Incident Investigation

Analyzing a Fatal Crane Accident

Investigation reveals practical preventive measures

By Wayne Johnson and Risto Rautiainen

A 29-YEAR-OLD WORKER for a water tank company was killed when the partially assembled water tower on which he was working was struck by a falling portable tower crane. The worker was part of a three-person crew that reconditions and relocates used water towers; this tower was intended for a small rural Iowa community. An independent crane company was hired to erect supports for the water tower and lift the tank into its final position. This company erected its portable tower crane adjacent to the new foundations for the water tower (Photo 1). After hoisting the tank and while swinging it into position, with just a few feet to go, the rear crane outrigger facing the water tower slipped between cribbing timbers and sank into the ground (Photos 2 and 3). The entire tower crane fell toward the tower, smashing everything in its path.

The victim was standing on a horizontal strut of the water tower base, approximately 80 ft. in the air, preparing to adjust and tighten bracing rods once the tank was in position. Two other workers were injured—a member of the tank crew, who was positioned inside the ladder cage for the water tower, and the crane operator, who was sitting inside the control box of the crane 120 ft. above the ground. Photo 1 was taken just a few minutes before the crane fell.

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Between 1984 and 1994, some 502 deaths occurred due to 480 separate crane accidents; this equates to about 50 deaths per year due to cranes in the U.S. Electrocution from overhead powerlines was the single largest cause of death (39 percent). Operator error in setup/use is the primary factor in most of these fatalities, with upset or overturn of the crane accounting for seven percent of deaths (*Times Republican*).

In July 2000, the Iowa Fatality Assessment and Control Evaluation (FACE) program became aware of this incident through the local news (KGAN-TV3), and began an immediate investigation. A site visit was conducted that afternoon, and photographs were taken of the construction site, the fallen crane and the smashed water tower. The investigator who conducted this visit returned one week later to take detailed measurements after the crane had been removed. Other information was gathered from newspapers, interviews with the company erecting the water tower, a national Internet forum on crane accidents and other companies using this same type of mobile crane. An operator's manual for the machinery was obtained as well. Additional photographs were obtained from reporters at the scene immediately prior to and during the incident.

As noted, the employer was a small company specializing in water tower/tank reconditioning and relocation. It had been in business part-time for six years, and full-time for the past 15 months. Its three employees had multiple combined years of experience working with and moving water tanks. In this case, two workers were positioned on the water tower itself, while the owner gave verbal instructions from the ground.

The company had a written safety program, and all three workers had completed safety training for this type of work. However, due to the complexity of the task and the unique circumstances of every job, specific written safety instructions were not possible. Safety was discussed each day on the job, and workers were aware of the risks and wore proper fall protection (including safety harnesses and shock-absorbing lanyards). The victim had seven years' experience working with water tanks and two years' experience with this company. This was the company's first fatal accident.

The crane company involved had experienced a fatal accident three years prior while erecting a windmill generator atop a 140-ft. column. The same type of mobile tower crane had been used on that job. Timbers under the outriggers were placed on recently backfilled soil adjacent to the new windmill foundation, and the timbers sank into the loose soil, causing the tower crane to fall with its hoisted load (see www.public-health.uiowa.edu/face/Reports/REPORT-028.htm).

(Clockwise from top, left): Photo 1: The water tower minutes before the incident.

Photo 2: Close-up of rear outriggers.

Photo 3: This photo was taken during investigation; it is shot from the rear of the crane trailer.

PHOTO 1: MARSHALLTOWN TIMES REPUBLICAN

Accident Investigation

The water tower, which had been used at a public facility, was to become the water supply for a rural community with a population of 250. The tower was 127 ft. tall; its 50,000-gal. capacity tank was 22 ft. in diameter and 23 ft. tall, and had an empty weight of 28,000 lbs. The tank company employees considered this a small job, as they had worked on much larger municipal water tanks.

Two months before this accident, a local contractor excavated the area to a depth of 18 ft. and structurally filled this area to a depth of seven ft., all according to specifications received from an engineering firm that specializes in water tower construction. The structural fill dirt trucked in for this situation was described as gray brown lean clay trace silt.

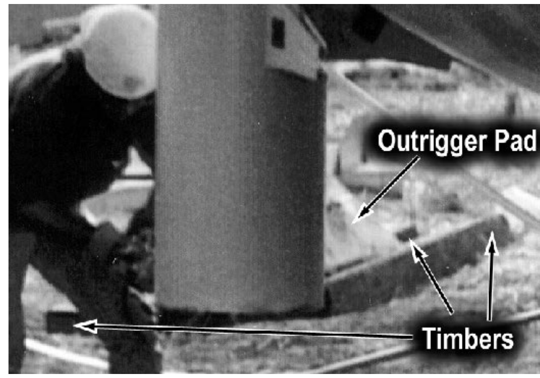
The fill was compacted to 98 percent of maximum, then later tested and certified (at seven ft. below grade) by an independent engineering firm as suitable for a load-bearing capacity of 2,000 pounds per sq. ft. (psf). This was the level where the foundations for the water tower were poured.

The next six ft. of soil were backfilled and compacted to 95 percent of maximum; although never tested, it would likely retain the 2,000 psf rating. The final six to 12 in. of topsoil were comprised of black dirt that had been scraped off the area prior to excavation. This soil had no certified bearing load—it was not compacted and was added to allow grass to grow in the area. The mobile crane trailer had difficulty maneuvering in this black dirt and required assistance from the excavation contractor on site.

The exposed sections of the four concrete foundations for the tower were 24 ft., 10 in. apart (Figure 1). The four legs of the water tower were bolted to these concrete pads, and horizontal struts and tightening rods were in place to keep the supports square.

The last major construction procedure was to lift the reconditioned water tank onto the legs of the water tower. The crane company was using a portable telescopic-type tower crane with a capacity of 30 tons. It had a platform height of 140 ft. with a 50-ft. boom, giving the entire crane a height of approximately 188 ft. The last crane from this manufacturer was made in 1980, so this crane was at least 20 years old. Although described as more complicated than other cranes, it is well-suited to set up and use quickly in urban settings.

The water tank was initially unloaded about 100 ft. from the water tower. Therefore, the crane was first erected at a suitable location to move the water tank into the proper position for the final lift, adjacent to the water tower legs. During this move, the capacity and reach of the crane were tested by "booming down" or "walking the load"—extending the swing radius to 30 ft., six ft. farther than would be required for the final lift, which required a swing radius of approximately 24 ft. The tank was kept just off the ground for the test lift in case of overloading. At this time, the crane had no difficulty moving the empty tank; subsequently, the tank was placed adjacent to the water tower and the portable crane was moved into position for the final lift the next day. The crane was not tested by booming down at this final location.



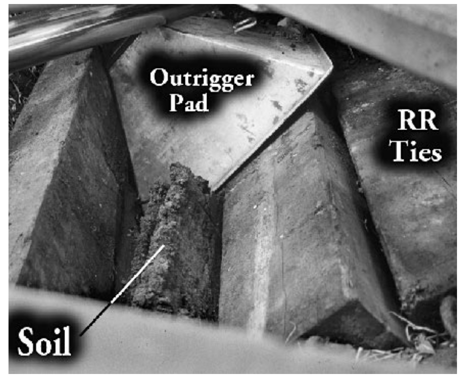


Photo 4: Tank worker preparing leg of the water tank.

Photo 5: Close-up of timbers under the right outrigger that failed 20 minutes later.

Photo 6: Failed outrigger pad and cribbing timbers.

Photo 7 (pg. 19): The trailer's right rear dual tires left a deep depression in the ground when the weight of the hoisted load and the crane was momentarily transferred to the trailer.

As mentioned, it was difficult for the semitractor to move the crane trailer into position because of the soft topsoil. Photographs show deep wheel tracks from the trailer's four sets of dual tires. A local farmer with 30 years' of farming experience described the soil as "hard as pavement on top, yet pure gumbo underneath." He said the soil was difficult to work; it drained poorly and retained moisture more than other soils. The jobsite was flat, the ground surface was dry, the temperature was in the 90s and essentially no wind was present that day.

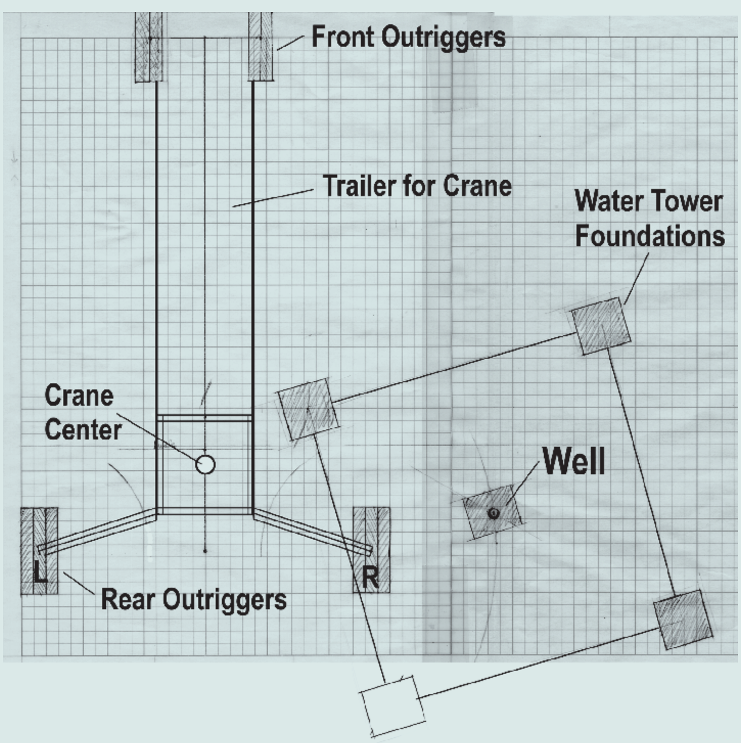
The crane was positioned at an angle to the water tower foundations, as close to the water tower as possible (Figure 1). This type of tower crane has four outriggers, two at the front (adjacent to the trailer edges) and two at its rear. The front outriggers are secured to the right and left sides of the transport trailer; they have no lateral movement but are hydraulically driven downward to level the crane. The two rear hydraulic outriggers are on nine-ft. extended beams, which produce a center-to-center distance between these outriggers of 27 ft. These outriggers swing into position manually, then are pinned in place with a steel strut. Each beam is extended hydraulically, forcing the outrigger pads downward to level the crane.

Each front outrigger was set on two timbers that were set directly on the ground. These timbers were 85 in. long, 12 to 13 in. wide and seven in. tall. Each rear outrigger was set on three of these timbers, which also were set on bare ground. No evidence suggested that any attempt had been made to move the topsoil in the area; all outriggers were set directly on this black dirt. The right rear outrigger was set inside the perimeter of the new water tower, approximately 11 ft. from the well opening. No plywood or steel plates were used under the timbers to distribute the load, nor were any bolts or other rigging used to secure the timbers together.

Shortly before the final lift, the water tank was raised a few feet off the ground to clean the bottoms of the support legs (Photo 4). This photograph shows a glimpse of the outrigger and cribbing timbers that failed 20 minutes later. A closer look reveals some noteworthy details (Photo 5): 1) the ground is not level under the timbers; 2) the cribbing timber to the right has already begun to roll out from under the pad; and 3) space is evident between the right and middle timbers. The appearance of the timbers is consistent with their final position after the accident (Photo 6).

Figure 1

Diagram of Work Area



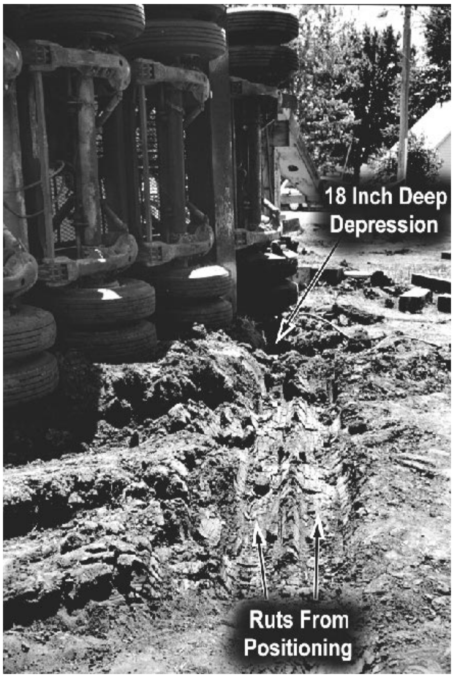
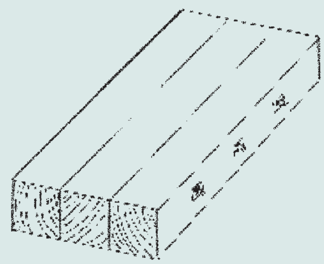


Figure 2

Bolted Cribbing Timbers



The crane involved can be controlled from two locations: 1) an elevated cab within the tower itself at a height of 130 ft. or 2) remotely, from the ground. The crane can be manuevered equally well from each location, although remote controls are normally used for safety reasons. In this case, however, the crane operator opted to work from the elevated cab position, apparently to more clearly see signals from workers located on the water tower.

As noted, two tank company workers were positioned on the water tower itself to "catch the iron"—direct the final positioning of the tank. One worker was inside the ladder cage at the top, to guide placement of the tank onto the water tower legs. As noted, the victim was on a horizontal strut, preparing to position and tighten the X-bracing immediately after the tank was lowered onto the tower's legs.

The water tank was raised to about 130 ft., then swung over the water tower structure to align it with the base; this procedure lasted approximately 11 minutes. Vertically, the tank was within four ft. of the water tower legs when the right rear outrigger on the tower crane suddenly shifted and sank between the timbers, causing the crane tower to fall toward the water tower structure. The soft soil was pushed upward, the stabilizer arm on the right outrigger snapped, and the outrigger arm swung to the rear of the trailer as the crane began to fall. According to witnesses, it took several seconds for the crane and tower to fall to the ground, knocking down nearby powerlines as they collapsed.

Several people rushed to aid the three workers caught in the wreckage. The crane operator was still inside the cab area, conscious, with facial wounds and other injuries. The worker inside the ladder cage clung to the ladder when it fell; he remained conscious, suffering only a broken ankle. The victim was unconscious and bleeding from head injuries, without a pulse or respirations. CPR was initiated by a newspaper reporter and other bystanders and continued until emergency crews arrived. The victim was airlifted to a hospital and was pronounced dead shortly after arrival. The official cause of death was "massive head, chest and abdominal trauma."

The investigation concluded that the crane tower fell directly in line with, and on top of, the right rear outrigger, with complete failure of the ground under the right rear outrigger occurring soon after the full load was upon it. Although the top of the ground in the area was dry, deeper soil under the three timbers was wet and soft. The weight of the load squeezed this soil upward between the timbers. The trailer's right rear dual tires left a depression approximately 18 in. deep in the ground (Photo 7); this evidently occurred when the outrigger failed and the complete weight of the hoisted load and the crane was momentarily transferred to the trailer before the tower fell to the ground.

Recommendations & Discussion

Recommendation 1: Crane owners and operators should ensure that cranes are properly set up with the outrigger pads supported by stable footing.

For More Information

The website www.craneaccidents.com was established because much can be learned from the experience of other crane operators. It is a lively forum that tracks new developments and offers various stories, accident reports, opinions and related information. The tower crane involved in this fatality was more than 20 years old, and identical units are successfully being used by other crane operators. Through continued dialogue, operators will become aware of crane hazards and adopt better safety practices.

The FACE Program

Additional information regarding the incident described here is available from the Iowa FACE Program; phone (800) 513-0998; www.public-health.uiowa.edu/face. FACE is an occupational fatality investigation and surveillance program of NIOSH. The University of Iowa, in conjunction with the Iowa Dept. of Public Health, administers the program in the state of Iowa. NIOSH's Morgantown, WV, office carries out an intramural FACE program and funds state-based programs in Alaska, California, Iowa, Kentucky, Massachusetts, Minnesota, Nebraska, New Jersey, New York, Ohio, Oklahoma, Texas, Washington, West Virginia and Wisconsin.

The program's purpose is to identify all occupational fatalities in the participating states, conduct in-depth investigations on specific types of fatalities and make recommendations regarding prevention. NIOSH collects this information and publishes reports and *Alerts,* which are disseminated widely to involved industries.

Iowa FACE publishes case reports, one-page warnings and articles in trade journals. Most of its information is available online as well. The Iowa FACE team consists of: Craig Zwerling, M.D., Ph.D., M.P.H., principal investigator; Wayne Johnson, M.D., chief trauma investigator; John Lundell, M.A., coordinator; and Risto Rautiainen, M.S., co-investigator.

Discussion: Construction projects often require the use of a mobile crane that must be used on soil which has recently been worked or backfilled for foundations, grading, etc. In addition, crane operators may encounter soil that is frozen/partially frozen, wet or layered, as well as changing weather conditions and related concerns. Because a crane's lifting capacity increases as the swing radius (distance from center of crane to lifted load) decreases, crane operators strive to set up as close to the worksite as possible. However, soil is frequently unstable in these locations and extra precautions are necessary to provide stable footing.

Based on information in the crane's operating manual, evaluation of the outrigger loading indicated that the ground under the rear outriggers was subjected to a pressure of about 3,600 psf—nearly 1,600 psf above the soil's certified 2,000 psf capacity. Evidence from the site (Photos 4 through 7) confirms that the ground was failing under the outriggers just before the incident. When the crane had been set up adjacent to the water tower, the rear outriggers had been set on three 12″ x 7″ x 85″ cribbing timbers, providing a bearing area of just over 21 sq. ft. To reduce loading to a level of 2,000 psf, the bearing area would need to have been increased to about 39 sq. ft. This could have been accomplished by using appropriately sized steel or timber mats under outrigger pads. In all cases, a certified P.E. should be consulted to ensure that mats are of sufficient size and strength to support the crane and its load.

The manner in which timbers were placed under the outriggers contributed to the incident as well. As Photos 4 and 5 illustrate, just before the incident, the cribbing timbers were rolling out from under the outrigger pads and spreading apart. Some crane companies report that they always (even if setting up on highway concrete) use plywood or steel plates under outrigger timbers to minimize shifting of the soil and/or cribbing rollout. In addition, some operators use long bolts through timbers to create a solid base in order to prevent cribbing rollout (Figure 2).

In this case, the rear outriggers were clearly set up improperly. The ground was not leveled under the outrigger, cribbing timbers were not placed close together and no other measures were taken to prevent cribbing rollout. It appears that much of the hoisted load was transferred to the middle timber, which was certainly not adequate to support the load. More significantly, adequate bearing area to reduce outrigger loading below 2,000 psf may have prevented this incident.

Recommendations Based on the Investigation

1) Crane owners and operators should ensure that cranes are properly set up with outrigger pads supported by stable footing.

2) Crane installations should be closely observed during lifting operations to detect instability caused by changing load and ground conditions.

3) Before crane operations commence, all involved—including construction companies, crane owners and operators—should evaluate the soil-bearing capacity at the lift site to ensure that crane equipment and procedures are compatible with site conditions.

Recommendation 2: Crane installations should be observed closely during lifting operations to detect instability caused by changing load and ground conditions.

Discussion: Evaluation of this incident indicates that the ground under the right rear outrigger began to fail early in the lift. As Photo 5 shows, the ground under the outrigger was already failing, yet the hoisted load was less than waist high above the ground. Had the ground condition under the outrigger been detected and correctly assessed at this point, the load could have been lowered and the outrigger set up stablized. During the lift, several workers were on the ground, including the tank company owner and foreman of the crane crew. The lift itself lasted about 11 minutes, during which the ground under the outrigger continued to fail to the point that the lean of the crane caused it to become unstable and fall. The ground observers were likely focused on the lifted load and the workers on the water tower. However, as a crane lifts then swings its load into position, outrigger loading changes, increasing as the load is swung over them. To detect potentially unstable conditions, the entire crane setup should be observed during a lift.

Recommendation 3: Before crane operations commence, those involved—including the construction companies, crane owners and operators—should evaluate the soil-bearing capacity at the lift site to ensure that crane equipment and procedures are compatible with site conditions.

Discussion. Closer evaluation of information available prior to this incident would have revealed the need for additional measures or the use of alternate lifting methods. The subsoil characteristics, including a 2,000 psf bearing capacity, had been identified two months prior to the lift. The crane operating manual contained information from which outrigger loading could be estimated. The crane company had experienced a similar incident in 1997; in both cases, the failing outrigger was setup on backfilled topsoil, which has no approved load-bearing rating. Evaluation of this information may have indicated that the crane and/or the lift procedures were incompatible with site conditions. Although it is not known whether each company involved was aware of all of this information, had it been shared and correctly evaluated, the need to take additional measures to ensure crane stability or to use an alternative type of crane may have been recognized and this fatality prevented. ■

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www.craneaccidents.com. Port Charlotte, FL.

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