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Forensic Engineering Analysis of a Concrete Pumping Accident

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Abstract

This paper describes the writer's forensic engineering approach in analyzing concrete pump lessor, pump operator, general contractor, and subcontractor roles and responsibilities in an accident where a concrete finisher was using a concrete pump in an unsafe manner. The paper also includes a discussion of the applicability of OSHA regulations regarding employer responsibility for construction safety at multi-employer jobsites.

Keywords

Forensic engineering, concrete pumps, construction sequencing, OSHA

Introduction

The writer was retained by the plaintiff's attorney to determine the cause of the accident.

Equipment Description and the Concrete Pumping Process

Truck-mounted concrete pumps with articulating booms permit concrete placement at considerable distances from the concrete delivery trucks or mixers. Some concrete pumps feature telescoping booms. Such booms, by reducing the overhead clearance required to deploy the boom, permit the concrete pump's telescoping boom to be positioned under structures located over the concrete placement location, such as structural steel. A photograph of a typical concrete pump is presented at right.



Figure 1
A Typical Concrete Pump with Articulated Boom.

The typical pump's specifications are presented in the following table.

Boom – articulating and telescoping	87 foot horizontal reach	100 foot vertical reach
Five (5) inch pipe diameter	Theoretical Concrete Output – 170 cubic yards/hour	
Max Pressure on Concrete – 1007 psi	Maximum Aggregate Size – 2.5 inches	

Figure 2
Typical Concrete Pump Specifications.

Concrete pumps, unlike less complex construction machinery offered for short term lease, such as skid steer loaders, require that the operator have specialized knowledge. Therefore, it is the usual and customary practice for the lessor to provide a trained operator with such leased equipment.

Safe, proper, and recommended operating practice with such construction machinery is to place the concrete using a vertically-oriented “tip hose.” When

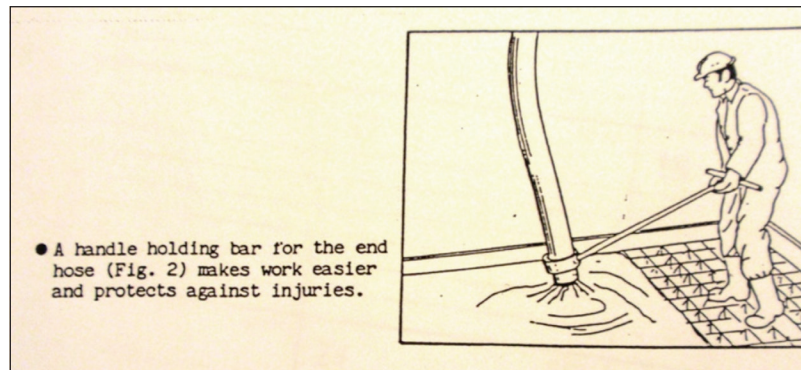


Figure 3
Use of a Tip Hose Holding Bar.

so used, the pump truck’s boom supports the weight of the tip hose and the plastic concrete and laborers are able to push or pull the tip of the vertically-oriented tip hose laterally during the placement. However, use of a holding bar as depicted in the figure above is suggested to make the work easier and prevent injury.

Background

The plaintiff indicated that he “was the hose guy” and described the incident as follows in his Answers to Interrogatories: “The person that operated the pumper is known as the pump guy. He decided to use a boom. He hitched five 10 foot long 5” diameter lines to the end of the hose hanging off the boom. Then he used a metal reducer and then four 4” diameter rubber hoses. My job was to direct the hose to shoot the concrete where we were doing the floor. I had the hose on my right shoulder. There was an increase in pressure in the hose and the force of that through the hose caused the hose to jump around and come down on my shoulder and snapped and crushed down on my shoulder and I could not lift the hose off of my shoulder.”

Photographs of the jobsite were taken by a concrete salesman immediately before the incident. The photograph presented below depicts how the men were distributing the concrete. The plaintiff is the man wearing the white-colored hardhat.

The plaintiff’s employer was a subcontractor hired by a concrete subcontractor to place and finish the floors. There was no written agreement between these two entities. The principal of the concrete subcontractor testified that the fact that the roof purlins were in place created pump setup problems and that ideally, “the concrete guy” should be there before “the iron guy.” He also testified that he had no conversation with the owner, acting as the General Contractor about how structural steel work might interfere with the ability to do concrete work.

The photograph presented below illustrates that the concrete pump’s boom had to be extended over the roof-related structural steel. A larger than expected concrete pump was dispatched to the site. It was too tall to be located inside the building. As a result, it was not possible to setup the pump inside



Figure 4
The Plaintiff and Co-Workers Dispensing Concrete
Using the Concrete Pump's Tip Hose.



Figure 5
Overall View of the Jobsite.



Figure 6
Concrete Pump's Boom Routed Above Roof Steel
Shortening the Pump's Horizontal Reach.

the building so that it could reach the most distant concrete placement location where the incident occurred.

The pump operator testified that he had 20 years experience with the operation of articulating boom type concrete pumps. He also testified that the boom initially had been routed through the doorway during the setup process but that he couldn't get the whole boom in the building. He further testified that the boom was not long enough to reach all of the places they needed to reach.

The principal of the concrete placement subcontractor testified that he had proposed to the pump operator that the boom be extended through the doorway and that hoses be run along the ground to reach the pour. He also testified that he and his men wanted to do it that way, they suggested it, but deferred to the pump operator, and that the men thought their way was safer, but not an easier way to deliver concrete. The subcontractor further testified that his crew had requested it be done their way but that the pump operator refused. He also testified that the pump operator decided to come down through the roof joists with hoses suspended from the boom, located above the roof. If the placement method recommended by the placement crew had been used, the laborers would not have had to support the weight of the concrete filled hose and placement would have been more easily controlled.

The concrete pump was manufactured by Schwing. The pump operator testified that he agreed with the manufacturer's concrete pump safety manual content that the operator was responsible for safe concrete pump operation and that it was his responsibility to speak up if he observed something unsafe. He also testified that it never was permissible to put a pump hose on your shoulder and that if he observed the placement crew do it, he would not allow it. The pump operator further testified that he was located by the pump, directing delivery truck drivers, was unable to see the placement crew, and that he assumed that the delivery hoses were located on the ground.¹

The principal of the concrete subcontractor testified that the concrete pump operator is responsible for safe pump operation and that the pump operator had the primary obligation for safety during the pumping operation. He also testified that the pump was radio-controlled; that the pump operator could have been at the placement location; and that the operator could have seen how the tip hose was being used. The principal further testified that he was aware of concrete pump related hazards, such as supporting the delivery hose on one's shoulder and of the clogging and kinking hazards.

The principal of the placement/finishing subcontractor testified that four hoses had been attached to the pump's boom that was up in the air. He also testified that he did not have holding bars, such as the one depicted in figure 3, on the job to drag concrete pump delivery hoses located on the ground as he did not expect to need them.

Forensic Engineering Analysis

Hydraulic systems and pumps are widely used on construction machinery. Engineers familiar with pumps are aware that such effects as pump cavitation, air in the fluid, restricted pump inlets, or a kinked flexible discharge hose can cause pressure variations at the pump discharge. It also is to be expected that high pressure variations would create movement in a flexible pump discharge hose, such as the tip hose of a concrete pump.

Furthermore, the substance being pumped by a concrete pump is slurry, not a liquid. Therefore a large diameter discharge hose must be used on a concrete pump. The slurry's heavy weight of about 150 lbs per cubic foot in the large diameter discharge hose could cause exaggerated movements of a relatively heavy object during a pressure variation, a potential source of laborer injury if the hose is supported manually by a construction worker.

From such an analysis, it was concluded that use of men to support the weight of the tip hose and concrete being delivered exposes them to the risk of injury, either from the effects of holding and carrying excessive weight or from unexpected hose movement during the pumping process. Therefore, it also was concluded that support of the concrete hose on laborers' shoulders as the plaintiff and his two co-workers were doing when the accident occurred, was an unsafe practice.

As the investigation continued, technical specifications were downloaded and reviewed from a

major concrete pump manufacturer's website. A review of the concrete pump manufacturer's safety manual also was done. The safety manual contained the warning and drawing presented at right relative to the hazard.

The content of the safety manual as well as the deposition testimony of the pump operator and the principal of the concrete subcontractor provided the information needed to formulate an opinion that the hazard of a laborer's bodily support of a concrete pump tip hose was well recognized in the concrete industry.

Regarding the pump leasing and pump operator's safety responsibility, my experience with construction machinery lessor/lessee practice and equipment operator obligations as well as the concrete pump manufacturer's safety manual provided the information required for formulation of opinions on the pump operator's awareness of the hazard and obligation to take steps to assure the pump was used in a safe manner. The pump operator failed to do.

The concrete pump safety manual also contained the following language:

- “Although much of the responsibility for everyday safety rests upon the pump operator, it is vital that everyone involved makes safety the top priority”
- “The operator is responsible for the safe operation of the machine.”
- **“WARNING! Closely monitor the placing crew (figure 48). If they are being unsafe, you must stop pumping and inform site management. Remember, the operator is responsible for the safe operation of the machine! Although, it may be the hose man's error, you may be held responsible for the accident if you could have prevented it.”**

The emphasis is not the writer's.

The plaintiff was part of the placing crew and was functioning as the “hose man” when he was injured. It was clear that the concrete pump operator, either by his failure to be aware of how the crew was placing the concrete, or by having observed the crew supporting the hose on their shoulders and having taken no corrective action, failed to operate the concrete pump in accordance with the pump manufacturer's safety manual.

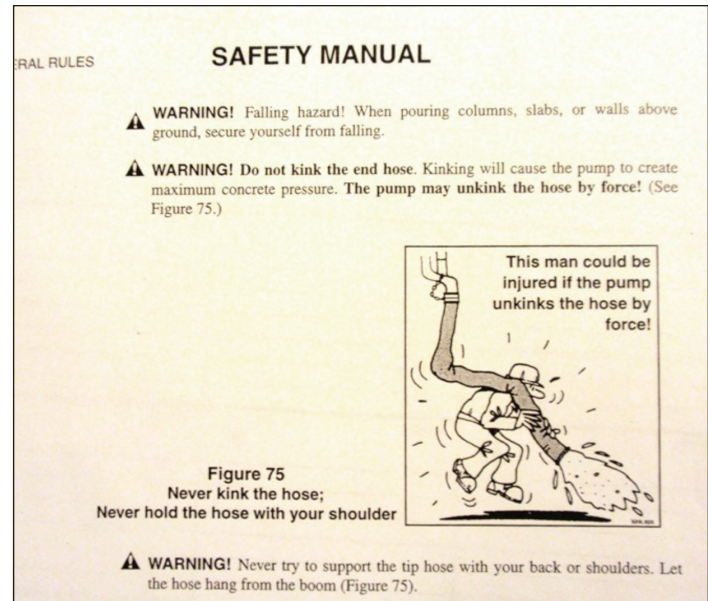


Figure 7
Tip Hose Warning in Schwing's Concrete Pump Safety Manual.

Improper construction sequencing also was an issue in this case. Specifically, the presence of the structural steel was an impediment to constructing the large concrete floor because it extended concrete pump setup times and prevented the pump's tip hose from being oriented in the safe, proper vertical orientation capable of reaching all sections of the pour. This fact was evident in the jobsite photographs figures 4-6. If the structural steel had not been present the concrete pump's boom could have reached all areas of the pour with the tip hose oriented in the proper, safe vertical position.

As stated earlier, the plaintiff was employed by a subcontractor hired by the concrete subcontractor. From deposition testimony it was learned that the building owner was acting as the general contractor. By industry practice, the general contractor is responsible for the sequencing of activity of multiple contractors on the jobsite. However, the testimony of the principal of the concrete subcontractor's firm demonstrated that the building owner's business was refuse handling, not general contracting.

However, notwithstanding the general contractor's business being refuse handling, not commercial building construction, the general or prime contractor always is responsible for safety regardless of his main line of business or experience level. This fact is demonstrated in 29CFR1926.16 – Rules of Construction, (a) which states: "...In no case shall the prime contractor be relieved of overall responsibility for compliance with the requirements of this part for all work to be performed under the contract." Furthermore, (c) states, "...the prime contractor assumes the entire responsibility under the contract and the subcontractor assumes responsibility with respect to his portion of the work."

The concrete subcontractor, with 12 years of experience, was familiar with concrete pumping hazards and with the floor construction impediment created by the structural steel's presence. In spite of such knowledge the concrete subcontractor had no conversation with the building owner's personnel about how the structural steel's presence would be a probable impediment to pouring the large concrete floor. Absent the structural steel, there would have been no impediment to safe proper use of the concrete pump and the incident would not have occurred.

The concrete supplier was delivering the concrete in transit mix trucks on the incident day. Excessive delays at the jobsite could have caused problems for the concrete supplier and delay-related extra costs for the concrete subcontractor. If the concrete pump was on site for more time than expected, there also may have been additional pump rental related charges.

From the photographs and the concrete subcontractor's testimony and drawing it is clear that the placement started furthest from the concrete pump and it was during this part of the placement that the plaintiff's incident occurred. The concrete subcontractor also testified that the group had tried several ways to setup the pump, including extending the boom through the doorway but were 15 feet short of getting into the corner. He also testified that he held the tip hose horizontally to deliver the concrete for the rest of the floor construction after the incident. Such testimony demonstrates that it would only have been necessary for the crew to support the tip hose on their shoulders for a small portion of the pour.

However, it also demonstrates that the crew had a safe option of adding one or two more sections of flexible hose routed horizontally on the floor.

Safe, alternative pump delivery methods were available that day. For example, the concrete pump's boom is rotatable. Absent information to the contrary, the boom could have been rotated over a different roof opening, either eliminating the need for the crew to support the hose on their shoulders or reducing the time that the hose was so supported, reducing the probability of an incident.

The concrete pump's delivery hose also was located over a previously constructed concrete island. It would have been possible to add additional hose to the pump and route the hose horizontally across the island and support it on several timber blocks placed on the floor as needed. So routed there would have been no need to support the delivery hose on the crew's shoulders. The men then could have used ropes to shift the tip hose laterally to reach all areas of the pour, exercising care to avoid kinking the hose. However, either delivery hose insertion through a different roof opening or a horizontal delivery hose setup would have delayed the planned large floor construction further, which already had been delayed because of the difficulty in locating and setting up the concrete pump.

OSHA Construction Safety Regulations

OSHA regulations were promulgated in the interest of improving construction job site safety and minimizing employee exposure to hazards. Part 1926.20 "General safety and health provisions" of the construction-related OSHA regulations contains the following clause relative to responsibility for job site safety:

"(b) Accident prevention responsibilities. (1) It shall be the responsibility of the employer to initiate and maintain such programs as may be necessary to comply with this part. (2) Such programs shall provide for frequent and regular inspections of the job sites, materials, and equipment to be made by competent persons designated by the employers."

In this case however, it was evident from the testimony that OSHA regulation content relative to accident prevention responsibilities utilizing regular inspections by competent persons was complied with. For example, such a competent person, the principal of the concrete subcontractor was on the jobsite. He also knew of the delivery method being used for the initial pour and that such method was hazardous. However, with such awareness, he directed or permitted the crewman to deliver the concrete in a manner that could cause an accident.

The OSHA regulations also contain the following language:

a) *"Contractor requirements"* of §1926.20 "General Safety and Health Provisions" stipulates that " - - no contractor or subcontractor for any part of the contract work shall require any laborer or mechanic employed in the performance of the contract to work in surroundings or under working conditions which are unsanitary, hazardous, or dangerous to his health or safety." OSHA's definition of "employer" is as follows: *"Employer means contractor or*

subcontractor within the meaning of the Act and of this part.” Their definition of competent person is as follows: “*Competent person* means one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has the authorization to take prompt corrective action to eliminate them.”

The general contractor, in this case the building owner, the concrete subcontractor, the company that leased the concrete pump, and the placement/finishing subcontractor were the “Contractor” and obligated for OSHA compliance. I focused my analysis of the available information and general knowledge of construction issues to formulate an opinion whether or not the various subcontractors by directing or permitting the plaintiff and others to deliver pumped concrete by supporting the delivery hose on their shoulders, violated the OSHA regulations.

Multi-Employer job sites, such as the jobsite involved in the incident, have been the topic of considerable historical discussion and disagreement relative to which entities are responsible for job site safety. In the late 1990’s, OSHA’s construction industry safety regulations that were promulgated in the early 1970’s were clarified relative to job site safety related responsibilities where job sites have multiple employers. An April 2000 article published in *Engineering Times* titled “Safety Responsibilities at Multiemployer Job Sites” summarized the four categories of employers, which are “Creating Employer”, “Correcting Employer”, “Exposing Employer”, and “Controlling Employer.”²

OSHA’s definitions of each type of employer are as follows:

- Creating Employer – “The creating employer is defined as one that causes a hazardous condition violating an OSHA standard.”³
- Correcting Employer – “The correcting employer is defined as one that is engaged in a common undertaking at the same job site as the exposing employer and which is responsible for correcting a hazard.”⁴
- Exposing Employer – “The exposing employer is defined as one whose own workers are exposed to a hazard. Regarding actions taken, if the exposing employer created the violation, it is citable for the violation as a creating employer.”⁵
- Controlling Employer – “The controlling employer is defined as one that has general supervisory authority over the job site, including the power to correct safety and health violations itself or require others to correct them. Control can be established by contract, or in the absence of explicit contractual provisions, by the exercise of control in practice.”⁶

The analysis required a determination of whether or not the lessor of the concrete pump and the concrete subcontractor were “employers” with employer related safety responsibilities according to the OSHA regulation.

Summary and Conclusions

The case presented concerned a leased concrete pump provided with an operator. The placing crew was employed by a subcontractor of the concrete subcontractor and constructing a large concrete floor for a refuse transfer station. The concrete placement crew was supporting the concrete pump's tip hose on their shoulders when it moved unexpectedly causing one of the crew to be injured.

An analysis was made of the hazard with the benefit of the writer's experience with hydraulic pumps and hydraulic systems. Industry safety literature was reviewed to determine the concrete industry's awareness of the hazard. The investigation included an analysis of the concrete pump operator's and the concrete subcontractor's awareness of the hazard and their responsibility to have prevented or not to have ordered unsafe acts by the subcontractor's placement crew.

In addition, the building owner, acting as the general contractor, had authorized the erection of structural steel before the floor was constructed, which, from my analysis and testimony, prevented the concrete pump's tip hose from being located over the furthest area of the pour from the pump. As a result, the analysis included evaluation of the concrete subcontractor's obligation to have advised the building contractor which structural steel erection would interfere with floor construction.

It was concluded that there were financial incentives that motivated the concrete subcontractor and the pump leasing company's personnel to take a chance; that is they either had directed or had permitted the placing crew to act in an unsafe matter, which caused the incident. Furthermore, both the concrete subcontractor and the concrete pump lessor were one of the "employers" as per the OSHA regulations and by acting as they did were in violation of the regulations and such violation also was a cause of the incident.

The case settled before trial for an undisclosed amount. However, several years after the suit was filed the plaintiff died of causes not related to the incident, which reduced his widow's settlement.

References

1. The deponents referred to this practice as the “old fashioned way” in their depositions.
- 2.– 6. “Safety Responsibilities at Multiemployer Job sites”, *Engineering Times*, April 2000, pg. 25.

Acknowledgements

Three sheet December 14, 2010 website download of specifications on Schwing America Inc.’s model S31XT, KVM34 X, and S42 X boom style concrete pumps from www.schwing.com/01.

Six sheet December 14, 2010 website download of sales promotional literature and specifications on Schwing America Inc.’s model S 31 XT concrete pumps from www.schwing.com/01.

July 20, 2006 twelve page website download of OSHA Directives CPL 02-00-124 through CPL 2-0.124 “Multi-Employer Citation Policy, which took effect December 10, 1999, www.osha.gov.

CFR 29, July 1, 2001 edition, parts 1926.20 “General Safety and Health Provisions” and part 1926.32 “Definitions.”