SHORING & STABILIZATION

Introduction

Rescue personnel within the fire service are accustomed to using shoring on a regular basis. The broad definition for shoring is the temporary support of structures during construction, demolition, reconstruction, etc. in order to provide stability that will protect property as well as workers and the public.

In the fire service the definition would also include:

- temporary support of structures, vehicles and objects during emergency incidents and training
- to provide stability
- to remove the suspension qualities of a vehicle
- to bring an object to a solid state
- to minimize the hazards associated with movement of objects
- to protect rescuers, victims and property

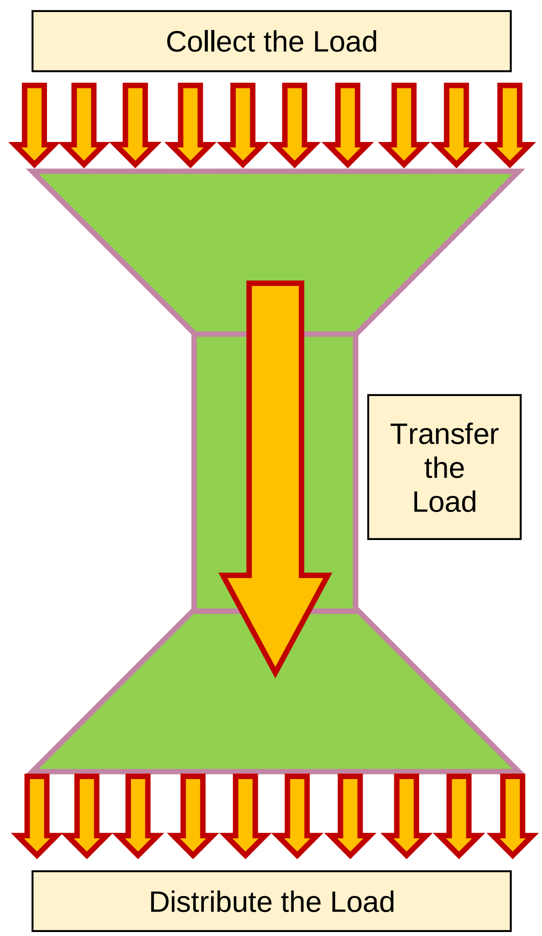
Basic Principals

The basic principal behind the use of shoring can be compared to a double funnel:

1. The top of the funnel collects the load from the object that is being supported.
2. The middle of the funnel transfers the load to the bottom of the funnel.
3. The bottom of the funnel distributes the load across the ground or other supporting structure.

If the double funnel approach is not used and a large load is placed completely on the center of the "funnel," the center item can punch through the load it is trying to support.

Viewed in relation to the fire service, wood cribbing and pneumatic struts use the double funnel approach to shoring.

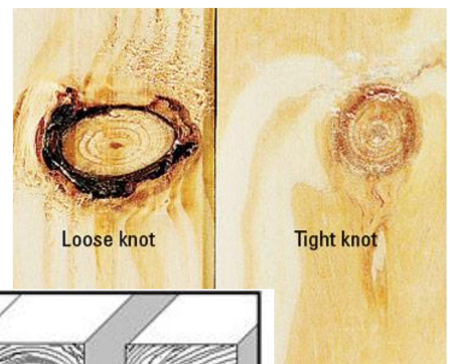


Wood Construction & Capacities

Features

One of the most desirable features of emergency shoring is that it provides the rescuer warning signs when it is becoming overloaded. These warnings will allow the rescuer to mitigate the situation, be that installing additional shoring material or the evacuation of the area.

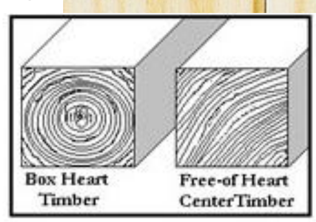
Wood inherently has a warning signal built in (or "grown in"). When wood shoring material starts being overloaded, it will begin to crush as well as produce the audible warning of groaning. Wood cribbing can crush up to 20% of its height before failing.



Strength

The strength of a specific piece of wood depends on several factors including the species of wood, the moisture content, the length and the thickness. When evaluating species of wood for use as cribbing one should look for:

- A minimum of 8 growth rings per inch
- A tight knot no more than 1 ½" in diameter
- A loose knot no more than ¾" in diameter
- No box heart timber

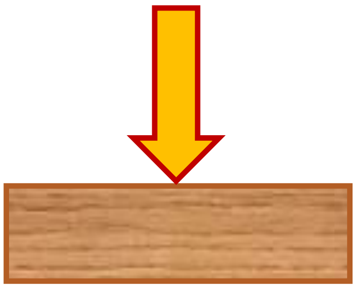


Based on their core material properties, soft woods such as Douglas Fir and Southern Pine are the most common types of lumber used for emergency shoring/cribbing. The table below compares the characteristics of Douglas Fir and Oak.

Douglas Fir	Oak
• Relatively lightweight • Inexpensive • Douglas Fir is the most common type of lumber in the U.S. • Gives warning of overload. • Disposable. • Good for unknown loads	• Twice as heavy as Douglas Fir • Expensive • Splinters and warps • Oak family varies • May have catastrophic failure • 1.5x stronger than Douglas Fir • Good for known loads

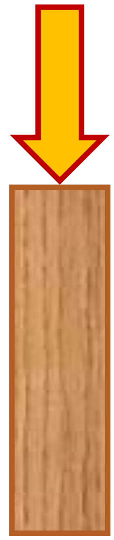
Strength (continued)

The strength of a piece of wood is dependent upon the direction of loading – either parallel or perpendicular to the grain. For Douglas Fir or Southern Pine, the allowable bearing stress parallel to the grain (longitudinal grain) is around 650 psi. For the same species of wood, the allowable bearing stress perpendicular to the grain (cross grain) ranges from 300 psi to 700 psi. (The average of 500 psi is used for load calculations).



Loading perpendicular to the grain

Allowable bearing stress of 500 psi



Loading parallel to the grain

Allowable bearing stress of 650 psi

The manner in which a piece of wood will fail under load is also dependent upon the direction of loading. While bearing stress may be higher parallel to the grain, the failure mode is undesirable in this configuration. Longer wooden posts overloaded along the longitudinal grain can buckle and fail suddenly. Conversely, when the wood is overloaded on the cross grain, crushing is observed both visually and audibly. This provides the early warning that is desirable in the emergency shoring environment.

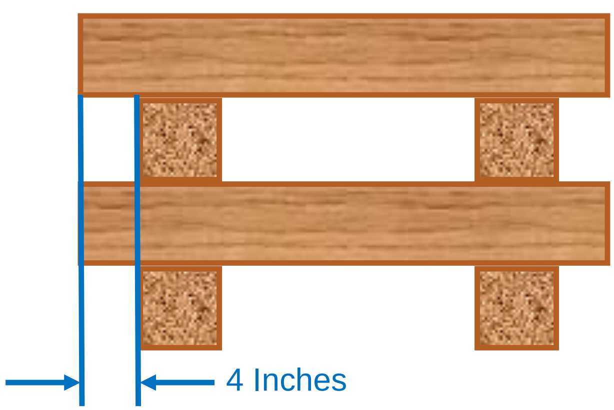
Cribbing

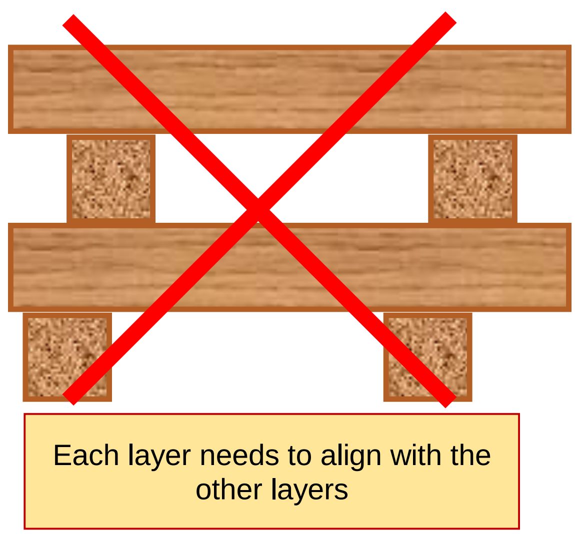
The fire service rescue squad cannot carry large quantities of 10” x 10” shoring material. To obtain the necessary height that is often needed, multiple pieces of smaller wood can be stacked upon each other to create a “pile” of wood. Of course simply placing the wood together in a pile does not create a stable foundation to support the load. To achieve the goal of creating a taller shore from small pieces we must create a box crib.

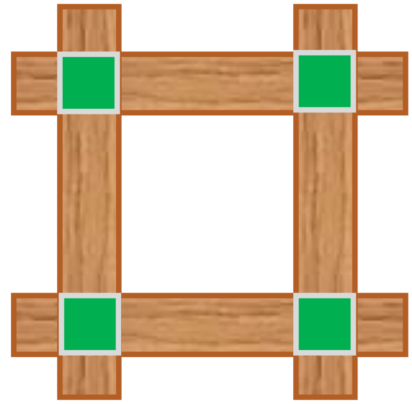
The box crib will resemble “Lincoln Logs,” the children’s tool erector set. Stacking two layers of cribbing perpendicular to one another starts to create the “box.” Adding additional layers following the same crisscross pattern will allow the box to grow.

The stability of the box crib will depend on the dimensional size of the wood used to create the crib. The maximum height to width ratio is **3 to 1**. The “width” is referring to the width of the box crib itself, not the length of the lumber used to construct it. This will be discussed in more detail later. The height limitations on box cribs are due to lateral stability. Testing done by the U.S. Army Corps of Engineers (USACE) has shown that stability is an issue in tall box cribs. Knowing this, the height to width ratio should be reduced to 2:1 when working with free, laterally unstable objects. Based on this testing, it is recommended to limit the height of box cribs using 4x4 lumber to 4 feet and cribs using 6x6 lumber to 6 feet.

The building of the box must be methodical so as to build a symmetrical box. When placing one piece of wood on top of another, the corners should be overlapped by a minimum of 4” to guard against splitting of corners of individual pieces and compromising the stability of the box.

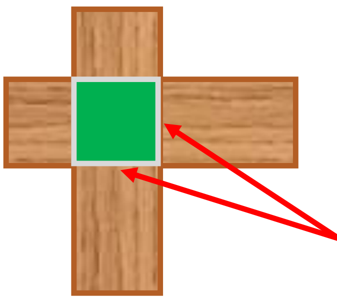






The point on a box crib where two pieces of cribbing overlap is referred to as a “Point of Contact”. These points of contact are what support and carry the load. This load carrying capacity is based on two things: the surface area of the point of contact and the bearing stress of the wood used.

The surface area is calculated by multiplying the length of the point of contact by the width. Dimensional lumber has two sizes: nominal and actual. Historically, the nominal dimensions were based on green, unfinished boards. After the wood was dried and planed, the finished, or actual, dimensions were smaller. Modern lumber is still referred to by nominal dimensions (e.g. 2x4, 4x4, 4x6, 6x6) but actual dimensions are smaller. So, a 4x4 piece of lumber purchased at a hardware store is actually closer to $3^{1}/_{2}$” x $3^{1}/_{2}$” and a 6x6 is approximately $5^{1}/_{2}$” x $5^{1}/_{2}$”.



Surface Area of a Point of Contact

4x4 = $3^{1}/_{2}$” x $3^{1}/_{2}$” = 12.25 in^2

6x6 = $5^{1}/_{2}$” x $5^{1}/_{2}$” = 30.25 in^2

As mentioned previously, the allowable bearing stress perpendicular to the grain for Douglas Fir and Southern Pine is 500 psi. So the calculations for capacity are as follows:

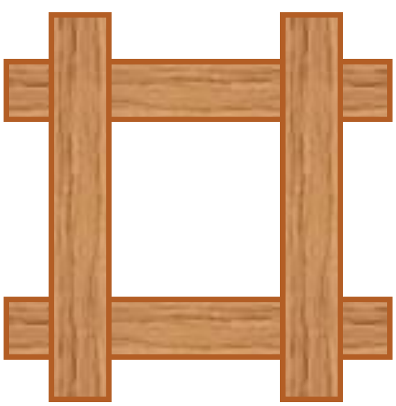
Load Carrying Capacity of a Point of Contact

Capacity = Surface Area x Bearing Stress

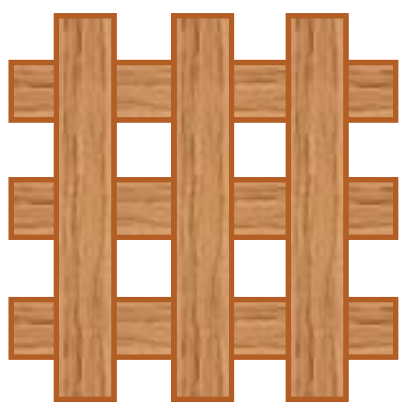
4x4: Capacity = 12.25 in^2 x 500 psi = 6,125 lbs.

6x6: Capacity = 30.25 in^2 x 500 psi = 15,125 lbs.

For ease of calculating crib capacities, round these numbers down to 6,000 lbs. and 15,000 lbs. Thus, the point of contact between two 4x4’s will support 6,000 lbs. and the point of contact between two 6x6’s will support 15,000 lbs. To obtain the overall crib capacity, add the capacity of the individual points of contact.



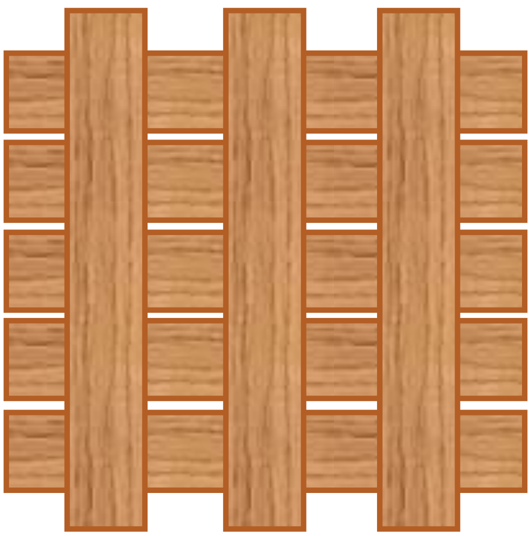
2 by 2 Box Crib: 4 Points of Contact
24,000 lbs. (4x4) and 60,000 lbs. (6x6)



3 by 3 Box Crib: 9 Points of Contact
54,000 lbs. (4x4) and 135,000 lbs. (6x6)

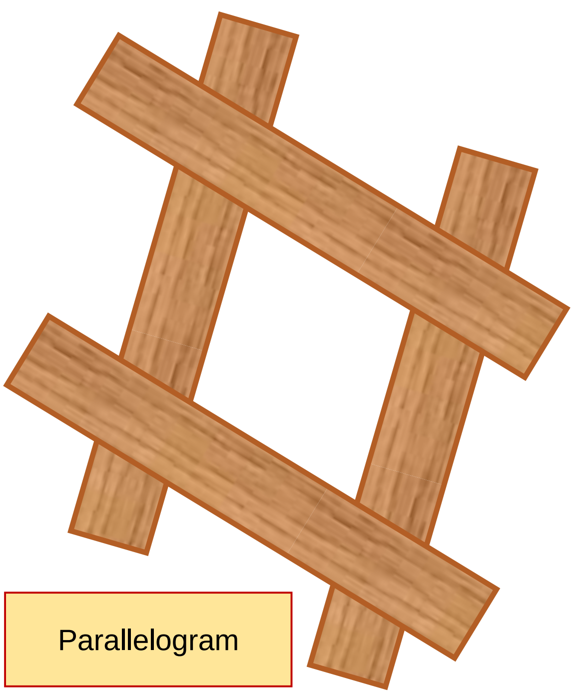
Rescue conditions will dictate how to construct a box crib. For example, when placing an air bag on top of box crib you want/desire a solid platform to support the airbag. A solid platform should also be used on the bottom of the crib any time the crib is not on a solid base (such as concrete). The load carrying capacity of the box crib is determined by the **minimum** number of contact points throughout the crib, not the number at the solid platform.

Although the design and shape of the crib should be symmetrical whenever possible, other configurations are possible. As shown in the pictures below, a triangular or parallelogram crib is possible. As these cribs are not as stable, the height to width ratio should be kept at 1:1.



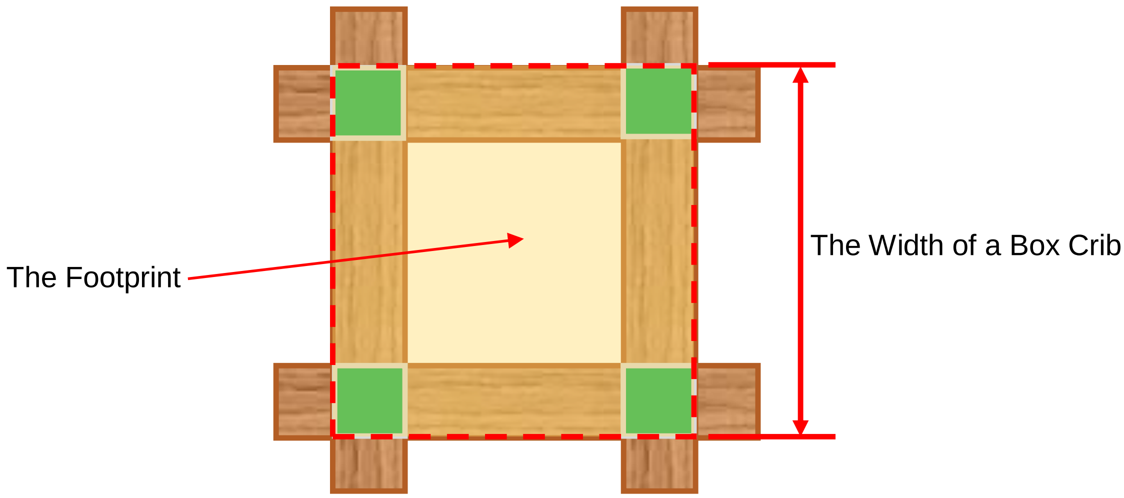
Solid Bearing

Triangular

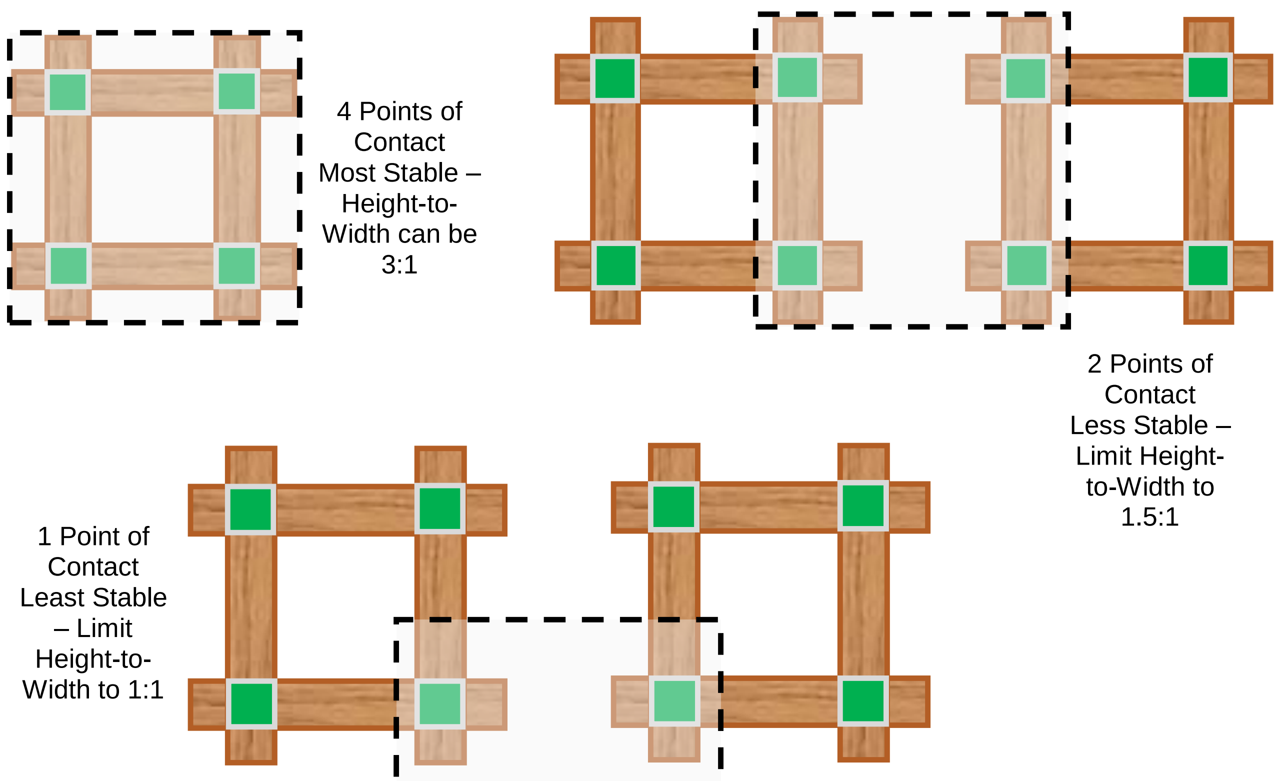


Parallelogram

As mentioned previously, when referencing the height to width ratio of a box crib it is important to note that the width is NOT the length of the piece of cribbing. Instead, it is the distance between outer edges of the points of contact. The area around the points of contact is sometimes referred to as the box crib's "footprint". The larger the footprint, the more lateral stability in the crib.



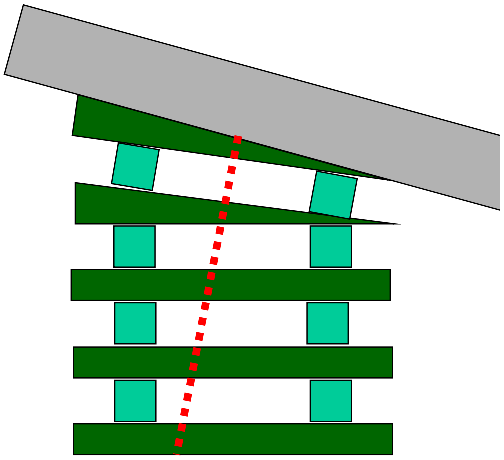
As we calculated earlier each point of contact can carry a specific load. The more points of contact under load, the more stable the box crib. As the number of points of contact under load decrease, the lateral stability of the crib decreases. This decrease in lateral stability results in a decreased safe working height of the box crib.



Slopped Box Crib

Box cribs can be “perfect” vertical structures or they can be built with a slight lean or incline. The incline is engineered into the crib to provide a solid base layer to spread the load and a top layer that offers as much surface to wood contact as possible.

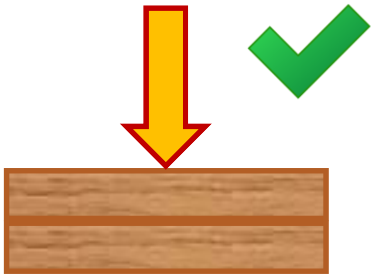
During construction of a slopped box crib, layers of cribbing are replaced with shims. The shims must be the same dimensional size as the cribbing (i.e. 4x4 cribbing and 4x4 shims). The shims are placed in a manner to create an angle that closely matches that of the load being supported. A row/layer of regular cribbing is placed perpendicular to the row/layer of shims.

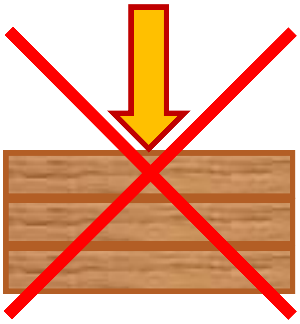


The design criteria of the slopped box crib requires the load path to be contained within the footprint of the crib.

Other Considerations

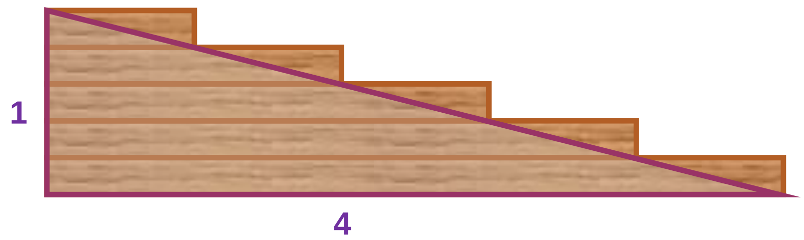
As mentioned several times in this module, stability is a very important aspect of stabilization. When working with cribbing, it is sometimes advantageous to stack multiple pieces of cribbing parallel to one another. Due to lateral instability, it is strongly recommended that no more than two pieces of cribbing be stacked in the same direction. Exceeding this number increases the risk of the cribbing layers rolling off and falling.





Step Chocks

Step chocks are portable, pre-fabricated versions of cribbing. The most common step chock is comprised of 5 pieces of wood, each 6” shorter than the one below it. The base of the step chock is 30” long and the last “step” is 6” long. For best load stabilization the length to height ratio should be 4:1. If the 4:1 ratio is utilized, the step chock acts as an incline plane redirecting the force to the ground.

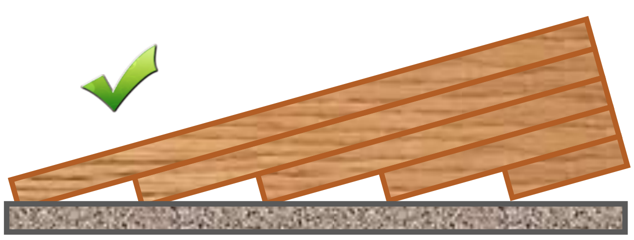


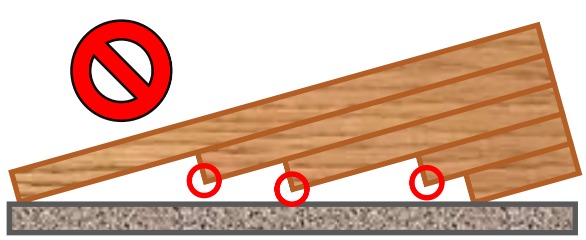
The chock is most often made with 2x6 lumber, although some departments use a 2x6 base with steps made from 2x4’s.

The primary goal in using steps chocks is to install the chock so that it does not interfere with patient packaging, does not prevent the opening of car doors and must importantly, does not become a trip hazard. Another consideration in the placement of step chocks is the potential to push a dash or the cutting of a rocker panel.

Place the step chock upright or inverted?

Both orientations of the step chock are acceptable under the right circumstances. If the chock does not interfere with the scene operations and does not pose a trip hazard, inverted is acceptable. One caveat to this statement is the use of step chocks with 2x6 bases and 2x4 steps. When inverted, these chocks are not adhering to the double funnel principle. The 2x6, now on top, is wider than the 2x4 base which causes the step chock to be unstable. Another situation where inverting would not be appropriate would be when all five corners of the steps are not in contact with the ground or stabilizing surface. Poorly constructed step chocks that do not have uniform step dimensions can create this issue. To properly distribute the load across the ground, all five corners must make contact.



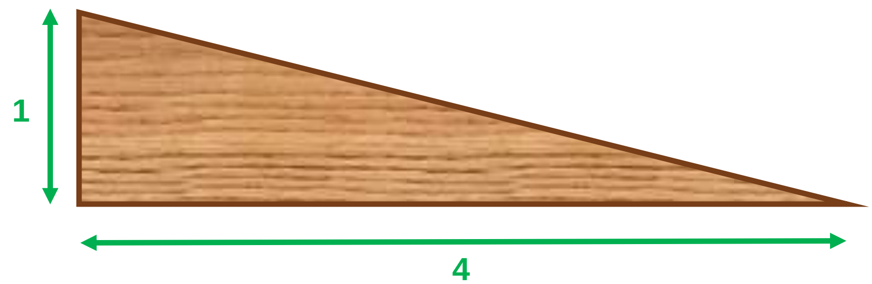


Step chocks are carried on nearly every frontline piece of heavy apparatus. They are a useful tool for stabilization. However, it’s important to remember that they are not the ONLY tool – there are many situations where step chocks cannot provide adequate stabilization and will not work.

Shims and Wedge Sets

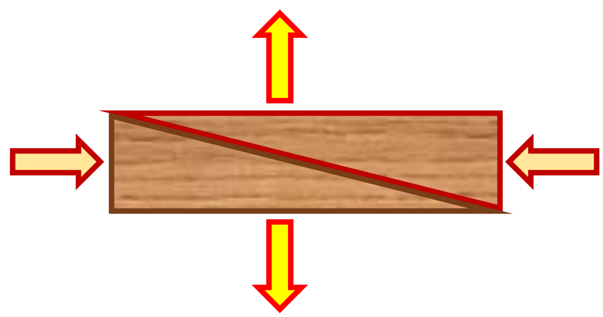
Shims

A shim is a piece of dimensional lumber that was cut diagonally to form a right triangle. This triangle creates an **inclined plane** – one of the six classical simple machines. Shims are used to fill voids when cribbing, change angles (e.g. sloped box cribs), and when acting as a **wedge** (another type of simple machine), to impart force upon an object. Similar to step chocks, shims are preferably cut with a 4:1 pitch.



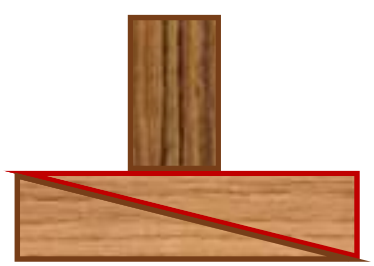
Wedge Set

A wedge set (sometimes simply called a “wedge”) is a pair of shims cut from the same piece of material. Since the cut is identical on both shims, the two fit together as a perfect married pair. Maintaining maximum surface contact in a wedge set is important. So it is best to keep married pairs of shims together and place the cut sides together.

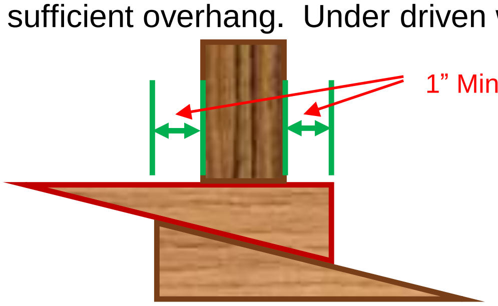


As mentioned above, a wedge is a form of a simple machine. As such, it uses the inclined plane shape to create mechanical advantage. When a wedge set is driven together, it can generate as much as 500-700 lbs. of force to lift or move an object. It is important to remember this because sometimes this force and corresponding movement is desired and sometimes it is not.

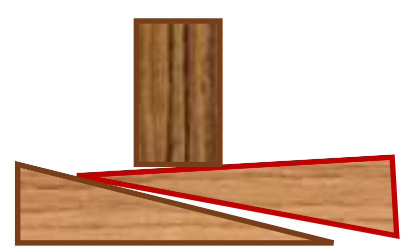
When marrying a wedge set together, it is important to understand the terms “Full Driven”, “Under Driven”, and “Over Driven”. Fully driven wedges are best. Over driven wedges are ok as long as there is sufficient overhang. Under driven wedges are undesirable.



Full Driven – *Best*

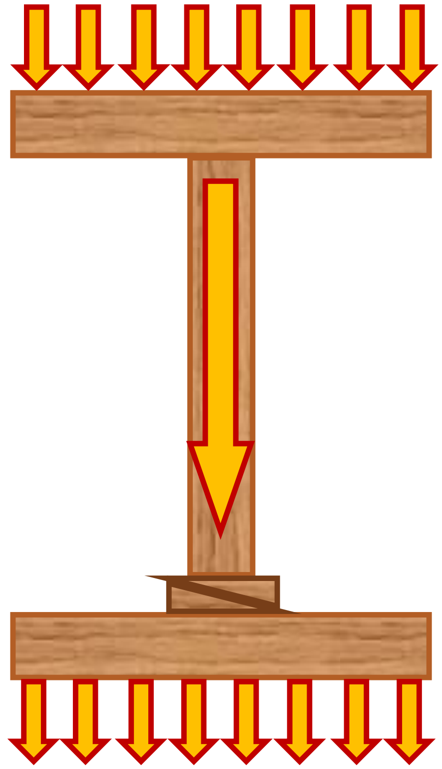


Over Driven – *OK*



Under Driven – *Wrong!*

Vertical Post Shoring



Often times, vertical post shores are utilized in addition to or in lieu of cribbing. Vertical shores tend to take up less space than a box crib and are able to provide stabilization at greater heights.

Wooden post shores are constructed of a header, post, and footer. These work together to achieve the double funnel principle in stabilizing the load. All components of the vertical shore should be connected together to form a complete system. The post height is adjusted using a wedge set (preferably a 2x4 wedge set).

The length of a post in a wooden shore is limited to prevent buckling. For longer post lengths, lateral bracing must be incorporated. The design strengths of wooden post shores are as follows:

Post Size	Design Strength	Length
4x4	8,000 lbs.	Up to 8 feet
6x6	20,000 lbs.	Up to 12 feet

In addition to wood, several manufacturers produce mechanical struts that serve the same purpose as a wooden post shore. These struts are usually constructed of aluminum and offer quick and easy height adjustment. Just like their wood counterparts, mechanical shores lose strength as they become longer due to buckling failure. Always adhere to manufacturer's working load limits when using mechanical struts/shoring.

Raker Shoring

Up to this point, this module has discussed stabilizing on object vertically. There are also times that a load must be stabilized for horizontal movement. This is the job of a raker shore.

Rakers can be constructed of wood or mechanical struts. Elaborate raker shore construction is usually reserved to structural collapse. However, day-to-day rescue squad operations can still involve the use of rakers. One such example is the vehicle tie-back.

Numerous different types of mechanical struts are used within the fire and rescue service. It is imperative that personnel have mastery of the construction, setup, use, and capacities of the specific struts carried on their particular apparatus.