Class: Dewey 623.65: Lefax 12

MILITARY BRIDGES

Condensed from Engineer Field Manual, U. S. Army

When once constructed a bridge is the most rapid means of crossing a stream. Its disadvantages are the time and material required and the small chance of secrecy in its construction.

Selection of Site—The site is selected as a result of reconnaissance to verify and complete the information shown by existing maps. To meet tactical requirements the near shore in an advance should afford concealment for the preparatory work in connection with the bridge, and should, if possible, facilitate a converging fire upon the enemy, while the farther shore should be open to favor development. In a retreat it is desirable that the near shore shall have high ground suitable for defensive positions, while the farther shore should favor concealment. The best site is in a straight reach or a gentle bend; if in a bend the passage should be toward the convex bank in an advance and toward the concave bank in a retreat. The immediate banks should be firm and of equal height, the current regular, moderate, and parallel to the banks, and the bed should afford good anchorage and be free from snags, bowlders, and other obstructions. The velocity of current can be measured by timing the passage of a floating object over a measured length of stream. If not in excess of 3 or 4 feet per second no special difficulty need be expected; with greater velocities it will be necessary to use precautions such as extra anchors or guy ropes leading to points on the banks upstream.

The reconnaissance should furnish information as to the liability of freshets and their probable height, the rise and fall in tidal streams, the width and depth of the stream, the presence or absence of navigation, the nature of existing facilities such as roads or fords, and the presence of bridge material such as timber, rope, or wire. The depth can be measured by sounding with a pole or a sounding line. The width should be measured as accurately as practicable. Narrow streams can be measured by stretching a line across. Wider streams can be measured by triangulation from a base line, using the most accurate instrument at hand. Tributary streams near the site, especially if concealed from the view of the enemy, are advantageous, as they may be used for storage of material or the construction of parts of the bridge which are afterwards floated into place. An island may facilitate crossing by reducing the length of bridge required or affording secure anchorage for a bridge built below the island. The approaches are important. An easy exit is particularly essential. A bridge easy of access and difficult of exit will cause crowding, accidents, and delay. Where possible, the approaches should be straight and in line with the bridge for at least 20 yards next to the bridge; the grades should not be steeper than 1 on 10 if possible, and in no case steeper than 1 on 7.

Kinds of Bridges—The kind of bridge to be built depends on the nature of the obstacle to be crossed, the load to be carried, and the materials and time available. Military bridges are divided primarily into floating and fixed The types of floating bridges most commonly used are the ponton bridge, built with the equipage carried with the army, and bridges built with boats or barges. Types less frequently used are the bridges built with casks, rafts, timber, inflated skins, and other means in the nature of bridging expedients, which are treated later. The fixed bridges best adapted to military use are pile, trestle, spar, and suspension bridges. Other types that may be used at times are cribwork, steel girder, trussed, and cantilever bridges. The type selected should fit the conditions of the site, should be of simple design, and should admit of easy and rapid construction.

PONTON BRIDGES

There are two kinds of ponton bridges—those built with the heavy equipage intended to pass large armies and their trains over streams of any size, and those built with the light

equipage intended to be used with rapidly moving columns, such as cavalry expeditions, and to carry all the loads incident to such service.

Heavy Equipage—With each Army corps there is an engineer train carrying, among other things, one ponton train of three heavy divisions—two motor-drawn and one mule-drawn. Each ponton division contains the materials for 225 feet of bridge. Each ponton division has 8 pontons, 2 trestles, and other necessary materials for 11 bays or spans. The supports are the abutments on shore, the trestles, and the pontons. The roadway bearers are wooden beams called balks, 5 inches by 5 inches in cross section, and of two lengths, 27 feet and 21 feet 8 inches. The roadway is formed of plank called chess, each 1½ inches by 12 inches by 13 feet. The chess are held in place by side rails, which are balks laid on top of the chess and lashed to the balks under the chess. The pontons are flat-bottomed wooden boats, 31 feet long, 5 feet 8 inches wide, and 2 feet 8 inches deep at the center.

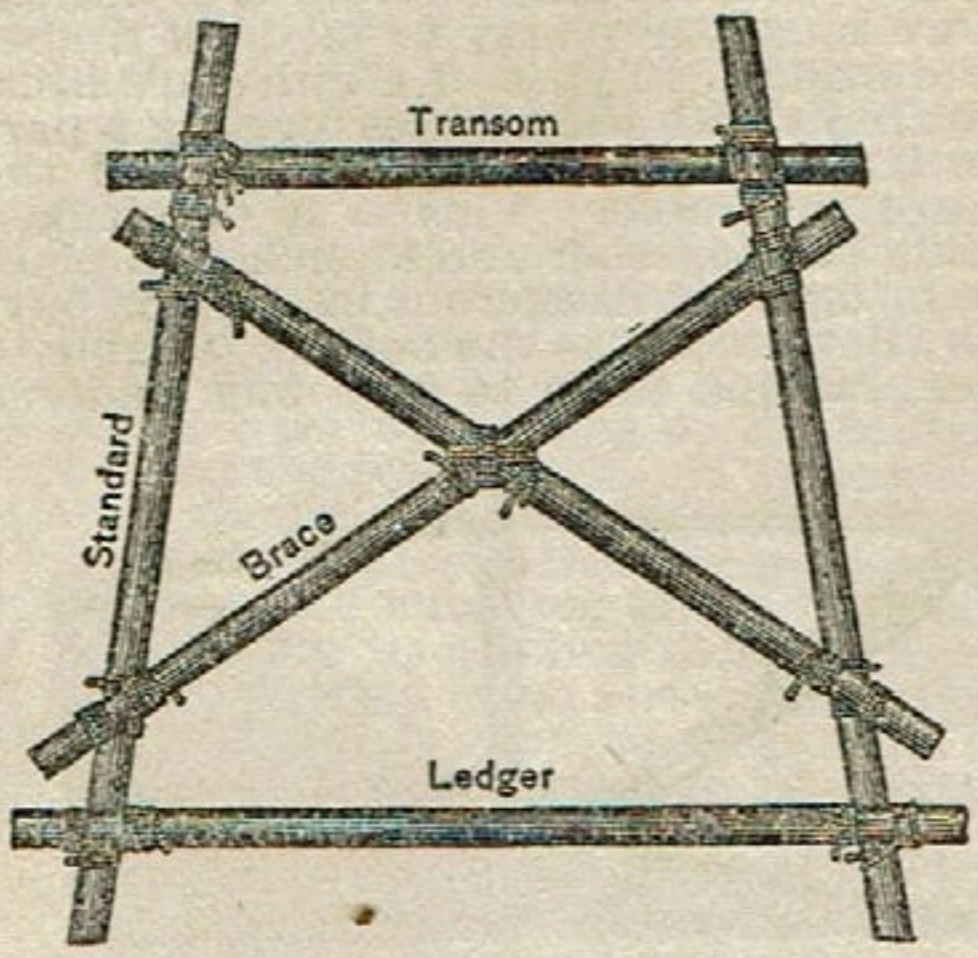
Light Equipage—With each cavalry division there is an engineer train, of which the ponton section consists of three divisions, each having 8 pontons, 2 trestles, and other materials sufficient for 185 feet of bridge. By combing the three ponton divisions a bridge about 510 feet long may be built. The ponton consists of a frame which is knocked down for transportation and assembled when needed. A canvas cover placed on the frame completes the ponton, which is 21 feet long, 5 feet 4 inches wide, and 2 feet 4 inches deep. The balks are 4½ inches by 4½ inches by 22 feet, except the trestle balks, which are 5 inches by 5 inches by 21 feet 8 inches. The chess are 1½ inches by 12 inches by 11 feet. The canvas pontons will not resist ice nor dirftwood, and they are liable to injury in handling on shore or in water containing snags. In spite of these disadvantages the light equipage makes a practicable and satisfactory bridge.

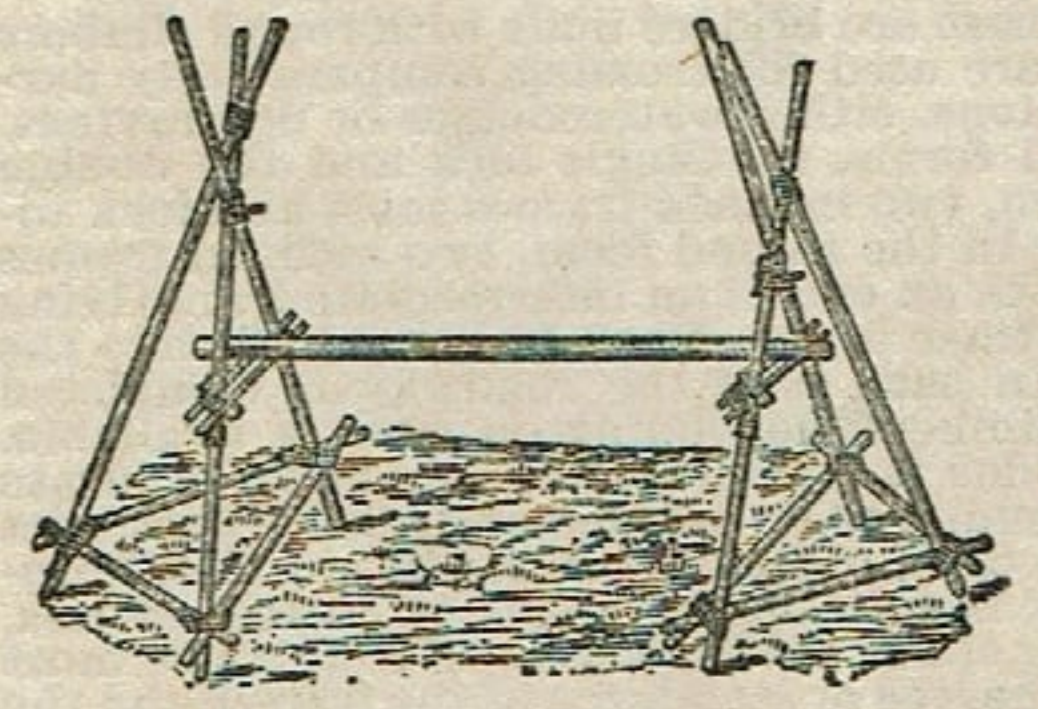
Standard Heavy Bridge—The bridge starts from a sill laid on the bank near the water's edge. If the water is too shallow for a ponton at 20 feet out from the sill, a trestle is used as the first support in the water. Additional trestles may be used if necessary and available. Pontons are then added to the bridge and are spaced 20 feet center to center. This is known as the construction by successive pontons and is the usual way of building the bridge. The bridge may be completed at the far side of the river with a trestle and a sill, or if there is deep water close to shore the trestle may be omitted. In a river with a moderate current each alternate ponton is anchored upstream and each fourth one is anchored downstream. Every ponton that has a downstream anchor must also have an upstream anchor.

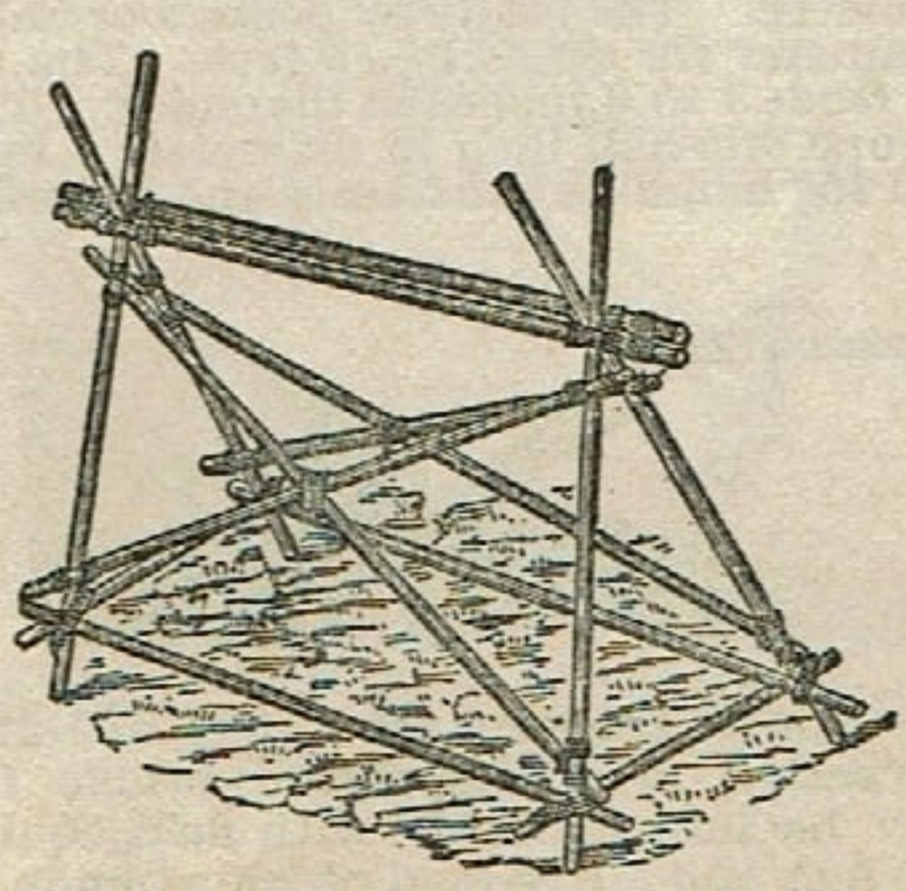
The normal heavy bridge will carry infantry in column of squads, cavalry in column of twos, or a concentrated load of 4,750 pounds. By increasing the equipage 25% and reducing the span between boats, the concentrated load may be increased to 6,700 pounds. By increasing the equipage 50% and further reducing the span, a concentrated load of 13,700 pounds may be carried. If there is a shortage of material, the interval between boats may be increased, in which case the capacity is reduced to a concentrated load of 3,400 pounds. The normal heavy bridge will carry the 3-inch field gun or the loaded escort wagon. It will carry the 1½-ton truck unloaded. If seven balk are used instead of five, it will carry this truck fully loaded, or the 4.7-inch gun, or the 3-ton truck unloaded. The 3-ton truck fully loaded can be carried only in case the equipage is increased 50% and the spans correspondingly reduced as mentioned above and then only if an additional or much heavier floor is laid over the balk. In no case should the concentrated load placed on the bridge exceed 13,700 pounds, and whenever it is desirable to pass a load in excess of the prescribed load for the bridge as built, the operation should be under the personal supervision of the engineer officer in charge of the bridge.

Standard Light Bridge—The bridge with the light equipage is built in the same way as the heavy bridge. The spans are shorter than in the normal heavy bridge, the pontons being

15 feet 6 inches center to center, or 10 feet 2 inches in the clear. The light bridge will carry infantry in column of squads, cavalry in column of twos, the 3-inch field gun, the loaded escort wagon, or the 1½-ton truck unloaded. Nothing is gained by increasing the quantity of light equipage in a given length of bridge, as the normal bridge will carry as great a load as the boats will safely support.







Weight of Troops—Some of the loads (in pounds per linear foot) to which military bridges may be subjected are as follows:

Infantry:	
Single file	140
Column of twos	280
Column of fours	560
Cavalry:	
Single file	196
Column of twos	392

Infantry in heavy marching order will average 200 pounds per man, and when unarmed 160 pounds. Infantry crowded in a disorganized mass may weigh as much as 133 pounds per square foot of standing room.

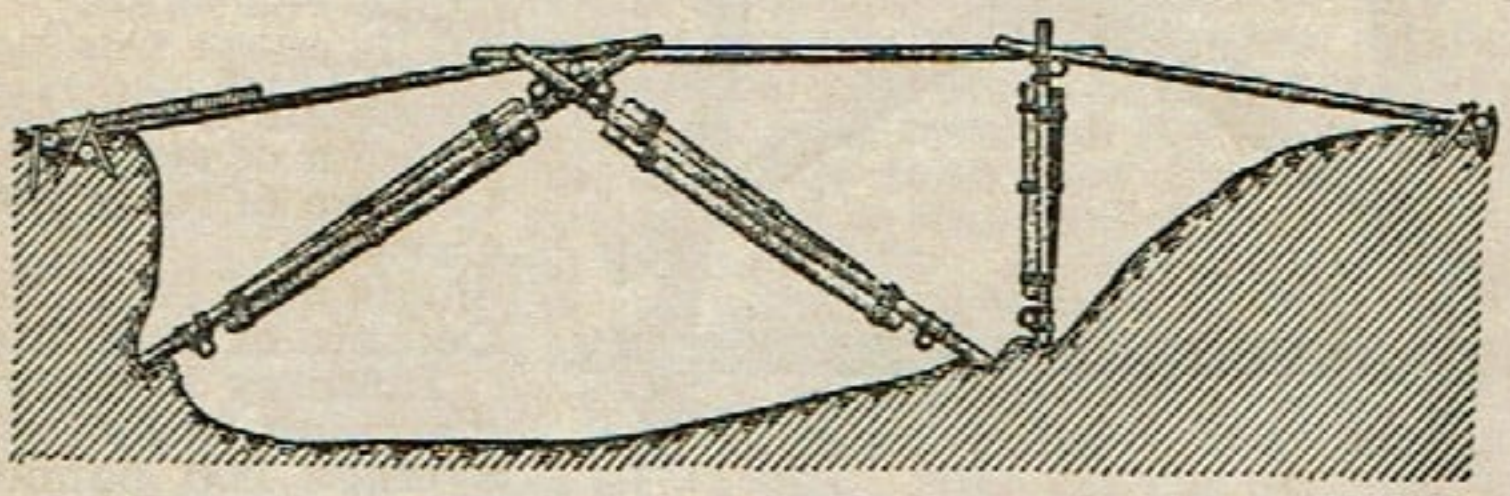
FIXED BRIDGES

Pile Bridges—Piles are posts driven into the ground, generally in a vertical position. They are driven in bents, usually of 3 or 4 piles each. If more than 10 feet high the bent should be strengthened with sway braces, which are diagonal planks spiked or bolted to the piles. The piles may be driven with a maul, or with a pile driver operated by hand or by machinery. The bent is completed by sawing off the piles at the same level and placing on them a heavy timber called a cap, which is fastened to each pile with a drift bolt. The roadway bearers are laid from bent to bent, preferably extending over two bents and breaking joints. The bearing power of a pile is given by the formula

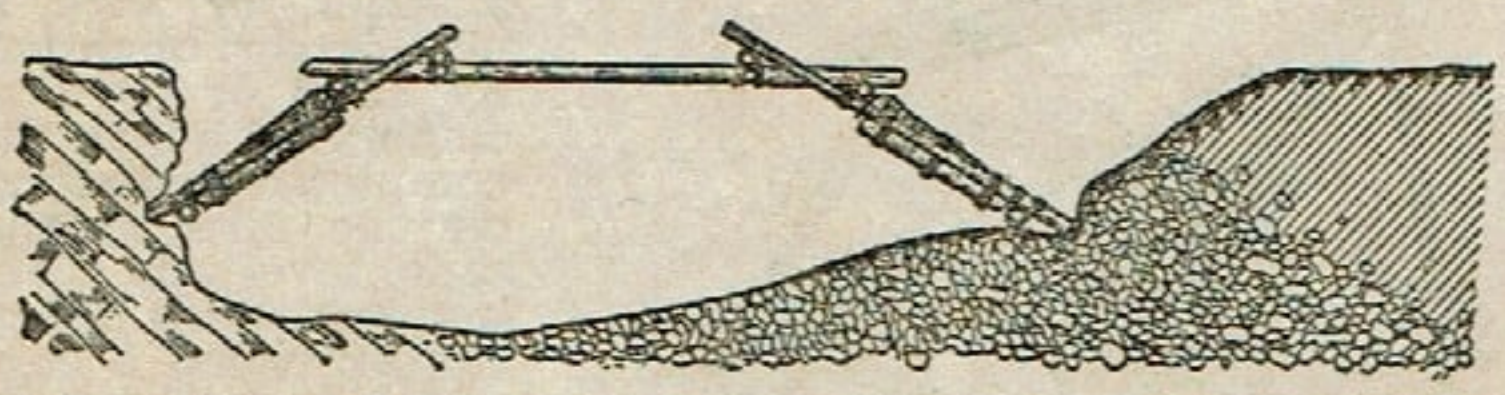
$$L = \frac{2wh}{s + 1}$$

in which
L is the safe load in pounds
w is the weight of the hammer in pounds
h is the fall of the hammer in feet (average of last few blows)
s is the penetration per blow in inches (average of last few blows).

Trestle Bridges—This type is applicable in a shallow stream with a firm bottom. Trestles may be framed of dimension lumber, or, as is more usual, they may be made of timber cut in the vicinity of the bridge. Types of trestles are illustrated. A bridge may be built with the trestles forming a part of the ponton equipage if the depth of the stream and the nature of the bottom are favorable. This is a two-legged trestle that may be quickly put together and launched in place from a ponton. Trestle bridges are dangerous in streams having a soft bottom and a swift current, as the bottom is liable to scour around the trestles, causing them to give way under a load.



Spar Bridges—These are bridges built with round timbers lashed together, and are used for crossing comparatively narrow and deep depressions, either watercourses or dry ravines. There are two general forms, the single lock and the double lock. In the first form, two inclined frames meet and lock together at their tops. In the second form, two inclined frames each meet and lock with an end of an intermediate frame lying horizontally between their tops. Each frame is built like the two-legged trestle. In each case the roadway is completed with round or sawn timbers, depending on what is available. In building a spar bridge it is important to make an accurate cross section of the opening to be bridged and also to construct the frames with great care, otherwise they will not lock properly. The single lock is suitable for spans of 30 feet or less, and the double lock for spans not exceeding 45 feet. The most important members, the legs or standards of the frames and the crosspieces or transoms that carry the roadway, should be timbers 8 to 10 inches in diameter. The roadway bearers or balks should be 6 inches in diameter for spans of 15 feet. The remaining timbers may be from 3 to 6 inches in diameter. The lashings are made with rope one-half inch in diameter; 1 inch diameter rope is required for handling the frames and lowering them into place.



Suspension Bridges—These are used for light loads and long spans. The construction of a suspension bridge for heavy traffic will usually be impracticable with field equipment. For a span of 150 feet and a live load of 200 pounds to the linear foot each main cable should consist of four ¾-inch steel wire ropes. The towers will usually have to be trees or timber trestles. The anchorages will be large stumps or bowlders, or ledge rock.

Cribwork Pier Bridges—Very satisfactory supports for a bridge may be made of cribs built up with logs or sawn timber. In dry locations the cribs are built in place; when the cribs are to go in water they are built on shore, launched and floated to position. Ballast is used to hold them in place. If the bottom is likely to be scoured by the current around the crib the crib should rest on a brush mattress covering the bottom. Railroad ties are good material for building small cribs.

MAINTENANCE AND CARE OF BRIDGES

A military bridge is placed under the charge of an engineer officer, with a detail of men to act as a guard. The officer has control of all movements across the bridge, and is responsible for its maintenance, repair, and protection. Special precautions are necessary in passing floating bridges. Infantry should break step; all riders and drivers dismount and all animals are led; halting on the bridge should be avoided, except when the bridge is found to be swaying, in which case the column should halt and wait till the bridge becomes steady. All movement across the bridge is at a walk; auto trucks are not to exceed 3 miles per hour. The bridge must be kept free of drift, either by guiding drifting objects through the bridge or by intercepting them above the bridge with booms or otherwise. The bridge may be built with a draw that can be removed to allow the passage of boats, large trees, or other floating matter.

USE OF EXISTING BRIDGE

An existing bridge may be found incapable of carrying military loads on account of weakness of original design, deterioration, or damage by the enemy. To determine whether an existing highway bridge can be used an examination should be made as to the condition of the abutments, the pile bents, trestles or other supports, the stringers, and the planking. Masonry abutments should show no disintegration of stone, and the mortar should be intact in the joints. Concrete should show no disintegration, displacement, or extensive cracking. Timber parts should be examined for decay, breaks, and extensive warping or cracking. Interior decay will be shown by the hollow sound noted when the timber is struck with a hammer and may be further investigated by driving nails or boring with an auger. Metal parts should be examined for rust, especially the rivets

and the threads of bolts and turnbuckles.

If the supports of the bridge are insufficient, the damaged or deteriorated parts may be replaced or additional pile bents or trestles may be built between those existing. Additional support may be obtained by introducing diagonals as suggested in the sketches in figures *a* to *c*. If timber is scarce and iron or steel rods are available, the method shown in figure *d* may be used. Another method is to build cribwork supports.

The strength of wooden stringers or roadway bearers may be judged from the formula for the strength of beams:

$$W = 1/3 \frac{bd^2}{l} \times C, \text{ in which—}$$

W is the concentrated safe load, in pounds. (If load is uniformly distributed, use two-thirds instead of one-third in formula.)
b is the breadth of the stringer, in inches.
d is the depth of the stringer, in inches.
C is a constant for the kind of timber used, which may be taken as 400 for ordinary timbers.
l is the span, in feet.

From this, having a given load and beam, we can determine the span that may be used: $l = \frac{1}{3} bd^2 \times C$.

For light artillery and wagons, bd^2 must equal or be greater than 15 × span, in feet.

For the 4.7-inch heavy field gun, bd^2 must equal or be greater than 30 × span, in feet.

The following table is useful in determining the sizes of round and rectangular stringers and corresponding maximum safe spans:

Round	Rectangular	Maximum safe spans in feet for 4 or more balks	
D.	b x d	Wagons and light artillery	Siege artillery
Inches	Inches		
5	2 x 6	4.8	.....
6	8	11.2	5.6
7	10	12.6	6.6
.....	12	15.6	9.6
.....	3 x 6	7.2	3.6
8	8	12.6	6.4
.....	10	16.0	10.0
9	12	20.4	14.4
.....	4 x 6	9.6	4.8
.....	8	14.5	8.5
.....	10	19.3	13.3
.....	12	25.2	17.6
.....	6 x 6	13.2	7.2
.....	8	18.8	12.8
10	10	26.0	18.0
.....	12	34.8	22.4
.....	8 x 8	23.0	16.5
11	10	32.5	21.2
.....	12	44.4	27.2
12	10 x 10	39.3	24.6
.....	12	52.0	32.0

For flooring a useful rule is that the thickness of the plank in inches should be at least equal to the distance apart of the stringers in feet.

The strength of steel stringers may be judged from the formula: $W = \frac{d^2}{10l}$ in which W is the concentrated safe load in pound; *d* is the depth of the stringer in inches; and *l* is the span in feet. From this having a given load and beam we can determine the span that may be used: $l = \frac{d^2.}{10w}$ For

light artillery and wagons, d^2 must equal or be greater than 1.5 × span in feet. For the 4.7-inch heavy field gun, d^2 must equal or be greater than 3 × span in feet.

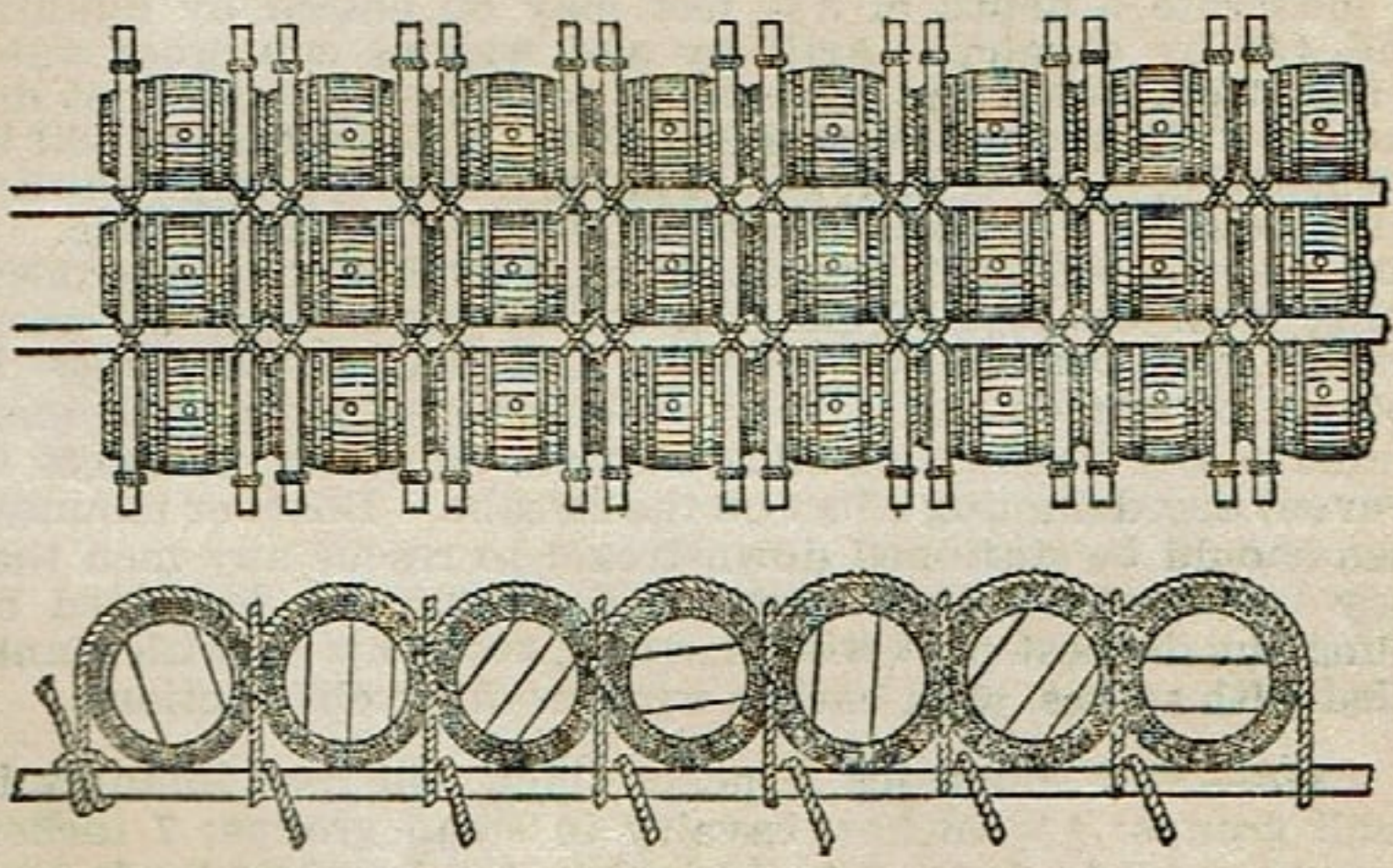
BRIDGING EXPEDIENTS

Boats—Ordinary boats may be used instead of pontons to support a floating bridge. They should, if possible, be of the same size and must have the necessary strength and stiffness. If a boat is not of sufficiently strong construction to permit the load to be applied directly to the gunwales, a transom may be placed lengthwise in the middle of the boat and so supported as to transmit the load to the keel.

Barges—In many rivers barges of various sizes and types will be found. The most useful are the decked barges, 50 to 100 feet in length and 20 to 30 feet in width. Small barges may be used as pontons; larger ones may be placed with their length crosswise of the stream so as to form part of the roadway of a bridge. When used in the latter position the barges must have especially secure anchorages, on account of the large area exposed to the current. Barges are useful in connection with ferriage operations,

Casks—When casks or barrels are available, they may be used to form supports for a floating bridge. Methods of assembling by means of timbers and lashings are shown. The casks should be placed with the bungs uppermost. An ordinary 50-gallon barrel has a buoyancy of about 400 pounds when completely submerged; the buoyancy of other sizes is in proportion to their capacity. In calculations a margin of 20 to 25% should be allowed, as it is not desirable that the barrels shall be completely submerged.

Rafts—Rafts are used when bridge material is lacking or is insufficient to span the stream, or when it is necessary to transport loads that are beyond the capacity of the bridge material. Excellent rafts may be made with the heavy pontons, balk, and chess. They may also be made with the canvas pontons or other boats, with casks or barrels, timber,



inflated skins, oil cans, wagon bodies covered with tarpaulins, or tarpaulins stuffed with hay. The essential features are two or more floating parts giving the necessary buoyancy, a framework placed above the floating parts and holding them together, and a floor on which the load can be placed. The raft is moved across the stream by rowing, poling, or pulling with a rope. Under favorable conditions the capacity of a raft made of heavy ponton equipage may be taken as 10,000 pounds for each ponton used.

Log rafts are best constructed in the water if possible. Arrange the logs side by side to form a point up stream; the upstream ends should be beveled on the lower side. The logs are held together by cross timbers pinned or spiked over the tops. Where the logs are of small size additional sticks may be placed in the intervals between the others, or two or more courses may be built up, the logs of each layer at right angles to those below. Log rafts may be used for floating piers when other materials are not at hand. They are durable if not disturbed and secure against being sunk by hostile fire.

Rafts are employed when the passage of a river is to be forced, and when the rafts can be constructed unobserved by the enemy, in which case the pontoniers will be exposed to fire but a short time; that is, while the rafts are floating into position and being connected. There should be, at a reasonable distance above the bridge, positions where the rafts can be constructed undisturbed by the enemy. Such positions would be afforded by islands or tributaries.

Ferries—The simplest method of moving troops across a stream is to take them across in boats. Use may be made of wooden or canvas pontons, ordinary boats, barges, or rafts. A ferry may be operated by stretching a cable across the river and pulling the boat by hand along the cable. Another method is to use a long rope fastened to a point upstream, either on the bank or to an island or anchor in midstream, and navigate the boat back and forth by utilizing the force of the current acting obliquely on the boat. This is called a flying ferry. The wooden ponton will carry 40 infantrymen armed and fully equipped, in addition to the crew, under favorable conditions. In rough water or swift currents the load should be reduced to 20 men besides the crew. The normal load of the canvas ponton is 20 men and crew; this should be reduced for unfavorable conditions.

Fords—Fords may be used by small bodies of troops without bridge equipage, but they are unreliable crossings and are generally unsatisfactory for large bodies. If the current is moderate a depth of 3½ feet may be passed by infantry and 4½ by cavalry. Artillery and wagons can cross water 3 feet deep, but if the contents of wagons are to be kept dry the depth should not exceed 2½ feet. The bottom should be even, hard, and tenacious. The presence of large stones, mud, or sand will make fording difficult or impracticable. A ford may be rendered impassible by a freshet or by the deepening from the loss of material stirred up and carried away during the passage of troops. Infantry should cross in column of squads and cavalry in column of twos. All men, animals, and vehicles should maintain sufficient distances to prevent any damming effect on the stream. Boats or mounted men should be stationed downstream to rescue any men that may be swept off their feet. A ford may be destroyed by filling the deepest part with harrows, teeth up, or with planks filled with spikes with barbed wire, or other obstructions.

Ice—New sound ice 3 inches thick will bear infantry in small groups; 4½ inches, cavalry in small groups; 7 inches, wagons and field guns; 9 to 12 inches, the heaviest loads with an army. Planks laid for the wheels will enable vehicles to cross on ice that otherwise would not bear them. A light coating of sand, earth, cinders, or straw will improve the foothold for men and animals. An officer should have charge of the crossing and the movement should be made with great care; crowding must be especially avoided.