The Bailey: The Amazing, All-Purpose Bridge

by Larry D. Roberts

World War II was the first great war of mobility. Motorized and mechanized armies covered hundreds of miles in large-scale offenses and counteroffenses. In those theaters with rugged terrain or numerous river systems, combat engineers built thousands of temporary and semipermanent bridges to maintain the momentum of the battle and ensure the logistical support of the fighting forces. For the Allied nations, the Bailey bridge provided a degree of versatility and utility unparalleled in combat engineering. Soldiers of all Allied nations used the Bailey in every theater of the war.

In the first year of the European war, British engineers were faced with the problem of inadequate bridging for certain armored equipment. The heaviest class of bridge could carry 19 tons, but the Matilda tank, fielded in 1939, weighed 23 tons. The first reaction was to modify existing material to accommodate the increased load requirements. Engineers modified the box girder and ponton bridges to take a 24-ton load. In a short time, improved Matildas exceeded that limit by 2 tons. However, engineers believed that the existing material could handle the 26-ton requirement. The advent of the Churchill, a tank of approximately 40 tons, was too much. The British were forced to return to the drawing board.

Donald Coleman Bailey, chief designer at the British Experimental Bridging Establishment, had toyed with the idea of a bridge built out of truss panels, rather than box girders. One day, after the failure of a new piece of equipment during testing, Bailey and his associates discussed his idea, sketching the panels on the back of an envelope. The idea seemed to have sufficient merit, and Bailey and his colleagues received permission to proceed with further testing. From the beginning, the project was a team effort. Major H.A.T. Jarrett–Kerr, Royal Engineers, did much of the detailed work on Bailey's design. Ralph Freeman, the designer of the Sidney Harbour bridge, also contributed.

The engineers decided that in designing and producing a new bridge they had the opportunity to correct many of the problems which had plagued similar projects in the past. To this end, they developed a set of criteria for the new bridge. First, the girder and deck system had to be capable of being strengthened at will and in place. This would allow flexibility in handling various vehicles. Second, all parts had to be made of readily available materials. Special steels were sometimes impossible to acquire during the war. Third, any engineering firm had to be capable of building the bridge. In the past some of the designs were so complex that only a few companies were able to produce the material. Similarly, close manufacturing tolerances would be avoided if possible. This would also simplify production by a variety of companies.

British floating Bailey bridge on Mark VI pontons. *(Engineer School Library)*

The engineers considered the realities of field use as well. They wanted the bridge to be transportable in the standard 3-ton lorry. Special purpose transportation vehicles compounded the problem of movement, maintenance, and supply. To eliminate the need for construction cranes and hoists, no part of the bridge would be heavier than a six-man load. In order to facilitate launching, the designers specified that the underside of the girders were to be kept smooth. A smooth under surface would also allow engineers to use the Bailey on pontons.

The bridge that finally emerged met virtually all of the designers' specifications. The central piece of the bridge was the Bailey panel. This was a welded truss, with vertical and diagonal supports, 10 feet long by 5 feet high. Each panel weighed 600 pounds. Panels were attached end to end with pins creating a multiple truss girder. The panels could be stacked three high and placed side by side. This resulted in such variations as the double-double Bailey (two panels side by side and two panels high) and the double-triple Bailey (two panels wide and three panels high). This meant that bridge components could be added to increase the load capacity of the bridge. For example, a single-single Bailey spanning 100 feet could support a 10-ton load. A double-single across the same span could support 28 tons. A 100-foot triple-single bridge could handle 45 tons, and a similar span double-double Bailey could support loads safely at 75 tons. In addition, the panels saved up to 40 percent in transportation space, were easy to handle, provided flexibility in construction, and were adaptable to float bridges.

The floor system of the Bailey was conventional. It consisted of floor beams placed at 5-foot intervals, with steel stringers, wood flooring, and wood ribands (curves). In time, steel ribands replaced the wooden material because tank tracks damaged the wooden components. The floor beams or transoms could be doubled, giving reinforcement to the floor. This also allowed construction of a two-lane bridge where the center girder was larger than those on the outside of the traffic lanes.

In a comparatively short time, a bridge was available for testing, and designers decided to load the structure to failure to determine its actual capabilities. Some of the loading techniques were unusual to say the least. On one occasion, a World War I vintage tank was placed on the center of the span. A timber platform was built on top of the tank, and by means of a ramp, two more old tanks were "poised" on top of the first. The lower tank was then filled with pig iron, and several additional tons of material were placed on the span wherever there was room. The bridge held. Engineers ultimately loaded the bridge to failure, the top cord of the center panels finally buckling. These failure tests did produce tables which units could use in deciding what form of Bailey they were to build for a given situation.

The sense of urgency which dominated the design team and the cooperation it received from the British manufacturing establishment resulted in one of the shortest design-to-production periods of the war. It generally took a full year during the war for material to get from the drawing board to troops; however, design and production of the bridge proceeded concurrently and a pilot model was ready for test in less than five months. Production was under way in approximately seven months, and troops began receiving the bridge three months later. Therefore, by December 1941, British combat engineers had solved their problems of bridging for the new armored vehicles. By the time American engineers began wrestling with new bridge requirements for their growing armored forces, British combat engineer units had confirmed the value of the Bailey in actual operations.

The American side of the Bailey bridge story began in May 1940 when the U.S. Army's Ordnance Department announced that the existing 15-ton medium tank was obsolete. Ordnance plans called for a newer medium tank of 25 tons and a heavy tank of 50 to 60 tons. Like the British, the American engineers' first response was to modify existing

Engineers lift the bascule span of a class 70 Bailey bridge.
(Engineer School Library)

equipment to the extent possible. Ponton boats could be enlarged; the H–10 and the H–20 fixed bridges could be strengthened by adding girders and shortening spans; but these solutions tended to add weight and material to the bridge train. In addition, it would take longer to build the heavy girder bridges such as the H–10 and the H–20. The advent of pneumatic floats solved some of the problem of weight and transportation. These floats were lighter and more easily moved than the ponton boats; however, there was no corresponding easy solution for fixed bridging.

In early 1941, the Chief of Engineers directed the Engineer Board, the Corps research and development organization, to investigate heavier bridging, both fixed and floating. One project involved the design of H–30 and H–50 bridging which would ultimately support 30- and 50-ton tank loads across a 150-foot span. In August 1941, the Chief of Engineers also directed the Engineer Board to investigate the "modification of the British Bailey Panel Bridge to fit standard U.S. sections."

Engineers working on the now formally designated Project SP 341, Portable Steel Bridges for Heavy Loads, considered five factors. Bridge types to be adopted would be held to a minimum, not more than two, preferably one. Weight was to be held to a practicable minimum. The design should involve maximum simplicity of construction and provide for a clear span of 150 feet. Finally, the bridge material should be transportable on standard military vehicles. Much like the British team which developed the Bailey, American engineers were concerned with simplicity, weight, and transportability. Several existing American bridges met one or two of these criteria, but none met all of the requirements.

Because the staff of the Engineer Board's Bridge Branch was already overtaxed, the board decided to assign the design requirement for "a bridge of the Bailey type" to the engineering firm of Sverdrup and Parcel of St. Louis, Missouri. The civilian engineers were to modify the Bailey design to compensate for the differences in British and American rolling mill techniques. Aware of the potential benefits of having a bridge whose components were totally interchangeable with the British bridge, the board was sensitive to any unnecessary design changes. When Sverdrup and Parcel submitted designs which made minor alterations in the floor system, the board told them to rework the design to comply with the British bridge.

After receiving a modified set of plans, the Engineer Board requested and received permission to procure a sample bridge for test and evaluation. The Commercial Shearing and Stamping Company of Youngstown, Ohio, received the contract for the first Bailey. A short time later, the contract was revised to include parts needed to adapt the Bailey for float bridge operations. The Carnegie–Illinois Steel Company of Pittsburgh, Pennsylvania, rolled the plates and shapes for the bridge. These initial contractors faced the two-fold problem of securing sufficient high-tensile steel for the bridge and developing the welding techniques for fabricating the panel trusses themselves. There was a great amount of discussion between the American contractors and their British counterparts. This exchange of information helped eliminate or prevent problems in the American manufacturing process.

The British approached the manufacturing of the Bailey differently than the Americans. In the United Kingdom, more than 600 firms manufactured parts of the bridge. A central depot assembled the major end items of the bridge and its assorted pins, connectors, and tools and issued complete sets to the Army. In Great Britain, companies of all sizes and types, from large engineering firms to small bedstead makers, window-frame makers, paper makers, and confectioners made parts of the Bailey. A rigorous inspection system using both master and contractor gauges ensured uniformity and therefore interchangeability. In addition, vital panels had to pass proof tests in the early days of the war.

By contrast, the American Army contracted with companies for complete bridge sets. Ultimately joining the Youngstown company were the Ceco Steel Products Company of Chicago, the International Steel Company of Evansville, and the Virginia Bridge Company of Roanoke. A number of smaller companies produced stampings, castings, bolts, pins, and wrenches. Given the goal of complete interchangeability between British and American bridges, it was critical that specifications be adhered to stringently.

In late 1942, the sample bridge was ready for test. The Chief of Engineers directed the Engineer Board to evaluate

Traffic crossing a class 70 panel bridge with a pedestrian walk.
(Engineer School Library)

the Bailey primarily as a fixed bridge replacement for the H-10 and H-20 bridges. Later, the board was to test both the Bailey and the H-10 bridge on the 25-ton pontons. The fixed bridge test took place at Fort Belvoir with the float bridge test scheduled for the Yuma Test Branch in the Southwest. The Engineer Bridge Branch submitted its fixed bridge test results on 5 December 1942.

The Bailey met many of the initial requirements described in the "Portable Steel Bridges for Heavy Loads" project. The British bridge possessed the requisite flexibility to serve as the single, multipurpose bridge. The Bailey could be reinforced in place without dismantling. Its heaviest component was only 600 pounds, compared with 1,732 pounds for the H-20 component and 1,132 pounds for the H-10. Finally, drivers expressed more confidence in the Bailey because the panels rising on both sides of the roadway gave them a greater sense of security than the other bridges. The report also pointed out the Bailey's deficiencies. It required more parts to assemble than did the other bridges, and the roadway could not be widened without redesign. A major liability was the need for precise cutting, welding, and fabrication. The Bridging Branch recommended the retention of both the H-10 and the H-20 for all but the European theater where the Bailey could be used by Allied nations.

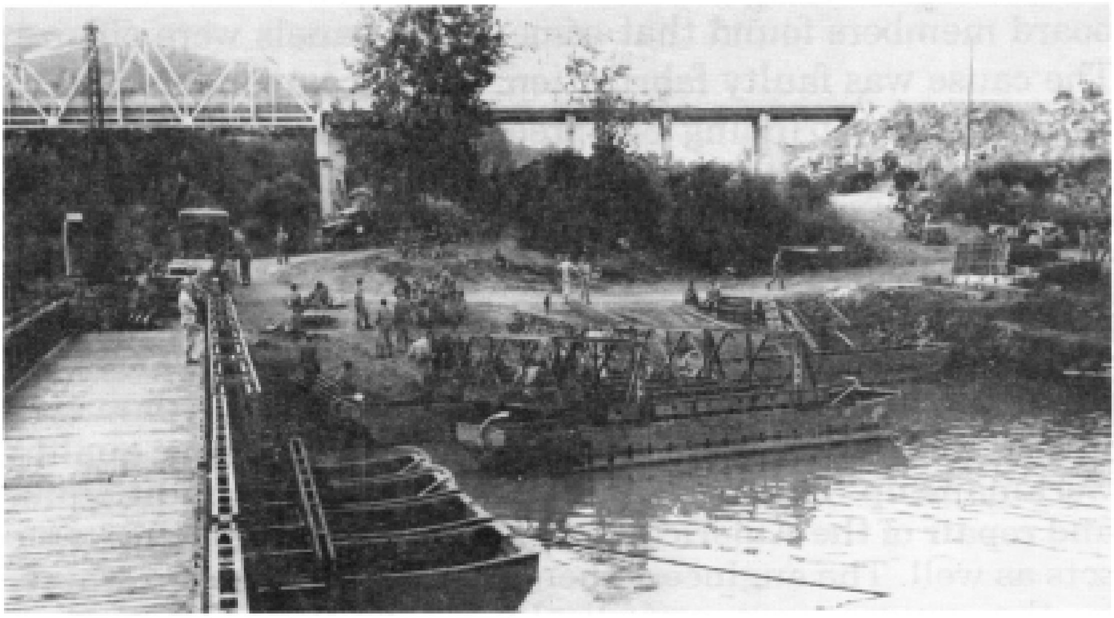
The recommendations passed to the Chief of Engineers from the Engineer Board did not, however, correspond with the suggestions of the Bridging Branch. There was sufficient support for the Bailey on the board to change one of the recommendations. The board recommended that the H–10 be retained, following the suggestions of the Bridging Branch. However, the board recommended that the panel bridge (Bailey type) be procured in place of the H–20 bridge. The flexibility of the Bailey and the possibility that it could serve both American and British engineers overcame the concerns about the close tolerances and exact measurements required during the manufacturing process.

It is possible that some American engineers were not overly concerned about the precision production challenges posed by the Bailey. The British had attained standardization for component parts in spite of the fact that hundreds of companies made parts of the bridge. The British ensured their interchangeability through the use of fabricator gauges and a single master gauge. The use of those instruments precluded acceptance of parts which did not meet specifications.

Early in the fabrication phase for the test bridge, American engineers borrowed a set of gauges from the Canadians. These gauges had been sent to Canada from England as part of an education program on manufacturing the bridge. However, the Engineer Board recognized that, in time, American manufacturers would have to have their own set of fabricator gauges. A master set would be used to ensure the accuracy of the fabricator gauges. After some hesitation, the Chief of Engineers approved the procurement of 25 sets of Bailey bridge gauges for the British army and six ponton-coupling gauges for use with the floating Bailey equipment. The Chief of Engineers approved the production of these gauges for the British in consideration of their cooperation in supplying the original master gauges via Canada. It was not until September 1942 that the engineers found two firms—the Industrial Tool and Die Works of Minneapolis and the R. Krasberg and Sons Company of Chicago—to produce the gauges. The contractors completed production of these instruments in January 1943.

As bridge sets became available, the Engineer Board intensified its testing. In an effort to develop procedures for employing the bridge while also evaluating its capabilities, the board conducted troop tests with the 31st Engineer Combat Regiment at Fort Belvoir. The 31st erected a number of bridges, both fixed and floating, with the Bailey panels. These troop tests confirmed the structural soundness and flexibility of the bridge. Board members concluded that the British capacity ratings for various spans were conservative, but did not recommend new classifications in their report to the Chief of Engineers. The success of the Bailey as a float bridge was significant in light of problems with the steel treadway float bridge which occurred in the fall of 1942.

In four separate instances-two at the Desert Training Center, one at Fort Benning, and one at the Tennessee maneuvers-- tanks crossing steel treadway float bridges had slid into the water. In each instance, excessive weight or off-centered loading caused the bridge to twist and floats to come out from under the treadway. Seven soldiers were killed in these incidents. Although the armored force insisted that the bridge was acceptable, engineers moved to improve the safety of the treadway and increase the size of the floats. These incidents also increased interest in the Bailey's capabilities as a float bridge.



Assembly of a floating Bailey bridge. *(Engineer School Library)*

Confirmation of the 31st Engineers' success with the Bailey as a float bridge came with the Tennessee maneuvers of 1943. The 551st Engineer Heavy Ponton Battalion constructed a 590-foot floating Bailey at Rome Ferry, Tennessee, during the second phase of the maneuvers. A large part of an armored division crossed the bridge shortly after its completion. Engineers monitored the bridge, which was under constant use for approximately one week. Engineers found that the Bailey did not require significant additional transportation assets when used with the 25-ton ponton. After the maneuvers were concluded, the 551st considered the floating panel bridge (Bailey type) superior to any standard ponton bridge. The battalion's report stated that the bridge was more stable and would carry a heavier traffic volume in given time. Maintenance problems were fewer and, as in earlier tests, drivers were more confident crossing the through-type bridge.

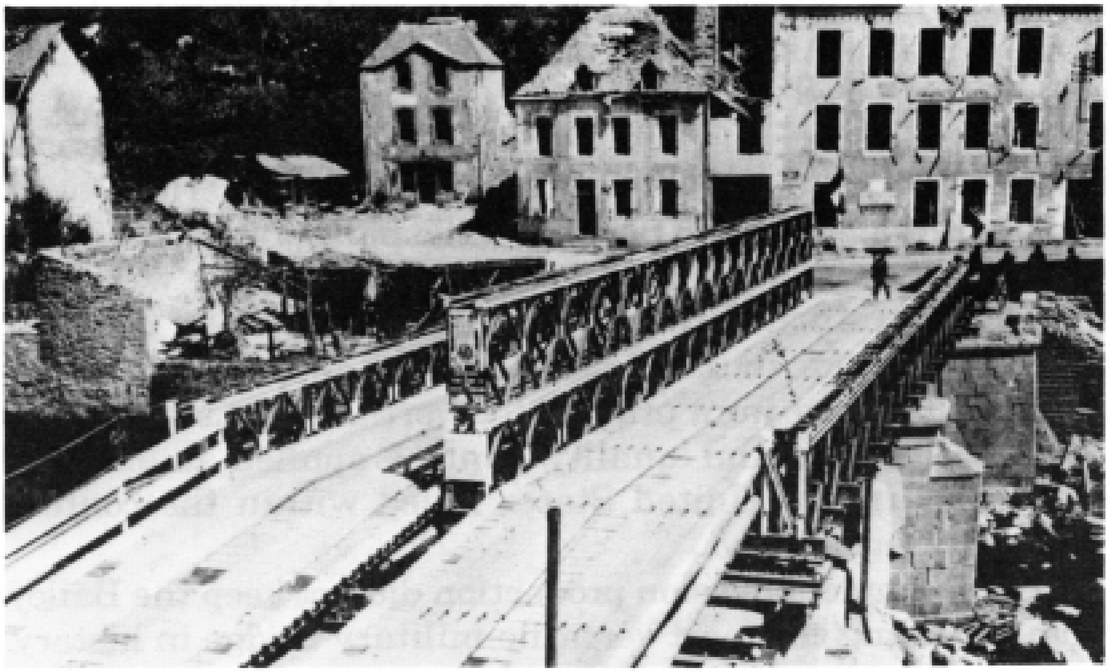
Although tests to officially confirm the Bailey's capabilities as a float bridge were not concluded until the end of 1943, troop tests in the United States and combat use in Europe had already established the bridge's amazing potential. Ironically, these same tests identified a problem with the production of the Bailey. The problem went to the core of the concept of an interchangeable bridge for both the British and the Americans.

During the troop tests with the 31st Engineer Regiment, board members found that some of the panels were off-size. The cause was faulty fabrication. These components had to be altered by grinding or spreading to fit with the other parts of the set. In theory, the fabricator's gauges should have detected these panels before they were issued to troops. In October 1943, the board decided to recheck the gauges to ensure that they were still accurate. The engineers again borrowed the Canadian gauges to use as a master. The comparison revealed that many of the gauges had been damaged in use and others were not accurate due to poor quality workmanship. This necessitated a thorough reconditioning and repair of the American master gauge and the fabricator sets as well. The engineers then instituted a program whereby the gauges were periodically reconditioned through a schedule that would not interfere with the manufacturing of the bridge sets.

The damage to the concept of interchangeability had already been done. It was not until August 1944 that engineers had gauges that corresponded in tolerances to those of the British. As a result, the 850 American-made Bailey bridges acquired in 1944 had to be segregated from the British bridges because the components were not interchangeable. Tests conducted by the Australians on American-built Baileys revealed that 75 percent of the panels were not interchangeable even with each other. After the war was over, the British returned the 25 gauge sets the Chief of Engineers sent them in 1942 because they were of such poor quality that they were practically worthless. The system of mass production and quality control applied to making the Bailey in the United States failed within the context of interchangeability.

The failure of precision production did not keep the Bailey from becoming the most versatile military bridge in history. Its greatest use was in Sicily and Italy where German demolitions created hundreds of river and dry land obstacles. In a 20-month period in Italy, the American Fifth and British Eighth Armies constructed more than 3,000 fixed Bailey bridges to cross different streams. The combined lengths of these bridges was 55 miles, with an average length of 100 feet. Engineers found that the panels could also be used to construct piers for bridges. The Eighth Army built one Bailey using panel crib piers of 70 feet. When Germans foolishly dropped bridge spans but spared the piers, Baileys were used to restore mobility quickly. For example the Germans dropped 19 spans of the Sangro River bridge, but left 14 piers standing. British engineers built a 1,126-foot Bailey on the standing piers. The Bailey was also adapted as a suspension bridge in Italy. One such structure over the Volturno River carried 240,000 vehicles in eight months.

In northwest Europe, the Bailey was used primarily as a fixed tactical or line of communications bridge. For the war of movement across northern France, most divisions relied on steel treadway floating bridges. These were much faster to use and easier to transport than the Bailey. The Third Army erected 53 treadway bridges with a total footage of 20,166 feet compared with 11 floating Baileys with 9,380 feet aggregate length. General George Patton's command built almost 27,000 feet of fixed Bailey bridging compared to approximately 9,800 feet of fixed treadway bridging. During the



Dual passageway class 40 Bailey bridge across the Varenne River, France
(Engineer School Library)

Rhine River crossings, American armies built nine floating Baileys, using the British Mark V pontons.

On the other side of the world, the Allies used Baileys primarily in the China-Burma-India (CBI) theater. There engineers constructed Baileys prior to building heavier, more permanent bridges. American engineers built the longest clear span of the war, 420-feet, over the Shweli River. This was a suspension Bailey with the two end towers built out of Bailey panels.

From a sketch on the back of an envelope from Donald Bailey's pocket, the Bailey bridge emerged as one of the most significant developments of the war It, much like the Douglas DC-3, was a work horse in its own area. Virtually every Allied nation used the Bailey during the war, and many countries continued to use the Bailey, with various modifications, into the 1980s.

Sources for Further Reading

Articles for additional readings on the Bailey bridge include: LTC S.A. Stewart, "The Conception of the Bailey Bridge," *The Royal Engineers Journal* LVIII (Dec. 1944), pp. 237–43; R.S. Bishop and K.S. Frazier, "Manufacturing the Bailey Bridge," *Military Engineer*, XXXVII (June 1945), pp. 219–222; John A. Thierry, "The Bailey Bridge," *Military Engineer*, XXXVIII (Mar. 1946), pp. 96–102; LT Richard G. Webb, "Military Construction of the Bailey Bridge," *Military Engineer*, 55 (Jan–Feb. 1963), pp. 28–30; and LTC Bruce W. Reagan, "Sir Donald Bailey's Little Gem," *Journal of the Institute of Royal Engineers* (Dec. 1984), pp. 269–271.