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Directing the Forensic Investigation of a Catastrophic Structure Collapse: The Jacksonville Parking Garage Collapse

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***Abstract*—**This paper discusses the forensic investigation of a fatality-involved catastrophic structure collapse and the special challenges faced when tasked with directing such an effort. While this paper discusses the investigation's findings and the outcome of the event; this paper's primary focus is on the challenges faced directing a forensic investigation that requires coordinating with governmental oversight while also having to accommodate multiple parties' investigative teams. In particular the challenges discussed within this paper included maintaining on-site safety and operations while accommodating outside investigator's interests. In addition this paper discusses unique challenges that one may face such as what to do about unethical conduct of interested party's investigative teams, "off the record" sharing of information, and clandestinely transmitted evidence.

***Keywords*—**Catastrophic structure collapse, collapse investigation, Jacksonville parking garage collapse, forensic investigation.

I. Introduction

IN December of 2007, a 6-story structure while under construction in Jacksonville, Florida, USA collapsed to the ground. At the time of the collapse five of the stories had been completed and concrete for the 6th story was being placed. While one individual working on the floor below the pour died in the collapse the workers atop the 6th story sustained injuries as they rode the structure to the ground.

Following the collapse a forensic investigation was conducted so as to determine the cause and to identify if the cause of the collapse was or was not beyond anyone's control. This investigation was overseen by the Occupational Safety and Health Administration (OSHA). However, given the scale of the collapse and the number of interested parties each with their own investigative team, a third party working on behalf of the owner was tasked to direct the forensic investigation, coordinate with OSHA and accommodate each interested party's investigation team.

II. The Structure

A. Structural Configuration

The parking garage was rectangular in plan with its main axis oriented in a North South direction. It had been designed utilizing cast-in-place concrete columns, beams and slabs each with differing forms of reinforcing.

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B. Columns

The design called for three rows of cast-in-place simply reinforced concrete columns. The rows of columns were also oriented along a North South axis with one row on each side and one row down the center. The columns maintained their size and location from the ground floor up through the 6th with the largest column measuring approximately 61 cm (2 ft) by 121 cm (4 ft) and the smallest 35 cm (14 in) by 71 cm (28 in).

C. Beams

The design called for the beams to run from each outside columns to its corresponding interior column. With one exception, the design only called for beams in the East West direction. The beams were simply reinforced and heavily post-tensioned using up to as many as 78 mono strand tendons. The beams were discontinuous at their center and their dimensions varied. The largest beam measured 84cm (33 in) deep by 152 cm (60 in) wide and the smallest measured 69 cm (27 in) deep by 46 cm (18 in) wide. These beams spanned between 12 m to 17.6 m (40 to 58 ft). The North South beam measured 183 cm (72 in) deep by 76 cm (30 in) wide and spanned 18.3 m (60 ft). An isometric view of the beam configurations is depicted in Fig. 1.

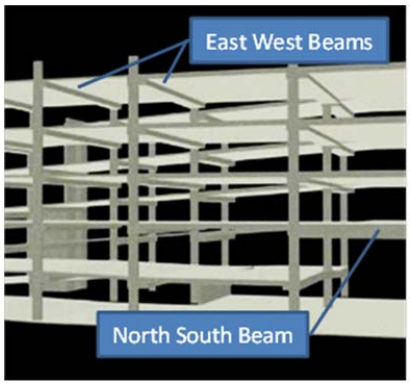

Fig. 1 Beam Configuration

D. Slabs

The slabs were designed as one-way slabs spanning North to South and supported atop the East West beams. These slabs contained very little mild reinforcing but were heavily post-tensioned with up to one mono strand spaced at 7.5 cm (3 in) on center running the entire North South length of the

structure, 75 m (246 ft) in length. The slab configuration is depicted in Fig. 2.

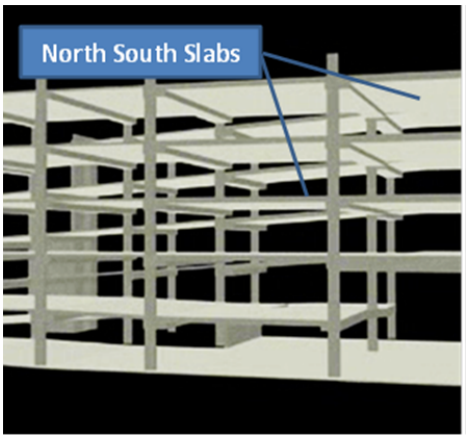

Fig. 2 Slab Configuration

E. Formwork

Throughout construction, conventional forming and shoring was used to support the beams and slabs until the concrete gained strength. The concrete was allowed on average 28 days to gain strength before pouring the next story above. The formwork designer called for the forming and shoring to run continuous through the structure all the way to the ground.

F. Parties Involved

According to OSHA's May 2008 report titled *Investigation of the December 6, 2007 Fatal Parking Garage Collapse at Berkman Plaza 2 in Jacksonville, FL* [1], the key participants included the structural design engineer, the threshold inspector, the formwork designer, the formwork inspectors, the general contractor, the formwork contractor, and the concrete subcontractor.

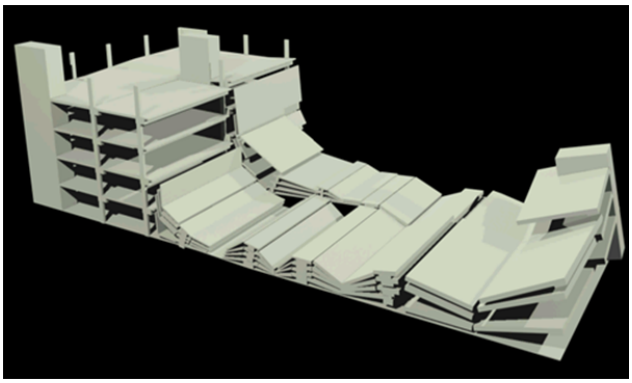

Fig. 3 Collapse Configuration

G. The Collapse

When the structure collapsed, more than 60% (the entire Northern portion) collapsed straight down in what rescue engineers described as a "pancake collapse". The portion left standing at the South end was badly damaged and ultimately required that it be razed. The disposition of the structure in its collapsed state is depicted in Fig. 3.

III. The Forensic Investigation

Due to the fact that a death and numerous serious injuries occurred during this collapse the Occupational Safety and Health Administration (OSHA), a governmental agency charged with worker safety was named as the authority having jurisdiction.

Given the scale of the collapse and the number of interested parties, OSHA selected and tasked a third party, working on behalf of the owner, to direct and oversee the forensic investigation. Specifically, this third party was tasked with coordinating the onsite investigation with OSHA while also accommodating each interested party's investigation team.

A. The Investigative Teams

In addition to OSHA, a second governmental agency, the Florida Board of Professional Engineers (FBPE), conducted its own investigation into the cause of the collapse. While not the authority having jurisdiction, the FBPE is responsible for adopting and enforcing rules regulating the practice of engineering throughout the state of Florida. Therefore the FBPE focused exclusively on the role that each of the engineers involved played.

The balance of the 19 investigative teams represented involved or potentially involved parties investigation teams not including OSHA, FBPE and the third party working to determine the cause of the collapse and the culpability of those involved.

B. Challenges

In addition to the technical challenges of removing debris without causing additional damages, performing testing and sampling, documenting conditions encountered and maintaining a consistent working schedule; this project included unique challenges. These challenges included maintaining on-site safety while providing outside investigator's the ability to investigate. Ethical challenges also presented themselves; what to do about alleged unethical conduct of interested party's investigative teams, "off the record" sharing of information, and clandestinely transmitted evidence.

C. On-site Safety

After a major structural collapse safety is the obvious primary concern. As seen in Fig. 4, a photo of the collapse immediately prior to the commencement of the investigation, the precarious nature of the debris was compounded by the number of potential secondary collapse hazards. Safety is accomplished through control of the scene. Control is accomplished by not just installing fences, guards and cameras but also through well-developed protocols that are published to all parties.

These protocols need to address:

1. How the site will be accessed,
2. Who will be provided access to the site,
3. Who will be able to examine the debris pile and when,
4. The methods and techniques that are to be used for deconstruction of the debris pile,

5. The methods and procedures to be used when performing on-site testing,
6. How items will be collected, stored and made available for subsequent review,
7. How and when collected items will be disposed, and
8. Methods of communication to include who will be copied on what types of communication.

However, even on a scene such as this where safety is the primary concern and protocols have been put in place, maintaining control of the site involves managing the balance between *Order of Control* and *Order of Importance*. Fig. 5 shows those items that typically compete for control.

Fig. 4 Hanging Slabs

Site conditions include constraints and limitations of the site that will impact the investigation. In this case the site was extremely limited and storage of items removed from the debris pile posed logistical hurdles.

Equipment availability was also an issue. In this case there were questions as to the placement of the steel within the slabs and the columns. The easiest way to make the examination would be to use a rope saw to cut the members and expose their cross section. The lack of availability of a rope saw precluded its use.

Time requirements were one of the greatest challenges. Aside from efforts to maintain construction on the balance of the site, OSHA had a six month window to complete its investigation and issue its report.

Cost of on-site activities included costs associated with security, specialized equipment used to facilitate selective debris removal and ever mounting investigative costs.

The greatest nuisance and biggest source of friction came in part from the investigators but mainly from the attorneys involved. Keeping the attorneys in line and out of the process proved to be both challenging and tremendously time consuming. This would have proven unmanageable were it not for the protocol dealing with the various methods and types of communication.

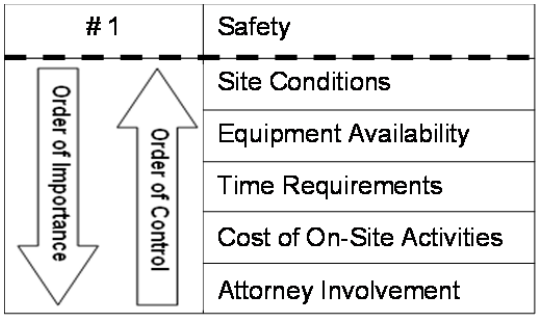

Fig. 5 Order of Control v. Order of Importance

D.Ethical Challenges

The ethical challenges that presented themselves included what to do about unethical conduct of interested party's investigative teams, "off the record" sharing of information, and clandestinely transmitted evidence.

Throughout the process certain members of some investigative teams failed to conduct themselves in an ethical manner. Instances included violating the established protocols by taking items from the site without authorization. Whether items were taken as souvenirs or taken so as to influence the investigation was never established. There were however instances where items ranging from sign-in sheets, to rebar segments, to pieces of shoring and in one instance an investigator's camera and notes were stolen.

"Off the record" sharing of information became rampant among the investigators. Given that clearing of the debris went on for 8 hours a day, 5 days a week for nearly 8 months, many of the investigators began sharing information. While problematic for the investigators, it was realized that there were instances of sharing information that were done so with the intent of influencing the investigation so as to create opportunities to challenge its findings.

Unfortunately displays of unethical conduct are to be expected. What was not expected were the instances of clandestinely transmitted evidence from witnesses to the team overseeing the investigation. In one instance the evidence included digitally stored footage of an inspection performed immediately prior to the collapse that served to document the manifestation of the beginning of the failure. Even more damning was the attitude displayed by those conducting the investigation toward the conditions being documented. The issue with anyone other than OSHA accepting such evidence is that it has the potential to call into question the objectivity of the investigation.

As these types of displays were encountered, the individuals involved were confronted and banned from the site which then brought about its own set of challenges; enter the attorneys and the *Order of Control* verses the *Order of Importance*.

IV. Investigation Findings

A. Findings Presented

This paper presents the investigative findings of the two governmental agencies: OSHA and the FBPE. OSHA's findings were published in their report titled: *Investigation of*

the December 6, 2007 Fatal Parking Garage Collapse at Berkman Plaza 2 in Jacksonville, FL [1]. This report focused primarily on construction and worker safety but also addressed the design and construction oversight as contributory causes.

As for the FBPE's findings, these were obtained through public records requests due to the fact that the FBPE is an administrative body as opposed to a regulatory body. The FBPE focused on the roles and responsibilities of each of the engineers involved.

B. Cause of the Collapse

In short, the collapse was not the result of a single incident beyond anyone's control. Instead the collapse resulted from numerous tragically avoidable errors with as many as six different companies and four licensed engineers all playing a role. These errors were categorized into two major areas; formwork and construction inspections, and engineering design related to the project as a whole.

C. Formwork and Construction Inspection

The formwork plans, prepared by the formwork designer, called for the shoring and reshoring to extend all the way to the ground. However, it was learned that the shoring and reshoring below the 3rd level had been removed shortly before the concrete on the 6th floor was placed. Within its May 2008 report, OSHA states "*There are conflicting reports about why the shoring was removed despite the fact that the design drawing showed the reshores extending down to the 1st level.*" Nonetheless, the shoring was removed and construction continued [1].

FBPE's records state that the formwork inspector depended principally on information provided verbally by the contractor and in fact never reviewed the reshoring drawings until after the collapse [6], [7].

FBPE's records also state that the threshold inspector failed to determine that the formwork inspector had inspected the shoring and reshoring for conformance with the plans [4], [5].

It was reported by OSHA that reinforcing steel for the primary structural components had been left out and/or misplaced during the construction [1].

FBPE's records state that the threshold inspector failed to adequately inspect the construction of the load bearing structural elements. In addition it was reported that this resulted in reinforcing steel for the primary structural components being left out and misplaced during construction [4]-[5].

D. Engineering Design

It was reported by OSHA that while the construction of the parking garage included many minor and major issues, "*the difficulties were compounded by the fact that the SER [structural engineer of record] was not forthcoming in resolving the questions, and had a nonchalant and dispassionate attitude towards the structure he designed*" [1]. OSHA also stated that the "*SER denied this during an interview with OSHA*" [1].

OSHA reported the following related to the design of the structure:

1. From the flexural aspect, the beam design was deficient under code prescribed load and phi factors [1].
2. The shear stirrups were significantly under-designed for the factored dead and live loads and did not meet the code requirements [1].
3. Of the eight columns, all except H4 were determined to be deficient as per the prescribed codes, based upon the 5,000 psi concrete, the strength specified by the SER [1].
4. The column C4 was considered the most critical. For load case No.1. C4 was barely able to support the dead loads even when the phi factor was not considered. This is the most serious design flaw in the structure [1].

FBPE's records state that the structural design engineer issued drawings that were materially deficient with respect to; the design of the beams, the design of the columns, and the design of the beam to column connections [2]-[3].

E. Parties Responsible

OSHA cited the general contractor, the shoring contractor and the concrete subcontractor as having played a role in causing and/or facilitating the collapse. In addition, the FBPE cited the structural design engineer, the threshold inspector and the formwork inspectors for having contributed to causing the collapse. Of the 4 licensed engineers, 2 had their license revoked (the structural design engineer and the threshold inspector), one surrendered his license (one of the formwork inspectors) and the fourth had his license severely disciplined (the other of the formwork inspectors).

V. Conclusion

Forensic investigations that require coordinating with governmental oversight and multiple parties' investigative teams will present challenges to those faced with directing them. However challenges such as *Order of Control* verses *Order of Importance* and unethical conduct of those that are being coordinated with can be overcome and even managed when dealt with in advance.

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