

FATALITY INVESTIGATION REPORT



Cedar Salvage Logger Killed When Struck by Falling Cedar Blocks During a Helicopter Logging Operation in Washington State

Investigation: # 98WA10301
SHARP Report: # 52-5-2000

Release Date: August 16, 2000



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Fatality Assessment and Control Evaluation (FACE) Program

SHARP Program, Washington State Dept. of Labor and Industries

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SUMMARY

On July 9, 1998, a 54-year-old cedar salvage logger died after being struck by one or more cedar blocks during a helicopter logging operation. Two cedar salvage loggers were working together on the ground in a heavily wooded area and had hooked up a load of cedar blocks to a helicopter drop line using a sling. As the helicopter was lifting the load, the sling failed by slipping, allowing the cedar blocks to fall. One of the loggers managed to get out of the way of the falling cedar blocks, but the second logger was hit directly by one or more of the blocks. The local emergency medical rescue unit was summoned via the helicopter's radio and responded to the incident scene. The victim died from the injuries sustained in the incident.

To prevent future similar occurrences, the Washington Fatality Assessment and Control Evaluation (FACE) Investigative team concluded that cedar salvage loggers involved in helicopter logging should follow these guidelines:

- **During rigging and hoisting operations, all personnel should be in the clear and stand out of the path of travel of the material being hoisted.**
- **A well-defined safe area and escape routes should be designated prior to any material lift so that all personnel will be "out of harm's way" in case of a failed lift.**
- **Slings must have properly spliced eyes. When using synthetic fiber rope, eye splices need to have at least four full tucks to prevent splice failure.**

- **All persons who direct, rig, and handle loads for lifting operations need to be specifically trained and knowledgeable in both safety and operating principles associated with the specific process.**
- **For all helicopter logging operations, a preflight briefing with the air and ground crews should be held to review the operation's safety plan.**

INTRODUCTION

On July 15, 1998, the Washington FACE Program was notified by WISHA* (Washington Industrial Safety and Health Administration) of the death of a 54-year-old cedar salvage logger that occurred on July 9th, 1998.

The Washington FACE personnel met with the regional WISHA representative who was investigating the case. After reviewing the case with WISHA, the WA FACE team traveled with the WISHA representative to the incident site. The WISHA representative helped pinpoint the incident location, the helicopter-logging site detail, and defined the position of the cedar salvage loggers involved in this incident.

The cedar salvage logging site was on private forest land owned by a forest products company. The company contracted with local logging firms to salvage harvest their forest lands on a regular basis. Trees were harvested according to a schedule defined in a forest management plan developed by the landowner. For this salvage logging operation, the land owner identified naturally downed cedar trees that still had wood in good enough condition for use as shakes or shingles and hired a contractor to cut and haul the wood to a mill. A contract was established with a local logging contractor who in turn hired an experienced salvage logger to conduct the salvage operation for the landowner.

The salvage logger (the victim) recruited an associate to work with him on the ground for this job. The victim also coordinated logistics with the helicopter company to transport the blocks from the forest where they were cut to a drop location on the side of a logging road. A trucking company was hired to move the cedar blocks from the drop location to the shake and shingle mill.

At the time of the incident, the 54-year-old male victim was working with his coworker at one of the pickup locations, which was accessible only on foot. The victim had been working this site for several days cutting, stacking and rigging cedar blocks prior to their being lifted out to the truck. The coworker had just started working with the victim on the morning of the incident. The coworker was primarily going to be the "hooker" for the helicopter "lifts." The hooker's job was to direct the helicopter to the load site and attach (hook) the slings to the helicopter's load hook. The hooker also controls the location of people prior to and during the lift. The helicopter then transported the load to the landing. The victim was supervising the hooker at the time of the incident.

The victim had been logging for about 15 years and had considerable experience with helicopter logging cedar salvage operations. The victim's coworker had been logging for more than 4 years.

INVESTIGATION

On July 9, 1998, a Thursday morning, the victim and a coworker went to work at a cedar salvage logging site. The weather that morning was good, but the start of work was delayed so the early morning fog could clear to allow for safe operation of the helicopter.

* The OSHA State Plan program in Washington State

This salvage logging operation consisted of identifying downed trees that would be cut into blocks, cutting the blocks, and then transporting them to a mill for cutting into shingles or shakes. Once the blocks were cut, they were stacked on a sling that was laid out on the ground in a clearing close to the cutting area. This would allow the helicopter to lift the blocks without interference from nearby trees. A thick forest canopy could prevent visual contact between the ground and air crews and interfere with the load as it was raised. If there was no clearing, the ground crew had to establish a reasonable site, by cutting down trees. When the ground crew had enough stacks to be lifted, they coordinated the lifts by communicating with the helicopter crew using a two-way radio. The helicopter transported the loads to a designated landing. The blocks were then loaded on a flatbed truck and delivered to area shingle or shake sawmills.

The ground crew had previously made the slings by taking a length of 5/8-inch, twisted three-strand, yellow polypropylene rope and tying an eye-splice on each end. The sling was then stretched out on the ground and a stack of blocks, approximately 4 feet by 4 feet, was assembled in the middle of the sling (Photo 1). The two ends were then brought together and one eye placed through the other to form a self-tightening loop around the blocks. The hook from the helicopter's long-line was clipped onto the eye at the free end of the rope.

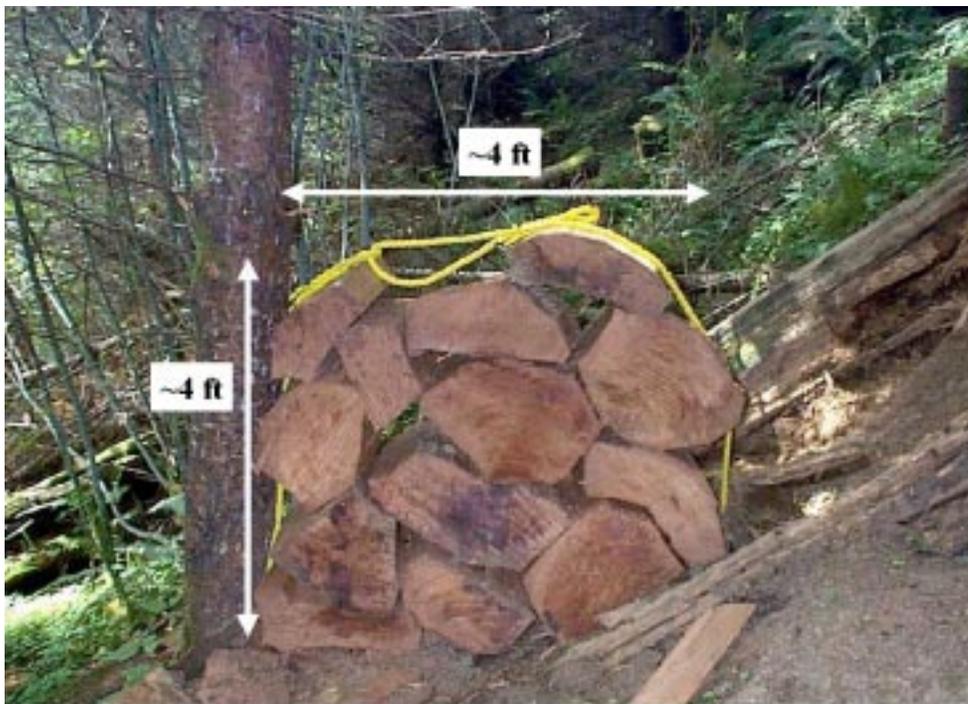


Photo 1 Stack of cedar blocks prior to lifting.

On the morning of the incident, the ground crew consisted of two persons, the victim and the victim's coworker, whose job was to assist the victim as the "hooker" for the day's operation. The workday started at approximately 7 a.m.

To get to the stacks of cedar blocks, the salvage team had to walk approximately 3/4 of a mile from the landing, which was adjacent to a logging road, through moderately heavy brush and trees.

All tools and materials had to be hand carried and backpacked into the area. The terrain was very hilly with slopes up to 40°.

Other than the morning fog, which was predicted to clear by mid-morning, there were no other adverse environmental conditions to affect the day's activities. While waiting for the fog to clear, the ground crew prepared the loads for lifting. After the fog cleared, the salvage team would guide the helicopter to each pickup location using a two-way hand-held radio and signal light.

After lunch, between 1:30 and 2 p.m., the helicopter started lifting the loads. The hooker was being guided by the victim (the cutter) to the lift sites. After about an hour into the lifting operation, the ground crew contacted the helicopter and advised them to fly to another crew conducting salvage logging in the same area. This would allow the victim and his coworker time to travel to the next lift location.

When the cutter (the victim) and the hooker got to the next lift site, they prepared the slings and stacks for the lift. They had two stacks at the incident site ready to lift. One stack was directly up slope from the second stack. When the ground crew was ready, they notified the helicopter to look for the signal light to designate their position. The hooker prepared the up-slope stack of cedar blocks for the first lift at this site.

The hooker coordinated the positioning of the helicopter with his radio and high-powered flashlight. The long line and hook were lowered over the up-slope stack. He hooked up the sling and signaled the helicopter to take out the slack from the long line and proceed with the lift. The first lift was routine and the helicopter flew the sling in a north/northeast direction to the landing.

As the ground crew waited for the helicopter to return, the hooker questioned the victim to find out where they were going after they had completed the second lift at this site. The victim pointed toward the northeast, to a slope opposite from where they were standing. The crew would have to travel downhill to a flat area, cross a beaver dam, and hike up the opposite slope to get to the next lift site.

When the helicopter returned, the hooker positioned the long line and hook for the second lift, which was the down-slope stack. In going through the same rigging process as the other lifts, the hooker attached the sling and signaled the helicopter to proceed with the lift. The hooker stayed with the sling as the slack from the line was taken out by the helicopter's hoist. Just prior to the sling being lifted, the hooker punched down on the threaded eye with his hand, which may help tighten the sling.*

As this second lift was in progress, the hooker and block cutter (victim) quickly headed downhill toward the next hookup/lift site. As the load was entering the forest canopy, at about 50 feet above the ground, the hooker stated that he heard a snapping noise. He then looked over his left shoulder and saw the load coming down.

* This is not a recommended practice because it exposes the hooker to getting his hand caught in the sling and load and also exposes the hooker to the load kicking out and swinging into him or her. The hooker would also be in "the line of fire" or the exposure zone in the event that there was a lift failure.

The hooker yelled a warning to the block cutter and tried to grab him to move him out of the way, but he was unable to. The block cutter was struck by one or more of the falling cedar blocks. Each block weighed up to 60 pounds with the entire sling of blocks weighing between 800 and 900 pounds (Photo 2 and Figure 1).



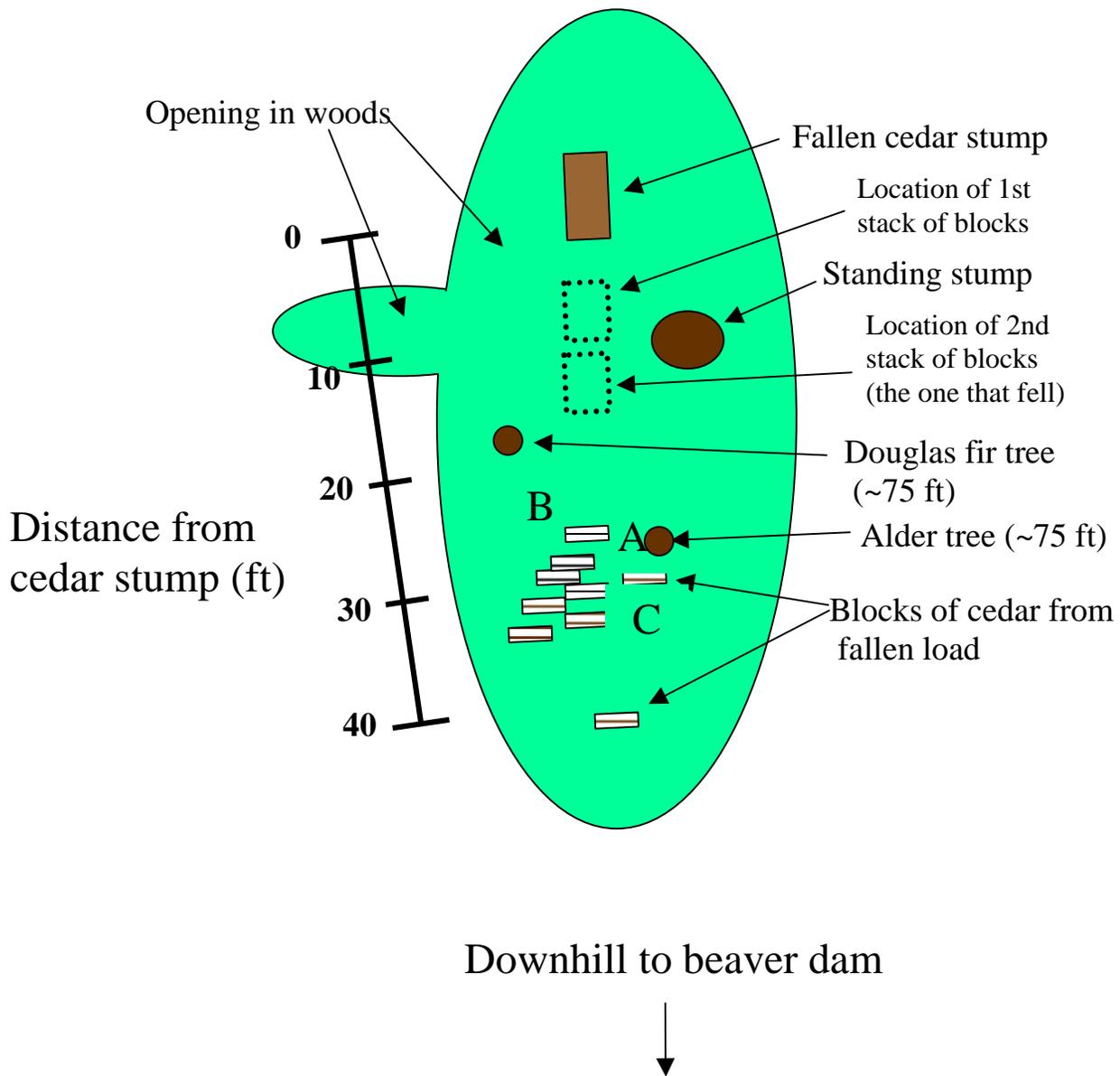
Photo 2 The site where the incident occurred.

The hooker immediately attended to the block cutter, but found him unconscious. He quickly radioed the helicopter for help and the helicopter crew radioed for an emergency rescue unit to respond to the incident. The landing crew heard the radio call for help transmitted by the hooker, borrowed a first-aid kit from a contractor working at the landing, and went to the lift site to perform first aid. Basic first aid was administered to the victim while they were waiting for the emergency rescue unit to arrive.

The victim was transported by helicopter to a local emergency medical facility. It was determined that the victim had died prior to reaching the emergency medical facility.

CAUSE OF DEATH

The medical examiner listed the cause of death as a massive head trauma - cerebral hemorrhage, due to or as consequence of a fractured skull.



A- location where decedent was standing when he was struck by blocks
B - location where hook tender was standing when blocks fell
C - location where decedent landed after being struck



Figure 1 The site layout.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: During rigging and hoisting operations, all personnel should be in the clear and stand out of the path of travel of the material being hoisted.

Discussion: The investigation revealed that the victim and the coworker were standing under the "load" of the helicopter as the lift was taking place and were travelling along the helicopter's flight path.

One of the first rules in conducting a safe material lift after securing the load is to ensure that all persons are clear of the load and out of its path of travel. This would be even more critical in this operation because they were relying on a single sling to lift a load of multiple blocks of wood. It was noted by at least one crew member that it was not uncommon for one or more blocks of wood to fall from a sling as it was being lifted.

Recommendation #2: A well-defined safe area and escape routes should be designated prior to any material lift so that all personnel will be out of harm's way in case of a failed lift.

Discussion: To be prepared for any type of unusual event in a helicopter logging operation, it is very important to establish a safe area and escape routes for all persons working on the ground.

The FACE investigation showed that in this incident, instead of moving into a safe area as the lift was taking place, the hooker and the victim headed directly toward the next lift site. Not only did the victim and the hooker not go to a safe area to watch the lift until it had cleared the area, they traveled beneath the helicopter, along its flight path, as it was heading to the landing site.

For helicopter lifting operations, it is recommended that once the hook and load have been set, the hooker and other ground personnel move to a predetermined safe location approximately 20 to 25 feet away from the lift and then signal the pilot that it is safe to proceed.

If the lift is taking place on a slope, the ground crew should, if possible, define their safe area uphill of the lift and away from the path of travel of the load. Once the helicopter has left the area, the ground crew can proceed safely to the next lift site.

Escape routes should be defined from the lift area as well as from the safe area. The escape route should be a path that can be used by the ground crew to escape from an errant load, helicopter failure, or other similar incidents. It should be cleared of obstructions and other hazards.

Recommendation #3: Slings must have properly spliced eyes. When using synthetic fiber rope, eye splices need to have at least four full tucks to prevent splice failure.

Discussion: During the investigation, it was discovered that one of the eyes of the sling used for the load came apart just prior to the load clearing the forest canopy. The sling eye failure occurred as the hooker and victim were traveling beneath the load toward the next lift site.

The failed eye had not been spliced according to recommended practices, but used a compression splice. This splice was made by passing the “dead” end of the rope through one strand of the rope and then the end skipped some of the lays or twists of the rope and finally passed through another single strand. An example of a compression splice is shown in Photo 3a. Approximately 3 inches of tail were left with this splice. There was no “knob” created at the end of the tail which would keep the rope strands from unraveling. A knob is created by melting the loose end of the rope together.

The failed eye was essentially a two tuck splice with a very short tail and no sealed knob. This is a very quick, simple eye to make but will not hold heavy load or shock stresses as was demonstrated by this incident. The eye on the other end of the sling was a five tuck splice and it remained intact throughout the incident. An example of a four-tuck splice without a knob is shown in Photo 3b, which is an appropriate splice for this application.

Other slings were found around the incident site that also had two tuck compression eyes.

The slings were made from 5/8-inch, twisted three-strand, yellow polypropylene rope that can be purchased in lumberyards, hardware stores, marine supply stores and logging and forest supply stores. It comes in a variety of bulk lengths and is relatively inexpensive. The bulk rope was cut into lengths of about 18 feet and the eyes were spliced by hand into each end of the rope by the salvage loggers. Slings were made specifically for this purpose.

When working on any job where material lifts are to be made, it is very important that all of the tools and equipment meet strict guidelines.

The slings and the eyes are very important items for this type of logging operation. The splices on slings made of synthetic rope need to have more tucks than those tied with natural-fiber ropes due to the fact that synthetic fibers have smoother surfaces and do not cling to each other like natural fibers. Synthetic fibers also have greater stretch and slippage properties than natural-fiber ropes.

A minimum of four to five tucks should be used for eye splices made of synthetic fiber rope. When dealing with heavy loads and/or where there is a potential for "shock" stresses such as in the cedar salvage operations, the number of tucks should be increased as an extra safety measure.



Figure 3a Example of a compression splice. This is not an appropriate splice for this application.

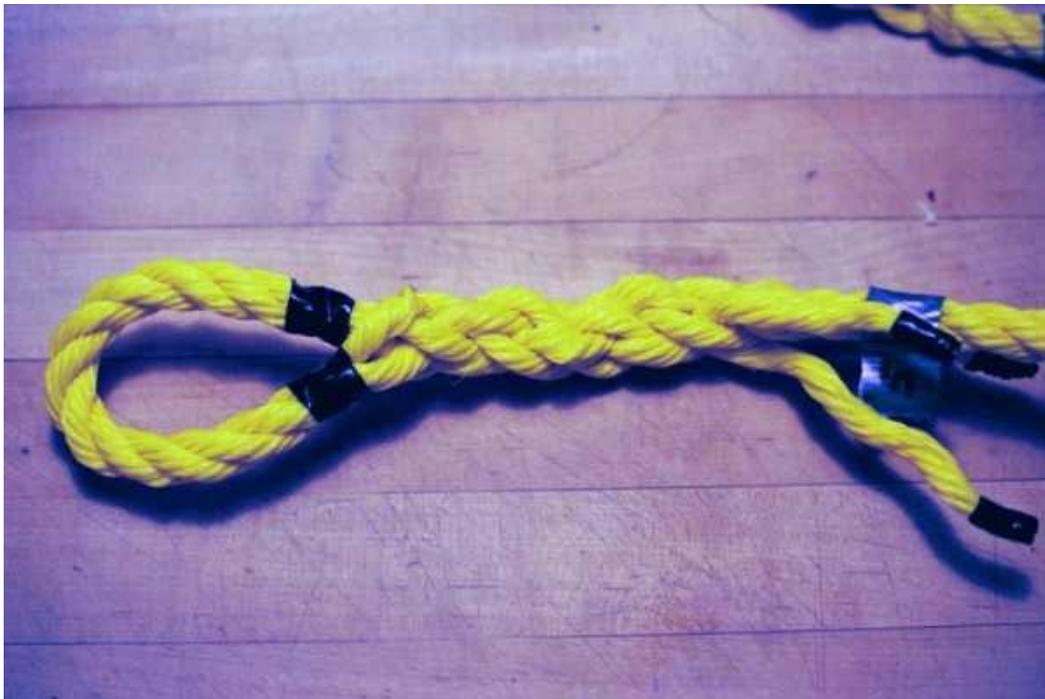


Photo 3b Example of a four-tuck splice without knobs. This splice is appropriate for this application.

Recommendation #4: All persons who direct, rig, and handle loads for lifting operations need to be trained and knowledgeable in both safety and operating principles associated with the specific process.

Discussion: Helicopter cedar salvage operations have numerous hazards. It is important that all persons have the training, knowledge, and skills to address the potential hazards of helicopter logging. This can be enhanced by making sure that the right tools are used for the job and the right safety and operating principles are followed.

Injury/incident prevention and job/skills training need to be synonymous concepts in materials handling. This need is expanded when it is taken into the forest products industry. Performing material lifts in remote forest settings, using a helicopter as the hoisting mechanism, conducting lifts on unstable terrain with poor visibility, and having high noise levels and air turbulence from the helicopter rotors, in combination with time pressures due to economic factors, all add to the hazards of the job and increase the probability of an injury incident.

An intricate knowledge of the equipment, the operations, and the materials used in the process are important factors in incident and injury prevention.

Eyes on all slings should be inspected to ensure that they were properly made and would meet material-handling requirements. The ropes used for the slings also need to be inspected for abnormal wear, broken or cut fibers, variations in size of the strands, discoloration, and any kinks or knots in the slings. If the slings do not meet safe operating standards and guidelines, or if there is any doubt whether they are fit for use, the slings should immediately be taken out of service and replaced.

There also may have been a poor understanding of the properties of the rope. The rope used in this incident, 5/8-inch 3-strand polypropylene, has a tensile strength of approximately 6,000 lbs. (derived from literature). With a splice in line, this would be reduced by approximately 90% to 5400 lbs. and give a working load of approximately 675 lbs. using a work load ratio of 8:1.* This means that the loads lifted should not exceed 675 lbs. If, as in this case, there is dynamic loading, the working load should be reduced appropriately.

Training is especially important in work practices that involve rigging operations. Errors made in rigging can yield serious consequences that can result in injury and death.

Knowledge of good rigging practices, procedures, and precautions is very important for the safe application of cedar salvage operations. Knowledge, understanding and familiarization also extends to equipment and materials used for the rigging and material-handling processes.

The training and education process should include some of the primary duties for persons involved in rigging to ensure that proper equipment is available and safe to use. Each day, prior to any lifts

* Working load -- is the weight that is recommended for safe working conditions. It is used for new rope with appropriate splices.

being made, riggers should inspect the slings and all rigging items for the day's lifts. The inspection and review process should include both the ground and the helicopter crew.

All individuals working in a high-hazard industry such as helicopter logging should be involved in a continuous training and education process. A training and education process should not only introduce innovations and new techniques to logging operations, but also reinforce best practices and provide for review of current safety and regulatory requirements for the industry.

Recommendation #5: For all helicopter-logging operations, a preflight briefing should be held to review the operations safety plan.

Discussion: Helicopter cedar-salvage logging involves lifting sling loads of cedar blocks from a variety of forest pickup points and flying them to one or more designated landings. This relatively straightforward process has numerous inherent hazards for not only the helicopter crew but also for persons working on the ground below.

Before any helicopter logging operation takes place, a job safety plan should be developed. It is important that the job safety plan be clearly understood by everyone working the salvage operation. The plan should have the work areas and hazards well defined and have contingency plans for emergency situations. Good planning is important in managing a safe operation.

A daily briefing should be conducted prior to each day's logging activities. The briefing should include a discussion of various elements of the job safety plan and a more detailed discussion of the plan of action for that day's activities. The discussion should have both the helicopter and ground personnel involved in the briefing. If there are any changes made to the plan for the day's activities, everyone needs to be made aware of those changes.

As part of the process, a site layout should be drawn. The layout should define the location of the pickup areas, the helicopter's flight path between pickup and drop points, and its flight path to and from its maintenance pad. The flight paths should be designed to avoid having the helicopter fly loads over ground personnel. The ground personnel should plan their work to stay clear of suspended loads and in particular to stay out of the planned helicopter flight path. The ground personnel should especially avoid working under a hovering helicopter. Helicopters generate strong rotor wash that can dislodge loose limbs and other materials causing them to fall on personnel below. The only time ground crew should be allowed under a hovering helicopter is the limited time that they need to secure, hook, and unhook loads. Another exception could include performing specific aircraft/equipment maintenance and/or inspections.

The briefing should also include provisions for first aid and the review of emergency evacuation plans. A process to address all types of injuries or health issues should be part of the first-aid emergency plan.

In this incident, no preflight briefing was conducted. The lift locations were communicated via radio and flashlight. The flight paths were not predefined and there was no coordination between the helicopter and ground crews. There were also no provisions made for emergency or first aid situations. The cedar salvage team did not discuss or review the equipment or the lift process for the day's operation and in particular did not review or inspect the slings and the eye splices.

Helicopter logging operations have many potential opportunities for serious injuries and fatalities. Many of the injuries and fatalities that occur can be prevented by having a clear understanding of the hazards and risks that are involved in the helicopter logging industry and then by taking specific action to address these hazards and risks. Good processes, good work practices, knowledgeable workers, and attention to detail all need to be partners in every aspect of helicopter logging.

ACKNOWLEDGEMENTS

In conducting this Heli-Logging Fatality Investigation, the Washington State FACE Investigation Program requested that the contents of this report be reviewed by key representatives from the business and labor communities and Washington State and Federal agencies prior to its publication.

Though we are not able to acknowledge specific individuals for their invaluable input into this document, we would like to recognize the following for their help and support to the FACE process:

- WISHA enforcement
- WISHA policy and technical services staff
- Alaska Field Station (NIOSH)
- Federal Face Program Management
- Washington Contract Loggers Association
- Woodworkers District Lodge 1 of the International Association of Machinists
- Helicopter logging safety association
- Rigging/materials handling distributor
- Safety and Health Assessment and Research for Prevention (SHARP) Program
- A former cedar salvage logger

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APPENDIX A

Sling Alternatives: Synthetic Fiber Web Slings and Cargo Nets

As part of Washington State FACE Investigation process, we research different ideas and safety applications that currently may not be used by the industry in their operations. Two of those suggestions are outlined in this appendix.

In researching the helicopter cedar salvage logging operation fatality, we reviewed a variety of alternative applications to make the process of lifting the cedar blocks safer. It was noted during the investigation that losing several cedar blocks or even the entire lift was not an unusual circumstance during block flying operations. This creates a serious risk to the ground crew working below. The loss of material seems to center upon the use of a single rope sling to perform the lifts. In reviewing alternative lifting devices, we generally found two that would fit this application: synthetic fiber web slings and cargo nets. Neither of these items are innovations or new technologies, but neither of these items are widely used in the industry. These may provide a greater degree of stability and thus safety in conducting cedar block lifts.

Synthetic Fiber Web Slings

Slings can be made from fiber and synthetic ropes, wire ropes, chains, metal mesh and synthetic webs in a variety of configurations. The type of sling used can dramatically affect the safety of materials movement when conducting a lift.

In the incident previously described, a polypropylene rope was used as the sling for the lifts. When reviewing alternatives to rope slings, we found that synthetic web slings appeared to have several advantages over rope slings.

Synthetic web slings are available in a number of widths, from 1 to 12 inches wide. Other widths with custom specifications can be made by the synthetic web sling manufacturers.

One of the pluses of the synthetic web slings over a rope sling is the increased stability that the extra width provides. The wider the sling, the easier it is for the rigger to set up the center of balance of the load. Synthetic web slings also minimize twisting and spinning during lifts. This provides for better material lift control and reduces the possibility of losing all or part of the load.

Synthetic web slings are available in a variety of configurations:

Endless or Grommet Sling – where both ends of one piece of webbing are lapped and sewn to form a continuous unit. Various hitch combinations can be used with this web sling including the choker used for the rope sling in this heli-logging incident.

Standard Eye and Eye – the webbing is assembled and sewn to form a flat body sling with an eye at each end.

Twisted Eye – is an eye and eye twisted at both ends. The body and sometimes the eyes are folded and sewn to add extra strength to the sling.

Metal End Fittings – are slings with metal fittings sewn into the ends.

The user can chose between not having an eye by using an endless or grommet sling or having commercially manufactured eyes for their process. They would not have to fabricate or splice the eyes themselves or rely on persons with little or no training to splice the eyes.

Just as with other slings, it is extremely important to inspect web slings daily and prior to each use. Web slings are generally easy to examine and to detect damage (e.g. worn eyes, cuts holes, frayed material, etc.). Damaged slings should not be repaired, but taken out of service, marked as unusable, and replaced.

In the selection of web slings, it is important that the use and application of the slings be reviewed with the distributor/manufacturer so the best product for the application can be selected.

A note on rope slings:

A safety application that may make rope slings safer, would be a self-tightening, one-way rope locking device. We have not conducted research on these items, but research and possible development would be needed prior to ensuring that they would be appropriate for the job at hand.

Cargo Nets

Cargo nets provide another option for helicopter cedar block lifts. Cargo nets have been in use for many years in the maritime industries. They are also used extensively in industrial and military materials handling and equipment deployment.

Helicopter cargo nets, also known as helicopter deck nets or underslung cargo nets, are available from manufacturers in a variety of material types and sizes. They come in natural fiber manila rope, nylon, polypropylene and dacron. Each material type presents different features and properties. When selecting a cargo net, one should carefully review with the distributor/manufacturer the intended use and potential exposure of the net. Safe handling and operating guidelines should also be discussed.

Cargo nets in the forest setting have some limitations. Cargo nets could possibly get hung up or snag forest canopy obstructions. They should be used in clearings and/or open areas with little to no forest canopy.

Cargo nets may be a good option to evaluate when moving loose and relatively short material such as cedar blocks. Cargo nets offer helicopter cedar block flying a greater degree of safety from the possibility of losing a partial or complete load and thus in turn provide greater safety to personnel working on the ground. Cargo nets can also provide greater production efficiency by effectively moving larger loads, thus minimizing the number of helicopter lifts required to move the material.

APPENDIX B

Testing of Rope and Splices

To better understand the properties of the rope and splices used in this operation, two tests were conducted. The first was a static test to simulate the situation where there is little or no movement between the load and helicopter. The second was a dynamic test to simulate a "shock stress" or quick movement of the load.

Methods

Twisted, 5/8-inch three-strand, yellow polypropylene rope (the same type of rope involved in the incident) was purchased from an industrial supply distributor. Ten-foot lengths were cut and tied with a test eye-splice on one end and a figure-8 knot on the other end to support the rope in the test apparatus. The ends of the ropes were taped with electrical tape to prevent them from fraying. Both four-tuck and compression splices were tested. A four-tuck splice was tied by separating all three strands of the rope and interweaving them back into the body of the rope four times, leaving at least 3 inches of a loose tail for each of the strands (Photo 3b). In this situation, a compression splice was one where, together, all three strands were woven into the body of the rope, leaving a short tail (see Photo 3a). Two types of tests were conducted; static and dynamic. Different types of compression splices were also examined. Some splices were tested with twists in the rope that would either loosen or tighten the rope's natural twist.

Static tests were run by placing the rope in the testing apparatus and "pulling" the two ends of the rope apart in a slow and controlled manner at a rate of 360 mm/min. These tests were run until either the splice, knot, or rope slipped or broke. The integrity of the rope and the force required to break the rope or splice/knot were recorded.

Dynamic tests were conducted to estimate the effects of a "shock stress." This was simulated by hanging a 1,000 lb. weight by the rope, letting it drop 2 feet, and catching the weight again with the rope.

Results

Static break tests of the rope and four-tuck splice indicate that the rope breaks at approximately 4,782 lbs. No difference was seen when the four-tuck splices were twisted. These ropes broke just below the figure-8 knot.

When the compression splices were investigated, these failed at approximately 4,500 lbs and broke at the figure-8 knot as well. When the compression splices were investigated with 1 and 2 "opening" twists, the ropes broke at the figure-8 knots at 4,321 and 4,839 lbs. respectively. When 5 "opening" twists were put in the rope, the rope maintained its integrity and the compression splices slipped at approximately 2,000 lbs.

When the four-tuck splices were tested using the dynamic set up, the rope, just outside the splice or figure-8 knot, failed at approximately 4,564 lbs. when the shock stress was exerted.

All three compression splices slipped at the splice when the shock load was exerted.

Two out of the three compression splices slipped at the splice after the rope had been twisted two turns in the "tightening" direction and had the shock stress exerted. One compression splice with 2 tightening twists held the load until 2,120 lbs. were exerted in the shock test.

Conclusions

Static testing showed that under most conditions the rope and compression splices would hold the load involved in this fatality. It is possible that under static conditions, with a heavily twisted rope and frayed ends of a compression splice, the splice could slip.

The dynamic testing results indicate that under very severe test conditions, with a shock load, the rope would break even with four-tuck splices and that a compression splice would slip. From the data collected, it is not possible to determine the minimum load or drop height that would cause the poorly tied splice to slip.

It was shown that under some conditions, the compression splices will hold, but when they are subject to a dynamic or "shock stress," they may slip. This may occur if a block of wood falls from the load, causing the loop around the blocks to get smaller, jolting the sling as it tightens; the load gets snagged and then released; or a kink in the rope sling suddenly straightens.

APPENDIX C

Applicable Regulations

In reviewing the WISHA standards, there are defined requirements that deal with helicopter logging and rigging operations. Although the investigation of this incident was not regulatory in nature, we offer the following code requirements for information and reference purposes. This is not intended to be a complete list of regulatory guidelines that address these issues:

Employees and equipment must remain in the clear and employees must never be under a suspended load. WAC 296-54- 581(2)

Employees must not work under hovering craft except for that limited period of time necessary to guide, secure, hook/unhook loads, and perform maintenance/inspections or other related job duties. WAC 296-54-581(3)

Prior to daily logging operations, a briefing must be conducted. The briefing must set forth the plan of operation for the pilot(s) and ground personnel. Anytime a change in operating procedure is necessary, affected personnel must be notified. WAC 296-54-581(1)

Splicing. Spliced fiber rope slings shall not be used unless they have been spliced in accordance with the following minimum requirements and in accordance with any additional recommendations of the manufacturer: WAC 296-24-29429(3)

In synthetic fiber rope, eye splices shall consist of at least four full tucks, and short splices shall consist of at least eight full tucks, four on each side of the center line. WAC 296-24-29429(3) (b)

Each day before being used, the sling and all fastenings and attachments shall be inspected for damage or defects by a competent person designated by the employer. Additional inspections shall be performed during sling use, where service conditions warrant. Damaged or defective slings shall be immediately removed from service. WAC 296-24- 29421