NIOSH

FACE

Fatality Assessment and Control Evaluation Program

Division of Safety Research • 1095 Willowdale Road • Morgantown, West Virginia 26505 • Phone:(304)285-5916

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Four Construction Workers Die after Cantilever Launching Gantry Collapses at Bridge Construction Site - Ohio

SUMMARY

On February 16, 2004, three male ironworkers (aged 30, 42, and 44 years old) were killed, and three male ironworkers and two male operating engineers were seriously injured while working on a bridge construction project. On February 18, 2004, one of the seriously injured ironworkers died in a local trauma center. The incident occurred during the launching and subsequent catastrophic collapse of a launching gantry (LG) (a horizontal framework of steel trusses that span the distance between two elevated bridge piers, designed to lift pre-cast segments of roadway - see photo above). The LG involved in this incident was positioned on an interstate bridge construction project. All four victims were performing various required tasks for launching (re-positioning) the LG when the collapse occurred. EMS and rescue units were dispatched and arrived within minutes of the collapse, at which time three of the fatally injured workers were pronounced dead on scene.

Fatality Assessment and Control Evaluation (FACE) Program

The National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research (DSR), performs Fatality Assessment and Control Evaluation (FACE) investigations when notified by participating states (North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, and Virginia); by the Wage and Hour Division, Department of Labor; or when a request for technical assistance is received from NIOSH-funded state-level FACE programs in Alaska, California, Iowa, Kentucky, Massachusetts, Michigan, Minnesota, Nebraska, New Jersey, New York, Oklahoma, Oregon, Washington, West Virginia, and Wisconsin. The goal of FACE is to prevent fatal work injuries by studying the work environment, the worker, the task the worker was performing, the tools the worker was using, the energy exchange resulting in fatal injury, and the role of management in controlling how these factors interact. FACE investigators evaluate information from multiple sources that may include interviews of employers, workers and other investigators; examination and measurement of the fatality site, and related equipment; and review of records such as OSHA, police, medical examiner reports, and employer safety procedures and training records. The FACE program does not seek to determine fault or place blame on companies or individual workers. Findings are summarized in narrative reports that include recommendations for preventing similar events in the future. For further information visit the FACE website www.cdc.gov/niosh/face or call toll free 1-800-35-NIOSH.

NIOSH investigators concluded that, in order to prevent similar occurrences,

Employers should:

- ***ensure that the manufacturer's operating procedures are followed or provide alternative protective measures such as engineering controls in order to ensure safe operations.***

- ***ensure that workers comprehend and understand safety training and safety instructions, and that issues such as language barriers do not interfere with the effectiveness of the training, particularly when employees are required to work with unfamiliar equipment.***

- ***develop and implement written standard operating procedures (SOPs) for unfamiliar equipment, and provide training on the SOPs to all employees involved in equipment operation.***

In addition,

Employers and general contractors should:

- ***ensure that various components of a construction process are compatible.***

State and Federal Occupational Safety and Health Administrations should:

- ***consider developing requirements for inspecting and certifying cantilever launching gantries similar to those currently required for mobile cranes.***

INTRODUCTION

On February 16, 2004, three male ironworkers (aged 30, 42, and 44 years old – victims #1, #2, and #3) were killed, and three male ironworkers and two male operating engineers were seriously injured during the launching and subsequent collapse of a 1.8 million pound launching gantry (LG).

On February 17, 2004, the National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research (DSR), became aware of the incident through national media coverage. On February 18, 2004, one of the seriously injured ironworkers (victim #4) died in a local trauma center from his injuries. On February 23-27, March 2-5, March 7-10, and April 13-15, the DSR Chief of the Fatality Investigations Team and a DSR Safety Engineer conducted an investigation of the incident. The incident was reviewed with: the Corporate Safety Director for the general contractor (GC) of the bridge project; officials from the state Department of Transportation (DOT) who managed the bridge construction project; representatives of the local unions including the ironworkers, operating engineers, and carpenters; consulting engineers investigating the incident for the state DOT and the GC; and officials of the local area office of the U.S. Occupational Safety and Health Administration (OSHA). The scene was photographed and measurements were taken. Meetings and interviews were conducted with the GC's representatives, the local fire and police department, and employees, including members of the local ironworkers, operating engineers, carpenters union, and surveyors that were on site prior to or during the incident. A meeting was also held with the LG manufacturer's representative. Daily inspection checklists, the manufacturer's

LG erection manual, copies of the state OSHA On-Site Consultation Program safety surveys, photographs, the employer's site-specific safety and health procedures manual, and the county coroner's reports were reviewed. The safety equipment worn by the victims was examined at the county coroner's office.

Employer

The GC involved in the incident employed approximately 240 workers at the site at the time of the incident. The GC had been in business for more than 125 years, and had performed construction work on large engineering construction projects, including civil, power and industrial facilities, buildings, roads, and bridges. The GC was a division of a larger corporation that employs approximately 2,800 employees worldwide. This was the GC's second fatal incident since 1992, when one worker was killed on a different work site.

The GC had a site-specific safety and health procedures manual for the jobsite, including fall protection, crane operations, and various other site specific operations, and employed a full-time safety and health coordinator on the site. Prior to this incident, the GC had experienced five lost-time injuries during the 1.3 million man-hours worked on this site. Each employee completed a mandatory 2 hour safety orientation prior to beginning work, which consisted of a video, oral presentation, and a question & answer session.

On March 10, 2003, the GC voluntarily entered into a safety partnership specific to this site with the U.S. Occupational Safety and Health Administration (OSHA), the state DOT, the state Civil Service Employees Association, the state OSHA On-Site Consultation Program,[a] the state Contractors Association, and contractors and labor union locals. The partnership was designed to "expand the OSHA's reach into the project, allowing OSHA to work with the companies involved to promote safety programs, management systems, and work with the methods utilizing the latest technologies and safest available methods."[1] All subcontractors on site were required to have an effective safety and health program, be in compliance with applicable OSHA regulations, and agree to provide safety and health records for evaluation–including injury and accident reports. The partnership was comprised of representatives from all partners working on or associated with the project.

Each skilled trade and subcontractor had a representative on the partnership committee, and the GC, state DOT, Federal OSHA, and state OSHA on-site consultation program each had up to two representatives on the committee. As part of the partnership effort, the committee reviewed safety and health compliance issues at the site on a bi-monthly basis, analyzed job site audits, made partnership improvements, and evaluated partnership modifications, achievements, and successes in an effort to improve safety. In addition, a subgroup of partners performed audits of the jobsite that included monthly checklists. The audit team consisted of a project safety representative from each of the following partners: the GC, the state DOT, the subcontractors, and the state OSHA On-site consultation program.

a A part of the Occupational Safety and Health Bureau of the state Department of Commerce, the OSHA On-Site Consultation program is a free service to the state's private sector employers, funded 90% by Federal OSHA and 10% by the state. Employers can find out about potential hazards at their work sites, improve their occupational safety and health management systems, and even qualify for a one-year exemption from routine OSHA inspections.

Equipment

There were two, 315 foot-long, "twin" LGs (designated LG1 & LG2) on this site that were designed to perform the work of lifting pre-cast concrete roadbed (bridge) segments, each 10 foot x 60 foot and weighing between 75 – 100 tons, into place to form each span between adjoining piers of an elevated roadway. *(Note: for the purpose of this report, a "span" is the length of bridge between two piers).* The LGs were designed and built specifically for this construction project. The LGs were being used side-by-side on the bridge approaches. Each LG had a structural capacity of 1,650 tons. The rated lifting capacities were 1,000 tons. After each span's completion, the LG overbridge was moved forward into position to erect the next span, and then secured to the next pier. Then, the underbridge was moved to the next pier beyond that one, and secured, before hoisting the new span. A basic process of launching and hoisting the new span can be viewed in diagram 1.

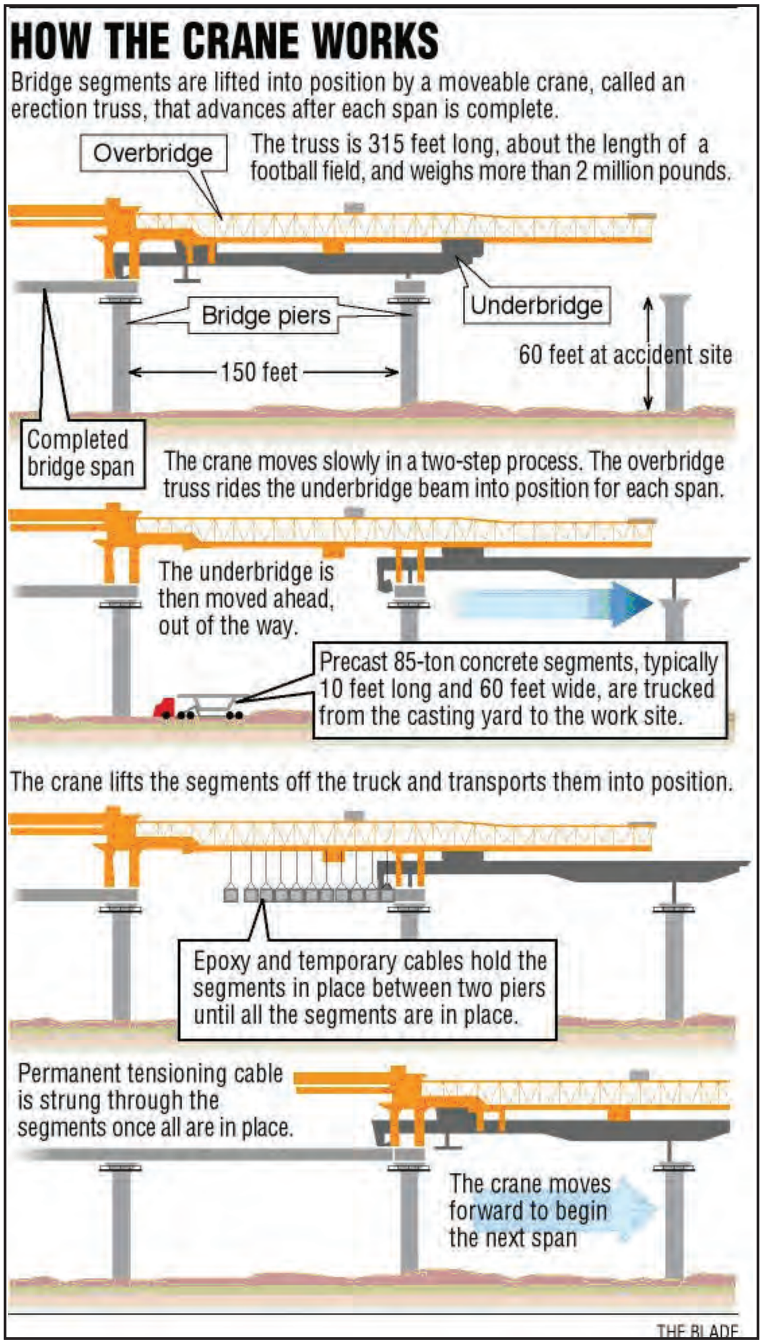

Diagram 1. Depicts the basic LG or "launching gantry" operation. Courtesy of the Toledo Blade Newspaper[2].

The major components and positioning of the LG at the hoisting position can be seen in Figure 1. The average time for a complete launch (move) between piers was about 6-7 hours. The average time to launch the LG and lift the next span was about one week.

Training

All of the victims received extensive apprenticeship training prior to this incident through their respective trade unions' apprenticeship programs. The only training or experience any of the employees had on the operation of the LG had been provided on-site by the Italian manufacturer's representatives during the assembly and initial-launch phases. None of the

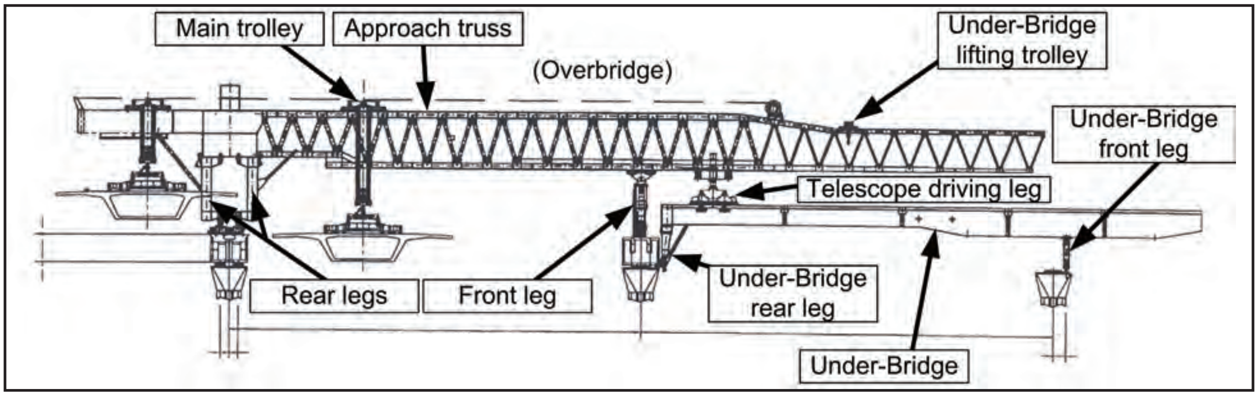

Figure1[3]. Main components of the cantilever launching gantry (Courtesy of the General Contractor.)

employees reported having any previous experience working with or on this type of equipment. It was stated by interviewed workers that the manufacturer's representatives, who trained the operators and iron workers, spoke Italian and only broken English, resulting in difficulty in interacting and understanding conversations. It was also reported that the manufacturer's representatives were present for and observed the 125% load test and three subsequent launchings of the LGs.[b]

Personal Protective Equipment

All employees at the job site were required to wear hard hats, hard-toed shoes, eye protection and hearing protection. A fall protection program was in place that required employees working at elevations or near hazardous areas to wear the proper fall protection. The victims were wearing the appropriate personal protective equipment at the time of the incident.

Weather

The weather conditions at the time of the incident included a temperature of approximately 32 degrees F., calm winds, and no precipitation.

INVESTIGATION

The bridge project involved in this incident was a part of the largest public works project in the state's history. The bridge project began on March 25, 2002, when the contractor mobilized on site. The bridge construction plans included the assembly of pre-cast concrete segmental spans, elevated approaches and ramps, and a pre-cast cable-stayed main span. The construction plans covered the casting of individual bridge segments on site. The bridge design called for 6-lanes (three lanes in each direction), with a single center pylon with glass and cable stays that would fan out like two large sails from the mast of a sailboat. When completed, the 1,225 foot-long main span was designed to carry an interstate freeway about 130 feet above a river (Photo 1).

The construction also included 7,277 feet of approach freeway on elevated piers (including the incident site) and 5,600 feet of entrance/exit ramps leading up to the bridge. The project plans estimated using 186,000 cubic yards of concrete – much of it pre-cast, bridge and elevated

b The 125% load test consisted of hoisting and suspending bridge segments from the LG until the total suspended load was approximately 125% of the rated capacity or 1250 tons.

Photo 1. Artists rendition of the finished bridge, courtesy of the Ohio Department of Transportation, District Two.

roadway segments [Photo 2] and piers [Photo 3], as well as 3,900 tons of steel post-tensioning cable and 14,000 tons of epoxy-coated reinforcing steel[4]. Overall, the bridge assembly would include over 3,000 pre-cast concrete segments. At the time of the incident, the project had been on track for completion 14 months ahead of the scheduled completion date of mid-2006.

LG Assembly

LG1 and LG2 were ordered from an Italian manufacturer on May 5, 2002, and component parts were shipped to the site in large cargo boxes between January 22, 2003 and April 4, 2003. The LGs were assembled between February 19 and July 16, 2003. It was noted by interviewed employees, DOT representatives, and the GC management that both of the LGs were difficult to assemble. It was also noted that some of the sub-assemblies of the LGs did not readily fit together, due to bolt-hole misalignment. Additional bolt holes and other modifications were required to be made on-site in order to achieve assembly. Manufacturer representatives were present and observed the assembly operation, including modifications. In addition, catwalks, which were not part of the original design specifications, were installed for employee protection while working on the elevated LGs. LG2 (the gantry involved in the incident) was placed in service on September 13, 2003, after the 125% load test was conducted. The 125% load test was successful and uneventful.

LG2 Launches and Section (span) Data

The activity of LG2 prior to the date of the incident showed that it had successfully launched and lifted 11 spans of bridge into place, as depicted below:

Launch	Lift	Span length
#1 - 08/25/03	9/13/03	130’
#2 - 09/18/03-09/23/03	9/26/03	145’
#3 - 10/07/03-10/08/03	10/9/03	144’1 3/16”
#4 - 10/18/03-10/20/03	10/22/03	145’1 13/16”
#5 - 10/29/03-10/30/03	10/31/03	145’
#6 - 11/07/03-11/10/03	11/11/03	130’
#7 - 11/15/03-11/16/03	11/19/03	129’9 3/8”
#8 - 12/1/03-12/04/03	12/06/03	143’3/8”
#9 - 12/15/03-12/17/03	12/18-12/20/03	135’7 1/8”
#10 - 01/05/04	01/09/04	135’11/16”
#11 - 01/19/04-02/02/04	02/03/04-02/07/04	135’6 3/8”

Photo 2. Pre-cast bridge segments in place at end of completed roadbed. The rear legs and underbridge of LG1 are visible at top of photo. Note the horizontal lines on the bottom of the completed bridge which indicate individual precast segments.

Photo 3. Cast-in-place concrete piers ahead of collapse site. Photo is facing north.

The segments in each span varied in size and weight, depending on the use of the segment. Approach segments were larger and heavier than a segment that was to be used for a ramp; main span segments for the actual bridge portion were the largest and heaviest. On average, each approach and main span segment was approximately 10 feet long, 58 feet wide and 9 feet 2 inches in depth. Any one segment weighed between 75-100 tons. The span that was to be lifted into place after the 12th launch was 135’6 ¼” in length. The grades of launch in relation to level ground for spans 1 - 6 were 4%, and spans 7 - 12 were 1%.

Operator’s Manual

The GC provided NIOSH investigators a Cantilever Launching Gantry Operator’s Manual[3] Instruction Portion, illustrating the launching process, for review. (34 pages of English text and 67 pages of instructional diagrams). The manual was an English translation of the original, Italian manual. The manual was not requested by, or provided to, the operating engineers or ironworkers by the manufacturer or the GC. It was noted that the launch procedures varied depending upon the type and length of span, the type of pier the gantry was landing on, and the type and length of segments to be lifted.

LG Operation / Employee duties

Typically, a total of 10 employees were used during gantry operations – one operator, one foreman, and 8 ironworkers. On the day of the incident, there was a foreman, an operator, and 7 ironworkers, with the eighth ironworker having left early due to illness. Although there were 9 employees instead of 10 at the time of the incident, this was not believed to be a factor in this incident. The process and employee duties are described below.

LG Launch Sequence

The following launch sequence description is a brief overview of significant processes and duties of the workers up to the incident, and does not include all details of the complex process of launching the gantry. The actual launch processes include a set of very exact and detailed operations.

Launch (Incident)

Once a bridge span between two piers is completed, the LG is readied to move forward to the next pier. This process is known as “launching.” Figure 2 shows the position of the gantry after the placement of a span.

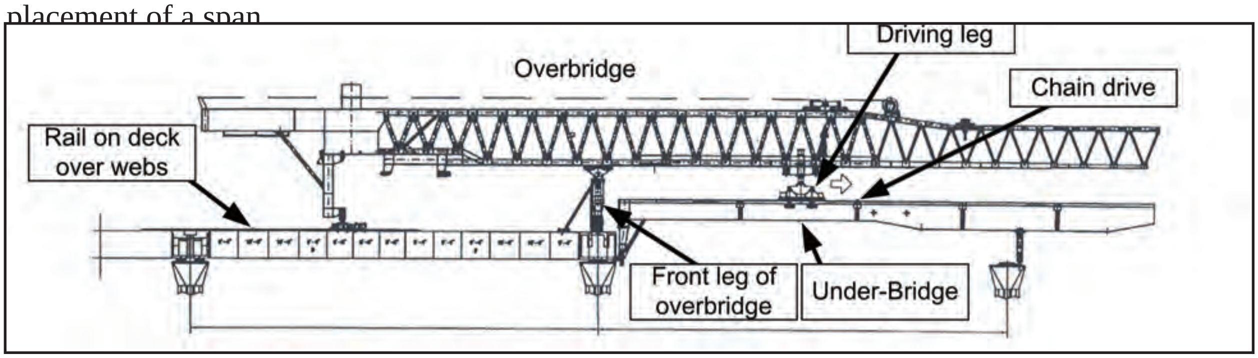

Figure2[3]. Position of launching gantry at start of launch. Front leg of overbridge is at end of completed bridge.

The railway is moved up to the newly completed deck and is positioned so that the rear legs of the gantry can be moved forward (See Photos 4 and 5).

Photo 4. View of the railway system behind launching gantry LG1.

At this point, the gantry has been made ready to launch by the ironworkers, who are stationed strategically around the front leg and the underbridge to make sure the overbridge is moving freely over the underbridge (no objects obstructing movement, adequate clearance, cables and hoses free, etc.).

The operator then activates a button on the operator's remote control box, and the drive leg (sprocket and chain system) pulls the overbridge truss forward on the rails, over the underbridge. It is stopped approximately 12 feet from the end of the newly completed bridge deck - in it's new position (See Figure 3).

Photo 5. Close-up showing roller beam resting on track.

The front leg of the overbridge is disconnected from the bridge deck by ironworkers, and it is picked up using the main hoist and moved forward to the next pier with the hoist trolley. (See Figure 4). The drive leg is used to move the overbridge forward until the front set of rear legs are in position to line up with the lifting holes of the last bridge segment. According to the operator's manual, the front set of rear legs and the support blocks are to be anchored to the roadbed by the ironworkers. ***Note: After the initial load test, the anchorages were not established. The manufacturer of the LGs provided anchor points (holes) on the gantries for the sole purpose of anchoring the LGs to the bridge deck and piers. The GC made the decision to reduce the number of anchor holes provided in the pre-cast bridge segments with the holes serving a dual purpose of lifting the segments into place then serving as anchor holes. The bolt holes (in the bridge deck and gantry legs) did not line-up because of the curve in the roadway (see Photo 6). (This was true for all of the 11 previous launches.)***

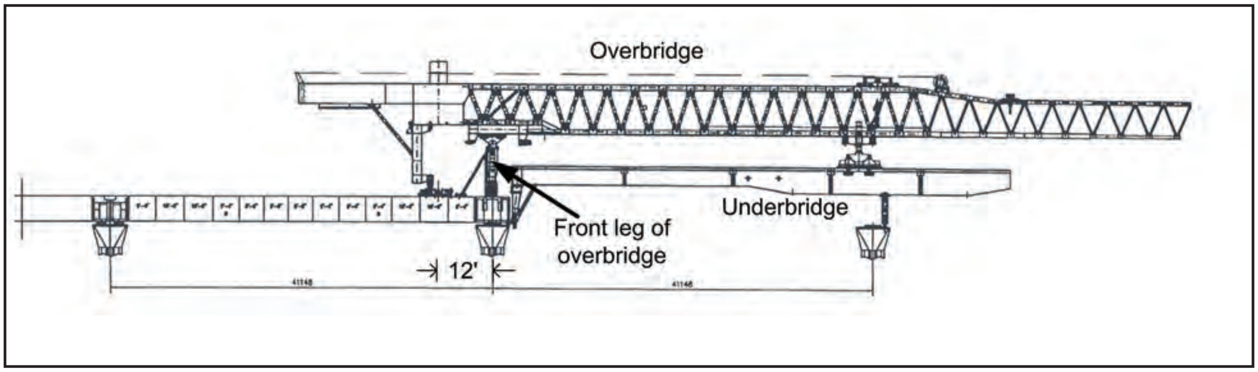

Figure 3[3]. Overbridge moved to about 12 feet from the end of the newly completed bridge deck.

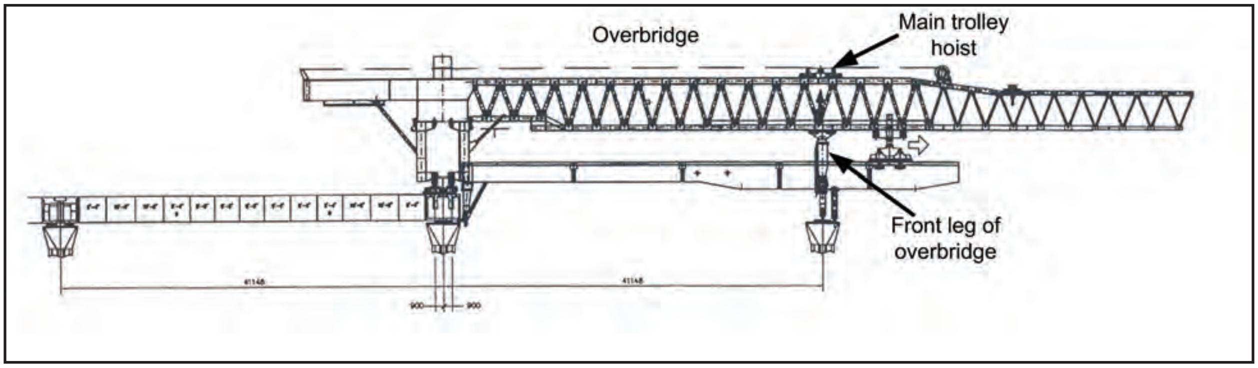

Figure 4[3]. The front leg of overbridge is lifted with main trolley hoist and moved forward to the next pier.

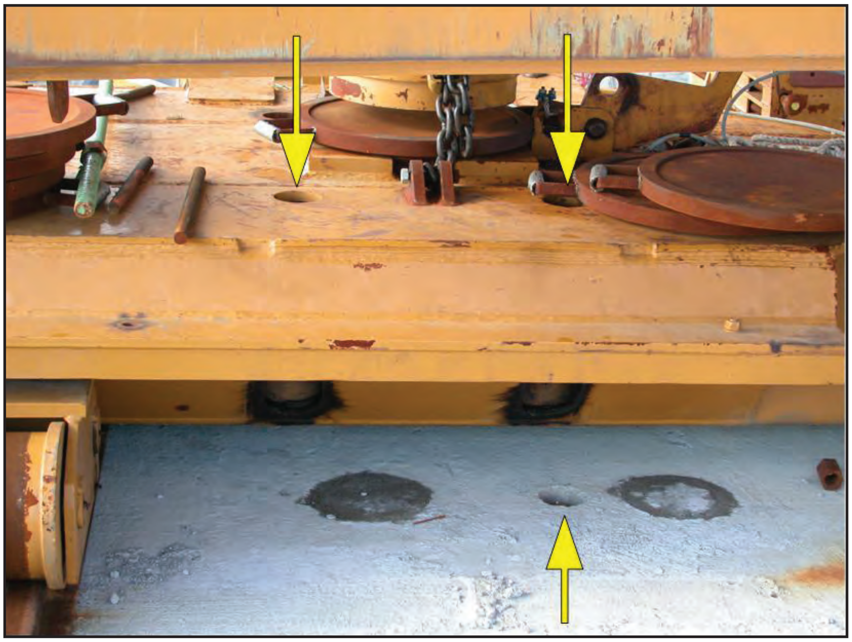

Photo 6. This photo was taken of LG1's position after the incident. Note the position of the hole in the roadbed relative to the holes in the roller beam (top yellow arrows).

The front leg is positioned over the next pier and is set in place on two mechanical legs which are extended downward to meet the top of the pier. The front leg is set plumb so that it is vertical (90 degrees from the horizontal axis)***. (Note: in practice, it was discovered that the front leg was set plumb with a 4 – foot level to within what was told to investigators as "3 or 4 degrees of plumb," and was secured with come-alongs in an attempt to ensure that the leg did not "tip" or move).*** The mechanical legs are then anchored to the pier top by the ironworkers.

The operator then prepares to launch the underbridge. The underbridge is untied from the piers and made ready to launch by the ironworkers. The underbridge is lifted clear of the piers by using the main lifting hoist (at the rear of the underbridge) and the hydraulic jacks on the driving leg. At this point, any curvature of the projected roadbed across the next two piers is taken into consideration by rotating the overbridge toward the inner part of the curve, or "side-shifting."

The underbridge is moved forward by the sprocket and chain drive system on the drive leg (Figure 1). Iron workers are stationed strategically around the front leg and the underbridge to make sure the underbridge is moving freely as it passes through the front leg structure (no objects obstructing movement, adequate clearance, cables and hoses free, etc.). ***Two of the ironworker victims (victims #1 and #2) were positioned on top of the underbridge in the area of the front leg of the overbridge and were performing these duties when the incident occurred*** (See Figure 5).

The front leg (Figure 1) of the underbridge is moved until it is located directly below the two large support rods suspended from the tip of the overbridge trusses.

The two support rods are disconnected from the underbridge and raised out of the way, and the underbridge is moved past the front leg and the pier and then moved backward so that it can be landed in the proper position. It is at this point that the underbridge can be "side shifted" to accommodate the curvature in the roadway, and be placed in position to land on the pier top. Once landed, large bolts are passed through the base to secure the leg to the pier. Iron workers are stationed around the top of each pier to guide the underbridge into position and to secure the

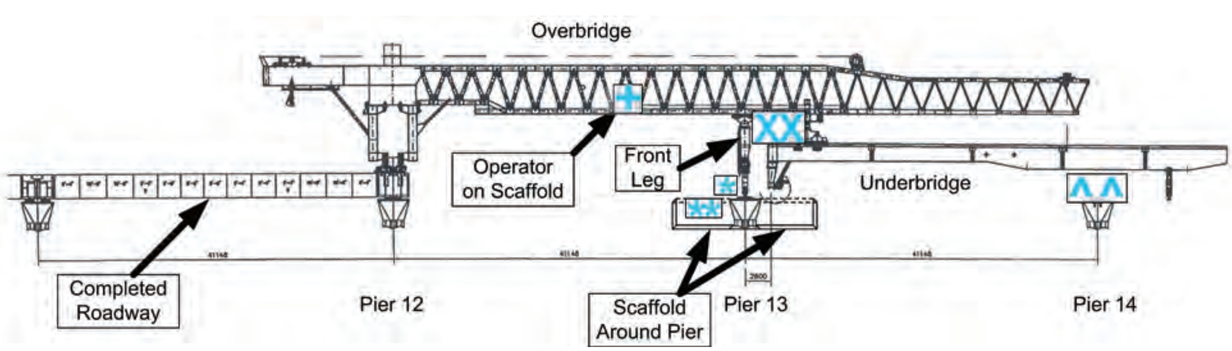

*Figure 5[3]. The underbridge is moved past the next pier so that the rear leg of the underbridge can be folded down. The underbridge is then backed up and landed on the piers. The *s depicts the position of the 3 injured iron workers; the Xs depict the positions of victims #1 and #2; the ^s depict the location of victims #3 & #4; and the + depicts the position of the operator at the time of the incident. (Note: the injured ironworkers and the operator were standing on catwalks.)*

legs to the piers. ***(Note: three of the injured ironworkers were on a catwalk around the middle pier preparing to perform this function when the incident occurred. The catwalk and all three injured ironworkers were dislodged from the pier and fell to the ground below. (See Figure 5) Also, at the time of the collapse, ironworker victims #1 and #2 were in position on top of the underbridge, and victims #3 and #4 were in position on top of the outer (furthest) pier, directly under the underbridge (Figure 5), waiting for the front leg of the underbridge to come into position so that they could bolt it to the pier. The operator was on a catwalk above and behind the front leg, and rode the LG down as it fell to the ground, suffering serious injuries).***

Possible Collapse Scenarios

The exact cause of the LG collapse could not be determined during this investigation; however, two plausible scenarios were identified. The scenarios are hypotheses based on information available at the time of the investigation. The first scenario considers the 1% grade of the roadbed the LG was setting on, and the lack of bolting the rear LG legs to the deck. As discussed above, several of the previous launchings (1-6) were performed with the rear legs set on a grade of 4%, which would have supplied a greater amount of backward-force to the rear legs of the LG, and off of the front leg of the overbridge. When the launches were conducted at a 1% grade, some of the back-force on the rear legs was transferred to the front leg of the overbridge, and the LG was subjected to a greater forward force. This increased forward force may have contributed to the unanchored LG falling off the bridge deck approximately 65 feet to the ground. In this scenario, it is unclear why the LG would not have fallen off in an earlier launch.

The second scenario is similar, and possibly more likely than the first. In this scenario, the greater curvature of the roadway and the positioning of the piers for landing the LG may have compounded the risks of the un-anchored rear legs, improperly anchored front leg, and forward force on the gantry described above. This curvature required the operator to “side shift” the overbridge and ultimately the underbridge to a greater degree in order to land the underbridge on the next pier. These factors, working together with the un-anchored rear legs, could have shifted the center of gravity and load forces on the front leg to the right (the direction of the side-shift). The shift may have caused the front leg of the overbridge, which was held in place by friction forces and the come-alongs, to tilt to the right and forward, causing the entire structure to slide off the bridge deck and fall to the ground. It was stated by several witnesses that they heard a very loud “ping” or “boom,” resembling the sound of metal snapping, just prior to the LG falling, and that it appeared that the LG “rolled” to the right as it collapsed. The “ping” or “boom” sound may have been the come-alongs or bars failing as the front leg tipped forward and to the right.

In each of these scenarios, it was not possible through this investigation to definitively determine whether the anchoring of the rear legs to the bridge deck would have prevented this incident. However, the anchoring of the rear legs to the bridge deck was a clear operating procedure recommended by the manufacturer.

CAUSE OF DEATH:

The official cause of death for each victim was determined by the county coroner to be multiple blunt-force trauma.

RECOMMENDATIONS

Recommendation #1: Employers should ensure that the manufacturer's operating procedures are followed or provide alternative protective measures such as engineering controls in order to ensure safe operations.

The manufacturer's operating manual[3] details the final positioning of the overbridge and the front leg as the following process: The drive leg is used to move the overbridge forward until the front set of rear legs are in position to line up with the lifting holes of the last roadbed segment. The main hoist trolley is moved forward so that the front leg lines up on the next pier. The front set of rear legs is lowered into position and set on support blocks on the roadbed. *The front set of rear legs and the support blocks are anchored to the roadbed. The back set of rear legs setting on the roller beam trailer are repositioned and anchored to the roadbed (4 bars for each leg x 4 legs = 16 bars).* In addition, the manufacturer's procedures specified that each of the 16 bars was to be pre-stressed to 600 kilo-newtons (approximately 135,000 pounds) for a combined total of 9,600 kilo-newtons (approximately 2,160,000 pounds). The manufacturer's procedures specified that the front leg was to be anchored to the next pier in a similar manner with 4 bars. These bars were also specified to be pre-stressed to 600 kilo-newtons (135,000 pounds) each.

In practice, however, after the initial 125% load test, the positions of the anchorage holes in the legs were not compatible with the anchorage holes in the roadbed. All subsequent launches followed the same methodology and the manufacturer's procedures for anchoring the LGs were not followed. According to the GC, drilling new holes in the roadway in order to facilitate the anchoring was not an option, and it was reported that the misalignment of the bolt holes became even more pronounced as the curve in the roadway increased (see Photo 6.) The misalignment of the bolt holes was exacerbated by pre-casting the bridge segments on site with only half the required number of anchorage holes per segment. It is surmised that following the manufacturer's procedures for anchoring the LGs to the bridge deck as well as providing the proper number of anchorage holes in the pre-cast segments could have prevented this incident. It is not known whether using an alternative bolting device or method of securing the LG to the bridge deck may have prevented the incident.

Recommendation #2: Employers must ensure that workers comprehend and understand safety training and safety instructions, and that issues such as language barriers do not interfere with the effectiveness of the training, particularly when employees are required to work with unfamiliar equipment.

Discussion: The launching gantries used for highway bridge construction in this investigation represented a technology that was virtually unknown to the local workforce prior to their arrival at the worksite. While representatives from the launching gantries' foreign manufacturer were present during the assembly and initial launching, communications between the contractor, the local workforce, and the manufacturer representatives were reportedly hindered by language barriers. Workers as well as management reported to NIOSH investigators that it was difficult to communicate with and/or understand the manufacturer's representatives due to their primary language being Italian.

Overcoming these barriers is crucial to providing a safe work environment. Employers should develop and provide training for workers in a language that the workers are able to comprehend.[5]

It was determined during interviews that the skilled trade workers on site were highly trained in many areas of construction, safety, and equipment types. However, none of the employees working on the launching gantries reported ever working with a launching gantry before, and the only training provided was on-the-job. The operators were not provided copies of the LG operator's manual and the manual was not used as training material during the operator training process. OSHA federal training standards require the employer to instruct each employee in the recognition and avoidance of unsafe conditions and the regulations applicable to the work environment to control or eliminate any hazards or other exposure to illness or injury.[6]

To be most effective, formal training should occur whenever new equipment is introduced into the workplace, and this training should be given by a person who has the knowledge, training, and experience necessary to train workers and convey information effectively. This formal training could consist of a combination of formal instruction e.g., lecture, discussion, interactive computer learning, videotape, written material, practical training (demonstrations performed by the trainer and practical exercises performed by the trainee), and evaluation of worker performance in the workplace. The evaluation will ensure that the instruction given was understood.

Recommendation #3: Employers should develop and implement written standard operating procedures (SOPs) for unfamiliar equipment, and provide training on the SOPs to all employees involved in equipment operation.

According to the manufacturer's operating manual,[3] there were up to 394 steps involved in launching the LG. When operating such complex equipment, employers should consider developing and providing operators and other employees working on or around the equipment with a comprehensive set of operating procedures to be followed while using the equipment, in addition to comprehensive training. The operating procedures and training should identify potential consequences of not following the established procedures. For example, such procedures could have noted that failure to properly anchor the LG to the bridge deck could result in instability and possible catastrophic failure. The launching gantry operators that were interviewed reported that they had never seen or been provided the operator's manual.

Recommendation #4: Employers and general contractors should ensure that various components of a construction process are compatible.

It was determined that properly anchoring each LG was not possible after the initial launch because insufficient anchorage holes were incorporated into the pre-cast bridge segments. The LGs were designed to incorporate a specific process for anchoring both the rear legs and the front leg of the overbridge prior to advancing the underbridge to the next pier. The LGs incorporated holes intended for the anchoring bars to pass through and connect to the bridge segments. According to OSHA, the LG manufacturer and the GC met and discussed anchorage hole requirements for both the LGs and the bridge segments several months before assembly of the LGs began in February 2003. Individual bridge segments were pre-cast on-site prior to the initial launches of both LGs. These pre-cast segments contained only half the required number of anchorage holes that were actually the lifting holes used by the LGs in the hoisting process. Thus, the LGs holes were not compatible with the pre-cast bridge segments' holes. Specifically, it was not possible to follow the manufacturer's procedures for anchoring the LGs to the bridge deck because sufficient anchoring holes were not provided in the pre-cast bridge segments and the lifting holes that were in the pre-cast segments did not line up with the holes in the LG structure.

In addition, State and Federal Occupational Safety and Health Administrations should consider developing requirements for the inspection, safe operation, and operator certification of cantilever launching gantries, similar to those currently required for mobile cranes.

Discussion: Launching gantries represent a new technology which to date has not been widely used in the United States. While launching gantries have similarities with mobile cranes (the ability to hoist and position a load, as well as being self-propelled), they are designed for one specific task – to position individual roadbed segments during bridge construction. Since the majority of the U.S. workforce is unfamiliar with launching gantry technology; equipment assembly; operation and maintenance, oversight of these activities is necessary to ensure safe launching gantry operation. This oversight should be no less stringent than regulations covering mobile crane inspection, operation, and maintenance.

Currently, there are no federal OSHA regulations requiring the certification of cranes, derricks, and material handling devices used solely in general industry (covered under 29 CFR 1910.179 and 1910.180[7]) or used solely in construction (covered under 29 CFR 1926.550) – which is directly applicable to the job site in this investigation. Current OSHA regulations (29 CFR 1926.550(a)(5)) require the employer to designate a competent person who shall inspect all machinery and equipment prior to use, and during use, to make sure it is in safe operating condition. Additionally, 29 CFR 1926.550(a)(6) requires that a thorough annual inspection of hoisting machinery be made by a competent person, or by a government or private agency recognized by the U.S. Department of Labor and that the employer must maintain a record of the dates and results of these inspections.[7,8] OSHA has proposed changes to 29 CFR 1926.550 that include crane operator certification by either a crane operator testing organization approved by a nationally recognized accrediting agency, or the employer's own qualification program which must be audited by a testing organization approved auditor. [9]

Additionally, OSHA does have an example of certification requirements for an impartial inspection of certain maritime cargo handling devices specifically required to be certified under the OSHA maritime safety and health standards. These standards are found in 29 CFR 1915 (Shipyards), 29 CFR 1917 (Marine Terminals), and 29 CFR 1918 (Long shoring). Third party applicants are granted accreditation to perform certification functions required under OSHA's Cargo Gear Certification Regulations found in 29 CFR 1919. Currently, only certain types of material handling devices used in specifically designated maritime operations are required to be certified. For example, Shipyard Regulations 29 CFR 1915 requires the certification of derricks and cranes which are part of, or regularly placed aboard barges, other vessels, or on the wing walls of floating dry-docks and are used to transfer materials or equipment to a vessel or dry-dock.[10, 11] Permanently installed cranes and derricks on vessels classified as "uninspected vessels" or "commercial uninspected fishing vessels" (46 CFR Part 28) by the U.S. Coast Guard must be certified by OSHA-accredited persons. Cranes and Derricks permanently installed on these vessels must be thoroughly examined and tested before being put in service initially, thoroughly examined every 12 months, and thoroughly examined and retested at least every 4 years in accordance with 29 CFR Part 1919 requirements. Similarly, mobile cranes that are placed on barges and used for purposes of shipyard employment must be certified by OSHA-accredited persons. These cranes must be thoroughtly examined and tested before being put in service initially, thoroughly examined every 12 months, and thoroughly examined and retested at least every 4 years in accordance with 29 CFR Part 1919 requirements.[11] In addition, several states including Alaska, California, and Washington have their own requirements for crane certification.

Regulated inspection and/or certification of the launching gantries throughout the assembly, initial launch, and bridge construction process as well as operator certification, could have identified a number of instances of failure to follow the manufacturer's operational procedures. This, in turn, could have identified the failure to properly anchor the launching gantry during the launch process. The identification of the failure to properly anchor the legs of the overbridge as a hazardous work practice may have identified the lack of sufficient anchorage holes in the pre-cast bridge segments as another failure to follow recommended procedures. Better inspections throughout the construction process may have prevented these fatalities.

INVESTIGATORS

This investigation was conducted by Robert E. Koedam, Chief of the Fatality Investigations Team, and Timothy Merinar, Safety Engineer, with the NIOSH, Division of Safety Research, Surveillance and Field Investigations Branch.

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