# Overhaul ball falls from crane, striking worker

A conventional crawler-mounted mobile crane was being used to lift and align sheet piles and drive them into the ground. During the final alignment, the crane's auxiliary hoist brake pedal inadvertently released, dropping the overhaul ball. The overhaul ball struck the top of the sheet pile and then struck a worker who was in a work bucket hooked onto an adjacent sheet pile. The worker in the bucket received fatal injuries.

**Purpose of this report**
The purpose of this online incident investigation report is to identify the causes and contributing factors of this incident to help prevent similar incidents and to support preventive actions by industry and WorkSafeBC. This online version is not the official WorkSafeBC report. It has been edited to remove personal identifying information and to focus on the main causes and underlying factors contributing to this incident.

**Notice of Incident information**
Number: 2005112130133
Outcome: Fatal
Core activity: Pile driving
Region: Lower Mainland
Date: June 2005

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# 1 Factual Information

## 1.1 The worksite and crew

A pile driving company was contracted by a construction company to install sheet piles as part of foundation construction for a new building complex. The deceased worker, a welder, was employed by the pile driving company.

At the worksite, a conventional crawler-mounted mobile crane was used to lift and align the sheet piles and then drive the piles into the ground to the correct depth using a vibrating ram attachment. The last pile in the group was being aligned when the incident occurred (see Photo 1).

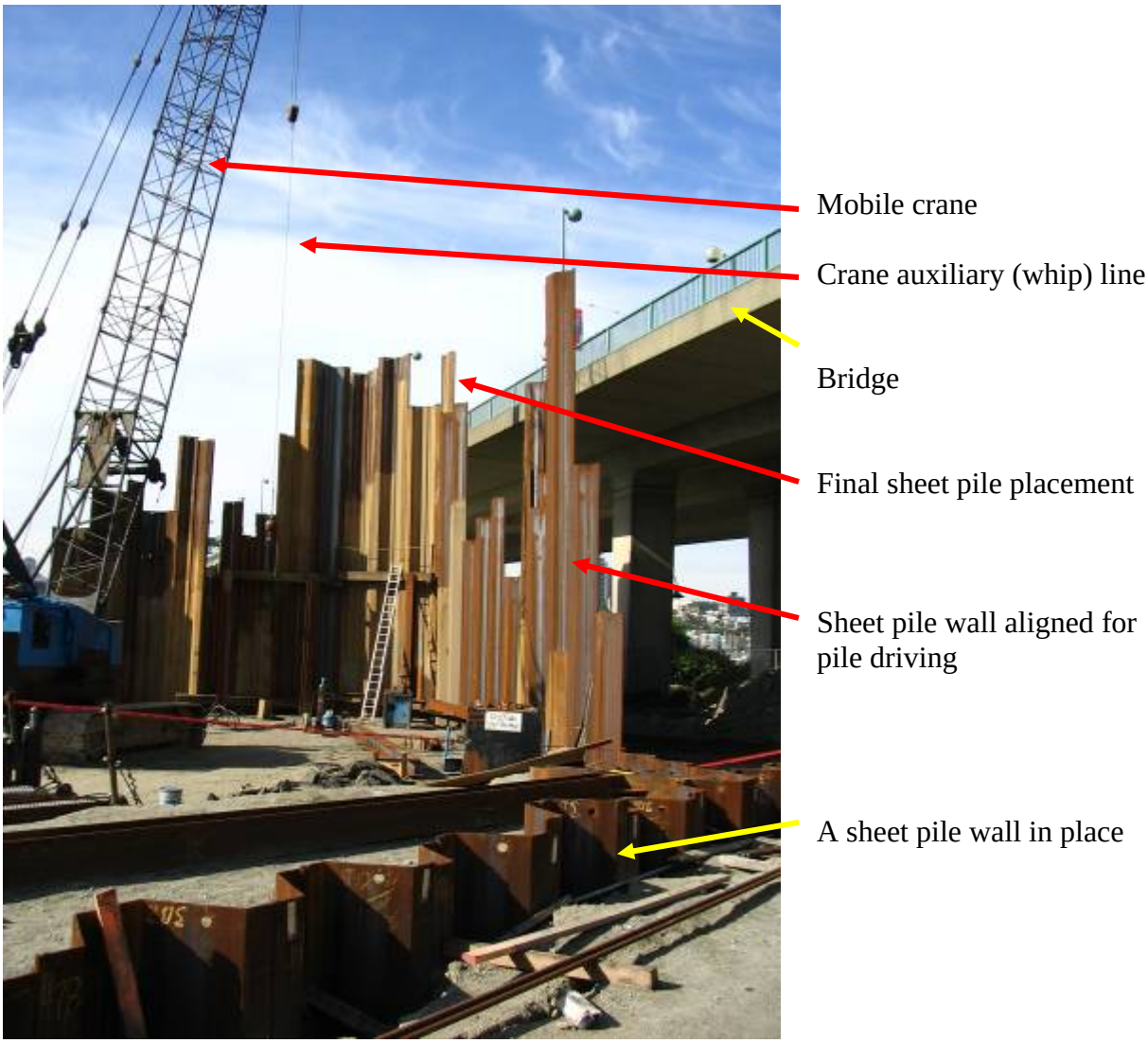



Photo 1: The worksite where the fatal incident occurred.

The work crew consisted of a crane operator/foreman, two labourers, and a welder.

The crane operator on the day of the incident was also acting as foreman for the pile-driving activities. In addition to his duties as crane operator, he was responsible for completion of the work and crew direction. The crane operator/foreman had more than 25 years of experience in the industry, with experience operating a variety of cranes, including the type involved in the incident.

The labourers were ensuring the correct alignment of the sheet piles as they were lowered into position by the crane operator. One of the labourers worked at ground level. The second labourer worked from an engineered work bucket, which was hooked onto the top of an adjacent pile that had previously been installed (see Photos 2 and 3). The labourer was raised by the crane in the work bucket from the ground to the location on the adjacent pile. When the bucket was hooked on the adjacent pile, the labourer was secured to the pile with a lifeline and harness in case the bucket fell.

The welder was constructing the support structures for the sheet pile wall. On the day of the incident, he performed welding duties for most of the day. During placement of the last sheet pile, he took over the duties of the labourer in the work bucket.

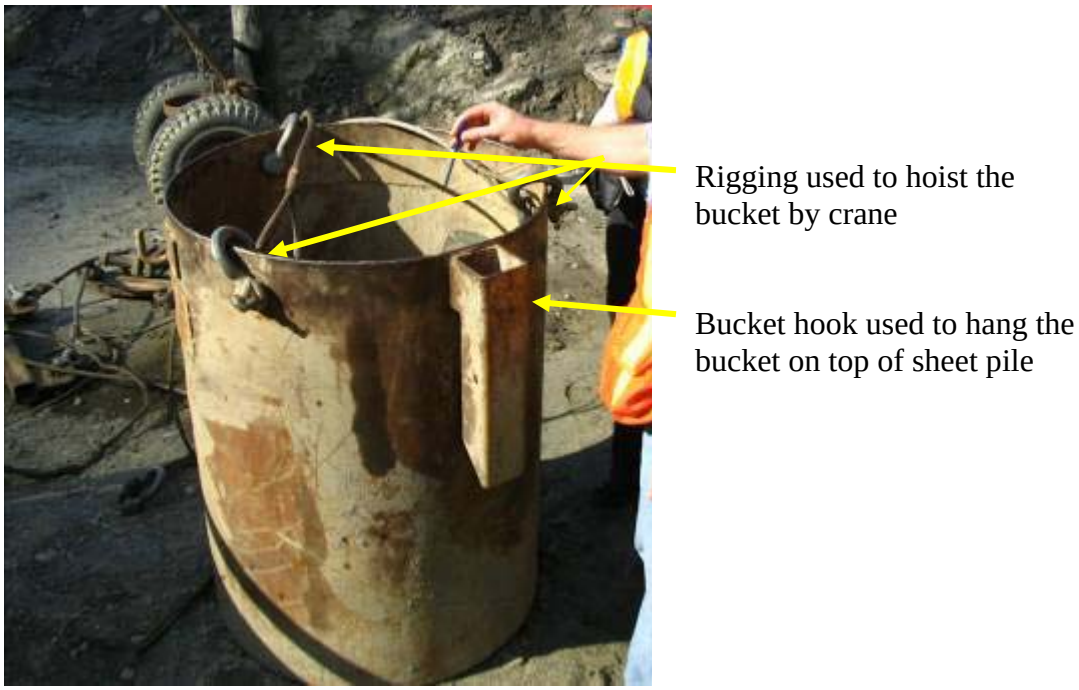



Photo 2: The photo shows the type of work bucket that was hooked onto an adjacent pile while the next pile was lowered into position.

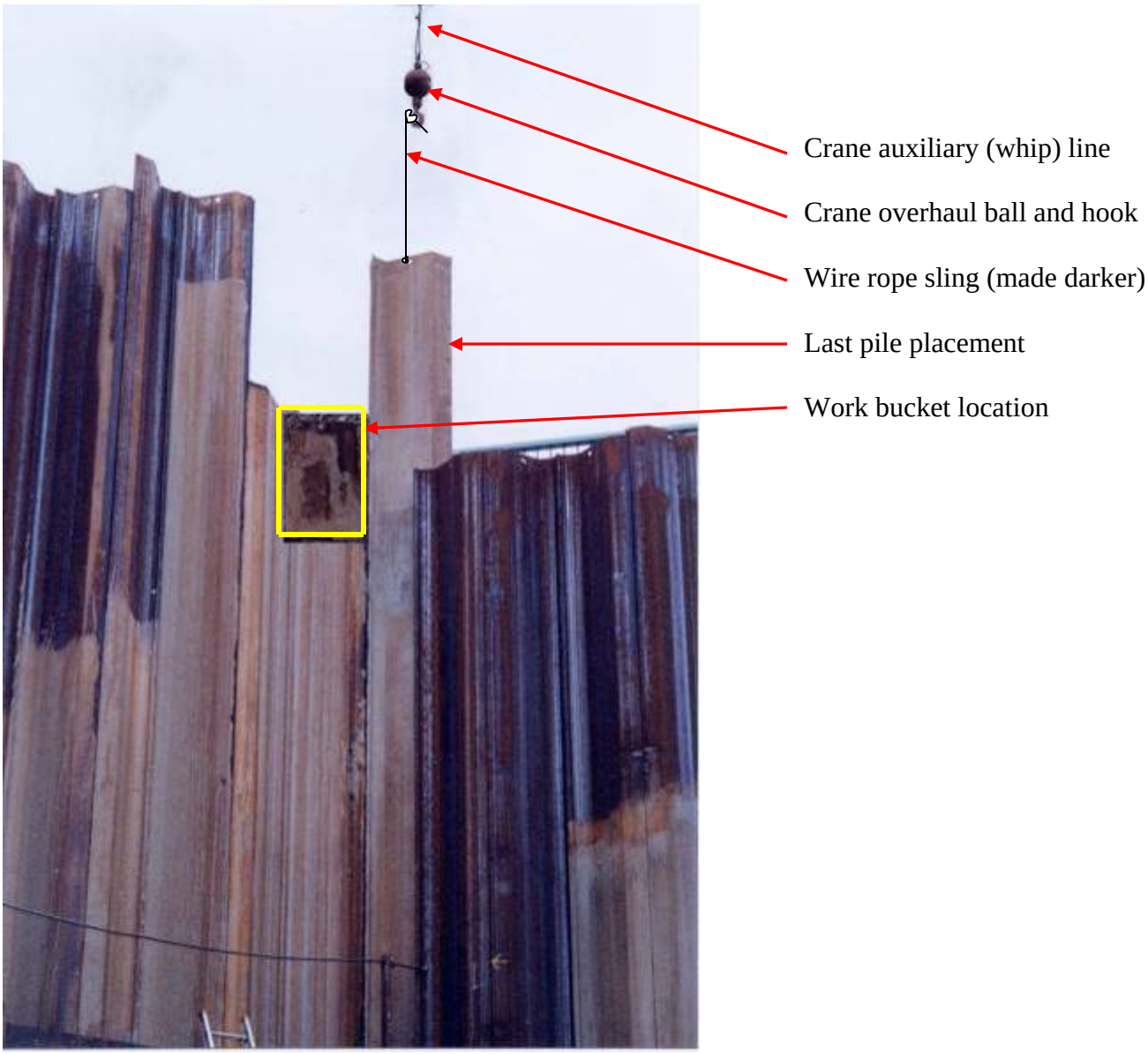



Photo 3: Sheet pile placement.

## 1.2 The crane

The crane involved in the incident was a conventional crawler-mounted mobile crane, estimated to be about 40 years old. The 80-ton-capacity crane was used primarily for pile-driving activities. The crane had its last engineering inspection and certification about six months before the incident. Other than routine inspection and maintenance, no significant maintenance items were noted in the crane log book entries from the time of this last certification to the day of the incident.

### *1.2.1 Crane hoist drums*

The crane was configured with the main hoist on the front drum and the auxiliary hoist on the rear drum (see Photo 4). On the day of the incident, only the auxiliary hoist was used.

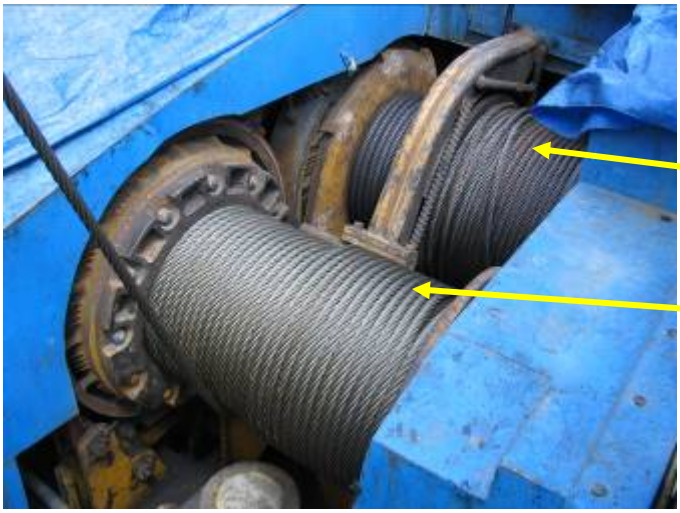


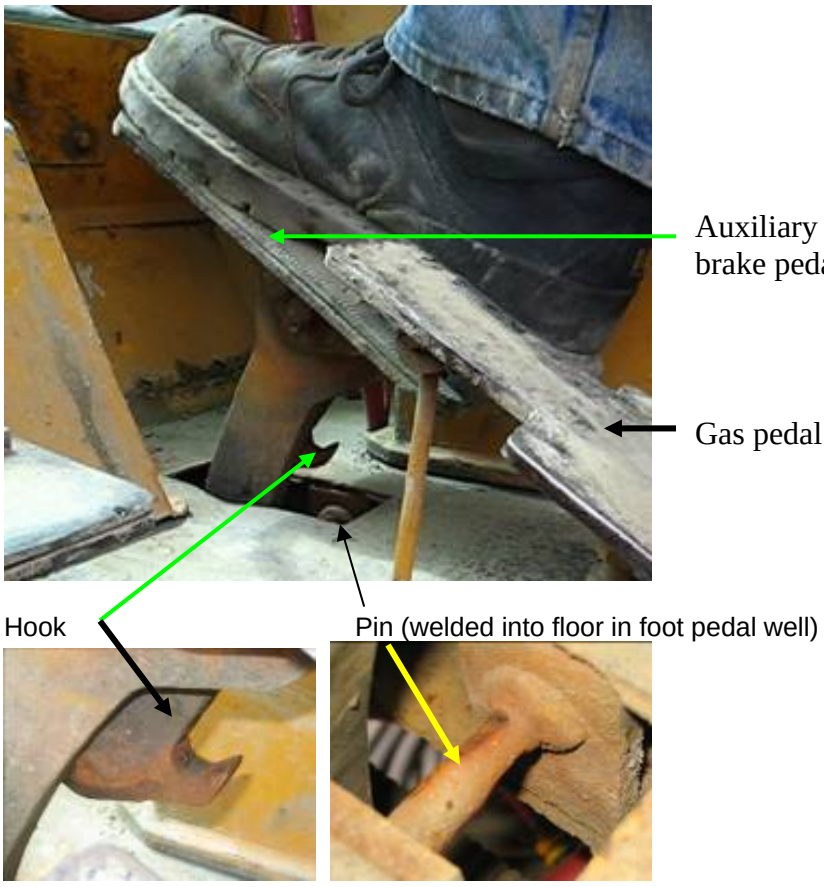

Photo 4: The crane hoist drums. On the day of the incident, only the rear drum was used.

The auxiliary hoist is powered to raise loads, and ascent is controlled by a hand lever. However, loads are lowered using gravity only, as the drum rotates freely. The rate of descent is controlled by the crane operator using a foot brake pedal, which applies a friction brake to the rear drum (see right pedal on the crane cab floor in Photo 5). The operator needs to keep pressure on the pedal to prevent the drum from turning. This task is continuous unless the brake is latched, permitting the operator to remove the foot from the pedal.


Photo 5: Brake pedals in the cab of the mobile crane.

There is a mechanism (a hook and pin) for latching the pedal in the down position, when the brake is fully applied (see Photo 6). The hook and pin are engaged by pushing the pedal to the floor, toeing forward, and releasing the pedal. When the hook and pin are engaged, the operator can remove the foot from the pedal and have the rear drum friction brake remain applied. On the crane involved in the incident, the friction brake is the only braking system for the auxiliary hoist (whip line).

This crane had an option to fit the rear drum with a ratchet and pawl that could prevent the drum from rotating. However, this secondary brake system was not installed since this crane was normally used for pile driving, where the drop hammer requires manual control with the brake to avoid the risk of locking the drum. In North America, cranes used for pile driving are typically older cranes that have been converted to that use (including disabling the secondary brake system if one was installed). On the day of the incident, however, a secondary brake system would not have presented a problem since the pile-driving crane was being used for placing sheet piles, which is done with a vibrating arm rather than a drop hammer.




Engaged hook and pin (as viewed from below cab floor)

Photo 6: Pedal latching mechanism.

Photo 7: Overhaul ball and load hook.

The working end of the auxiliary hoist (whip line) is equipped with a steel overhaul ball and load hook weighing an estimated 500 to 600 pounds (see Photo 7). The overhaul ball provides a weight to keep tension on the auxiliary hoist when there is no load on the hook. This ensures the line spools and unspools properly on the rear drum.

The overhaul ball and hook provide sufficient weight alone, without any other load, to drop the line rapidly when no braking is applied to the rear drum.

## 1.3 The incident

On the day of the incident, work commenced at approximately 0700 hours. Four remaining sheet piles were to be installed this day. Work proceeded without incident until the last sheet pile was placed at about 1430 hours.

The welder exchanged positions with the labourer in the work bucket for the placement of the last sheet pile. In the bucket, the welder assisted in the threading of the last sheet pile with the adjacent sheet piles by applying lubricating oil to the overlapping edges. This was done successfully.

As foreman, the crane operator was required to leave the crane cab occasionally to verify the positioning of the sheet piles. At approximately 1440 hours, he left the cab to ensure proper placement of the last pile. Before leaving the cab, he fully applied and latched the right pedal, engaging the rear drum brake for the auxiliary hoist. The sheet pile was still rigged to the load hook with a single 10-foot wire rope sling, but the line was slackened off so no load was on the line. The crane operator/foreman determined that a minor realignment of the pile was required. He returned to the crane cab, lifted the sheet pile about 12 to 18 inches, had assistance in positioning the sheet pile, and then dropped it into the correct position. Photo 3 on page 5 shows the estimated positions of the overhaul ball and work bucket at this time.

The crane operator/foreman again applied the auxiliary hoist brake and started to leave the cab to verify the pile placement. As he was sliding off the crane cab seat, the overhaul ball fell and struck the top of the sheet pile and then struck the welder in the work bucket.

The crane operator/foreman immediately returned to his seat and, finding the right brake pedal fully disengaged, he reset it in the latched (brake applied) position.

Access to the work bucket was difficult as it was not rigged to the crane at the time of the incident. Only the worker in the bucket can rig the bucket to the crane. A high-angle rescue was performed using access from the bridge. The bucket was rigged to the crane and lifted to the bridge, but the welder could not be revived. He had received fatal injuries when he was struck by the overhaul ball.

## 1.4 Mechanical assessment of the crane

### *1.4.1 General condition*

The crane had been inspected and certified for use a few months prior to the incident. Following the incident, WorkSafeBC visually inspected the crane and tested the auxiliary hoist (rear drum) brake for any operational issues. The auxiliary hoist was tested both with and without a load. The load was provided by hoisting a welding unit weighing approximately 3,000 pounds. The equipment load was hoisted and dropped, followed by immediate application of the auxiliary hoist brake pedal. The visual inspection and auxiliary hoist brake testing found the crane to be in normal operating condition.

### *1.4.2 Auxiliary hoist brake pedal*

The auxiliary hoist brake pedal was removed for inspection by WorkSafeBC. Some wear was found on the hook and pin of the pedal latch mechanism (see Photo 8).


Photo 8: Wear on the pin and hook of the brake latch mechanism.

The resistance of the pedal can be adjusted for the weight of loads being handled. On the day of the incident, the crane operator/foreman had not made any adjustments to the pedal resistance. The crane operator/foreman described the pedal resistance as high.

# 2 Analysis

Examination of the functioning of the auxiliary hoist braking system has ruled out a mechanical failure to explain why the brake released and the overhaul ball fell unexpectedly, striking the welder. Although there was significant wear on the hook and pin, none of the components had failed at the time of the incident and component failure is ruled out as a cause of the brake pedal not engaging correctly.

The investigation team examined the human factors involved in the incident. Several factors were investigated for their possible influence on the release of the auxiliary hoist brake pedal. The following analysis looks at the underlying factors to explain why the latch mechanism did not successfully engage and why the crane operator was unaware that the brake was not properly latched.

## 2.1 Brake pedal's latching mechanism

To prevent the load line from descending, the crane operator needs to keep continuous foot pressure on the pedal unless the brake is latched, or locked. Once the pin and hook latch together, the operator can remove his foot from the pedal. The brake pedal has to be latched when the operator leaves the cab or, if the operator remains in the cab, to alleviate the resistance on the pedal for a time, thereby reducing the likelihood of muscle fatigue.

The operator of this crane must go through a specific sequence to ensure the brake is latched correctly:
1. Press the heel on the back of pedal down to floor (see Photo 10).
2. Press the ball of the foot on the front of pedal down close to the floor while the back of the pedal rises (see Photo 11).
3. Maintain resistance to hold the pedal in horizontal position as the pedal comes up.
4. Remove foot from brake.

Photo 10: To latch the brake, the heel is first pressed to the floor.

Photo 11: When the ball of the operator's foot presses down on the front end of the pedal, the back of the pedal rises, putting the pedal in a horizontal position.

When locked, the pedal rises 3.5 inches to the horizontal position. This indicates that the pedal cannot rise any further and the hook and pin are fully engaged (see Photo 12).

Photo 12: The pedal is properly latched and the foot can be removed.

During the examination of the auxiliary hoist brake pedal, one issue surfaced. When a crane operator attempts to latch the pedal, the hook can come to rest on the underside of the pin, giving the impression (and sound) that the hook has fully engaged the pin (see Photo 13). This can occur if the pedal does not completely or sufficiently complete stage 2 (ball of the foot moving the front of the pedal down). In this configuration, the hook will readily slip off the pin when the operator's foot leaves the pedal. It may engage or disengage the latch, depending on the direction the hook moves relative to the fixed pin. During the examination of pedal functioning, this particular pedal action could be reproduced only intermittently.

If the ball of the foot pushes down on the front of the pedal too soon while engaging the brake, the back of the hook will strike the pin before the pedal reaches the bottom of its travel. The pedal will release immediately as the latch is not engaged.


Photo 13: The hook is resting on the underside of the pin rather than being fully latched under the pin. In this position, the brake pedal may release when the operator's foot is removed.

The crane operator/foreman attempted to apply the brake before leaving the cab. The investigation concluded that the latching mechanism did not successfully engage in that attempt, resulting in the inadvertent release of the brake pedal. The latching mechanism may not have engaged for one or both of the following reasons:

- The latching hook was incorrectly positioned relative to the pin during the downward motion of the pedal, resulting in the back of the hook striking the pin rather than engaging it.
- The ball of the foot did not move the front of the pedal down sufficiently to correctly engage the latch mechanism.

## 2.2 Force required to work the auxiliary hoist brake

The investigation looked into the human factors that may explain why the auxiliary hoist brake pedal had not been successfully latched in position in this incident. The force required to latch the brake and possible resulting muscle fatigue were examined.

When a crane is used for pile driving with a drop hammer (as this one usually was), the pedal resistance is usually set higher than is used for driving sheet piles. The resistance on the brake pedal can be adjusted to accommodate the weight on the load line. The crane involved in this incident was usually used with a drop hammer, but at the time of the incident it had been used for a day or two for driving sheet piles without a hammer. For short durations such as this, crane operators feel that it is unnecessary to reduce the resistance on the brake pedal and will use it with more resistance than necessary for the load, as in this particular incident.

The standard that applies to this crane, according to the Occupational Health and Safety Regulation, is *CSA Standard Z150-1974, Safety Code for Mobile Cranes.* Section 3.6.2 of this standard specifies that foot pedal controls should not exceed 50 pounds of force. For the mobile crane involved in this incident, to activate the brake in its *starting* position (the most upward position of the pedal), the force was measured at 90 pounds. In mid-range, the force reduced to 70 pounds, and flat to the floor it was 50 pounds. The crane operator spends the majority of the time in the mid-range (70 pounds with this crane).

In order to generate the required amount of force, this crane operator was observed assuming a position of moving forward in the seat, pressing the mid-back against the top of the seat, and clasping the underside of the seat with one hand. This motion would be continuous while the crane is in active operation and the brake pedal latch is not in use.

The investigation into human factors concluded that an operator on a crane with this pedal resistance may have muscle fatigue at the end of the shift. The motion of operating the brake is continuous apart from the time spent outside of the cab to co-ordinate work activities and scheduled breaks. In addition, the operator has to climb over the crawler track to get in and out of the cab. This dynamic activity coupled with the force necessary to operate the brake may cause muscle fatigue over the period of a day's activity. This muscle fatigue would eventually reduce the force that the operator could apply to the brake.

## 2.3 Feedback from latching mechanism

Another aspect of the examination of human factors was the feedback the crane operator/foreman might have received to let him know that the brake was latched.

A crane operator receives several forms of audible and tactile feedback as the brake is being engaged, in the following order:

1. The sound and tactile cues from the pedal initially hitting the floor when the crane operator strikes the floor with his heel
2. The position of the pedal and its relative distance from the floor once the brake is latched
3. The lack of resistance, or pedal push back, once the brake pedal is latched

There are no visual or audible devices to alert the operator as to whether or not the brake is latched correctly.

If the crane operator/foreman had put his heel down but had not successfully gone through the complete range of motion necessary to latch the brake, it is possible that the hook did not fully connect under the pin and may have only balanced on the underside. If that was the case, then the operator would have received the first audible and tactile cues from the pedal hitting the floor.

In this scenario where the brake had only partially engaged, the only difference in the second feedback would be the last horizontal position of the pedal before the foot is removed. In partial engagement the foot pedal raises 2.5 inches off the floor instead of the full 3.5 inches. It is unlikely that the operator would feel this difference, especially through the sole of a heavy work boot. In terms of the third feedback cue, the operator may even have felt that the latching mechanism had alleviated the resistance from the load line. However, if the hook was precariously placed on the underneath side of the pin, a small amount of force would disengage the brake.

## 2.4 Duties as both crane operator and foreman

One of the underlying factors that may have contributed to this incident was that the crane operator had duties as both a crane operator and a foreman. In his role as a foreman, his duties included the coordination of on-site activities. He had to be alert and pay attention to all activities outside the cab as well as to the operation of the crane. Overload of attention (information overload) can cause deterioration in performance because a person's mental processing system cannot handle all the information presented to it. Research has shown that individuals will switch the focus of their attention among different stimuli, attending to some and ignoring others, based on the priority of the stimuli.[1]

As the crane operator/foreman was latching the brake, it is probable that he did not dedicate much processing memory to this automatic, skill-based task. It is likely that he processed the audible and tactile cues of the first heel strike. These cues would have indicated to him that the brake was in position and would actually latch. After that, his attention was likely focused outside of the cab.

The operator had a conflict of responsibilities. Not only did he have to operate the crane but he had to co-ordinate on-site activities outside of the crane. Human factors specialists call this "divided attention." The responsibility of operating a crane should be scheduled and sequenced to reduce an overload of sensory input from other assigned duties.

## 2.5 No secondary braking system

In this crane, pushing on the brake pedal controlled the descent of the auxiliary hoist load block, similar to the action of a brake pedal in a vehicle. Latching the brake with a sequence of foot actions is similar to applying a parking brake in that the operator did not have to maintain pressure once the brake pedal was latched to engage the brake. The braking system meets the relevant standards by having a continuous mechanical linkage between the foot pedal and the friction brake (externally contracting bands). This crane was not required to have a secondary or backup braking system.

[1] G. Matthews, D.R. Davies, S.J. Westerman, and R.B. Stammers, *Human Performance: Cognition, Stress and Individual Differences* (East Sussex, UK: Psychology Press, 2000), pages 67–106.

A secondary braking system was available as an option for this crane model but had not been installed on the crane involved in this incident. However, if a secondary braking system (such as a ratchet and pawl) had been available to the crane operator/foreman when he left the crane cab and if it had been used, it would have prevented the drum from turning and allowing the overhaul ball to descend.

# 3 Conclusions

## 3.1 Findings as to causes

The welder in the elevated work bucket hooked on the top of an installed sheet pile was struck and fatally injured by the falling overhaul ball of the crane's auxiliary hoist line. The overhaul ball fell when the auxiliary hoist brake pedal inadvertently released.

## 3.2 Findings as to underlying factors

### *3.2.1 Divided attention when crane operator is also the foreman*

The crane operator/foreman had a conflict of job responsibilities. Not only did he have to operate the crane but he had to coordinate on-site activities outside of the crane. This can cause a situation with divided attention. The responsibility of operating a crane should be scheduled and sequenced to reduce an overload of sensory input from other assigned duties.

### *3.2.2 Insufficient feedback to operator on whether brakes are properly latched*

Feedback to the crane operator/foreman to indicate that the brake has been latched is limited, through brake position and change of resistance only. There are insufficient feedback mechanisms (audible or visual) to indicate to the crane operator/foreman that the brake has been applied successfully.

### *3.2.3 Possible muscle fatigue from applying pedal force*

The pedal force required to be applied by the crane operator/foreman exceeded the established standard. The crane operator/foreman may have experienced right leg muscle fatigue at the end of the day, which would have inhibited his ability to safely operate the brake pedal and latching mechanism.

### *3.2.4 No secondary drum brake*

No secondary, positive, drum brake system (such as a ratchet and pawl) was available to prevent the overhaul ball from dropping in the event of an inadvertent release of the hoist brake pedal.

## 3.3 Other findings

The pin and hook, which are critical components of the crane's braking system, were not inspected as part of routine inspections. Braking components were badly worn, although no components had failed.

# 4 Orders Issued after the Investigation

WorkSafeBC issued two orders after the investigation. An order requires an employer to take steps to comply with the *Workers Compensation Act* or Occupational Health and Safety Regulation, to take measures to protect worker health and safety, or to fix a hazardous condition. An order is not intended to identify fault on the part of the employer but to ensure that unsafe conditions are identified and corrected and that the employer complies with the Act and the Regulation. An employer may ask the Review Division to review an order; the Review Division may confirm, vary, or cancel an order.

In addition to issuing orders, WorkSafeBC may recommend proceeding with an administrative penalty against an employer. In order to protect the privacy of individuals, this report does not give details of any penalty proceeding arising from this incident as that would identify the employer. Penalties are fines for health and safety violations of the *Workers Compensation Act* and/or the Occupational Health and Safety Regulation. For information on when penalties are considered and how the amount of the penalty is calculated, see the penalty FAQs on WorkSafeBC.com. Companies that have been penalized are also listed on the web site.

## 4.1 Orders to the employer

This section summarizes the orders to the pile-driving company. The investigation found that this employer was in contravention of the Occupational Health and Safety Regulation, section 14.2(1), which states that a crane or hoist must be designed, constructed, erected, disassembled, inspected, maintained, and operated as specified by the manufacturer or a professional engineer, and to meet the requirements of the applicable standard. The employer was ordered to ensure the crane operator is not required to exceed the maximum forces and travel distances in manipulating the controls as stated in *CSA Standard Z150-1974, Safety Code for Mobile Cranes*, section 3.6.2, Control Forces and Movements for Controls.

When the crane's auxiliary hoist was used to position the work bucket and worker onto the sheet piles, the employer was in contravention of the Occupational Health and Safety Regulation, section 13.29(1)(c). This section states that cranes, winches, and other devices used for hoisting and lowering movable work platforms must not be equipped with a free running boom or hoisting winch controlled only by brakes.

# 5 Health and Safety Action Taken

In addition to the specific actions below, employers, workers, or others in industry may have taken measures to prevent a recurrence of this type of incident. At WorkSafeBC, the Lessons Learned committee examines recommendations from incident investigations to see what can be done to prevent similar incidents.

## 5.1 The employer

- The auxiliary hoist brake pedal assembly that included the worn pin and hook was replaced.
- An ergonomic (human factors) assessment was done by the employer. Several recommendations were made including an assessment of all the company's cranes for force measurements and recommendations concerning the inspection and maintenance of crane controls.