Chapter 11: Anchorages

Chapter Overview

Anchor-system terminology has evolved differently in different industries. As a result, the terminology used in the field can be confusing. The rescuer must familiarize themself with the proper terminology in order to minimize instances of miscommunication and ensure the safety and integrity of all operations. An understanding of the principles of anchoring as well as the type of anchorage system that might be present in a given environment is likewise necessary.

Well-constructed anchorage is an important building block in all rope rescue systems. A lack of suitable anchors places the ropes, hardware, and other hear are in danger of falling. Secure and appropriate anchorage must be established before the rest of the system can be rigged; therefore, it is important to be knowledgeable of the various types of systems that are available, the circumstances in which each type should be used, and the hazards associated with each.

Objectives and Resources

**Knowledge Objectives**

After studying this chapter, you should be able to:

 Define common anchorage terms. (pp. 198–199)

 Explain how to weigh the considerations of strength, direction, and position in anchor selection or placement. (NFPA 1006: 5.2.5, 5.2.6, p. 199)

 Describe the considerations for positioning anchor systems. (NFPA 1006: 5.2.5, 5.2.6, p. 200)

 Identify the considerations for back up anchor systems. (NFPA 1006: 5.2.5, 5.2.6, pp. 200–201)

 Describe the principles of single point anchor systems. (NFPA 1006: 5.2.5, pp. 202–205)

 Describe how force is distributed among anchor points. (NFPA 1006: 5.2.6, pp. 207, 209)

 Explain the difference between load sharing and load distributing anchor systems. (NFPA 1006: 5.2.6, pp. 207, 209)

 Explain the principals of multi-point anchoring systems. (NFPA 1006: 5.2.6, pp. 206–211)

 Discuss the use of directionals. (NFPA 1006: 5.2.5, 5.2.6, pp. 212–213)

 Explain how and why to back up anchors. (NFPA 1006: 5.2.5, 5.2.6, pp. 214–215)

 Describe how to safety check anchor systems. (NFPA 1006: 5.2.5, 5.2.6, 5.2.7, p. 216)

**Skill Objectives**

After studying this chapter, you should be able to:

 Tie a tensionless hitch. (NFPA 1006: 5.2.5, p. 202)

 Construct fixed and focused multi-point anchor system (NFPA 1006: 5.2.6, p. 208)

 Construct a protected self-adjusting anchor system. (NFPA 1006: 5.2.6, p. 210)

 Back up an anchor using a pretensioned tie back. (NFPA1006: 5.2.6, p. 213)

 Complete an anchor system safety check. (NFPA 1006: 5.2.5, 5.2.6, 5.2.7, p. 216)

Support Materials

 Dry-erase board and markers or chalkboard and chalk

 LCD projector, slide projector, overhead projector, and projection screen

 PowerPoint presentation or slides

 **Navigate for Students**

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Reading and Preparation

Review all instructional materials, including *Rope Rescue: Principles and Practice,* Fifth Edition, Chapter 11, and all related presentation support materials.

Chapter Presentation Overview

Pre-lecture

I. You Are the Rescuer

Small-Group Activity/Discussion

Purpose

The purpose of this activity is to introduce students to concepts surrounding the understanding and management of water rescue incidents.

Instructor Directions

1. Direct students to read the “You Are the Rescuer” scenario found at the beginning of Chapter 11 (p. 198).

2. You may assign students to a partner or a group. Direct them to review the discussion questions at the end of the scenario and prepare a response to each question. Facilitate a class dialogue centered on the discussion questions.

3. You may also assign this as an activity and ask students to turn in their comments on a separate sheet of paper.

Lecture

I. Introduction

A. Review the learning objectives.

B. All rope rescue systems must incorporate a solid, well-constructed anchorage as a foundational element.

C. The best anchorages are well positioned to achieve the objective, and both strong and stable enough to support the intended load.

D. Without suitable, secure anchors, the remainder of the rope rescue system (ropes, hardware, and other gear) is in danger of failing, no matter how well established they are.

II. Anchor Terminology

**A. Natural versus artificial anchorage**

1. Anchor system terminology is confusing.

a. This is largely because terms have evolved differently in different industries, but as the world becomes smaller and regulatory language overlaps, these have begun to collide.

2. Historically, rope users typically borrowed terminology from recreational climbing and mountaineering usage – in which the big differentiation was between the following:

a. Natural (e.g., a large boulder or tree that would be left intact after use)

b. Artificial (e.g., a chock or other climbing pro that would be removed at the end of a climb)

c. Climbers began to install bolts in rock, and slings were left on protrusions, so the lines between natural and artificial anchors began to blur.

3. Likewise, similar concepts were evolving in the fall protection world, where the primary considerations revolve around the level of training required for a worker who is expected to use these systems.

4. For regulatory purposes, the Occupational Safety and Health Administration (OSHA) and American National Standards Institute (ANSI) use the following terms:

a. Permanent anchorage

b. Temporary anchorage

c. These terms were introduced to help hone in on this critical distinction: that is, installing and using temporary anchorages takes more training and experience than clipping in to an existing permanent anchorage.

**B. For purposes of this text, we will follow the OSHA and ANSI approach and terminology:**

1. Anchorage (or anchor point) is a single secure connection for an anchor.

a. An anchor point is used either alone or in combination with other anchor points to create an anchor system capable of sustaining the actual or potential load on a rope rescue system.

b. Anchor points take a number of forms, from structural beams to trees.

2. Anchor system is one or more anchor points rigged to provide a structurally significant connection point for rope rescue system components.

3. Anchorage connector is how rope rescue system components are secured to an anchor.

4. For clarity and precision, rope rescuers should use the full terms, such as anchor point or anchorage connector, instead of referring any type of anchorage system or component as just an “anchor.”

**C. The two final common anchorage terms indicate the type of anchor point**

1. Structural anchorages already exist in nature or in engineered structures (e.g., trees and rocks, around which anchorage connectors such as webbing or rope can be wrapped or tied).

a. Before using a tree as an anchorage, you should examine it for weakness, such as possible rot or a shallow root system. Even a tree with sound wood may not be a good anchorage if the root system is shallow or thin or if the tree is in wet soil.

b. Boulders weighing tons can be pulled over by stresses applied in the wrong direction.

c. In industrial and urban environments, structural anchorages may include building elements and supports.

2. Installed anchorages are anchor points that have to be created.

a. In industrial and urban environments, installed anchorages may consist of davit arms and D-rings.

**D. In the workplace, it is crucial that rope rescuers avoid making assumptions, especially about installed anchorages, as they may not always be what they appear to be.**

1. Most fall arrest anchor systems in industrial settings are rated to 5000 pounds (2267 kg), or to a strength that is at least twice the maximum anticipated load during a fall event. However, some workers using rope systems for access may operate with anchor system strengths as low as 2700 pounds (1225 kg).

2. Restraint anchor systems, which may look a lot like full-strength anchor systems but are intended only to prevent a worker from reaching an edge, may be rated to only 1000 pounds (453 kg).

III. Principles of Anchoring

**A. Anchorage strength**

1. Anchorages must be able to sustain the maximum anticipated load that is likely to be imparted on them, plus an appropriate safety factor.

2. Bombproof is a term used to describe anchor points deemed to be of a strength that far exceeds any force the rope rescue system could possibly deliver to them are said to be.

3. There is no magic number that is necessary for the rescuer to achieve in anchoring.

a. This is a judgment call that only a component person should make, but should be of a strength that is sufficient to withstand the maximum anticipated force times a relevant safety factor.

4. The ability of an anchorage to withstand the forces that may potentially be imparted upon it depends on a number of factors, including the following:

a. Condition of the anchorage – a live tree usually can withstand greater forces than a dead one.

b. Structural nature of the anchorage – a load-bearing structural column in a building generally can withstand greater forces than a handrail.

c. Location of force on the anchorage – a tree with the force pulling on it near the ground generally can withstand greater force than a tree on which the stress is located higher up.

**B. Direction of pull**

1. The specific direction in which a vector is applied; can greatly influence anchorage strength.

2. An anchor system that is strong in one direction may not be so strong in another.

a. Try to set anchor points that are in line with the direction of pull.

b. Consider the effects if the direction of pull changes – for example, as a result of variance in the fall line, or due to the difference between lowering and raising. With some anchor point placements, if the direction of pull changes, the anchor system could weaken or fail.

IV. Positioning of Anchorage Systems

**A. An anchor system that is in close proximity to and directly above the subject to be rescued will provide the most stability and will best facilitate edge transitions and loading of the subject.**

**B. In some circumstances, however, it may be preferable to have the anchor system off to the side, such as the following situations:**

1. Rocks or other dangerous objects may fall on the rescue subject or rescuers.

2. Conditions exist between the anchor point and the rescue subject that could endanger rescuers or damage rope or other equipment.

3. A flashover and fire erupt from a window.

4. A hostile or deranged person is in the area.

5. No suitable anchorages are available directly above.

**C. In some rescue systems, it may be preferable to have additional systems pre-set off to the side to provide adequate working space and to avoid entanglement (e.g., a separate haul system or a nonloaded belay line).**

**D. In any case, care should be taken to ensure that the angle between systems is not likely to create additional hazard by dragging debris over the edge, or by creating unnecessary swing-fall (or pendulum) potential.**

1. Anchoring techniques such as directional deviations or rebelays may be worth of consideration in situations such as these.

V. Redundancy

**A. Most rescue system anchorages are made of two subsystems: a working system for moving the load, and a backup system (or “belay”) to protect against potential failure.**

1. Each of these systems should be anchored independently from the other, although it is not uncommon to make a connection from the working system anchor to the backup anchor system, and vice-versa, just for added security.

**B. Anchor systems present a number of opportunities for failure, including the following:**

1. Uncertain strength of anchor points. Anchor point failure is one of the most common causes of anchor system failure.

2. Failures in human judgment and experience. A poor anchor may be chosen, knots may be tied incorrectly, or carabiner gates may be left unlocked.

3. Equipment failures. Abrasion and cutting of rope and webbing and stressing of both hardware and software can occur.

**C. Because of the potential for anchor system failure and because the rest of the rope rescue system depends on the anchor system, it is good practice to back them up.**

**D. Backing up is the implementation of redundant anchorages for safety. There are two primary methods of backing up an anchor system.**

1. Backing up to the same anchorage

a. Do this only if you are absolutely certain the one anchorage can sustain any forces to which it may be subjected by the rope rescue system (i.e., it is bombproof).

b. This type of backup is used when the possibility of failure exists in other portions of the anchor system (e.g., carabiners, knots, and slings).

2. Backing up to a separate anchorage

a. This requires a system that incorporates multiple anchorages.

b. If the direction of loading will be shifting from side to side, you should make the multiple anchorages load sharing.

**E. The specific method of backing up the anchor system and the number of anchor points you need depend on a number of variables, including the following:**

1. The condition of the anchor points

a. If the potential exists for failure of one of them or of the equipment attached to it, more than one anchor point is needed.

2. The nature of the rope rescue operation

a. If both a main line and a belay line are used, for example, you should use separate anchor systems for each.

b. If the main line and the belay line originate from the same anchorage, the danger exists of line tangles or heat-fusion damage to the rope if the ropes cross. The belay system would also have to be substantial enough to catch a fall, which means you would need a substantial second anchorage.

3. The loads and stresses involved in the system. These vary in intensity depending on the ways in which the anchorages are used, such as for the following:

a. Supporting only equipment

b. Supporting the weight of only one person

c. Creating directionals that create forces greater than the load (load amplifiers)

d. Potential shock loads resulting from a fall or a partial system failure

e. Rescue lowering operations

f. Hauling systems

g. Highlines (a system of using a rope suspended between two points to move people or equipment)

**F. Rescuers should monitor anchor systems continuously during an operation.**

1. The shifting of loads and other actions can cause anchorages to become less secure than when they were first rigged.

VI. Connecting to an Anchorage

**A. There is a difference between an anchorage and an anchorage connector.**

1. Anchorage – a potential anchorage only becomes viable if you can attach to it effectively (e.g., a stairwell beam).

2. Anchorage connectors – artificial devices specifically designed for creating temporary anchor points or protection in places where no natural anchors (e.g., a strap, a carabiner, or a special device such as portable beam clamps and removable bolts)

a. Many artificial anchorage connectors are inserted into rocks or spaces in rock. These types of hardware include bolts, nuts, chocks, and cams.

b. If such devices are to serve as safe, effective anchor points, they must be placed by a person skilled and practiced in their use.

VII. Single Point Anchorages

**A. Single point anchorage is an anchorage system that utilizes one anchorage to provide the primary support for the entire rope rescue system. This may be achieved in any number of ways:**

1. Making a direct connection between the rope and the anchorage

2. Using another piece of equipment (e.g., strap, clamp, or tripod) as an anchorage connector, and then connecting the rope to that

**B. Tensionless hitch**

1. A tensionless hitch may be a good choice in urgent situations, in which time is critical.

a. It also means a simpler anchor system can be utilized, which reduces the number of components that may fail in a more complicated system.

2. A tensionless hitch offers the following advantages as a termination around an anchor point:

a. It is simple.

b. It reduces stress on rope and equipment.

c. It can be adapted to changing conditions.

3. To create a tensionless anchor system, simply wrap the standing end of the rope around the anchorage several times so that the friction of the wrap takes the load.

a. The benefits of this technique include the following:

i. With enough friction, all the force is applied to the object around which the rope is wrapped.

ii. With each successive wrap the amount of tension in the successive strand becomes less and less.

iii. When the rope is anchored correctly in this manner, it is not weakened by a knot and therefore retains its full strength. This assumes that the size of the object is more than four times the diameter of the rope.

4. See Skill Drill 11-1: Tying a Tensionless Hitch

5. An alternative approach to securing a tensionless hitch is to simply use a hitch or knot to replace the figure 8 knot and carabiner.

a. In this case, the rescuer must tie off the end in a way that prevents the rope from unwinding around the object and without placing any bends in the loaded section of the rope.

**C. Knots**

1. A line simply wrapped around an anchorage and then terminated with a knot is often a good choice for creating an anchor point where there is low likelihood of needing to move or adjust the anchor system quickly.

2. If the rescuer is using a vertical member as an anchor point that is short enough for them to get a loop of rope over it easily, they can tie a figure 8 on a bight in the end of the rope and place the loop over the anchor.

a. Otherwise, a loop of rope may be tied around the structure with a knot such as a figure 8 retrace or a bowline.

3. The strength of the knot must be taken into consideration when analyzing the strength of the anchor system.

4. Care should be taken to keep the inside angles of the loop narrow enough to maintain the shape and structure of the knot and to ensure good management of forces.

5. A disadvantage of rigging the mainline rope directly to the anchorage is that it limits the ability to modify the anchor system, and modifications could become necessary because of the changing conditions that can occur in rescue situations.

a. A possible solution is to use a separate piece of rope or webbing for the anchor system that is as strong as or stronger than the main line and to attach the main line to it.

**D. Soft slings as anchorage connectors**

1. Webbing can be conveniently used as follows:

a. Material for connecting to an anchorage

b. Making continuous loops known as runners or slings

2. The advantages and disadvantages of using manufactured webbing loops instead of ropes include the following:

a. They are less expensive and there are fewer knots to learn.

b. Webbing cannot be tied into as many different knots as rope can, and it does not absorb shock loading as well as most ropes.

3. You can create a sling from a piece of webbing by tying it into a loop using a ring bend knot (also known as a water knot, overhand bend, or tape knot).

4. Presewn slings

a. Properly sewn slings are an easy alternative to tied slings offer several advantages:

i. They may be used as a quick, convenient means of connecting to an anchorage.

ii. They are quicker to use and there is less chance of tying the wrong knot when making a continuous loop.

iii. Several brands of presewn slings that can be used for anchoring are available.

b. Presewn slings are available in a variety of webbing widths and lengths.

c. When buying presewn slings, ensure the following:

i. They have adequate tensile strength for the safety factors you are likely to need.

ii. The manufacturer of the presewn slings tests them for strength. Anchor slings can have strength ratings based on being pulled end to end, pulled when rigged using a basket technique (wrapped around the anchorage), or pulled when girth hitched around an object.

d. Presewn webbing must always be inspected for wear on the stitching and the web material before and after you use presewn webbing.

5. Anchor straps are webbing lengths with hard rings sewn into each end where a carabiner can be clipped.

a. These straps can be a quick way of setting reliable anchor points; advantages include the following:

i. Anchor straps are available with different strength ratings, as outlined in NFPA 2500 (1983).

ii. The heavy-duty ones (with the NFPA G designation) typically have an end-to-end breaking strength of about 8000 pounds (35.6 kN).

iii. The lighter-weight versions (NFPA rated T) typically have an end-to-end breaking strength of about 4945 pounds (22 kN).

b. Strap breaking strengths may be higher when the straps are rigged to form a basket, but this is not necessarily always the case.

i. The internal angle formed by the sling will greatly influence its capacity.

ii. When rigged with extreme angles, the basket configuration could result in strengths even lower than the end-to-end rated strength.

c. Anchor straps rigged in a choker configuration will always have a lower capacity than end-to-end, especially when the choke angle is extreme.

d. NFPA differentiates between end-to-end straps and multiple-configuration straps, with only the multiple-configuration straps being required to report strength ratings for basket and girth hitch configurations.

e. Some anchor straps have a heavy-duty buckle so that the strap can be adjusted to various lengths. The buckle may slip with a force less than the strap’s overall breaking strength.

f. Some of these straps can also be used for such purposes as litter bridles or as a quick anchorage connector for an edge attendant.

g. As with other presewn slings, make sure the anchor straps you use have the following:

i. Adequate tensile strength for the system safety factor

ii. Specifications from the manufacturer on how much loading causes the adjustable buckle to slip

h. The problem is that a simple loop of webbing around a vertical anchorage tends to slip down on the anchorage.

i. There are several techniques for holding webbing in place on a vertical anchor point:

(i) Basket hitch (previously discussed)

(ii) Girth hitch

(iii) The wrap 3, pull 2 (W3P2) system

j. Girth hitch is a technique in which the webbing is tied around the anchor point in a girth hitch.

i. The drawback to this technique is the temptation to cinch the webbing back on itself.

ii. This should not be done because it puts potentially dangerous stress on the webbing.

k. Wrap 3, pull 2 (W3P2) system – in this system, there are three wraps around the anchorage with two loops pulled out; this is a stronger alternative to the firth hitch.

i. One advantage of the W3P2 over a girth hitch is that it tends to stay in place better once snugged up and not slip down the vertical anchorage like a girth hitch often does.

ii. Note that for maximum strength, the webbing knot is on the interior loop, where it will incur the least stress.

iii. Specific rigging methods—including internal angle of the anchorage connector material as it protrudes from the anchorage, and how layers of the anchorage connector material interact with one another—will have a strong influence on overall performance.

l. A secure method of placing webbing around an anchorage is to tie it in a loop around the point using a ring bend knot.

i. However, if the object used as the anchorage is very large, this procedure can be awkward and time-consuming for one person.

ii. An alternative method is first to tie the runner into a loop, then wrap it around the anchorage, and then clip the two ends together with a carabiner. Such tied runners, however, require double the length of an untied length of webbing.

m. If you use tied webbing for slings, do not leave knots tied in the webbing unless each runner is carefully inspected before the webbing is returned to the equipment cache and then inspected again before the next use. Be aware of the following:

i. You may not know who tied the knot and what kind of knot it is.

ii. Knots in webbing often work their way out.

iii. The knots may have been spot welded in webbing that has been shock loaded.

VIII. Portable Anchorages

**A.** Portable anchorages are prefabricated anchorages that can be moved from place to place and may serve as an actual anchor point, or as a directional aid to help route a rope for more optimum rigging.

1. Tripod

a. May be used to create a standalone anchor system over a space such as a maintenance hole cover, or it may be used as an artificial high directional to assist with load management

b. Monopods, bipods, and quadpods are variations on the tripod; these, too, are often used in rope rescue systems.

2. Beam clamp

a. Can be quickly attached to overhead structures such as steel beams

b. Some meet the anchor system requirements for one-person loads set by the ANSI, the Canadian Standards Association (CSA), and the U.S. Occupational Safety and Health Administration (OSHA): 5400 lbf (24 kN).

c. For large or heavy loads, two or more beam clamps may be used together as multi-point anchorages as needed to ensure appropriate system safety factors.

3. Removable bolts

a. This type of portable anchorage that is useful in certain situations.

b. Holes of adequate depth and diameter must be predrilled.

i. When placing removable bolts, take care to ensure that the version you are using is the correct size and strength for the application in which you are using it, and that the interface is sufficient to ensure adequate holding power.

4. Picket system

a. An alternative in a natural area where there is a shortage of natural anchorages.

i. Different types of pickets are available for soil versus snow.

ii. A picket system can work very well when correctly rigged, but establishing it properly requires proper training, and setting a system up can take a great deal of time for an inexperienced user.

iii. Not all soil or snow types can hold pickets securely. Loose, sandy, or muddy soil, or snow, may not hold well regardless of the number of pickets used.

iv. Most picket anchorage systems consist of several rows of pickets.

IX. Rigging Plates

**A. Rigging plates can be used as follows:**

1. As a part of an anchor system to help organize rigging

2. To help spread out the various components so that they are easier to see and manage, and to prevent multiple components from jamming together

3. To draw multiple anchor points together to a single point

4. To disperse multiple lines from a single anchor point

**B. Rigging plates also can be used for other purposes:**

1. To collect the several lines involved in a mechanical advantage system

2. As the master attachment point in a litter spider for vertical systems

**C. Because the very purpose of rigging plates is to collect multiple points, special care must be taken when using these to ensure that the anchorage and anchor system are not being overloaded.**

1. Look for rigging plates that are strong (NFPA rated G) and that have contoured edges that are less likely to damage rope and carabiners.

2. The holes should be large enough to accept large locking carabiners easily.

X. Multi-point Anchor Systems

**A. There are circumstances where the location of a single anchor point is not suitable for the task:**

1. Where the strength of a single anchor point may not be sufficient to provide desired levels of safety

2. Where the anchorage is not in line with the intended direction of travel

**B. A multi-point anchor system a system in which multiple anchor points are collected together to form a single connection point; can remedy circumstances in which a single anchor point is not feasible.**

1. When the load is applied at the point of collection, the force is distributed and shared by the all the anchor points.

2. How these forces are divided among the anchorages will depend on the method of connection and the relative angle between the various points.

**C. Anticipating—and mitigating—the probability and consequences of a potential failure is a necessary part of the rigging even though the goal is to build a robust multi-point anchor system.**

1. Multi-point anchor systems work best when anchorages are positioned somewhat adjacent to one another and not too far apart.

2. Properly positioned anchorages lend to well-placed anchor points, which help to reduce probability of failure.

**D. When arranged such that the load-connection point is fixed and focused (i.e., it does not/cannot move under load), the force on individual anchor points may vary as the direction of pull changes. This type of anchor system is sometimes called a load-sharing anchor system.**

1. When using a fixed and focused multi-point anchor system, care must be taken to keep the forces distributed as evenly as possible across the different anchor points.

2. Alternatively, the legs of a multi-point anchor system can be rigged to float, so that the load-connection point is self-adjusting as the direction of pull changes.

**E. Regardless of which type of multi-point system is used, it is determined to be one anchorage.**

1. Multiple anchor points rigged into one fixed and focused anchorage system equals one anchorage, just as multiple anchor points rigged into one self-adjusting anchorage system equals one anchorage.

**F. The simplest way to create a load-sharing anchor system is to use two anchor ropes or slings, and run one from each of the two anchor points, clipping them together into a single point using one or two large locking carabiners.**

1. The place at which you clip the two lines together with the carabiners is known as a focal point.

2. A similar effect may be created by placing a single sling between the two anchor points and tying a knot between the two where you wish to fix the focal point.

a. Using this method, the location of the knotted connecting point can be adjusted to accommodate a variety of fall-lines.

**G. See Skill Drill 11-2: Fixed and Focused Multi-Point Anchor system**

**H. When rigging a multi-point anchor system, care must be taken not to create too wide an angle between the anchor points.**

1. Ideally, this angle should not exceed 90 degrees, because beyond this angle the forces on each anchor point begin to multiply drastically.

2. Beyond 120 degrees, the forces on each anchorage would actually begin to exceed that of the supported load.

**I. The best application of a fixed and focused multi-point anchor system is where the direction from which the load is applied does not change significantly during use.**

1. When force from the load pulls directly on the center of the angle, the stress is applied relatively equally to the different anchor points.

2. In a fixed and focused system where the direction of pull changes during the course of the operation, the entire rescue load could be supported by just one of the anchor points in the system. Presuming that the multi-point anchor system was created for a reason, this would seem to be an undesirable outcome and should be avoided.

**J. Equitable distribution**

1. More equitable distribution of the load in a multi-point anchor system can be achieved by arranging it as a self-adjusting anchor (or load distributing anchor system).

2. This type of multi-point system involves two anchor points and uses a sling to form the letter X and a carabiner to lock it in place.

a. Clipping the carabiner across the X in the line helps to ensure that should one anchor point fail, the webbing will reset itself to pull on the other anchor point.

3. Even with this built-in redundancy, if there is any significant distance between the two anchor points, the failure of one could impose a significant shock load on the other.

4. Self-adjusting anchor systems should only be considered when the probability and/or the consequence of associated risks can be mitigated.

5. See Skill Drill 11-17: Fixed and Focused Anchor System

**K. Redundancy**

1. Redundancy can be a good thing, but when redundancy begins to diminish efficiency, it can actually compromise safety.

2. There are a few ways to mitigate potential shock load:

a. Create a protected self-adjusting anchor system with built-in redundancy.

i. Redundancy simply describes the concept of incorporating parts that protect against failure of other components.

ii. A rescue system is truly redundant when the failure of any one point will not result in the failure of the entire system.

b. Reduce potential fall distance by extending the anchor points.

i. See Skill Drill 11-4: Protected Self-Adjusting Anchor System

3. Reduce the potential impact force in the event of a failure is to reduce the length of the adjusting component in the multi-point anchor system.

a. This can be achieved simply by using a sling to extend each anchor point to a smaller self-adjusting focal point. In this case, a small sling made of slick material such as HMPE provides a smooth self-adjusting function.

b. Using a cordelette or nylon sling to extend the anchor points will also help to mitigate the low elongation of HMPE.

c. This type of system, when correctly constructed and when conditions are right, can have some important advantages:

i. The forces on anchor points should remain distributed and shared by all anchor points (albeit not equally), whatever the direction of pull.

ii. If any anchor point fails, the system should readjust to help redistribute loading on the remaining anchor point or points – albeit not equally, but without imparting excessive impact forces.

**L. Self-adjusting anchor systems**

1. These systems are sometimes called self-equalizing anchor systems. However, it is important to note that no anchor system can be made completely “self-equalizing” because of the following:

a. With the angles involved in rigging any self-adjusting anchor system, the elements of the system are subject to varying forces, and the system therefore can never be completely equalized.

b. In a shock-loading situation, redistribution of forces does not occur instantaneously. During this transition to redistribution, some elements of the self-adjusting anchor system receive greater loads than others.

2. Hazards have been associated with misuse of self-adjusting anchor systems, but they should not be completely discounted, as they are a useful option when implemented by appropriately trained and skilled rope rescuers.

3. The following guidelines can help ensure the best distribution of forces and adaptation to shock loading with failure of an anchor point:

a. Keep the angles small, both to reduce magnification of forces on anchors and to help the system readjust to the new loading.

b. Design the systems so that as little drop as possible would occur should any anchor point fail. One way to do this is to keep anchor point leg as short as possible.

c. Choose less bulky rope or webbing for the self-adjusting mechanism, and adjust the system so that knots are less likely to run through carabiners when the system readjusts.

d. Use Kevlar or Spectra in an anchor system only if you include shock-absorbing materials somewhere in the overall rescue system to help reduce impact force in the event of uncontrolled loading; rope and webbing made of materials such as Kevlar and Spectra do not have the shock-absorbing qualities of materials such as nylon.

e. Make all the anchor points in a self-adjusting system as bombproof as possible, given the constraints of time and efficiency.

f. Self-adjusting anchor systems have the potential for dangerous shock loading as one anchor point pulls out and others take the load. Reduce potential shock loading by keeping angles small and slack to a minimum. Also:

i. Try to keep anchor points close to each other. If this is not possible, it may be better to extend faraway anchor points with static rope to keep the load-sharing anchor system’s loop as small as possible.

ii. Keep the outside angle to less than 90 degrees.

1. Even better, limit the angle to 60 degrees.

2. This limits the forces on the remaining anchor points if one of the inside anchors fails in a self-adjusting anchor system with three or more points.

3. The outside angle is measured from the two outermost anchor points down to the focal point.

iii. Rig self-adjusting anchor systems with a minimum of slack in the system.

1. Keep rope or webbing length to a minimum (approximately 8 feet [2.4 m] or less) in the tied loop of a three-point system.

2. Rig for a maximum 1-foot (0.3-m) drop with the failure of an anchor point.

**M. Multi-point anchor systems, whether fixed or self-adjusting, are not for casual use in rescue.**

1. While the probability of overloading a single point may be higher in a fixed and focused multi-point anchor system, the consequences of doing so may be higher in a self-adjusting anchor system.

2. Construction and use of these systems requires a knowledge of how the orientation of the anchorages and their method of connection affect the ability to support the intended load.

3. Failure to recognize how these forces are distributed in a multi-point anchor system can lead to overloading of the system or one of its elements, possibly resulting in catastrophic failure.

4. These systems should be used with caution and only when the benefits outweigh the risks.

XI. Directionals

**A.** Directional is a technique for bringing a rope into a more favorable position or angle; also known as a deviation.

1. A directional can be created in many ways, and each method must be judged on its advantages and disadvantages specific to a given situation.

**B. When rigging anchorages, it is important to always be aware of the need for protecting rigging materials, such as rope and webbing, from damage from sharp edges.**

1. Loaded rope and webbing can easily fail when damaged by unprotected edges.

**C. Location of directionals**

1. When you establish anchorages for primary systems and directionals, you must keep in mind how safe and accessible they are for the rope rescuers who work with them.

XII. Back-Tie

A.It is good practice to back up single anchors with a second anchor.

1. Backing up is essential when you have an anchor that is in the right position but not strong enough alone for a rescue load.

2. The anchor point on the right is near the edge and in a good position, but it does not have the strength to take the load.

a. You may consider this a primary anchor; behind the primary anchor and directly in line with it is a second anchor.

b. The strength of this secondary anchor, combined with that of the primary anchor, will be enough to sustain the rescue load.

c. To combine the two anchors, a rope or sling is run between them; this connector is known as a back-tie. Two things must be kept in mind when using a secondary anchorage:

i. The back-tie anchorage must be as strong as or stronger than the primary anchorage.

ii. The back-tie must have no slack that would allow shock loading, which could cause both anchorages to fail.

B. **Pretensioned back-ties**

1. Inherent slack is sometimes caused in anchor systems by rope or webbing stretch and by flexing of anchor points.

a. If an untensioned anchor system receives shock loading, elements could fail.

b. One way to reduce the chance of shock loading is to pretension the system with a pretensioned back-tie, which is a method of removing slack in a back-tied anchor system before it is loaded.

2. One technique for creating a pretensioned back-tie is to connect the back-tie to the anchorage with a simple mechanical advantage system.

XIII. Structural Anchorages

**A. A rope rescue must be adept at finding and analyzing structural anchorages in any and all environments in which they are likely to work, as these are what rescuers use most often.**

**B. Experience and training are necessary to have when analyzing structural anchorages for rescue, because rescue often occurs in places where preplanned anchorages do not necessarily exist.**

**C. The most common structural anchorages in natural environments are boulders and large trees.**

1. However, these types of anchorages are less prevalent in urban environments, especially on buildings.

**D. When you rig anchor systems on buildings, choose anchorages that are inherently part of the building’s structure or specifically constructed to support high loads. Some examples of anchorages in urban environments most likely to be acceptable would be the following:**

1. Structural columns

2. Projections of structural beams

3. Supports for large machinery

4. Stairwell support beams

5. Brickwork with large bulk (e.g., corner walls)

6. Anchorages for window-cleaning equipment

**E. Some examples of structures that may be deteriorated and inappropriate for use as an anchorage are as follows:**

1. Corroded metals

2. Weathered stonework

3. Deteriorated mortar in brickwork

4. Vents constructed of sheet metal

5. Gutters and downspouts

6. Brickwork without bulk (e.g., small chimneys)

7. Fire hydrants/standpipes

**F. Less-obvious anchorages**

1. Some manmade structures and buildings at first may appear to have no anchorages. However, after some practice in working this type of problem, riggers may find some unexpected but good anchorages.

a. Elevator and machine housings

i. Elevator and machine housings often are larger and more substantial than what is expected for an anchorage.

ii. By taking a length of rope, running it around the housing several times, and tying the ends together with a figure 8 bend, a rescuer may be able to create a secure anchor point for several lines.

b. Scuppers (roof drain holes)

i. Many buildings have low parapets with drain holes set in them at roof level.

ii. An anchor point can be created by running rope or webbing through the drain hole and back over the top of the parapet.

iii. If possible, the rescuer should use the scupper on the side of the building opposite the one over which you will run the main line. This allows space on top of the building for rappellers to rig into the rope and to set other rigging, such as lowering and raising systems.

iv. The more substantial parapets are those constructed of reinforced concrete. If the parapet is constructed of brick or block, riggers should strongly consider other options. If this truly is deemed the best option, riggers should least make sure that several brick or block courses are involved and that the mortar is in good condition.

v. Even under the best of conditions for a brick or block parapet, it would be wise to rig with at least two anchor points. All sharp edges must be padded.

c. Wall sections between windows and/or doors

i. Windows and/or doors can be used to create a substantial anchor point if they are close enough together.

ii. Pass the anchor rope or webbing through an open window or door, around the intervening wall, and back through an adjacent window or door to tie off the rope or webbing.

iii. The anchorage wall should be on the side opposite where the main line will run out of the building. This provides more safe space for rappellers to rig into the rope or to set rigging, such as lowering and raising systems.

d. Stairwell beams

i. When anchoring to stairwell beams, it is important to make sure they are the structural members; these are the open steel beams to which the stair risers are secured.

e. Installed anchorages

i. Installed anchorages are placed expressly for the purpose of forming an anchor for a safety or rescue system, either permanently or temporarily.

ii. Placing bolts takes time, require a great deal of practice and training are required to learn to set them correctly, and do permanent damage to the material or location in which they are installed.

iii. Preplanned permanent anchorages such as bolts (or predrilled holes for removable bolts) should be installed in locations where work at height or rescue is frequent.

iv. Many newer tall buildings are likely have permanently installed anchor points on the roof for window-cleaning equipment. Documentation will note if the installed anchorage was professionally installed and certified by an engineer.

v. Industrial sites often will have pre-engineered fall protection anchorages over the entrances to confined spaces such as tanks and vaults.

vi. Window-cleaner eyebolts must not be confused with guy wire hooks. Window-cleaner eyebolts are substantial (usually 3/4-in. [19.1-mm]), closed eyebolts in structural concrete. Guy wire hooks are used to stabilize items such as signs and antennae; they are not designed for life support.

vii. Many window-cleaner eyebolts are designed to be pulled vertically with cantilevered rigging; these may fail if pulled sideways. Always back up window-cleaner eyebolts with other anchorages.

XIV. Adapting to a Lack of Anchors

**A. Extending anchor points**

1. When anchorages are not found nearby, you may be able to establish them by running lengths of rope, sometimes for a few hundred feet, to suitable objects. This should be done only with static rope.

a. Polyester core static ropes typically have even less stretch than nylon static ropes of similar construction, making them a good choice in this application of extending long anchor ropes.

b. Attempting to extend anchor points in such a manner with dynamic rope could create a dangerous situation because of the large amount of stretch.

c. Even with static rope, undesirable stretch may occur if only one line is used. Depending on the load, the lines can be doubled, tripled, or quadrupled to reduce the stretch.

2. An example of a situation in which extended anchor points may work would be the roof of a building where (absolutely, positively) no anchorages exist. Often, static rope can be run through a stairwell or the top-floor windows to lower floors where anchorages exist.

**B. Using vehicles for anchorages**

1. An emergency vehicle can be used as a portable anchorage.

a. As these are not generally specifically designed to serve as anchorages, and performance can vary so widely based on conditions, these should be considered and used only under the direction of a competent person.

b. The following safety guidelines should be observed when using a vehicle for an anchorage:

i. Park the vehicle on a solid surface. High load forces can drag a vehicle across loose material, such as sand or gravel.

ii. Set the parking brakes.

iii. If the vehicle has an automatic transmission, set it in Park. If it has a manual transmission, set it in a gear in opposition to the pull (e.g., Reverse if the pull is from the front).

iv. Chock the wheels. Forces created in a high-angle system can move a vehicle with its brakes set. If no chocks are available, use spare tires.

v. “Error-proof” your portable anchorage by removing the ignition key and perhaps even applying caution tape to the steering wheel or driver-side door.

vi. Avoid contact between the rope and hot exhaust, sharp edges, and substances which may cause damage.

2. Potential anchor points in a vehicle include structural parts, such as axles and cross members

a. It is important to protect rope and webbing from oil and grease.

b. Rope and webbing also must be protected from destructive substances such as battery acids.

3. Some parts of a vehicle such as tow eyes and bumpers may appear to be both convenient and substantial but may not make suitable anchorages because they are not actually connected to a structural element of the vehicle or may be weakened by damage.

4. Always perform an inspection of the connections and condition of the anchorage connections on vehicles to ensure that they are adequately connected to the vehicle and in good repair.

XV. Placement of Anchor Systems

**A. Regardless of the type of anchorage or anchor system, placement of secure anchors depends very much on good judgment, which is developed through experience and practice.**

**B. Although their specifics may vary from place to place, all anchor systems share certain characteristics:**

1. Aside from the physical aspects of the anchorage itself, it is important also to consider how safe and accessible they are for the rope rescue who work with them.

2. It generally is good practice to set an anchorage connector as close as possible to an intersecting structural connection point to minimize the torque and leverage applied by the rope system.

a. For vertical elements such as posts and trees, this is typically closer to the base.

b. More robust components can be used as an anchor mid span or higher up on a vertical element when the position better suits the needs of the operation, such as:

i. Creating a better angle for an edge transition

ii. Reducing abrasion on an edge

iii. Managing a loaded litter

iv. Reducing friction on mechanical advantage systems

XVI. Evaluating an Anchor System

**A. Before any anchor system is subjected to a live load, a safety check should be made to ensure the following:**

1. The anchor system components are physically checked to ensure that they are correctly oriented, knots are properly tied, and all mechanical components such as carabiners and links are closed and locked.

2. The overall strength of each individual anchorage is sufficient to support its intended load and offers an adequate margin of safety.

3. The configuration and alignment of the anchor system is checked by applying a nominal force in the direction of the intended load and observing the angle and tension on the individual elements to ensure they react as intended.

4. The anchorage and anchorage connector(s) are in good condition.

I. Summary

 **Utilizing standardized terminology is key in maintaining safety during a rope rescue. Because the terminology of anchor systems evolved differently in different industries, ensuring that all team members utilize a common terminology is essential.**

 **Anchorages must be able to sustain the maximum anticipated load that is likely to be imparted on them, plus an appropriate safety factor.**

 **The ability of an anchorage to withstand the forces that may potentially be imparted upon it depends on a number of factors, including the condition of the anchorage, the structural nature of the anchorage, and the location of force on the anchorage.**

 **An anchor system that is in close proximity to and directly above the load will provide best stability and usability.**

 **Because of the potential for anchor system failure and because the rest of the rope rescue system depends on the anchor system, it is good practice to back them up. Anchor systems may be backed up by backing up to the same anchorage or backing up to a separate anchorage.**

 **An anchorage is what a system connects to and an anchorage connector is how a system connects to an anchorage.**

 **A single-point anchorage is a type of anchorage system that utilizes one anchorage to provide the primary support for the entire rope rescue system. This may be achieved in any number of ways, including a tensionless hitch, knots, soft slings, presewn slings, and anchor straps.**

 **Portable anchorages are prefabricated anchorages that can be moved from place to place. They may serve as an actual anchor point, or as a directional aid to help route a rope for more optimum rigging. They include beam clamps and picket systems.**

 **Rigging plates may be used as a part of an anchor system to help organize rigging. They can help spread out the various components so that they are easier to see and manage, and to prevent multiple components from jamming together.**

 **Rigging plates are commonly used to draw multiple anchor points together to a single point, or to disperse multiple lines from a single anchor point.**

 **Multi-point anchor systems collect multiple anchor points together to form a single connection point so that force is distributed and shared by the all the anchor points. Multi-point anchor systems may be fixed and focused or self-adjusting.**

 **A directional anchorage may be placed midline to change the direction of travel of the load.**

 **Backing up is essential when you have an anchor that is in the right position but not strong enough alone for a rescue load. This may be achieved with pretensioned back-ties.**

 **Structural anchorages are both natural (boulders) and human-made (structural columns).**

 **If no anchors are available, extended anchor points or vehicles may be used.**

 **Before any anchor system is subjected to a live load, a safety check should be made.**

Post-lecture

I. After-Action Review

Individual/Small-Group Activity/Discussion

On Scene

This activity is designed to help the student understanding how to approach a fire investigation. This activity incorporates both critical thinking and the application of basic trench rescue knowledge.

Purpose

To allow students an opportunity to develop responses to critical thinking questions.

Instructor Directions

1. Direct students to read the “On Scene” questions located in the After-Action Review section at the end of Chapter 1 (p. 218).

2. Direct students to read and individually answer the discussion questions. Allow approximately 10 minutes for this part of the activity. Facilitate a class review and discussion of the answers, allowing students to correct responses as needed.

3. You may also assign these as individual activities and ask students to turn in their comments on a separate piece of paper.

Answers

1. How might misuse of anchor terminology lend to confusion or even hazards in rigging systems?

Without common terminology, a rescuer could misinterpret instructions given for rigging, or even the application of an anchor point as a complete anchorage system, or vice-versa, which could in turn result in an insufficient or inappropriate anchorage being used for a rescue.

**2.** What factors should be considered when choosing to rig a single-point anchor system as compared with a multi-point anchor system?

Whether the location of a single anchor point is suitable for the task at hand, including strength, safety factors, and direction of pull.

**3.** When might a fixed and focused multi-point anchor system be preferred over a self-adjusting anchor system, and vice-versa?

Fixed and Focused preferred: Where the direction of pull will not change much during use, so that the forces are sure to remain distributed relatively evenly across the different anchor points.

Self-Adjusting preferred: Where the direction of pull is likely to change during an evacuation (due to slope variation or other factors) and where the length of the adjusting mechanism can be kept small to reduce potential force in the event of failure of one anchor point.

**4.** What purpose might a direction change anchor system serve in a lowering system?

It could be used to align the rope into a more favorable position or angle relative to the slope, anchor system, and/or desired direction of travel.

**5.** How does redundancy play into anchor rigging?

Anchor systems should be built such that the rescue system as a whole enjoys a level of redundancy such that the failure of any one point in the anchorage(s) will not result in catastrophic failure.

**6.** What considerations are involved with inspecting an anchor system for use?

The anchorage and connectors should be in good condition with components correctly oriented and secured, knots properly tied, and rigged correctly so that the configuration and alignment of the system is appropriate the strength adequate for the load to be applied.

II. Lesson Review

Discussion

Note: Facilitate the review of this lesson’s major topics using the review questions as direct questions or slides. Answers are found throughout this lesson plan.

1. What is the difference between natural and artificial anchor systems? (Lecture II A)

2. Define *bombproof*. (Lecture III A)

3. What arrangement will provide the most stability to an anchor system? (Lecture IV A)

4. Describe two methods for backing up an anchor system. (Lecture V D)

5. Describe the difference between anchorage and anchorage connectors. (Lecture VI A)

6. Describe the circumstances under which a tensionless hitch might be necessary. (Lecture VII B)

7. Identify four examples of portable anchors. (Lecture VIII A)

8. What is the purpose of rigging plates? (Lecture IX C)

9. What is the easiest way to create a load-sharing anchor system? (Lecture X F)

10. Identify examples of anchorage that might be found in urban environments. (XIII D)

III. Assignments

Lecture

A. Advise students to review materials for a quiz (determine the date/time).

B. Direct students to read the next chapter in *Rope Rescue: Principles and Practice,* Fifth Edition, as listed in your syllabus (or reading assignment sheet) to prepare for the next class session.