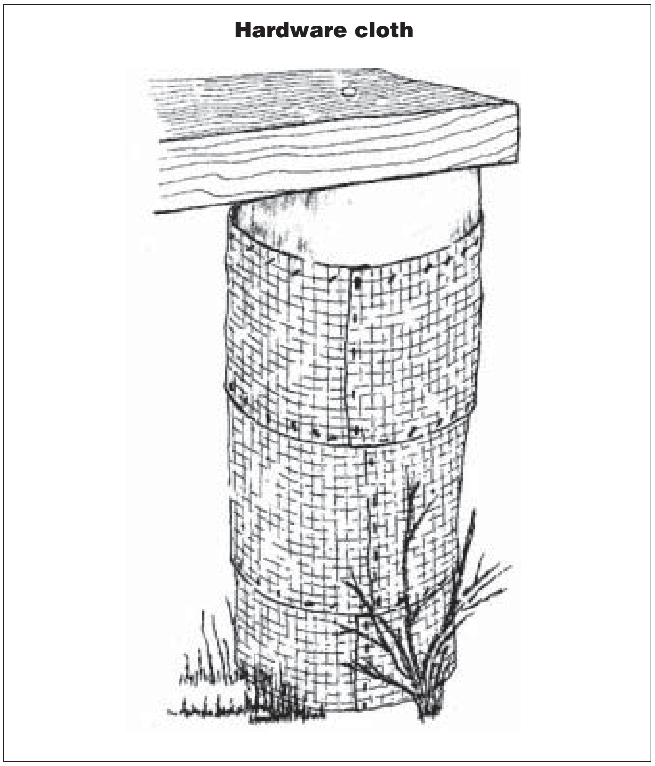


Figure 43—Hardware cloth stapled around piles helps discourage beavers.

Old beaver ponds present something of a problem in bog bridge construction, especially in mountainous areas. The original soil may have been of glacial origin and capable of supporting end-bearing piles. However, beaver dams trap silt, which drops to the bottom of their ponds. While end-bearing piles may work well in some locations in such ponds, friction piles are needed elsewhere. When concrete end-bearing piles were used at one pond, some settled 1 to 2 feet in 5 years. After 10 years, all concrete end-bearing piles had to be replaced with log friction piles (figure 44).

Puncheon

Puncheon are essentially short-span footbridges or a series of connected short-span footbridges. The term puncheon means different things to different people. Puncheon on the Appalachian Trail is not the same as puncheon built in the Cascades, Rocky Mountains, or Sierras. Puncheon built in easily accessible areas may not be the same as that built in the backcountry. Puncheon can be used where the soil is wet but does not contain enough water to seriously hamper trail work. The one thing common to all puncheon construction is the use of sleepers or sills.

Figure 44—Know your soil conditions. Concrete end-bearing piles settled 1 to 2 feet here, and had to be replaced with these log friction piles.

Type 1 Puncheon

On the Appalachian Trail, 3- to 6-foot-long logs are commonly used for the sleepers or sills. The sleepers are notched to receive one or two tread logs and then placed in a shallow trench. The tread logs are hewn, split, or sawn, roughly in half, to provide a level plane for the walking surface or tread. The tread logs are spiked or pinned in the notch of the sleepers (figure 45).

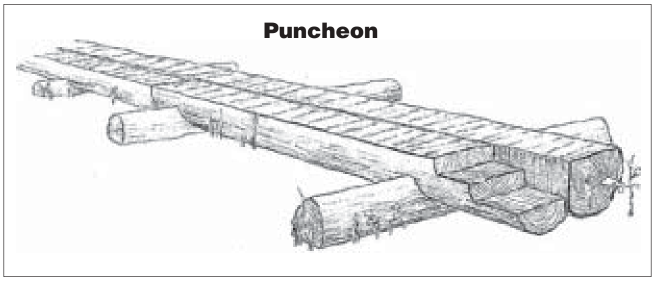


Figure 45—A rustic type of puncheon with stringers and tread logs.

If the area to be crossed is longer than the logs available for the tread, the puncheon can be built as a series of connecting sections. Hiking any distance on single-tread-log puncheon can be unnerving because the hiker is looking down to avoid stepping off the tread. This is especially true if there is quite a drop from the tread to the ground or water below. Two tread logs placed side by side on longer sleepers will help. For two-tread-log construction, the inside face of each log should be hewn or sawn to butt closely to the adjacent log. A narrow gap between the two logs will help drain water, snow, and ice from the tread. This will reduce the chances of a slippery tread and delay rotting.

Two or three small spacers can be nailed to the inside face of one of the logs to control the width of this gap. The spacers can be short, straight lengths of 2- to 4-inch-diameter branches or wood scraps, hewn flat on opposite sides to provide a piece of wood about 1 inch thick.

Type 2 Puncheon

In the Western States, puncheon uses log sleepers placed in a manner similar to that used on the Appalachian Trail. The sleepers are a few feet longer, however, and the space between them is spanned by two or three log stringers, or beams, spaced 1 to 3 feet apart (figure 46). The tread is made from 6- to 12-inch-diameter split logs, 4 to 6 feet long, or split planks. The split face becomes the tread. The bottom of the tread half-log is notched to rest on the stringer log, and the tread is spiked in place. If three stringers are used, do not spike the tread logs to the center stringer. The top of the three stringers will probably not be at the same height. Use a long carpenter's or mason's level to quickly determine the height of each stringer in relation to the others. Ideally the tread should be level from one side to the other. Handtools normally used in the field for construction make it difficult to get the tread perfectly level. Adjusting the depth of each notch, as needed, will allow for variations in stringer height. Shims under the decking also help to level the structure from side to side.

Half logs can be placed with their split sides facing up as a tread. Smaller half logs are placed split side facing down resting on the stringer and butted tightly against the tread log. These logs serve as brace logs, preventing the tread logs from wobbling. Succeeding tread log are butted snugly against the brace logs (figure 47).

If large logs are available, tread plank can be sawn from the logs, producing a number of pieces of plank of varying widths from one log. An Alaskan sawmill can be used at the site to produce planks with a uniform thickness. With this plank, there should be little—if any—need to notch or shim the stringers.

Excessive cross slope will make the surface very slippery. The meaning of excessive will vary, depending on the climate expected when the trail is being used. In a dry climate, the cross slope should not exceed ½ inch per foot of tread width; in a wet climate, or where snow, ice, or frost can be expected, the cross slope should be no more than ⅛ to ¼ inch per foot of tread width. If the trail leading to the puncheon is wet, no matter what the season, hikers will track mud onto the tread, making it slippery throughout the year.

Puncheon with stringers and decking

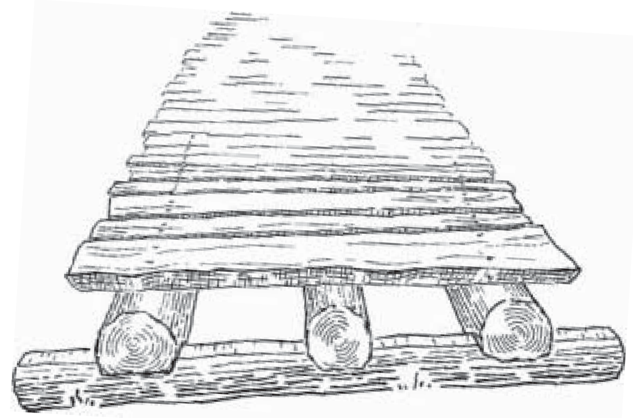


Figure 46—A second type of puncheon with stringers and decking.

Rustic tread

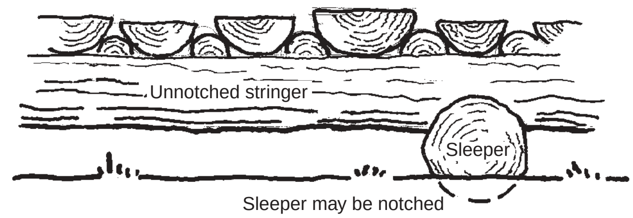


Figure 47—Rustic tread or decking made from half logs (logs cut in half lengthwise).

Type 3 Puncheon

The third type of puncheon also uses sleepers to support the structure, but the material is sawn timber or lumber, which should be treated with wood preservative (figure 48). This construction is popular at more accessible sites where materials are easier to transport. The longevity of treated wood and the environmental consequences and labor of cutting trees onsite make the use of sawn, treated timbers increasingly popular at remote sites as well. Helicopters, packstock, all-terrain vehicles, and workers carry in the materials.

The sleepers can be either 6- by 6- or 8- by 8-inch-square timbers placed as previously described. Two or three stringers rest on the sleepers and may be toenailed to the sleepers and bolted or nailed to the stringer in the next span. The stringers may also be attached to the sleepers with steel angles and extended (cantilevered) a short distance beyond the sleepers.

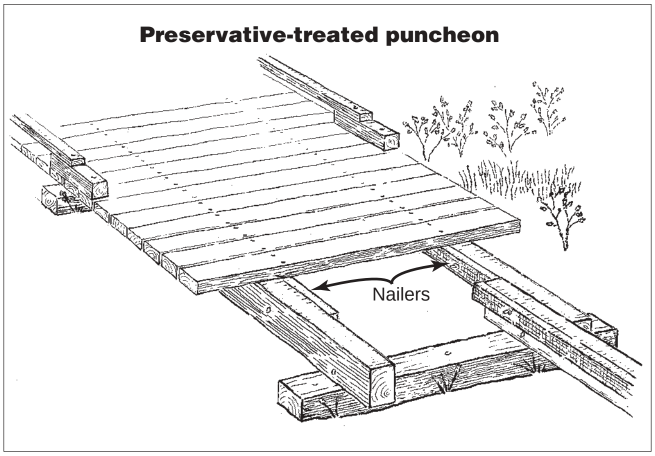


Figure 48—A third type of puncheon. This type of puncheon is constructed from preservative-treated timbers. The nailer bolted to the inside of each stringer helps keep the stringers from rotting by concentrating screw holes and associated rot in the easily replaced nailers instead of the stringers.

The size of the stringers is determined by the maximum weight they can be expected to support, which may be the snow load in snow country. For foot trails, usually the size of the stringers is calculated to support a weight of 100 pounds per square foot, the maximum weight expected for trail users standing on one section of trail. Heavier, wider puncheon is needed for horse and mule traffic.

On foot trails, the tread is often 2 by 6, 2 by 8, or 2 by 10 lumber nailed to the stringers. When three stringers are used, do not nail to the center stringer. The nails work their way out and pose a tripping hazard. The stringers are the most expensive and most difficult items to bring to the site. Do everything you can to extend their useful life; usually this means keeping them dry.

The tread will need replacement more frequently than any other portion of this type of puncheon. In some areas the wood tread will require replacement every 7 to 10 years. After three or four replacements of the tread, the top of the stringers will show signs of rot and wear. Water from runoff and condensation will follow the nails down into the wood, and repeated nailing in the same vicinity will soften the wood. To avoid this, a nailing board (nailer) of 2 by 4s or 2 by 6s can be nailed to the top or side of the stringer. A better solution is to bolt rough-sawn 2 by 4s or 3 by 4s to the side of the stringer with carriage or machine bolts. The bolts can be 2½ to 4 feet apart. The tread is nailed to the nailer instead of the stringer. Eventually, the nailer will require replacement, but the nailer is much easier to replace than the stringers. Esthetically, it is better to attach the nailers to the inside face of the stringers.

Puncheon Summary

The type 1 and 2 puncheon do not represent sustainable design. They damage the resource if onsite trees are cut to provide construction materials. Offsite timber materials may be from more sustainable commercial sources. The type 3 puncheon meets the criteria for sustainable design because the material used is more easily renewed. Although the tread may require replacement in 7 to 10 years, the heavy stringers have a much longer life expectancy.

All three types of puncheon are raised high enough above the ground to provide little interference with the movement of floodwater. The tread width of types 2 and 3 puncheon may affect the growth of plants under the tread.

Gadbury

Gadbury (figure 49), a structure similar to puncheon, was developed in the Pacific Northwest. Gadbury uses two half logs, as described for puncheon, and longer notched sleepers. The notch cut for gadbury must be about twice as wide as the notch cut for puncheon. The two half logs are placed on each side of the center of the notch with the flat surface up. Two full logs are placed in the notch on the outside of each of the half logs.

An experienced crew can construct gadbury without using spikes or steel drift pins. Such construction requires considerable skill and experience with woodworking tools. Lacking this experience, the pieces can be spiked or pinned together. Earth may be placed on the half logs and held in place by the full, outside logs.

Gadbury uses more wood than puncheon. From a standpoint of sustainable design, gadbury is less suitable than other techniques.

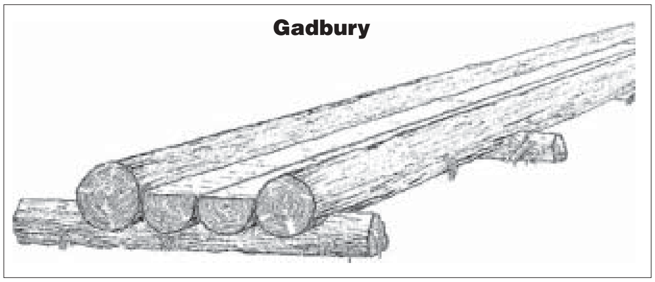


Figure 49—Gadbury is another rustic structure similar to puncheon. Use peeled logs for gadbury.

Bog Bridge

A bog bridge is a form of puncheon. Normally, bog bridges have a single- or double-plank tread surface resting directly on mud sills (sleepers) (figure 50), cribbing, or piles. A puncheon, by contrast, will usually have stringers resting on the mud sills or sleepers, with tread decking nailed perpendicular to the stringers.

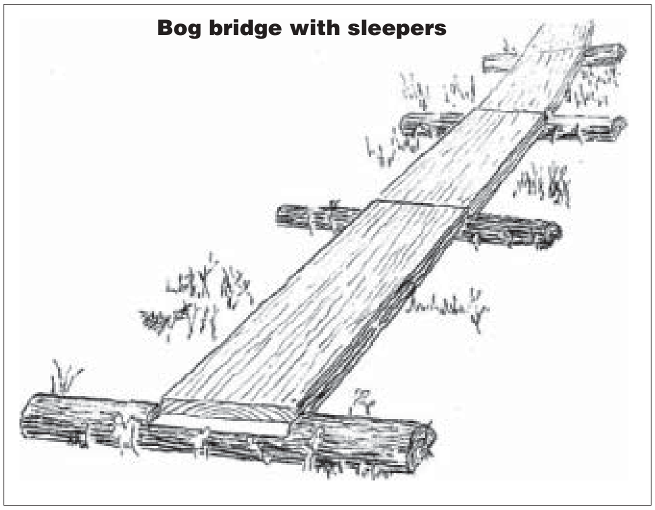


Figure 50—A simple bog bridge with sleepers. This common structure is also called a single-plank boardwalk in coastal Alaska.

To add to the confusion over terminology, in coastal Alaska, bog bridges are called boardwalks, or step-and-run boardwalks if spacers are used to create steps (figure 51). In other places, the term bog bridge is synonymous with puncheon. In parts of the Rocky Mountains and Sierras, bog bridge equates to turnpike, a structure we described as a raised walkway of stone and fill material. We define bog bridges as a series of connected, short-span bridges close to the ground.

The tread of a bog bridge is usually treated, rough-sawn 3- by 12-inch plank that is 6 to 9 feet long. The plank parallels the centerline of the trail and rests on closely spaced, lightweight foundations. This means that the tread of the bog bridge can be closer to the ground, perhaps only 6 to 12 inches above it, providing 3 to 9 inches of clear space below the tread. There is little to block the flow of water (in either direction) below the plank, and little to resist the force of floodwater going over it. In the backcountry, bog bridges are normally one 12-inch plank wide. A plank this narrow does little to interfere with plant growth underneath. The span of each of these small bridges will vary with the type of wood used for the plank, the thickness of the plank, and the anticipated weight on the plank. In areas of heavy, wet snow, the snow may be the heaviest weight on the bridge. Snow load may be as much as 300 pounds per square foot in such areas.

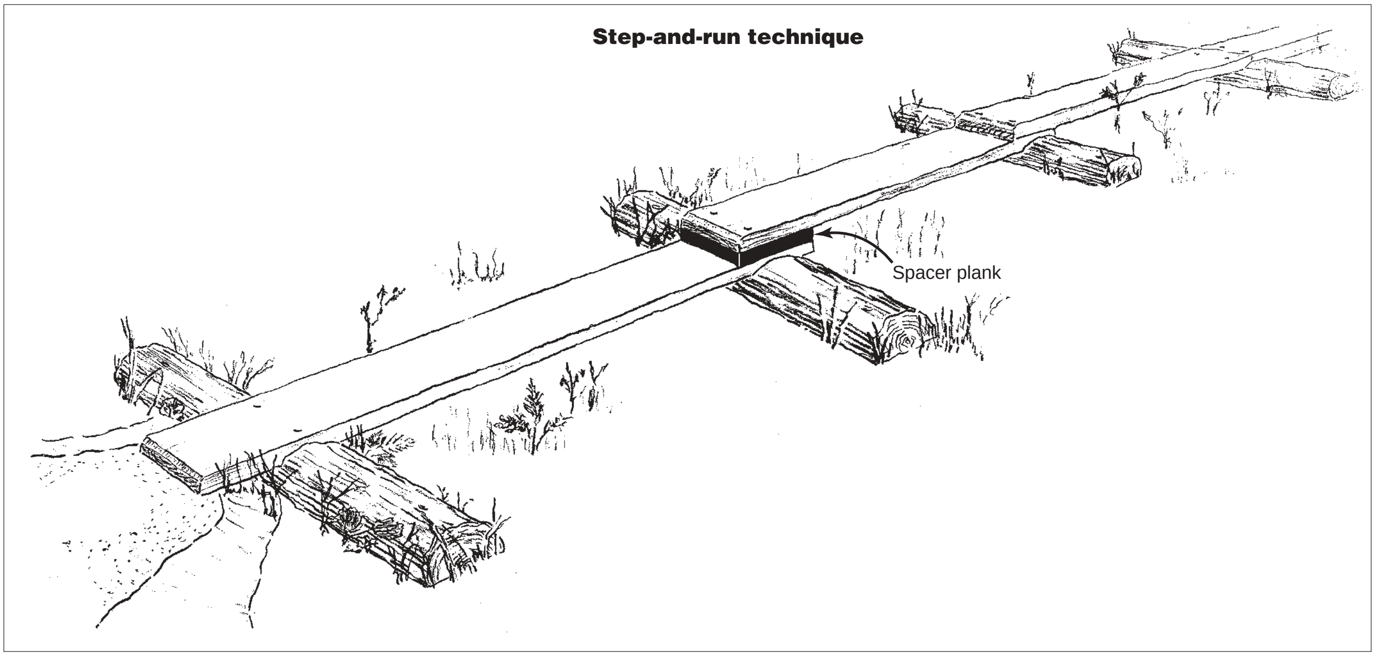


Figure 51—The step-and-run technique is a way of keeping planks level as elevation changes. Level planks help reduce slipping in wet climates.

Bog Bridge on Sleepers or Sills

In its simplest form, the plank of the bog bridge rests on sleepers or sills. A sleeper is placed in a shallow trench at right angles to the trail centerline. A second sleeper is prepared and placed in another trench 6 to 9 feet away. This distance is the span, which is determined from older installations or with the help of someone with carpentry or structural engineering experience. Place the plank flat in the notches of the sleepers, with one cut end centered in line with the centerline of the log. Mark the plank where it meets the centerline of the next sleeper and saw it to the proper length. The plank is nailed to the sleepers at each end with two 50- or 60-penny (appendix D), ring-shank nails driven through previously drilled pilot holes. This process continues across the wetland.

Bog Bridge on Cribbing

Occasionally, log or timber cribbing can be used to support the plank of a bog bridge. Plank can either be nailed to each of the top logs or timbers, or one large-diameter log can be notched and pinned to the top logs (similar to the sleepers described earlier). If the bog bridge is more than 2 feet high, the plank should be two planks wide for safety.

Bog Bridge on Piles

Another technique for building bog bridges is to rest the plank on pile foundations. The three types of suitable piles are end-bearing piles, friction piles, and helical piles.

After installing a pair of bents or piers, pressure-treated 3- by 12-inch planks are nailed to the ledger or ledgers as described for the bog bridge on sleepers. The ledgers do not have to be notched. When piles are used, the plank may be more than 2 feet above the ground or water. In such cases, the tread should be two planks wide.

Bog Bridge Summary

Whether a bog bridge is built on sleepers, cribbing, or wood piles, it lends itself to backcountry construction. The bog bridge requires no large machinery. The materials are wood, steel washers, bolts, nuts, and nails. The pieces of wood are relatively small and can be carried by hand. No concrete is needed.

Boardwalk

For the purpose of this book, a boardwalk is a structure that uses widely spaced bents or piers as a foundation. Stringers, parallel with the centerline of the boardwalk, rest on the ledgers of the bents or piers. The stringers support the deck, which is usually 2 by 6 or 2 by 8 lumber laid perpendicular to the centerline and nailed or screwed to the stringers, or to nailers bolted to the stringers. Boardwalks usually have a curb or handrail along their edges (figure 52).

Basically, a boardwalk is a series of connected bridges, each with a span as long as is practical, perhaps 8 to 40 feet. At most wetland sites, longer stringers are not practical because they are difficult to transport. Also, building adequate foundations for the long spans often requires large pieces of specialized equipment that cannot negotiate unstable soil.

Figure 52—A typical boardwalk. Boardwalks are expensive and somewhat complicated, so seek the help of engineers and landscape designers during planning.

Stringers

At least two stringers or beams rest on the ledgers and span the space between consecutive bents or piers. As the space between bents or piers increases, a third stringer, or heftier stringers, must be used.

Long, thick stringers are more expensive than smaller ones. However, they permit the bents or piers to be farther apart. Studies of soil conditions and problems of construction access to the site will indicate the costs for stringers compared to bents or piers. Bring in some engineering help to figure out the most economical spacing of bents or piers. Large stringers should be bolted to steel angles that have been bolted to the ledgers. Nailers should be used to attach the deck, as described for type 3 puncheon (figure 53).

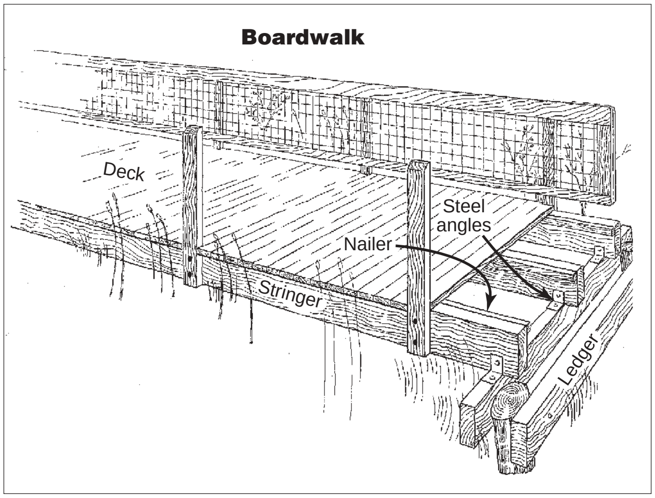


Figure 53—Details of boardwalk construction. Large stringers and ledgers connected with steel angles and nailers help increase the life of the stringers.

Ideally, the bottom of the stringers of a boardwalk should be above high-water levels, but this is often impractical. To reduce maintenance, the design of the boardwalk should avoid interference with the flow of floodwater and floating debris. To check for evidence of flooding, look for clusters of dead, broken branches stuck in shrubbery or the crowns of trees. Bark on the upstream side of trees may be scraped or stripped off. The height of anticipated floodwater may seriously affect the design of a proposed handrail. Joists can be toenailed to the ledgers, or steel joist or truss hangers may be nailed to the ledgers to support the joists (figure 54). Joist and truss hangers reduce the distance between the deck and the ground below, perhaps eliminating the need for a pedestrian railing.

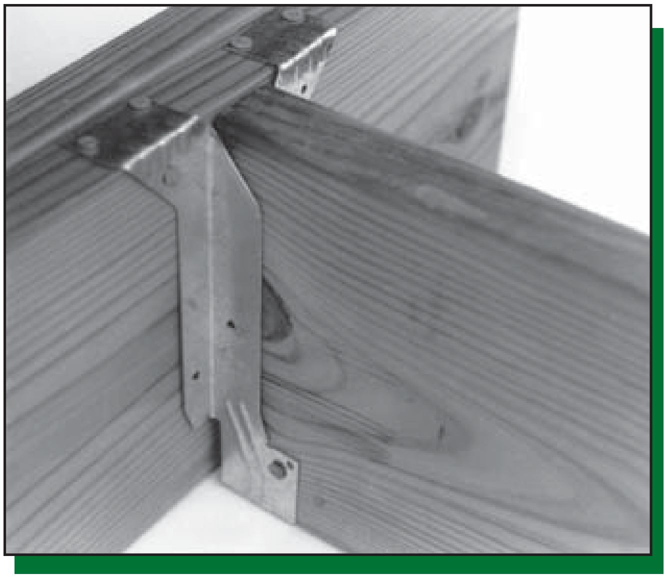


Figure 54—Supporting joists with truss hangers helps keep a boardwalk closer to the ground.

Boardwalk Summary

Often boardwalks, as described here, are found around visitor centers, heavily used interpretive trails, or at other high-use sites. The sophisticated construction and materials needed for a boardwalk are less appropriate in the backcountry where the trail user expects simpler, more rustic construction and more challenging facilities.

During floods, the posts and rails can catch debris and form a dam. In most situations it is better to build as little as possible that will have to resist the force of high-velocity floodwaters. A decision on how much or how little to build should be based on the type and age of the visitors who will use the finished facility—schoolchildren, senior citizens, day hikers, or backpackers. Professional geotechnical and structural engineers and landscape architects are needed for effective design of these big-budget structures.

Finishing Details

Although constructing the basic structure right is most important, often the mark of craftsmanship is most evident in the finishing details. Most of the following discussion applies to boardwalks. However, some finishing work can be used with other construction techniques.

Decks

Plank used for a deck often contains heartwood and sapwood. If the plank is placed with the heartwood face up, alternating moisture and drying—and the effects of freezing and thawing—will cause knots and some of the annual rings in the wood to lift. To reduce tripping hazards and future maintenance, deck plank should be placed "green side up" (the heart face down and the bark face up) (figure 55).

Decking

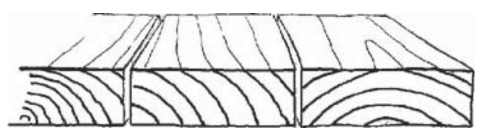


Figure 55—Place decking with the growth rings facing down to help prevent cupping. Cupping causes the wood to rot faster and creates a tripping hazard.

Posts

A pedestrian railing system may be needed along the edge of a deck to prevent visitors from falling off. Various building and highway codes call these railing systems "handrails," "guardrails," or "railings." If you are planning to install a pedestrian railing, the details of the installation of the posts need to be thought out before placing the deck. Railing posts need to be sturdy. They are a potential liability. Flimsy railings installed as an afterthought are the ones most likely to fail. Usually, it is the connectors, not the railing, that fails.

The deck, posts, and handrail are all closely related in their construction. As a minimum, 4 by 6 timbers should be used to support handrails. Actually 4 by 4s that are surfaced on all four sides are only $3\frac{1}{2}$ by $3\frac{1}{2}$ inches. They make a flimsy post. The deck should extend beyond the stringers to the back of the post, or at least 4 inches. If this is not done, people standing on the deck and leaning on the railing will have their feet sticking out beyond the deck. (figure 56).

Handrail post construction

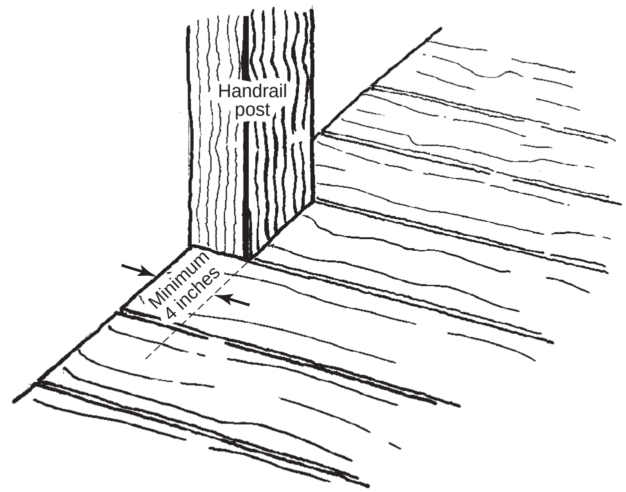


Figure 56—When the handrail post is attached to the stringer below the deck, the decking should extend at least 4 inches beyond the stringer.

There are two ways to install railing posts. The most common requires the deck to be in place. The posts are toenailed to a deck plank. By itself, this is a weak connection and requires an angle brace for support. Therefore the plank supporting the post must extend beyond the edge of the rest of the deck. If the plank is too short, the angle brace will be too close to vertical to provide much support (figure 57).

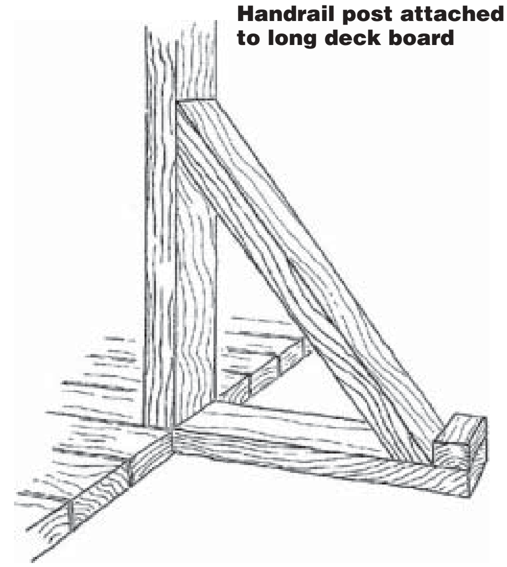


Figure 57—Attaching the handrail post directly to the decking requires long deck pieces to support an angle brace.

The second method is to attach the posts to the outside of the stringers. It is much easier to bolt the post in place before attaching the adjacent deck plank. To provide solid support, 12 inches of post should contact the stringer. The posts can be accurately cut and drilled in a shop and brought to the site. To avoid the awkward and time-consuming work of notching the planks, the width of the post should match the width of the deck planking (figure 58).

Handrail post attached to stringer

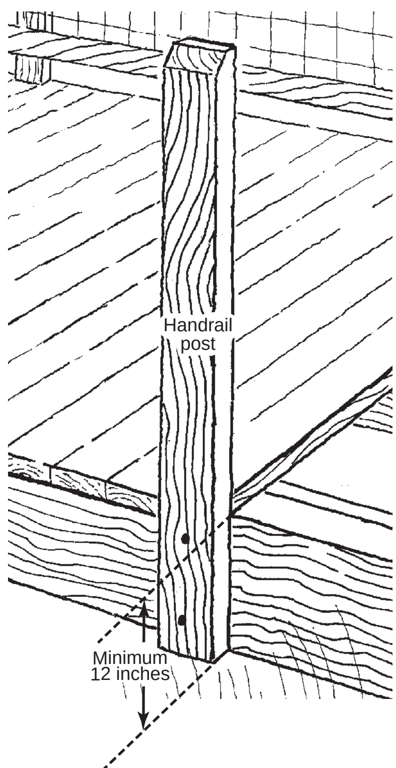
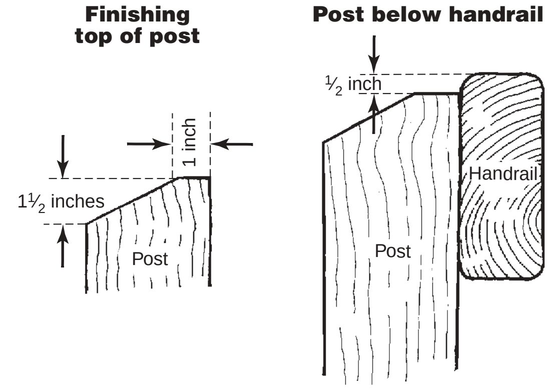


Figure 58—To provide proper support, at least 12 inches of the post needs to be in contact with the stringer.

The top of each post or pile should be cut at an angle to shed water and to help prevent rot. To avoid a sharp corner at the top of the post, a narrow 1-inch area closest to the handrail should be cut level, and the sloping portion should be pitched away from the boardwalk (figure 59). For esthetic and safety reasons, the posts should not extend above the top of the handrail (figure 60).

Finishing top of post **Post below handrail**



Figures 59 and 60—Cut the top of the post at an angle, but leave 1-inch flat on the inside edge. The post should not extend above the top of the handrail.

Pedestrian Railing Types

Safety must be the first consideration in selecting a railing system. Safety requirements are primarily determined by the relative accessibility of the trail. Railing types must fit the appropriate Recreational Opportunity Spectrum class. Railings are of three basic types:

➥ Railings attached to buildings, such as visitor centers, must meet building code requirements such as the Uniform Building Code (UBC) 509. This code requires a railing at least 42 inches high that a 4-inch sphere will not pass through.

➥ Handrails on bridges need to meet the American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges. Although most of the structures described in this book are not bridges, we offer these specifications for information. AASHTO requires 42-inch-high guardrails on all pedestrian highway bridges. Bridges on fully handicapped-accessible trails usually need this type of railing. This code requires handrail at least 42 inches high for pedestrian traffic and at least 54 inches high for bicycle or equestrian traffic. A 6-inch sphere must not pass through the railing in the bottom 27 inches, and an 8-inch sphere must not pass through the area above 27 inches.

➥ Handrails for more remote trail bridges must be at least 42 inches high for pedestrian traffic and at least 54 inches high for bicycle or equestrian traffic. These handrail systems must also have at least one intermediate rail so that vertical distances between rails do not exceed 15 inches. Three-fourths of all Forest Service trail bridges fall in this category.

Not all wetland trail structures need railings. If the trail itself has more hazardous drops than the trail bridge would have without a handrail, a handrail is probably not required. Other considerations, such as convenience, may justify installing a handrail. Although UBC requirements and AASHTO specifications do not govern trail construction, they can serve as guidelines. As a general rule, any fully accessible trail with a drop of 4 feet or more, or a more remote trail with a drop of 8 feet or more, should have a pedestrian railing system. All accessible trails should at least have a curb. A wheelchair handrail is required for any accessible trail bridge on a grade of 5 percent or steeper.

Railing Installation

Install the railings after the posts and deck are complete. Most railings consist of a top and bottom rail, usually 2 by 6s, although 3 by 6s make a better splice and a stronger rail. The stronger rail permits posts to be spaced more widely than if 2 by 6s were used for rails. The rail can also be cut and drilled in a shop where the splices can be cut accurately and more efficiently.

Often there is no clear direction regarding splicing the railings if the span exceeds 16 feet, the longest lumber that is readily available. It is difficult to butt splice a railing to the surface of a post that is less than 6 inches wide without an awkward splice or a maintenance problem (figure 61).

Walking on the top rail is a potential problem. Round logs or poles have been used to discourage visitors from walking on them, as well as 4 by 4s and 6 by 6s laid diagonally with one corner up. Another technique is to cut the tops of all posts at an angle and place a 2 by 6, or 2 by 8, on the cut surface.

Rail splices

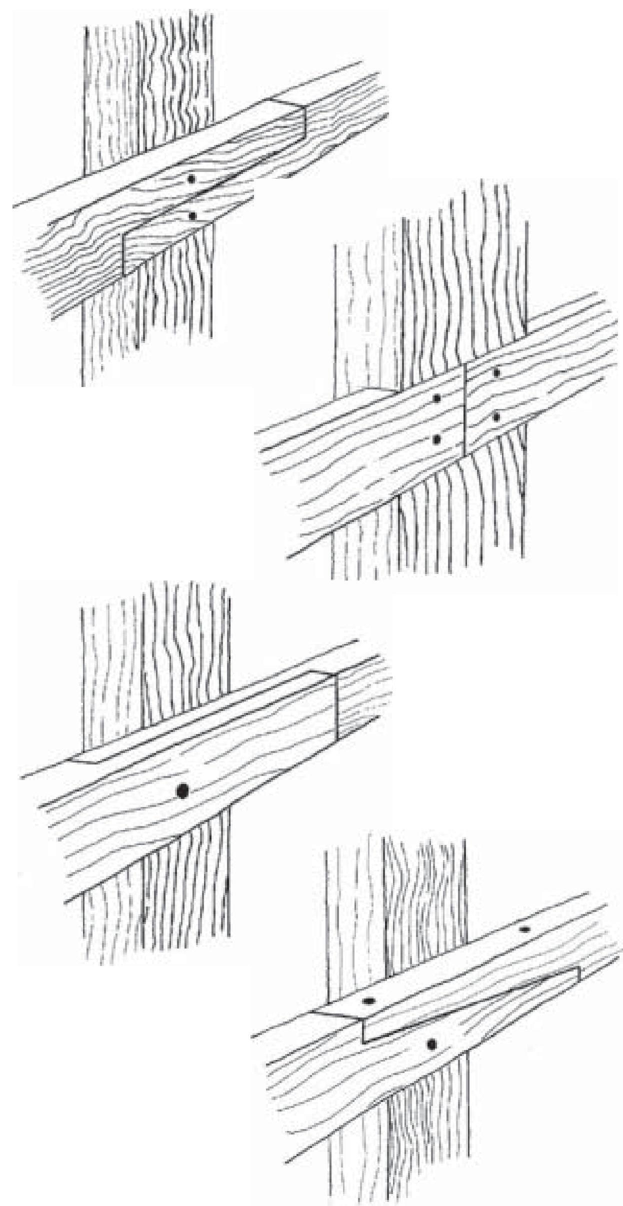


Figure 61—Four methods of splicing rails. It is best to cut the rails in the shop.

The edges of all rails should be "edges eased." Edges eased is a trade term indicating that the corners along the edges of the piece of wood are rounded. To reduce splinters, the radius of the handrail edge should be ½ inch or more.

Installing a handrail on a curved bog bridge or angled boardwalk can be a challenge. One way to do this is to use steel angles. Measure the distance between posts and cut the rail to that length. Nail or screw the angles at the ends and to the outside of a 2- by 4-inch or 2- by 6-inch rail. The angles will have to be bent slightly to conform to the different alignment of the posts. Hold the rail in place and nail or screw the angle to the side of the post with the inside face of the board flush with the inside face of the post. Measure the distance between the centerline of the two posts and cut a 2 by 6 to that length. Round the ends slightly and bolt the 2 by 6 to the 2 by 4. The result will be a stronger rail than a single piece of material. This technique may also be used for straight sections of railing to avoid nailing or screwing into the face of the post (figure 62).

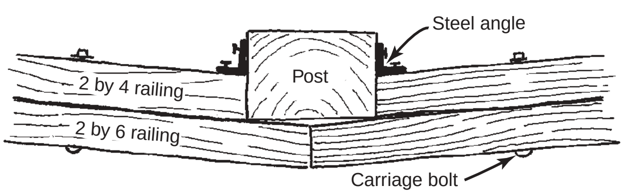


Figure 62—One method of installing rails on curving boardwalks using steel angles bent to accommodate the curvature of the structure.

For rails on curved trails, short wedge-shaped pieces of lumber can be used as shims between the posts and the rails. The wedges should be oak or cedar. Wedges are difficult to cut in the field. You could notch posts to the correct angle to accept the rails, but this is also difficult.

Cable or wire rope can be used as a railing system in some specialized applications (figure 63). Often the posts are close, 4 to 6 feet, and the cable is strung through holes drilled in the posts or through screw eyes. A single piece of cable may be strung through all the holes in the upper part of the posts, down the last post to the next lower hole and continuing this process back to the beginning through the lower holes, reducing the need for many splices. Use cable tensioners as needed.

Figure 63—Wire rope is used here as part of the railing system.

Curbs (Bull Rails)

Curb and bull rail are two names for the same thing. If the drop from a boardwalk is about 30 inches or less, a curb is usually installed. A curb is required for accessible trails. Curbs present a potential tripping hazard for pedestrians (figure 64).

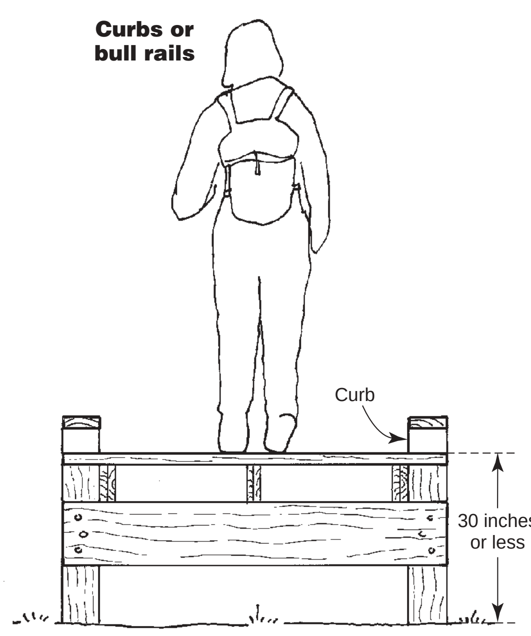


Figure 64—Curbs or bull rails are typically used when the deck is no more than 30 inches off the ground.