a competent investigation
- Facilitating a rapid recovery
- Minimizing economic losses

Emergency Response

Key Engineering Aspects of Emergency Response

- Support of Search and Rescue
- Stabilization of accident scene
- Assessment of Adjacent / consequential damage
- Assessment of Safety of remaining, similar structures

Emergency Response

Which type of accident poses the greatest risk for emergency response?

- Failure of cranes and hoisting equipment
- Collapse of scaffolding and formwork
- Collapse of completed or partially completed structure
- Fires & Explosions

Emergency Response

Search and Rescue

- Site controlled by Fire Dept. but owner/contractor cooperation is essential
- Owner/Contractor establish point of contact with Incident Commander and maintain open communication throughout incident
- Provide essential information to rescue team:
  - What happened
  - Known victims
  - Personnel unaccounted for
  - Known hazards
  - Availability of equipment, personnel to assist

Emergency Response

- Maintain clear communication
- Establish clear transition of responsibility following rescue operations
  - OSHA?
  - Building Dept?
  - Owner?
  - Contractor?

Emergency Response

Stabilization of accident scene

- Stabilization required for safety of
  - Rescue personnel
  - Adjacent property / public ROW
  - Investigators
  - Resumption of construction

Emergency Response

Stabilization of accident scene

- Mitigate safety hazards
  - Unstable debris and falling hazards
  - Potential additional collapse
  - Electric and gas utility lines
  - Hazardous materials
- Monitor environmental effects
  - Wind, rain, snow, temperature changes
- Consider destabilization due to debris removal
- Continuously review stabilization measures as conditions change

Emergency Response

Assessment of adjacent / consequential damage

Emergency Response

Assessment of safety of remaining, similar structural components

Emergency Response

Assessment of safety of remaining, similar structural components

Emergency Response

First Responder Training

- www.disasterengineer.org
  - "Structural Collapse Awareness"
- https://rsc.usace.army.mil/teeca/level2training/sca/

Accident Investigation

Process of Investigation

- Define questions to be answered
- Data collection
  - Site documentation & field testing
  - Collection and review of project documents
  - Laboratory testing and analysis
- Failure Analysis
  - Interpretation and analysis of data
  - Derivation of conclusions
  - Communication of findings

Accident Investigation

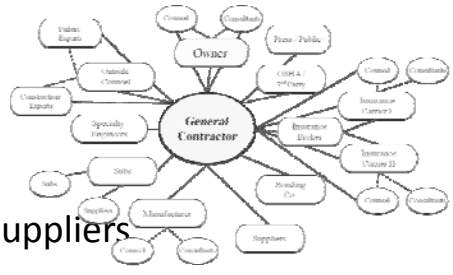
Common Questions to be Answered

- What was the root cause?
- What was the trigger?
- What was the status of construction?
- What loads were present?
- What defects were present?
- What activities were underway?
- What were the contributing factors?

Accident Investigation

"What happened?" Stakeholders

- Oversight Agencies
  - Civil
  - Criminal
- Owner
- Contractors & subs
- Equipment and material suppliers
- Victims
- Insurance carriers
- Etc.



Accident Investigation

Site & Evidence Management

- Who's in charge?
- Site safety
- Protocols for collection, labeling, and storage of physical evidence
  - Accident / exemplar
- Protocols for field and laboratory testing
  - Accident / exemplar

Accident Investigation

Data Collection – Site Documentation

- Documentation / preservation of perishable evidence
  - Collapse configuration
  - Fracture surfaces and witness marks
  - Eye witness recollections, photos, video
  - Weight and distribution of snow & ice
  - Concrete strength (time dependent)
- Collection of physical evidence
- Documentation of configuration and details of construction
- Field testing

Accident Investigation

Documentation of perishable evidence

- Begin as early as possible, preferably during search and rescue activities and under direction of an engineer
- Well-documented images
  - Video, stills
  - Webcams
  - Aerial photos – oblique and orthogonal
  - Who, when, where, what

Eye Witness Interviews

Information Sought

- Status of construction at time of collapse:
- Sequence of collapse
- Possible triggering events
  - Activities underway
  - Unusual loading
  - Environmental factors
- Photos, video

Collection of Physical Evidence

- Establish protocol for marking, collection, documentation, and storage of physical evidence
  - Key failed components
  - Exemplar components
- Establish protocol for extraction of physical samples
  - Concrete cylinders
  - Steel coupons
  - Soil samples

Field Sampling & Testing

Field Sampling:

- Collection and preservation for laboratory testing of representative samples of bulk materials too massive for preservation or transport to laboratory such as concrete, steel, soil
- Collection and preservation for laboratory testing of representative subset of components too numerous to salvage and store

Field Sampling & Testing

Field Testing:

- Physical in situ testing to determine behavior of bulk or large system
  - Soil stiffness, permeability
  - Structural systems
- "One test is worth a thousand expert opinions"

Field Sampling & Testing

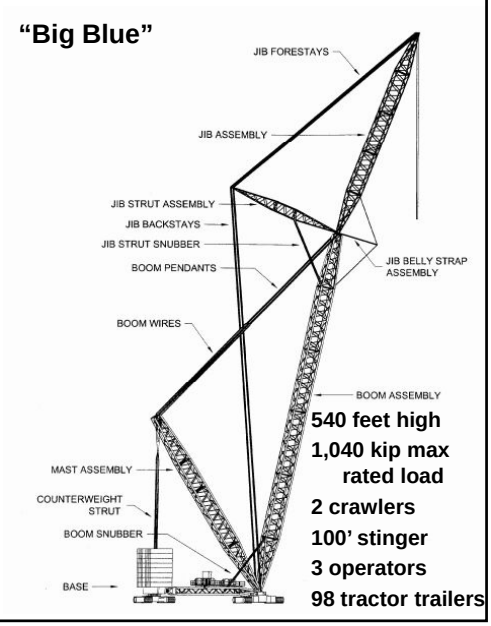
Protocol

- Why necessary
  - "Destructive" testing methods
  - Multiple parties, limited material
- Protocol Content
  - Procedure to be followed
  - Who is responsible for conducting
  - Documentation
  - Sample preservation

Project Documents

- Design drawings
- Specifications
- Boring logs
- Calculations
- Erection drawings, shop drawings, submittals
- Submittal logs
- Inspection reports
- Daily reports
- Test reports
- Correspondence

"Big Blue"



540 feet high
1,040 kip max rated load
2 crawlers
100' stinger
3 operators
98 tractor trailers

Other Valuable Information

- Climatalogical data
- Relevant codes & standards
- Manufacturer's manuals and specifications
- Industry standards of practice

BUILDING CODE OF THE CITY OF NEW YORK

OSHA 1971 35 2006

Data Interpretation & Analysis

- Develop hypotheses of failure sequence
- Extract relevant information from data to test hypotheses
  - Photogrammetry
  - Microscopic / chemical analysis
  - Numerical analysis
  - Parametric studies
  - Statistical analysis
- Refine hypotheses

Failure Analysis

- Numerical analysis provides insight, not answers!
- Assemble all puzzle pieces
- Apply insight and judgment
- Derive conclusions
- Communication of findings
  - Root cause, trigger, contributing factors
  - Correction / prevention

Recovery

Key components for timely recovery

- Thorough investigation leading to clear understanding of causes of catastrophe
  - Physical
  - Procedural
- Development of bulletproof solution
- Thorough review of overall design

Recovery

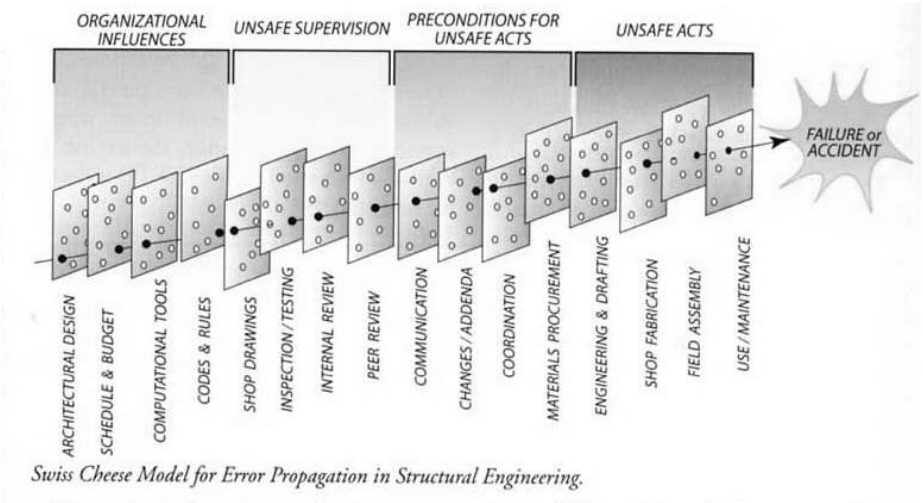
Project Controls

- Establish project cost and schedule status prior to event
- Post event – a revised set of project controls, cost, schedule, daily reporting, may be required
  - Remaining base (adjusted) scope of work
  - Increased scope resulting from event
  - Expediting / Acceleration / Inefficiency Costs

Accident Prevention / Avoidance

- Catastrophic workplace accidents are low probability events
- Frequently the result of bad alignment of a series of low probability events
  - Single point failures are rare
- Frequently stem from minor details
- Warning signs often lost in the “fog of battle”

Failure Trajectory



Swiss Cheese Model for Error Propagation in Structural Engineering.

The Devil is in the Details – Mighty Failures From Little Acorns Grow

For want of a nail,
the shoe was lost.
For want of a shoe,
the horse was lost.
For want of a horse,
the rider was lost.
For want of a rider,
the battle was lost.
For want of a battle,
the kingdom was lost.
And all for the want
of a horseshoe nail.

Closure

- Most failures are a sequence or intersection of multiple events and are preceded by warning signals
  - Heeding warning signals averts failure!
- Catastrophic accidents are low-probability, high consequence events
  - Not necessarily avoidable with reasonable measures
- Focus on accident avoidance, but be prepared with Emergency / Catastrophe Response Plan

Thank you

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Good luck

Success is the ability to go from one failure to another with no loss of enthusiasm.

Winston Churchill

Contact Information

John Osteraas, Ph.D., P.E.

Exponent Failure Analysis Associates

149 Commonwealth Drive

Menlo Park, CA 94025

650.688.7206

osteraas@exponent.com

http://www.exponent.com