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TITLE: THE DEVELOPMENT OF HEAVY FLOATING BRIDGES

SCOPE: A brief historical account of the development of tactical, heavy, floating bridges to include the Rhine crossing in March, 1945, and its influence on subsequent ponton equipment.

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# THE DEVELOPMENT OF HEAVY FLOATING MILITARY BRIDGES

## INTRODUCTION

Military bridges are portable, temporary structures designed to meet the load requirements of troops with their armament, equipment and supplies, and erected to facilitate their movements in field operations. In this study, we shall be concerned only with that type used in the crossing of water obstacles, of which the river is the principal example, and that depends for its support either in whole or in part on the buoyancy of floats or pontons. In this category, only the heavier type with maximum load supporting ability will be considered. However, it should be kept in mind that a flexible structure, capable of being adapted to the maximum range of loadings, is one of the principal requirements. The structural difference between the company foot bridge and the army vehicular bridge should be merely in the number and arrangement of the components.

Though the distinction between a tactical and a nontactical bridge is not a sharp one, so much so that the semitactical type is also recognised, it is further intended to limit these remarks to the tactical type of structure where speed of movement, assembly of parts, and erection with minimum essential equipment under battle conditions are prime requirements.

The floating Bailey bridge is regarded as a semitactical type since it requires considerable more time to construct than either the heavy ponton or the treadway float equipment, the latter taking less than half the time needed to build the Bailey structure.

It is theoretically essential that the construction of a bridge follow the seizure of the second objective in the bridgehead operation which will eliminate ground observed artillery fire from the selected site, in addition to effective small arms fire which is presumed to be removed upon capture of the initial objective. The early urgent requirements for the forward displacement of armor and supporting artillery in a coordinated attack beyond the far shore, on the other hand, frequently lead in practice to the initiation of construction well in advance of the capture of the first two bridgehead objectives. Since time is of such tremendous advantage in consolidating the bridgehead before enemy reserves can be assembled for a counterattack, the tactical conditions under which the bridge may be required to be constructed merit particular attention in the design of floating structures.

The development of floating bridges since the advent of motorized vehicles has become like reconnaissance a continuous requirement. Prior to the advent of the heavier loads of modern wheel and track vehicles, floating bridge equipment changed slowly. It was not until after the experiences of the First World War that the heavy bridge train, Model 1869, developed during and after the Civil War, was superseded by the Ponton Bridge, 23-ton, Model 1924. The model 1869 bridge had a normal capacity of 2½ tons of gross load which was sufficient to accomodate the loaded escort wagon. Rapid progress of necessity followed as increasingly heavier loads were introduced in an accelerated period of development as shown in the chart of load capacity of heavy floating bridges on page 15 in the appendix.

## BRIDGE REQUIREMENTS

In order to evaluate progressive steps in the development of floating equipage and to use the experience of the past to assist in the solution of present problems, it is desirable to review the characteristics of a serviceable bridge. Commencing with general features and a study of how requirements have been met, it is proposed to develop the definite requisites of the present and the indications of future demands. Since a healthy discontent with present limitations is one of the best ways to escape the pitfall of complacency, our present progress, like that of the past, should be considered a stepping stone to future improvements. For this reason, the emphasis should be on continuous effort to overcome our present shortcomings and anticipate future trends.

A bridge must have the required capacity which will expediently accomodate loadings of the weight, size and type employed in the unit for which the structure is designed in average stream velocities.

It should be light in weight as a whole to keep transportation loads at a minimum, and in its component parts to permit erection by manpower as an alternate method. High strength and light weight alloys should be utilized to the fullest extent. The size of individual members should permit them to be readily transported in standard vehicles and trailers as mobile units. Rapid and simple erection is required if the equipage is to serve its purpose of permitting tanks and mobile heavy weapons to closely support the assault waves. It should be flexible, insuring an economy of material and efford through use of component parts for rafts and lighter load structures capable of conversion to the heaviest type bridge. Damaged parts should be easily replaceable. The design should permit removal of floating bays for passage of river traffic and debris, and shore connections should provide adequately for water level fluctuations.

Maintenance should be facilitated by a durable structure.

The bridge must be resistant to enemy action or stream irregularities including high velocities and debris. Briefly summarizing, the desirable bridge should have the following characteristics:

1. Strong
2. Light
3. Mobile
4. Simple
5. Flexible
6. Durable
7. Invulnerable
8. Stable

## EARLY HISTORY

Modern ponton bridges are a development of the ancient bridge of boats. The most important of the earliest structures of this type were the two bridges of Xerxes built over the Hellespont in 480 B.C. by his Egyptian and Phoenician engineers. According to the historian, Herodotus, these structures were about three quarters of a mile in length. Buoyancy was provided by triremes and pentecontors placed alternately side by side, lashed together and anchored, except where the pentecenter was omitted to permit waterborne traffic to pass. Six cables, two of flax and four of papyrus were stretched from shore to shore across the row of boats. These cables, with their ends well anchored, supported a heavy plank floor which, in turn, was covered with brush and topped with a thick layer of earth to form a hard, smooth roadway. This bridging operation, though unopposed and non-tactical, was a complete success. In the course of a week, the two bridges were reported to have carried without accident a military force of more than three and a half million men and many thousands of camp followers, horses, elephants, camels and mules.

The first historical use of ponton trains was made by Alexander of Macedonia in the crossing of the Hydaspes River against Porus about 327 B.C. in his India campaign. While no floating bridge was constructed in this crossing, it is significant that the pontons were cut in half for transportation by carts, moved to the river up-stream from the guarded banks where the halves were joined and used for ferrying.

Military engineering was further developed by the Romans, particularly by Julius Caesar who placed great emphasis on the engineer training of his army which contained the first distinct trace of an engineer corps. By the time of Julian's campaigns against the Germans from 357 to 361 A.D., the Roman army was equipped with light ponton bridging including boats consisting of a wooden frame covered with a leather skin. By the seventeenth century, the French and Dutch were using similar type pontons in their bridge trains, but utilized tin and copper, respectively, for the covering. In our Light Ponton Bridge, 7½ ton, Model 1926, an aluminum skin was first used over a duralumin frame. In the middle of the eighteenth century, the Russians developed a collapsible ponton of tarpaulin stretched over a wooden frame which was dismantled for transportation. In 1853, the French adopted a flat bottom wooden boat as their standard ponton. In 1861, at the start of the Civil War, the engineer floating equipage consisted of about 160 boats of the French model with the necessary balk (stringers), chess (flooring), anchors and cordage; and a number of trestles and Russian canvas boats, according to General J. G. Barnard's report on engineer operations in the Peninsular Campaign.

Prior to the introduction of the French and Russian types it is interesting to note that in 1846, ponton equipage utilizing inflated rubberized canvas floats was adopted and furnished to Generals Scott and Taylor for operations against Mexico. The floats, consisting of three rubber connected cylinders were about 20 feet long and five feet wide. Each cylinder was divided into three compartments, each being furnished with an inflating nozzle.

Though the equipage arrived too late to be of any real service in the war, it was standard equipment until 1858. By this time, the sulphur used in vulcanizing the rubber had formed sulphuric acid which destroyed the canvas. Damage by wear and gravelly beaches, vulnerability to rifle fire, and oscillation enough to render the bridge unsafe for the passage of animals were the principal defects attributed to this type of float.

## MODERN DEVELOPMENT

The first important change in heavy floating equipage from the Civil War type was the 23-ton ponton bridge, Model 1924. A steel trestle was used to accommodate changes in water level, which consisted of a steel latticed girder transom, columns of steel tubing, steel shoes and chain hoists for adjusting the transom on the columns. The river end of the hinge span was supported by a hinge sill suspended transversely between the first and second boats instead of directly on the first boat as in the old model. This model provided a stronger trestle and distributed the load on the hinge span raft. The size of balk, chess, sills, and pontons were increased to take the heavier loads. Through the use of rigid metal balk fasteners which replaced the rope lashings on the former model, a considerable amount of continuous beam action was introduced so that as many as five pontons assisted in providing buoyancy.

In 1938, the 25-ton ponton was adopted. In this model, the wooden ponton weighing approximately 4000 pounds was replaced by the aluminum type, followed later by a steel one, owing to the use of the lighter metal in the airplane industry. The aluminum ponton weighs 2600 pounds and the steel type 4200 pounds. The ability of a light metal to reduce weight was clearly demonstrated in this model. The steel type was too heavy to be lifted and carried about readily by hand though this means could be used. A three-boat hinge sill raft was used to receive the load coming on to the floating section of the bridge from the trestle. This bridge continued as the standard ponton type until replacement by the M 4 bridge after World War II.

A distinct change in type of equipment occurred in 1942 with the introduction of the steel treadway bridge designed to furnish a rapid means of stream crossing for vehicles of the armored force. It consists of pneumatic floats supporting a pair of steel treadways rigidly joined end to end to form a continuous set of tracks. When shallow banks or shoals prevent the use of floats, the steel treadways can be supported on 25-ton trestles. The M 1 model was superseded in 1943 by the M 2 model with a wider track, greater clear width between outer curbs and rubber floats with increased buoyancy.

In addition to transporting the bridge equipment, bridge construction trucks are equipped with a hydraulic crane which can lift two treadways from the truck and place them in position on a float in a single operation. Three lengths of single track or two lengths of double track may be raised into position after first unloading and then connecting the treadway sections.

## LESSONS FROM THE RHINE RIVER CROSSING

Based on the number of personnel engaged and the quantity of equipment utilized, the assault crossing of the Rhine River was the largest military operation of this type in history. Study of an undertaking of this magnitude and importance should reveal much information of value in the future development of heavy floating equipage.

Perhaps the most significant lesson of the operation is the influence of the current velocity on the capacity of the bridge. A study of the characteristics of the Rhine flow showed that during floods the river has velocities as high as 12 feet per second in the upper reach and eight to nine feet per second in the lower reach below Mannheim except in the gorge sections. Since currents over seven feet per second seriously reduce the capacity of floating equipage, this condition created an important problem. In particular, it was planned to reinforce the 25-ton ponton bridge to carry class 40 loads but the damming effect of pontons, in addition to their shortage, led to reinforcement with rubber floats for class 36 capacity. Tests showed that bow adapters were helpful in streamlining the blunt ends of pontons and they were manufactured and used on the upstream bows. The need for special anchorage and booms was also demonstrated.

The value of armor and heavy weapons in the close support of the assault waves led time and again to the construction of bridges while the enemy still had observation and small arms and artillery fire on the bridge and assembly sites. From experiences on the

Rhine, as well as other river crossing operations, such a condition must be considered the rule rather than the exception.

The M 2 treadway bridge at Milchplatz was completed on D $\neq$ 2, with light artillery fire still falling, after delays caused by the collision of three LCM's with the bridge and the destruction of seven floats by artillery fire. Assisting the engineers under these conditions, however, were air cover, antiaircraft and ground target artillery, antitank guns, tank destroyers, river patrols with demolition charges, searchlight batteries, smoke generators, barrage balloons and an underwater listening device.

The treadway is perhaps slightly more vulnerable than the heavy ponton type. Since the balk and chess of the latter float, their equipment can be salvaged and the damaged pontons replaced. On the other hand, the steel treadways are sunk with the destruction of the rubber floats and separation of that section of bridge. This deficiency of the treadway, however, is more than made up by the ease of float transportation and the speed of erection which made it the best tactical bridge used in Europe. Table I, page 16, lists data on the length, time of erection, and average speed of erection in feet per hour of several bridges of each type.

In general, the loads required to be moved over the Rhine tactical bridges reached or exceeded the capacity of the equipment in swift water. The M 26 tank with a weight class of 40 tons was successfully crossed on the reinforced 25-ton ponton bridge at slow speeds with a ponton freeboard reduced to four inches and a few balk being cracked. Fully reinforced with metal pontons, this bridge is capable of carrying only a safe load of 30 tons with restricted movement in a stream velocity of 7 feet per second. Though the deck can accommodate the present heavy tank, it was found desirable to lay wear treads for protection against the steel tracks.

It was necessary to modify the M 2 treadway to pass the M 26 tank by spreading the steel treadways 24 inches further apart with I-beam spacers to provide an eight inch clearance on each side for the tanks total track width of 138 inches. A plywood treadway laid between the steel treadways accommodated narrower vehicles.

## PRESENT DEVELOPMENTS

In 1945, the M 4 bridge was adopted which replaced the 25-ton ponton model, but does not embody all of the desirable characteristics of the treadway. The deck is formed of hollow aluminum alloy deck balk which serve as both stringers and flooring. The balk being buoyant preserves the flotation characteristic of the wooden type in addition to providing increased strength. The balk can be used as floats and decking for a foot bridge, or for bridging short ditch spans. A light load can be put across the M 4 bridge with a ponton knocked out.

The floating spans are supported on streamlined nestable half-pontons of aluminum alloy fastened stern to stern to form a whole ponton and spaced 15 feet center to center. For 25-ton loads only the half-boat need be used, an additional half-boat being added later when the need for increased capacity develops. In a like manner, damaged pontons may be readily replaced by half-boats. As a result of model studies of streamlining requirements, the ponton "nests" in a high velocity current so well that while the water may be higher than the gunwale, none enters the boat. Improved streamlining has also minimized the problem of debris in high velocities. With currents of 10 feet per second, or greater, a 100 percent reinforced bridge will pass debris beneath the pontons.

Continuous deck connections are used when possible between shore pontons and abutments, but where high banks or variations in river stage require them, trestle bays are available.

The M 4 bridge can be utilized as a floating or fixed bridge, a combination of both, or as a raft. In a five foot per second current with a 20-balk deck measuring 15 feet in width, it will carry a class 60-ton load. The capacity can be increased to 100 tons through reinforcement with the same stream velocity, and to an estimated 75 tons in a current of nine feet per second.

Under favorable conditions, the floating bridge M 4 has been erected from transportation at the rate of about 125 feet per hour when no trestles were used. Under similar conditions, the treadway bridge can be constructed at the rate of about 170 feet per hour.

Pneumatic floats with saddle adapters designed for use with aluminum deck balk are utilized in the M 4 bridge for sites on soft or swampy ground where adequate support for trestles does not exist, and on long shelving beaches where pontons may be grounded.

## CONCLUSIONS

In the floating bridge M 4, many changes in design have improved the operating characteristics found deficient in the equipage of World War II. The progress made to date is indicative of further successful developments at a rate which should keep well ahead of future requirements.

Reviewing our bridge requirements, we must have a structure that will carry the present division loads and any forseeable future ones. While the M 4 bridge has adequate capacity for present needs, the way for increased loading is open through the use of a three-section ponton with a square-end center section to which the outer half-boats may be fastened.

The accelerated advances in metallurgy during the war and the enormously increased productive capacity of aluminum and its alloys have served and should contine to provide increased strength of bridging material without excessive increase in weight. While the M 2 treadway has a weight in pounds per linear foot of only 460 as compared to the M 4 floating bridge with value of 550, the weight per linear feet per ton capacity is 10.0 for the former and 9.2 for the latter.

As previously pointed out, the treadway type constructed with the use of the bridge truck continues to be the more mobile of the present bridges due to space requirements for transportation and lighter weight. Single unit truck transportation such as is used for the treadway type is desirable over the trailer form of transportation used for the M 4 pontons. Lighter weight of parts and less of them make the treadway bridge easier to construct than the

M 4. The elimination of chess as used in the 25-ton ponton bridge is a progressive step in simplification, and further progress may be expected.

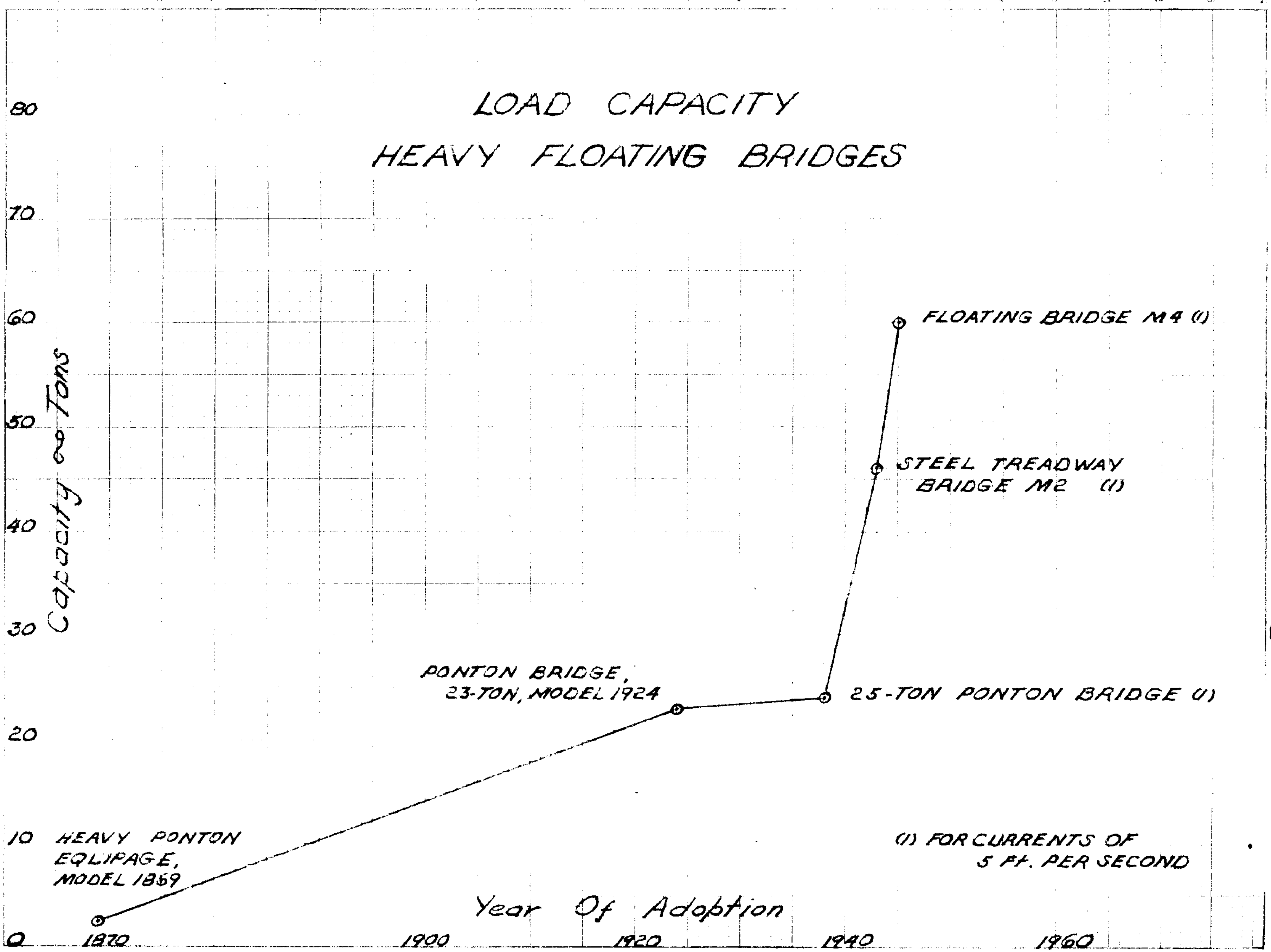
Flexibility has been improved considerably in the M 4 type which permits increased load capacity by additions to the bridge in the water of boat sections. Through the addition of deck balk as needed, the required deck space to accomodate vehicles of varying width may be readily obtained.

It is believed that the M 4 type has resulted in improved durability. The metal deck has removed the need of floor treads required with the 25-ton type.

Due to the ease of removal of boat sections and the buoyancy of pontons and balk, the M 4 type is less vulnerable to enemy action. The use of metal in place of wood or rubber has decreased its weakness to incendiary attack.

Streamlining has produced a bridge in the M 4 type which is more stable, particularly in rapid currents, than any type which we have previously employed.

Much development and testing are still needed, including use under cold and tropical conditions, and ground and air transportability studies. The goal is an all-purpose type of structure embodying the inherent advantages of the best type of single purpose bridge under all foreseeable conditions.


LOAD CAPACITY
HEAVY FLOATING BRIDGES
Capacity ~ Tons
80
70
60
50
40
30
20
10
0
Year Of Adoption
1870
1900
1920
1940
1960
HEAVY PONTON EQUIPAGE, MODEL 1869
PONTON BRIDGE, 23-TON, MODEL 1924
25-TON PONTON BRIDGE (1)
STEEL TREADWAY BRIDGE M2 (1)
FLOATING BRIDGE M4 (1)
(1) FOR CURRENTS OF 5 Ft. PER SECOND

## TABLE I

## RATE OF CONSTRUCTION - RHINE RIVER BRIDGES

### 25-TON PONTON BRIDGE

| LOCATION | CLASS | LENGTH (Feet) | TIME OF CONSTRUCTION (Hours) | RATE OF CONSTRUCTION (Feet/Hour) | REMARKS |
|---|---|---|---|---|---|
| Wallach | 40 | 1150 | 19 | 47 | Delayed by work on far approach and placing treads. |
| Wesel | 36 | 1230 | 22 3/4 | 54 | Float reinforced. Pierced steel planking used for treads. Bow adapters on up stream bows. |
| Kripp | 40 | 969 | 30 1/2 | 32 | |
| Königswinter | — | 1170 | 18.2 | 64 | |
| Orsoy | 40 | 1080 | 54 | 20 | |

### TREADWAY BRIDGE

| LOCATION | CLASS | LENGTH (Feet) | TIME OF CONSTRUCTION (Hours) | RATE OF CONSTRUCTION (Feet/Hour) | REMARKS |
|---|---|---|---|---|---|
| Milchplatz | 40 | 1260 | 56 3/4 | 13 | Seven floats knocked out by artillery fire. Light artillery fire still falling when completed. |
| Mehrum | 40 | 1110 | 26 | 43 | 144 feet of bridge destroyed by artillery fire during construction. |
| Wallach | 40 | 1150 | 9 | 128 | Intermittent artillery fire interfered with construction. |
| Wesel | 40 | 1284 | 13 | 99 | |
| Remagen | 40 | 1030 | 33 1/2 | 31 | Nearly continuous heavy artillery shelling. |
| Honnef | 40 | 1176 | 37 1/2 | 31 | |
| Romerset | 40 | 1308 | 11.8 | 110 | |
| Hönningen | 40 | 1368 | 12 | 114 | |

| LOCATION | CLASS | LENGTH (Feet) | TIME OF CONSTRUCTION (Hours) | RATE OF CONSTRUCTION (Feet/Hour) | REMARKS |
|---|---|---|---|---|---|
| Mainz | 40 | 1896 | 24 | 79 | |
| Oppenheim | 40 | 972 | 11 1/2 | 85 | |
| Oppenheim | 40 | 1116 | 20 | 56 | |
| Boppard | 40 | 1044 | 25 1/2 | 41 | Rapid Current. |
| St. Goar | 40 | 828 | 36 | 23 | Rapid Current. |

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