MILITARY ENGINEERING AND CONSTRUCTION IN WORLD WAR II

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

Kenneth A. Clapp

1947

Military Engineering and Construction in World War II

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

By

Kenneth A. Clapp

Candidate for the Degree of

Bachelor of Science

December 1947

"The Engineers -- those unsung heroes, have mastered the trickiest instruments of modern warfare."

DWIGHT D. EISENHOWER

CONTENTS

Introduction

In September, 1945, the people of the United States saw a magnificent war effort consummated in complete victory for the Allied forces. It was a victory wrought by many diverse functionary groups, both civilian and military.

If one had been in a soldier town at the time of the Japanese surrender, he would have heard many good natured arguments concerned with the relative merit of one branch of service over another.

"If I hadn't gone in and taken the ground", said the infantryman, "the war wouldn't be over now".

"Without my support", offered the airman, "the infantry wouldn't have taken any ground".

"And", argued the sailor, "I transported both men and planes to battle areas all over the world".

The veracity of these contentions is indisputable. However, the above accomplishments would have been virtually impossible without the bridges, roads, airfields, docks, and innumerable other installations and services, conceived and provided by the engineers and construction men, who contributed an impressive sum to the total job of winning a war.

The conditions under which the overseas projects of the engineers had to be completed were anything but normal in a majority of cases. Between the lines of the following description must be read much which adds to the credit due these men who paved the way to victory.

When raw materials were unavailable from any other source, adequate local substitutes had to be chosen. When shortages of basic equipment hampered progress, improvisations had to serve. When replacement parts were nonexistent, they had to be manufactured or procured through means ethical or otherwise.

The following report is intended to present an overall picture of the activities of the engineering and construction groups of the United States during the recent conflict.

Part 1

European Theater

The engineering units which operated in the European Theater engaged in the construction of every conceivable type of installation. It is not the writer's intention to discuss in detail every one of the projects undertaken, but to present a comprehensive report on the different types of problems encountered and the usual methods used in the solution of these problems.

Section 1

Great Britain

Before the invasion of the continent by the Allied forces, our engineering units stationed in Great Britain had been at work for two years. They built airfields, resurfaced roads for increased military loads, constructed artificial invasion harbors, and provided beach ramps, waterproofing tanks, barracks, hospitals, and leave camps. In addition to, the aforementioned, the engineers engaged in the setting up of emergency housing and the repair of livable dwellings for the thousands of British families left homeless by the blitz.

Airfields

Men of the Corps of Engineers started as early as 1942 to build air bases in the British Isles. Since haste had been the prime factor in construction, the condition of the runway subgrades was usually overlooked, and little attention was given to drainage. These errors, plus the fact that the concrete slabs were seldom of sufficient thickness to withstand heavy bomber loads, resulted in a tedious program of repair. It was found that the most frequent points of failure were the ends of the runways where the heavily loaded ships congregated before takeoff, and the taxiways where the planes used the same tracks incessantly because of the narrowness of the concrete. Factors contributing to these failures, exclusive of enormous loads, were poor subgrades, inadequate slab thicknesses, and defective concrete. As repair work progressed, it took on the aspects of virtual reconstruction in some areas, and when patching was practicable, it was found that it interfered too greatly with needed bombing sorties. As a result, the following program of maintenance was agreed upon.

The runway to be worked on was closed to airplane traffic for a few days, during which the entire area of concrete was resurfaced by topping with asphalt macadam, $3\frac{1}{2}$ inches thick at the ends and one inch elsewhere. While this was being done, the perimeter tracks were covered with entirely new 6-inch concrete slabs.

Roads

When existing roads were to be resurfaced, the work involved several operations. The road was first gone over with a pavement breaker, followed by a skimmer scoop to remove the broken concrete from the area to be patched. Then came a unique, fast-moving paving plant. It consisted of a water tank and a 14-cubic foot mixer mounted on a trailer and pulled

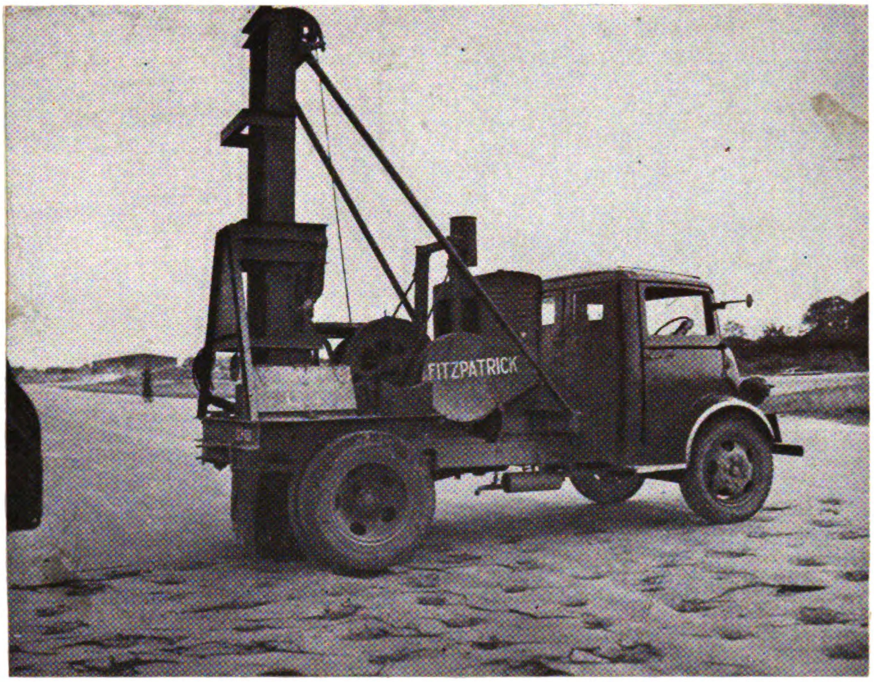

Fig. 1. Pavement breaker for use on roads and runways.

by a truck in which were loaded the cement and aggregate. This paving plant was able to pour quickly and to move out of the way rapidly when necessary.

Fig. 2. Unique portable paving plant.

Beach Ramps

For the purpose of facilitating the beach landing of vehicles too heavy to move on the natural beach terrain without bogging down, the Engineers developed the "chocolate bar". This was a precast slab of concrete with heavy scoring on either side. It measured 2x3 feet in plan, and had a usual thickness of 10 inches. These slabs were laid on the beaches and wired together to form a hard and relatively smooth surface for the landing of vehicles. In some instances, rails were laid on the bars for the accomodation of freight cars, but for the most part they were used for highway vehicles only. The heavy scoring provided excellent traction for the vehicle on top and served as a stabilizing factor on the beach underneath.

Waterproofing Tanks

The vehicles that landed on the Normandy beaches frequently did so by breaching considerable expanses of shallow water. For this reason, it was necessary to waterproof each of these vehicles. To test this waterproofing, the Engineers provided two types of tanks. The first of these was made by damming streams so that a depth of 5½ feet of water was available for the test. In places where streams were not present, tanks of concrete were erected with a ramp at either end for entrance and exit.

Hospitals and Leave Camps

These buildings were, for the most part, Nissen huts with refinements. These huts were enclosed with brick ends, lined with boards of insulation, and set on concrete floors. A colony of such buildings served as a leave camp. In constructing hospitals, considerable work had to be done to provide interior partitioning, as well as enclosed or covered corridors running from building to building. Brick walls and corrugated asbestos roofing served these functions. After all these extra-Nissen improvements had been made, it was difficult to realize that the basic structure was a simple, 24-foot, corrugated steel arch building.

Section 2

On the Continent

When the Engineers moved to the mainland of Europe after the invasion, it is doubtful that they realized the magnanimosity of the total work that they were subsequently to perform. For they were destined to invent, repair, construct, and reconstruct from the beaches to the heart of Germany. But not only did they build. The writer has seen men of the Combat Engineers lay down their construction tools, take up their weapons, and assist the infantry in the repelling of an enemy counter-attack. An account of the individual accomplishments of these men would require an historical document of voluminous proportion. Let us now consider some of the typical installations provided by the engineering units on the European continent.

Harbors

The first great task to be undertaken by our engineering units on the continent was the repair of Europe's demolished harbors, vital to the maintenance of an expeditionary force in urgent need of a steady flow of supplies and equipment. Allied bombers and German demolition units had wrought a tremendous amount of damage to these harbors. Sea walls were wrecked; power sources were cut off; harbor entrances were choked with sunken vessels; water supplies were in bad shape; loading spaces and loading equipment were useless. An extreme example of the foregoing was Cherbourg on the coast of Normandy. Let us consider the repair of this great port as typifying the conditions facing engineers of the Army and Navy.

Before the actual construction could begin, it was necessary to rid the harbor and the beach of considerable debris and rubble. The Navy salvage crews moved the sunken craft and swept the harbor of mines, without which service the port would have remained unusable. The Army Engineers and men of the Transportation Corps expended millions of man-hours in clearing the beaches and docks of the debris that had been reinforced concrete buildings and steel port equipment.

It was decided to build over and around the wreckage, using its landing spaces for improvised structures.

An undamaged recreation beach in the center of the harbor coast provided a good landing space for amphibious craft. The Engineers paved this beach with 160,000 square yards of 6-inch slabs in roads and turn-around areas. In order for these roads to go inland, holes had to be cut in the sea wall behind the beach. In order further to speed up the landing of cargo, two platforms, 150 feet long and 40 feet wide were built on this paved area. These consisted of earth fills dumped between two retaining

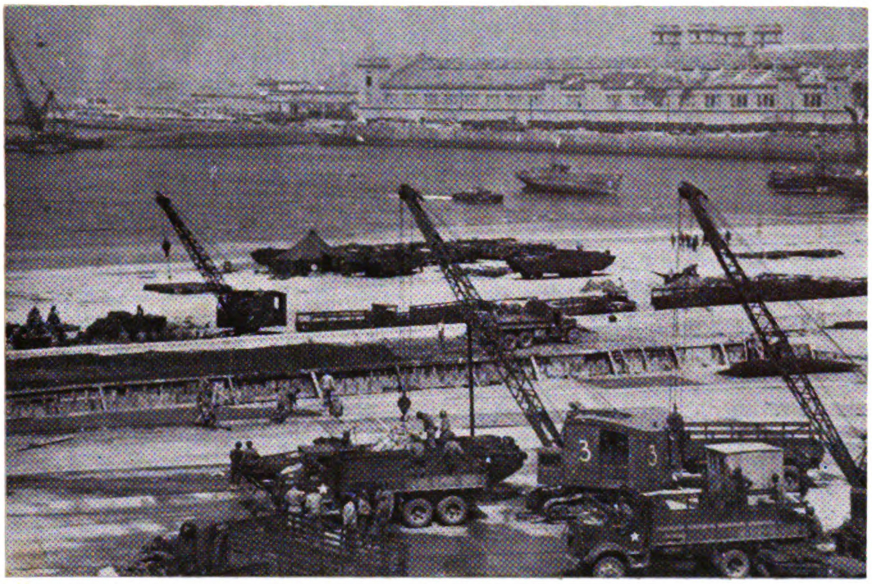

Fig. 3. Construction of loading platform.

walls and surmounted by reinforced concrete slabs. The amphibious craft discharged their loads on these platforms while men sorted the cargo and transferred it to waiting trucks.

Where a portion of a retaining wall had not been damaged, 4200 feet of timber wharf was built to serve barges carrying cargo in from ships anchored in the harbor. The 42-foot deck section of the wharf extended 30

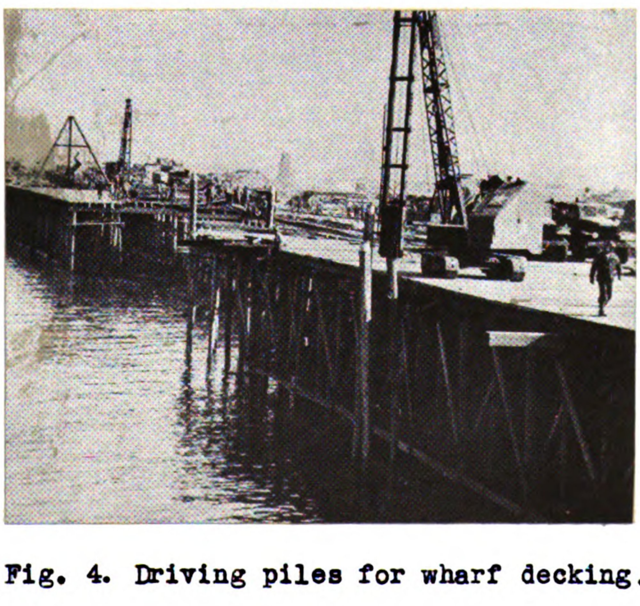

Fig. 4. Driving piles for wharf decking.

feet out from the face of the wall to reach deep water, and 12 feet inland to be adjacent to a railroad siding. This decking was supported by wood pile bents and was tied to the shore by digging holes in the wall,

Fig. 5. Engineer's pile driver in action.

concreting piles in these holes, and securing the piles to the deck sections. The driving of these piles was done by a drop hammer travelling in leads suspended from the boom of a crawler crane. Cargo was unloaded by

Fig. 6. Stiff-legged cranes on wharf.

means of stiff-legged cranes set on 256-foot centers throughout the entire length of the wharf.

The next project undertaken in the harbor was the providing of wharf facilities for deep-draft vessels, principally LST's. This was accomplished by repairing holes in a usable jetty and building sections of timber wharf to coincide with the hatches of the ships to be served. The huge holes in the jetty were patched by filling with earth if possible. When necessary, the holes were closed by bridging them with timber trestles. One such gap measured 400 feet in length, 70 feet in width, and was 45 feet in depth. The wharf deck construction was basically the same as that for shallow-water craft described above. A typical section is shown at the right.

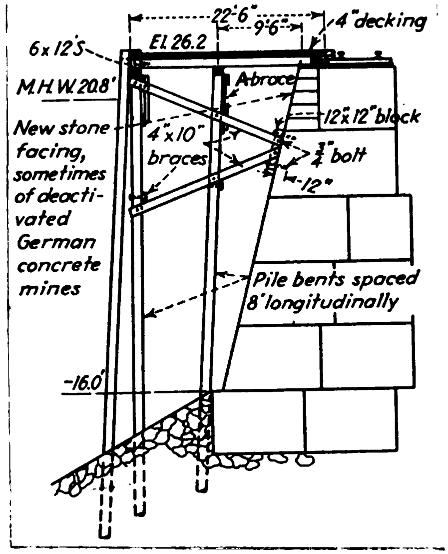

Fig. 7. Typical section of deep-water wharf.

The main source of power for the port of Cherbourg was a transmission line from Caen. This line was, naturally, cut by the retreating Germans. The city operated two standby stations, but one was destroyed by Allied bombers. The remaining station was unable to cope with the heavy emergency load, and one month after it was put into use, its generators burned out. For a remedy, the city power lines were connected to the power plant of a Navy destroyer escort, and a captured German diesel-electric system was put into operation. Two portable units were installed in the water plant. These emergency measures served adequately until the line from Caen was subsequently restored.

Water supply is essential to any port before it can operate efficiently. The Cherbourg plant, like most of those in France, depended upon ozone for the treatment of its water. This was found to be inadequate because of the many breaks in the lines and the emergency repairs thereof. As a result of this, portable chlorinators were installed in the plant. The operation of these units provided a residual of 0.4 ppm. in the distribution system.

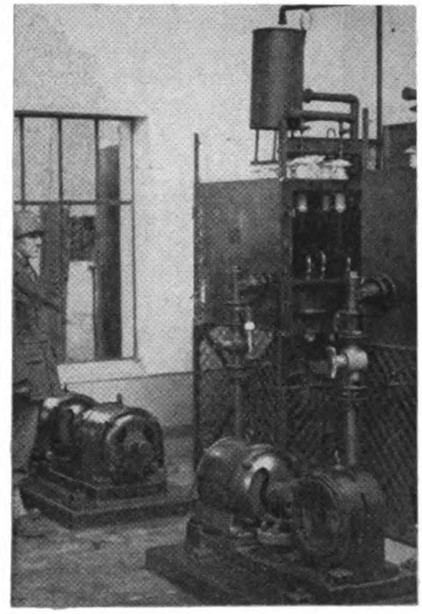

Fig. 8. Portion of Cherbourg's ozone water treatment plant.

When it was discovered that all available cold storage space had been bombed out, the Engineers found three tunnels extending into a nearby hillside. By equipping these with double doors and installing some second-hand refrigeration machinery, many thousands of cubic feet of cold room were made available.

Roads

In the building of roads in the European theater, it was found convenient to restrict the construction to two basic types, although variations and combinations were used somewhat.

Where very little or no mud was encountered, roads of pierced steel plank were constructed. As a base for the steel plank, the Engineers first placed a layer of burlap. On this was poured a layer of tar followed by three layers of open steel mesh. This base provided a stiff, watertight membrane upon which the steel planks were laid and welded. A high crown, usually 16 inches in 14 feet of roadway, assured rapid drainage.

Muddy ground upon which roads were to be built necessitated a different type of construction lest the entire structure be swallowed up by the mire. For this reason, timber plank roads were built. The first step in the construction of these was the laying of 12x12 mudsills, placed as close together as the mud condition necessitated. In some cases this meant a solid platform had to be laid. Next, 8x8 stringers

Fig. 9. Timber plank road.

were set on the sills and on the stringers was placed a deck of 4x4 planks spaced for drainage. Finally a running surface consisting of two rows of longitudinal planking protected on either side by curbs was set on the decking.

In the building of roads and in many other phases of engineering and construction, generous assistance was given to the American units

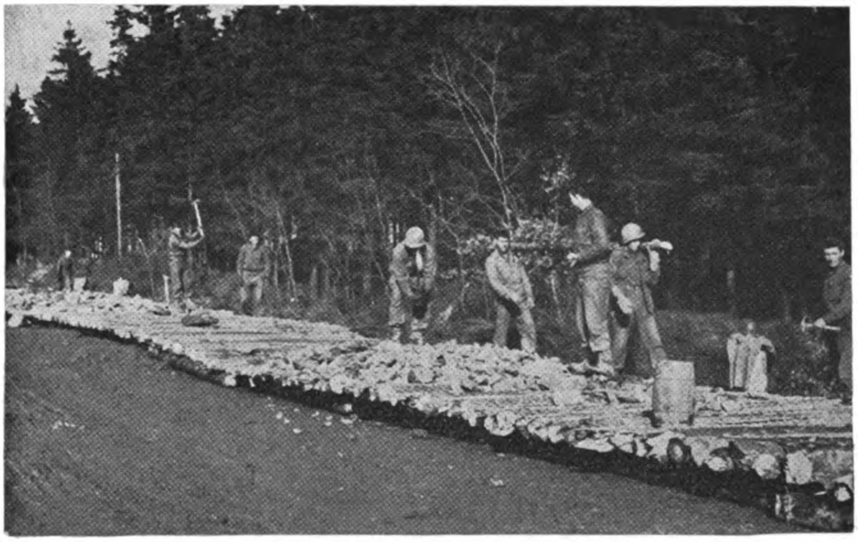

Fig. 10. Corduroying as an alternate method.

by the "Service des Ponts et Chaussees", the French highway and bridge organization.

Boat Basin Repair

Boat basins, in which ships were protected from the 25-foot tides prevalent on the European coastline, required a great deal of repair before they could operate at anything near capacity. These basins were entered from deep-water anchorage by means of locks. The locks operated at high tide only, assuring that the basins were always full of water, and, hence, unaffected by the tides. The Germans again had done an expert job of demolition on the gates of the locks, and the Engineers did an expert job of expeditious repair.

A gate consisted of a structural steel framework to which was riveted or welded a skin of steel plate. Where repair was practicable, the damaged framework was reinforced with available structural members, while the layers of plating were patched or Entirely replaced. Where the damage was irreparable, entirely new gates were manufactured and installed by means of heavy floating cranes provided by the Trans-

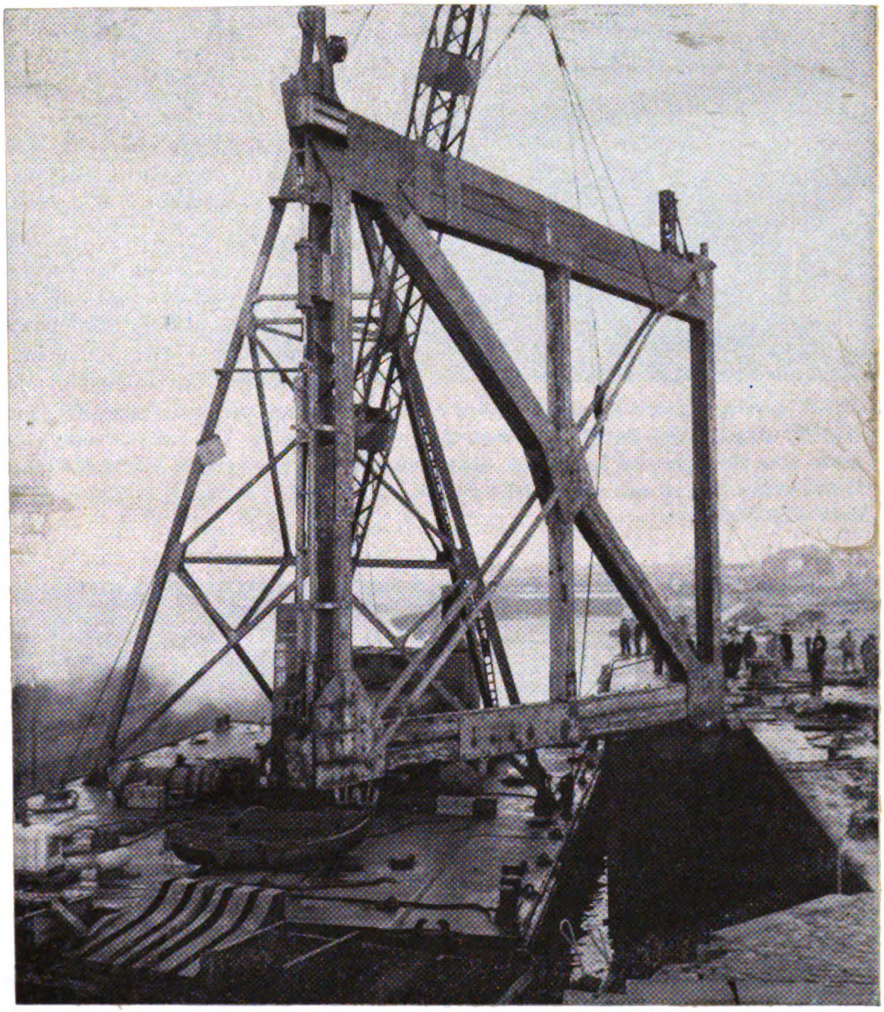

Fig. 11. Installing a gate strut.

portation Corps. The rapid return of these gates to operation status meant that the boat basins could be used at full capacity weeks ahead of schedule.

Pontoon Piers

In many cases the cargo handling capacity of a port could be increased by the addition of piers to the existing unloading system. One of the most popular methods of erecting these piers was through the use of pontoons. The completion of these piers exemplified the ever-present cooperation between units of the Army and Navy. The basic unit for the piers was the 5x5x7-foot steel pontoon, which will be described in detail later. A number of these pontoons were fastened together in the de-

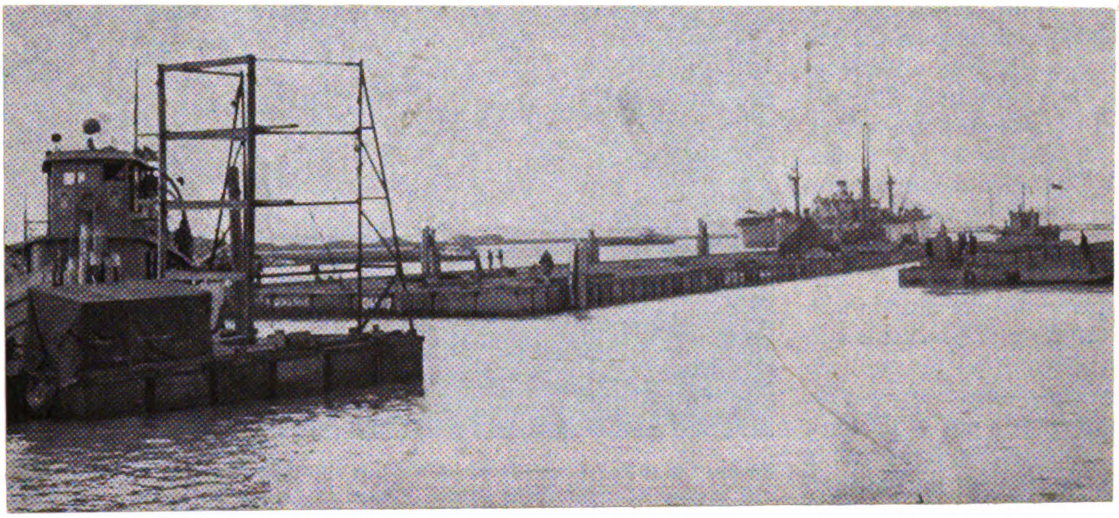

Fig. 12. Pontoon pier being floated into position.

sired shape at a shore site and floated into position. This work was done by the Navy Construction Battalions. Then the Army's floating drivers sunk pile dolphins around the perimeter of the pontoon cluster and fastened the two together, thus forming a floating pier. In order to avoid trouble from the tide, the pier was connected to the shore with a Bailey bridge span resting on pivot bearings. A ramp provided the transition from pier to bridge.

Railroad Bridges

Probably the most important work done by the Engineers in Europe, and that which was most emphasized, was the task of providing bridges of all types. Here was needed a railroad bridge; there a pontoon bridge; somewhere else a single span was required to put a wrecked bridge into operation. Each bridge that was built or repaired by the Engineers had some peculiarity that distinguished it from all others.

In railroad bridging, the units of construction because of restricted availability and convenience were few. The following are those which were used almost exclusively.

The German "meter beam" became a very popular addition to the standard units of construction because it was particularly adaptable for use without pier support for spans up to 95 feet. The specifications of this beam were a depth of 39.37 inches (hence, "meter beam"), flanges 11.81 inches wide and 1.42 inches thick, web thickness of 0.75 inches, a weight of 210 lbs/ft., and section modulus of 787 $inches^3$. Standard practice in the use of these beams involved placing one under each rail for

Fig. 13. Railroad bridge of meter beams.

spans up to 55 feet, a third beam in the center for spans of 60 and 65 feet, two under each rail for 70- and 75-foot spans, a fifth beam in the center for 80- and 85-foot spans, and three under each rail for spans of 90 and 95 feet. The beams were rolled to a maximum length of 95 feet. Using those meter beams captured at first, the Engineers later received them upon order from a Luxembourg mill.

Another of the units of construction was the UCRB (Unit Construction Railroad Bridge). This was a parallel-chord, Pratt-type truss span,

Fig. 14. UCRB units (right).

made up of light individual pieces bolted together. It was installed as either a through or a deck span.

Light Steel Trestling (LST) and Heavy Steel Trestling (HST) were prefabricated columns in 3-,4-,8-, and 12-foot lengths, and bracing members. These could be assembled into tower piers of varying heights and plan dimensions. Figures 13 and 14 show bridges supported by this trestling. Rolled Steel Joist spans (RSJ's) were merely two or more I-beams welded together side by side.

At Dreux, France, the Engineers erected a 295-foot railroad bridge using all of the units mentioned above. It will serve as an excellent example of railroad bridging in the ETO.

The original bridge spanning the Eure River at Dreux had been a high masonry viaduct, but was completely destroyed by the local French citizens because the frequent attempts of the Allied bombers to destroy the span had become an extreme annoyance to the townspeople. The replacement structure consisted of a UCRB deck span of 70 feet at either end, two 49-foot spans of 32-inch RSJ's, and a center span of 57 feet made

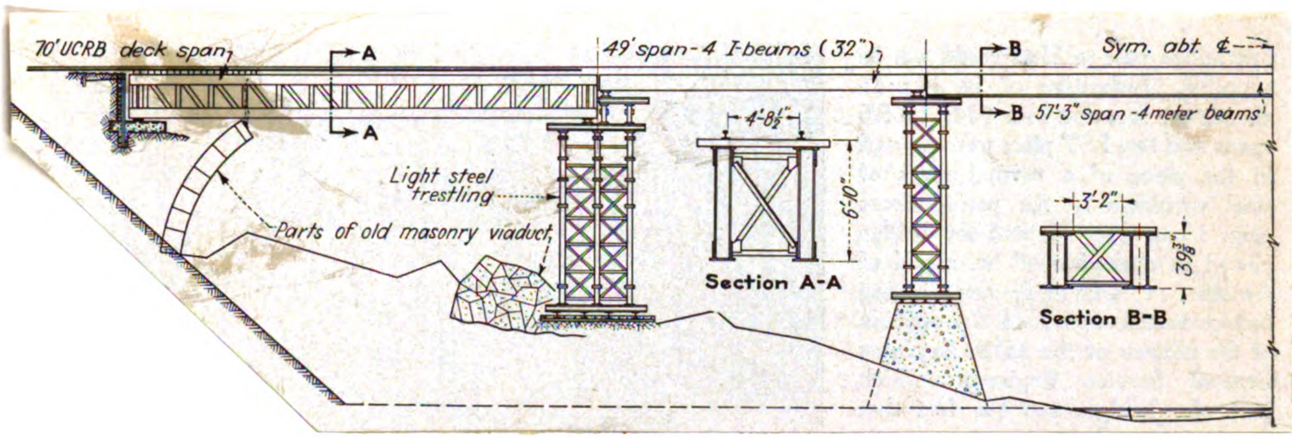

Fig. 15. Side view of Engineer's replacement bridge at Dreux.

up of two meter beams under each rail. At each point of junction between the different types of bridge units was a pier of Light Steel Trestling. Two of the piers were supported on the old footings and the others on

Fig. 16. LST piers.

new footings built over the rubble of the old bridge. Included in the equipment available for the job were a 5-ton crawler crane with a 40-foot boom, one of 30-ton capacity with a 70-foot boom, a truck mounted crane, a heavy and a light crawler tractor, two arc-welding sets, and a 7-S mixer.

Fig. 17. 30-ton crawler crane at work

The UCRB units were installed as deck spans by assembling them on wheel dollies on the track adjacent to the end abutments, launching them over the span to cribbing erected on the LST towers (see Fig. 17), and lowering them into position by means of chain hoists suspended from gantrys set up also on the LST framing. The chain hoists did away with the lugubrious lowering with screw jacks.

The center spans of the bridge were installed in a like manner, with the exception of the final unit which was one of the 49-foot RSJ's. This was assembled in its place by the 30-ton crane operating from the ground.

This construction provided a single track span, but it was found necessary subsequently to add another track. This was done by widening the towers sixty percent and duplicating the completed bridge. The erection, however, was done entirely by lifting the units into place after they had been assembled on the ground. Again the 30-ton crane was used. Erecting this second unit in the same manner as the first would have necessitated closing the entire structure to much-needed traffic. The Engineers completed the first track span in 18 days.

In the construction of long, low bridges, the work was simplified somewhat by the fact that it was required only to build timber or hollow steel pile bents to support beam spans. When one or two spans had to be installed to put a damaged bridge into operation, the usual work involved reinforcement of the piers and abutments and the launching of UCRB's or beam spans as described above in the case of the Dreux bridge.

Fig. 18. Construction of a low bridge.

Bailey Bridges

No account of recent military engineering would be complete without some reference to the Bailey bridges; those that use as the basic unit the Bailey truss panel. Very few of these bridges were built "according to the books". Let us look at one that was. It was the Bailey bridge erected over the Albert Canal in Belgium by the Ninth Army Engineers.

The construction of this bridge took place at a site where the canal flowed through a deep cut. The first step in construction was the building of piers on either side of the canal. These were supported on timber cribbing. Each pier was made up of two legs of triple truss construction, was 52 feet high, six panels (30 feet) wide at the bottom, and two panels (10 feet) wide at the top. The superstructure was of 3 by 2 construction; that is, three truss panels wide, and two tiers deep. Each of the piers contained 45 tons of Bailey truss panels. The west pier was erected in units by a crane on the ground, and it was planned to set up the east pier

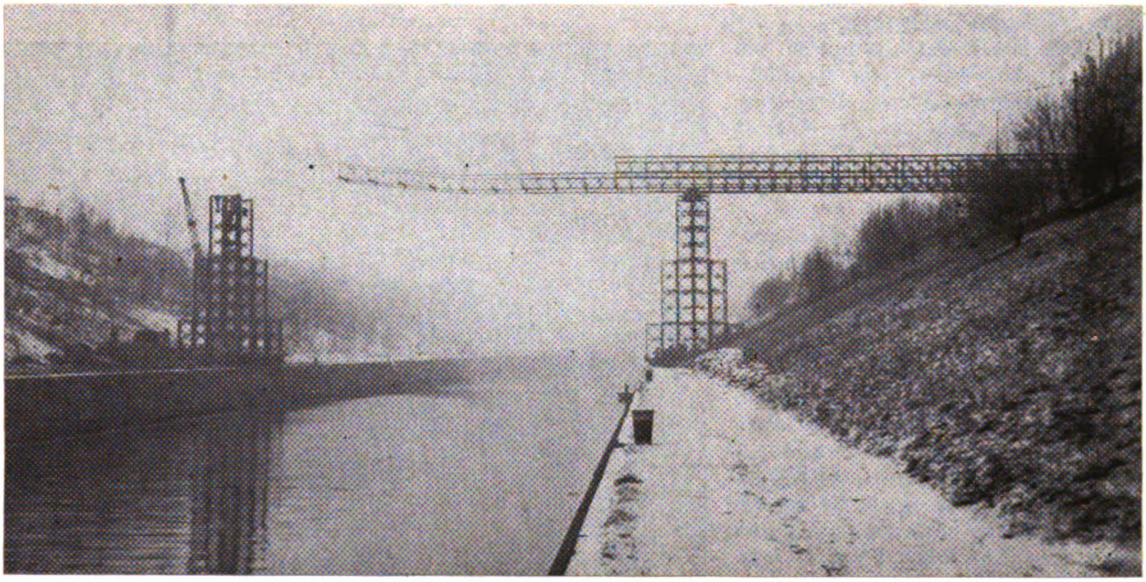

Fig. 19. Piers as well as span of Bailey panels.

with the aid of a cableway. Unforeseen difficulties necessitated impeachment of the plan. The superstructure, consisting of three spans of 151, 152, and 121 feet, was assembled on the east bank, and pushed out over the gap with a bulldozer. When it was launched as far as the uncompleted east pier, the Engineers took advantage of the centilever action of the suspended portion, attaching block and tackle thereto, and hoisted the remainder of the pier into position. The entire structure was then pushed the remaining distance, and lowered to the piers by the use of screw jacks. This formed the largest Bailey bridge in the ETO.

Floating Bridges

Before the fixed bridges could be built, it was necessary to provide first temporary floating bridges for the infantry and its immediate support. After a beachhead had been established by the foot soldiers who crossed the stream in assault boats, the Combat Engineers moved up to erect the famous pontoon bridges. These consisted of pneumatic pontoons or

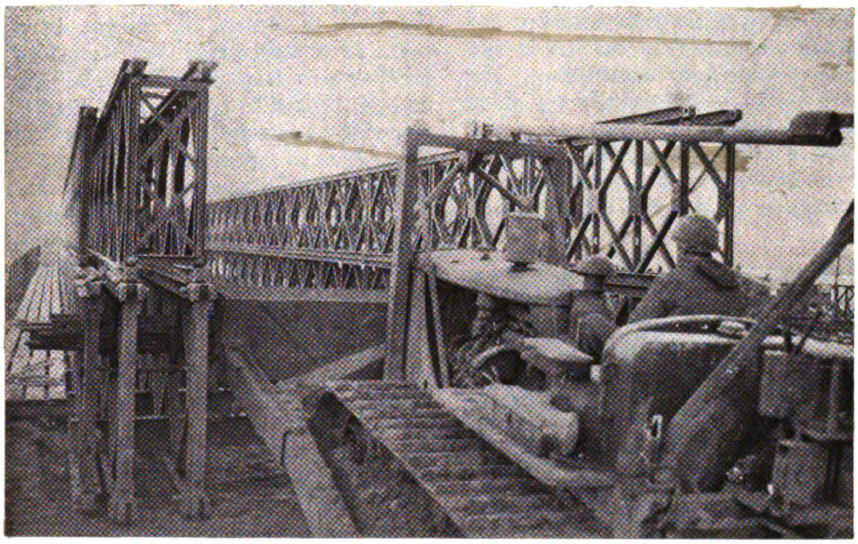

Fig. 20. Launching the Albert Canal Bailey bridge.

assault boats anchored in the stream and tied together. If the bridge were to support only foot traffic, the pontoons or boats were surmounted

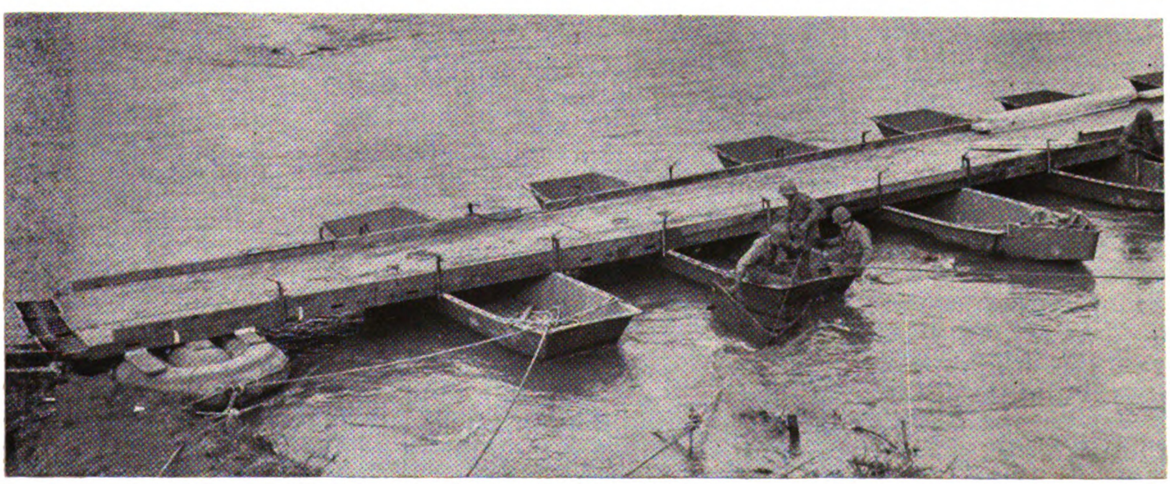

Fig. 21. Floating foot bridge.

by a wooden plank catwalk. For heavier traffic, Bailey truss panels were

Fig. 22. Floating Bailey bridge.

put up on the pontoons and a plank roadway laid between them, thus forming a floating Bailey bridge. Another type of "heavy" pontoon construction was used employing sections of curbed steel treadway. Each of these sections was about ten feet in length and consisted of two tracks like those

Fig. 23. Floating treadway bridge.

of a grease pit, protected on either side by curbing. The sections were laid longitudinally and bolted together, thus forming a continuous running surface for trucks and other wheeled vehicles. The author had the dubious pleasure of crossing the Rhine over such a bridge.

Airfields

Most of the existing airfields overrun by the Allied armies had been badly damaged by their own bombers. The concrete runways were pock-marked with bomb craters of all sizes, and the buildings were all but obliterated; evidence of the omnipresent German policy of demolition before retreat.

A large construction job was involved in the repair of these damaged runways. Before work could begin, most of the craters (some 150 feet in diameter) had to be pumped dry. They were then filled with rubble, which was usually available in the wake of destruction. The cracked pavement was then cut back to sound concrete, and forms were built to fit the odd-shaped holes. These forms were of 1x6's or 1x8's and were left in place to provide some protection against the expansion and contraction of the concrete. The practice of filling the holes with concrete from a portable mixing plant had to be abandoned, since the process was too slow. Instead, batches of ready-mix from a centrally located plant were hauled in by dump truck.

When it was necessary to build an airfield where none had been before, or to add to an existing installation, the employment of the famous pierced steel plank or Marston mat was almost standard practice. The laying of the plank did, however, vary with varying conditions of the soil. Where the ground was relatively dry and stable, the work was simplified, since it was necessary only to grade, increase the stability of the soil with heavy rollers, lay the planks, and weld them together. In many instances, severe mud conditions prevailed and the technique had to be modified to an extent in proportion to the depth and consistency of the mud. In an extreme case, rubble was hauled to the site of construction and dumped until it was a foot in depth above the mud. This required many hauls, since the first two or three layers frequently disappeared entirely in the gummy mass. The rubble was then

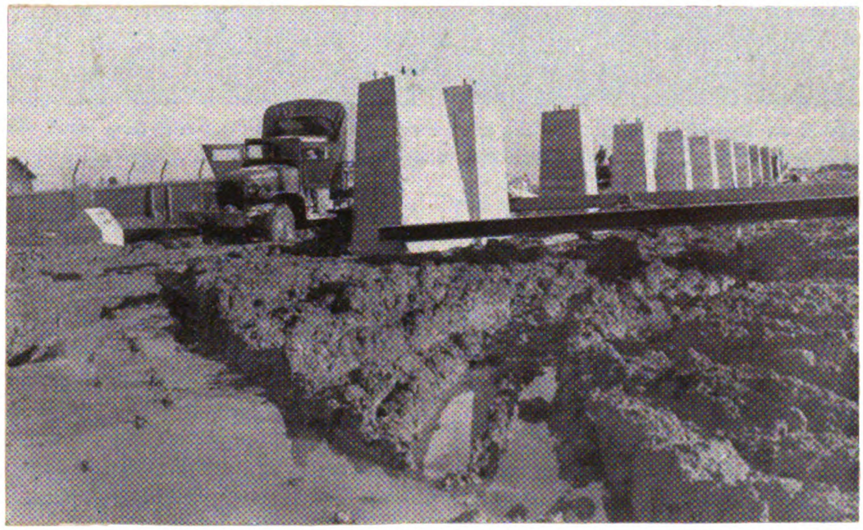

Fig. 24. "Severe" mud.

covered with a layer of smaller stone, after which the steel planks were laid and welded. Sometimes it was found advisable to top the layer

Fig. 25. Laying pierced steel plank.

of rubble with a layer of straw before setting the planking to enhance the resistance to mud seepage. The straw layer was about a foot in depth when placed, being subsequently compressed to four or five inches. Under normal conditions, a battalion of the Engineers could lay a 5000-foot runway of this type in two or three days.

Part 2

Pacific Theater

The chief purpose of the engineering and construction groups operating in the islands of the Pacific was to take over an island as soon as possible after its capture (or during its capture) by combat troops, and to convert the masses of jungle and/or rugged terrain into efficient air bases, from which the Allied air attack could be brought nearer to the home bases of the Japanese.

At the start, several distressing problems loomed. These were the vast ocean spaces to be breached by men and equipment, supply lines thousands of miles long to be maintained, and a critical shortage of construction resources necessary for the carrying out of an immense program of providing military installations. The solution of these three problems did not directly concern conventional engineering techniques and for that reason they will not be treated here.

The problems that promptly did confront the military engineer in the Pacific islands were those of terrain and climate. With the exception of arctic, every type of topography and every condition of weather was encountered. The adeptness and alacrity with which the engineer met and reduced the importance of these conditions have been described as "incredible" by even seasoned construction men.

The work in the Pacific islands entailed items such as earth moving, paving, providing facilities for gasoline storage, refrigeration, water supply, sewage disposal, and bomb storage, and the construction of hangars, warehouses, barracks, shops, and power plants.

Unloading Techniques

Unlike the operations in most of Europe's ports, a great deal of the heavy equipment and armor used in the Pacific had to be unloaded directly from the ship to the beaches. Conventional cargo vessels were unsuitable for this type of operation for two reasons. The first of these was the fact that because of the nature of the holds, equipment could not be loaded in a way such that the items needed first on the beach were the first to be unloaded. The second reason was that, due to a lack of large spaces in their holds, equipment such as long-boomed cranes and wide-bladed bulldozers had to be dismantled for shipment. The solution to these problems came with the development of new types of cargo vessels; principally, the Landing Ship Tank (LST), the Landing Craft Tank (LCT), and the Landing Craft Medium (LCM).

The familiar gaping "mouth" identified the LST which was capable of carrying an entire engineering unit with its equipment. Its capacity was rated at 20,000 tons. This vessel could, in many instances, run in close enough to the beach so that equipment needed to cross only a short expanse of water, not deep enough to bog down even a jeep. In instances where the LST could not approach near enough to the beach, the smaller craft took the cargo in several hauls. The LCT had a capacity of 90 tons, while that of the LCM was 25 tons. None of the long-boomed cranes or wide-bladed bulldozers had to be dismantled for shipment, and items that were to go ashore first were not tucked away, inaccessible behind piles of lumber or sacks of cement.

Steel Pontoons

One of the most useful construction units to be employed in the recent war was the Navy's 5x5x7-foot steel pontoon. This steel building block, made of 3/16-inch plate and welded throughout, was internally braced and served many interesting purposes. The single pontoon weighed about a ton and had a net buoyant capacity of four tons. The pontoon had self-tightening interlocking bolts and straps - called "jewelry" - which connected one pontoon to another, for very seldom were they used as individual units. The most frequent way in which the pontoons were used was in the form of a string; that is, a series of individual units were fastened together by means of the "jewelry" and long steel members along the edges of the pontoons. Thus, a "2x12" unit would consist of two strings of twelve pontoons each. These strings were used as piers, barges, or bridges when necessary, and were capable of withstanding enormous loads because of the internal bracing.

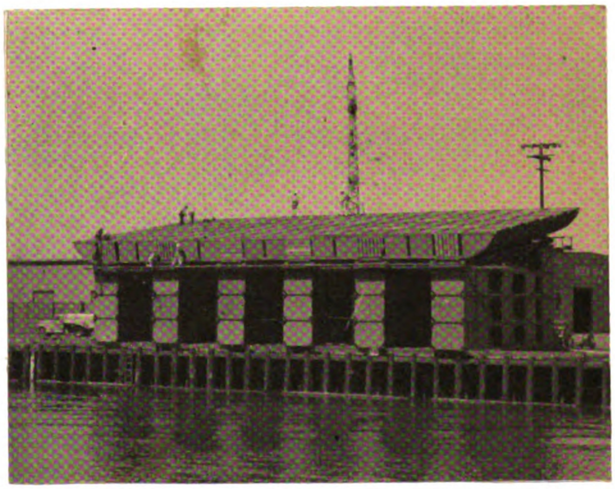

Fig. 26. 6x18 steel pontoon unit.

One of the most interesting uses to which pontoon sections were put was that of momentum beaching. This was employed when an LST was unable to reach a shore or beach and the building of a pier became necessary. The process consisted of carrying strings of pontoons fastened thinly to the sides of the LST and running in until the ship grounded on the bottom, at which time the strings were cut loose and allowed to float to the beach. By means of cables and winches on the ship, the strings were jockeyed into the desired position where they overlapped one another slide-rule fashion. They were then fastened together and vehicles and men sped ashore, frequently without wetting a tire or a foot. In a test of this process, an LST grounded 550 feet from shore, and in just seven minutes the pier was in position and a heavy vehicle was rolling up the beach.

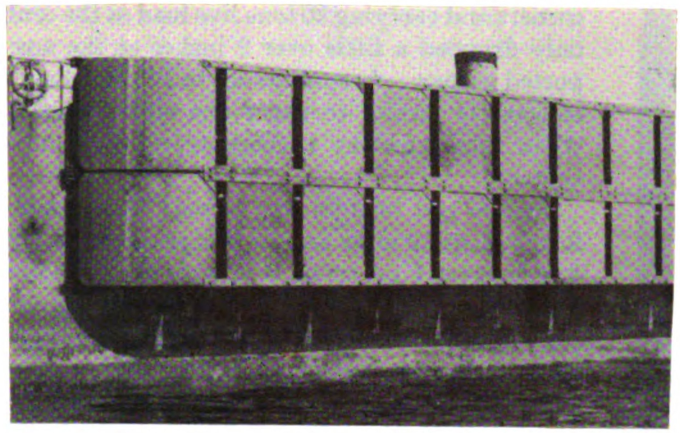

Fig. 27. LST carrying pontoon string.

Barges made up of pontoon strings were usually standardized as to dimensions. The most commonly used units were 3 strings of 7 pontoons, 4 strings of 12 pontoons, 6 strings of 18 pontoons, and 6 strings of 30 pontoons. The latter unit made available a deck space of 43x175 feet with a carrying capacity of 500 tons with a draft of four feet with that load.

Fig. 28. Pier formed by momentum beaching.

Bridges

Bridge building in the islands of the Pacific was not as elaborate as that practiced in the European theater. Usually, the span to be bridged was not wide enough to warrant "Big League" methods, and there was practically no call for railroad bridges. For our discussion, therefore we shall restrict the construction to the two types which were used most in the islands. These were the timber bridge and the pontoon string bridge.

A typical timber bridge can be discussed using one of a number built on the island of New Britain. All of the timber bridges built on the island were of identical construction, varying only in span and width. Using native grown logs throughout, stresses were determined by the heaviest vehicle in operation in the area, and strength values were arrived at by comparing the timber with similar hardwoods of the United States. The first operation was the erection of timber pile bents. Each of these consisted of five 25-foot piles having 18-inch butts and 10-inch tips. The piles were driven to refusal and held together as a unit by a capping log laid across the top of the line of piles and fastened to each by means of a one-inch pin. The distance between bents was an average of 20 feet. Retaining walls were formed by logs placed horizontally one on top of the other against the end bents. These logs extended from the stream bed to the underside of the stringers. Wing walls were made in the same fashion as the retaining walls. Stringers were placed so that they overlapped the supporting bents by at least three feet, there being usually five stringers per bay. Surmounting the stringers was a deck of 8-inch logs, the crevices between which were filled with smaller logs and sticks. Curbs of long, large-diameter logs were laid along the outside edges of the bridge, after which the decking was covered with gravel, volcanic slag, or other suitable and available ma-

Fig. 29. Timber bridge under construction.

terial. This material served also as fill behind the retaining and wing walls.

The construction of a steel pontoon bridge entailed much less labor, material, and equipment than did the timber bridge. The first step, as

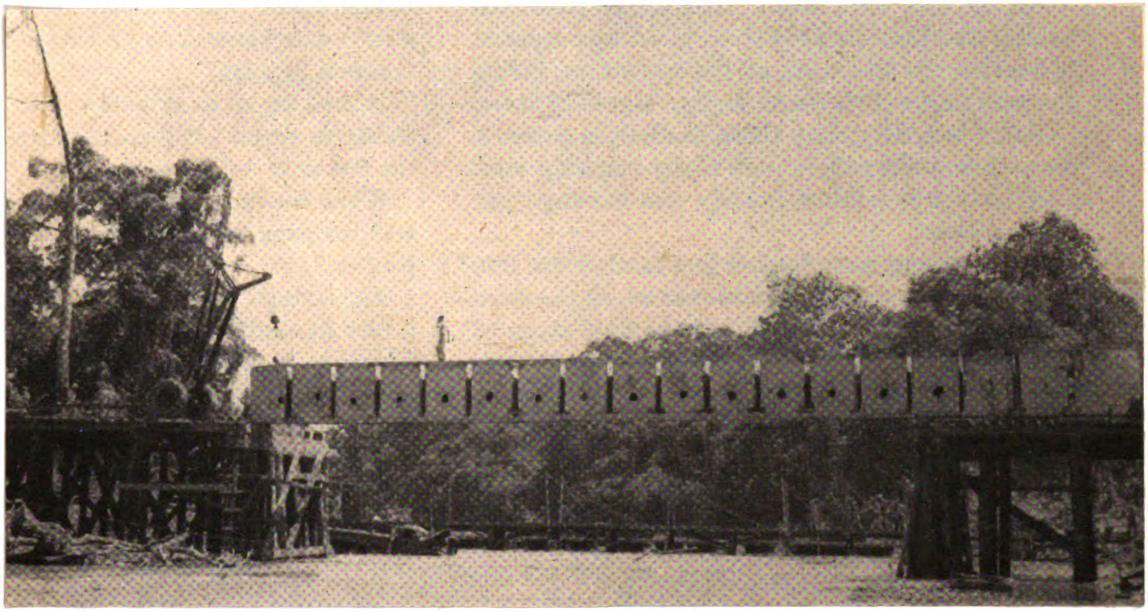

Fig. 30. Launching the pontoon string bridge.

in the case of the timber bridge was the erection of timber bents, which was done in the same manner as described above, but only the end bents were put in. The superstructure of the bridge was a string of pontoons supported by the bents. The string was frequently installed by pushing over the gap with a bulldozer. The landward pontoons of the string were filled with water to provide a counterbalance so that the string could be pushed as far as possible without needing help from the opposite bank, on which was a crane ready to ease the span into position on the bent. When more heavy equipment was at hand, the pontoon string was lifted bodily by cranes on either bank and lowered directly to the supports. The methods of bridging herein described may seem to the engineer a trifle crude, but the structures served a purpose - - speed of completion.

Harbors

Many of the Pacific islands which were designated as advance bases of operation were totally without harbor facilities. To the Seabees fell the task of providing these facilities for the more important bases. The island of Peleliu was singled out as such a base because of its fine Japanese airfield. The work involved in making a harbor for this island will serve as an example to illustrate the general problem.

Peleliu, like many Pacific islands was surrounded by a coral reef which prevented the landing of large vessels. In order to convert the rock-girdled coastline into a port for the unloading of supplies, the Seabees decided to construct a boat basin and a number of unloading piers therein. The approach to the basin was to be a channel cut through the reef.

The problem of dredging a channel and excavating for a boat basin was a difficult one because of the hardness of the coral. The solution

Fig. 31. Channel leading to boat basin (background).

was blasting. Using forty percent gelatin and TNT, Seabee demolition squads placed 50- to 100-pound charges at six-foot intervals. The charges were shot at high tide to gain the advantage of the water cushion.

These tactics loosened the coral to a depth of approximately two feet, and it required 100 pounds of explosive to produce about seven yards of dredgable coral. The approach channel and the basin were excavated to a depth of ten feet below mean low water by four cranes using drag-lines and clamshell buckets. Two of these operated from the shore, while the others were mounted on pontoon barges in order to excavate the channel and the seaward portion of the boat basin.

When the causeways on either side of the channel were to be built, the versatile pontoon was again given preference as a basis for the structures. Strings of pontoons were floated into position to form the outline of the causeways and then they were filled with coral to sink them. The entire structure was then covered with the coral from the dredging operation and smoothed to grade. Protection for the causeways on the sides toward the sea was furnished by riprap of limestone from a deposit on the island. The limestone was quarried in chunks weighing as much as ten tons, which provided an adequate breakwater.

On the channel side of each causeway, the Seabees constructed unloading piers, or docks. These were merely pontoon strings set on piling out over the edge of the coral backfill. The finger piers extending from the shore out into the boat basin were also of pontoons, but were constructed in a different manner. The outlines of the piers were strings of 19 pontoons set 4 pontoons apart. These strings were filled with coral spoil as was the space between them. Surmounting these

Fig. 32. View of boat basin showing one of piers.

two "stringers" were decks consisting of 14 strings of 7 pontoons each.

Roads

It will be convenient to classify road building in the Pacific according to the type of terrain encountered. Usually this terrain was of two sorts; either swampy jungle whose soil was difficult to handle, or an island whose main constituent was coral.

The latter type presented little difficulty because of the very nature of the coral, which has been described as an ideal road building material. In many cases, a road in this type of terrain could be built very rapidly. If the coral was loose, the large chunks were broken up and bladed into shape. Otherwise, blasting would loosen the material sufficiently to permit crushing and spreading. Crushed coral, according to engineers who served in the Pacific, possesses a high degree of inherent stability, and when grouted, provides a high-type surface capable of withstanding heavy traffic.

In the case of the jungle islands, road building took on more formidable aspects. The first "roads" were nothing more than one-way trails pushed by bulldozers, avoiding the largest trees and the worst swamps. However, when the fighting lines moved many miles inland from the beaches, it was necessary to move heavy equipment and armor long distances. For this reason, the trails had to be converted into highways. The bulldozers could no longer avoid trees. If they were unable to push them down, blasting was employed. Heavy rains often made the trails into merely series of deep mud holes, which had to be filled four or five times before the subgrade was stable enough to support traffic; the degree of stability being determined by the weight of the vehicles to be held. The fill material consisted of beach or stream gravel or volcanic slag, when it was at hand. The latter proved to be a very satisfactory filler, as well as a highly stable surfacing material.

In the swamp areas, the road building problem was solved by corduroying, which proved the most effective means of combatting mud. Corduroying consisted of stringers laid along the road on 10- to 12-foot centers, and 20- to 30-foot decking logs placed on the stringers at right angles to the road alignment. The decking was then covered with gravel or volcanic slag from the nearest deposit.

Airfields

As in the case of roads, the construction of airfields was carried on either in the jungle islands or the coral islands. The Corps of Engineers and the Seabees performed with such speed in the building of runways, that they could, in coral terrain, have a fighter strip ready for operation in three days. This greatly increased American air activity in the Pacific, preparing the way for ultimate Japanese surrender.

For the purpose of illustrating the construction of airfields on jungle islands, let us use as an example the one built on the island of Guadalcanal. Work on this airbase was carried on by three different agencies. The Marine Corps furnished the engineers; the Seabees did the actual construction; and the Army was to operate the field after its completion.

Carney Field, which had been in use for years, was in poor shape because of consistent Japanese air attack, and because of an inadequate subbase. The site chosen for the new field was the only piece of level ground on the island large enough for an air base. This site was a low, grassy plain at a bend in the Metapona River. The first thing done was the building of a camp for the working crews. This was erected in a grove of trees to gain protection from the sun and from air reconaissance. The airfield was built around this grove of trees. The grass on the plain was head-high, and when mowing was impossible, it was burned off. A topographic map had been made of the area, and while the grass-clearing was being done, a ditching machine was busy draining the field.

In order that the work be expedited, a conference was held by the three groups, and their differences were arbitrated. The final master plan called for a longitudinal grade of 1 percent maximum, and a transverse grade of 1.5 percent on either side of center. The runway was to be 7,000 feet in length, 250 feet between shoulders, with a 500-foot overrun at each end. In addition, six miles of taxiways were planned, as well as 101 bomber hardstands spaced at 450 feet. Culverts were made of empty gasoline drums welded together and encased in concrete.

Excavation proved to be a problem because of the type of soil encountered. The topsoil was heavy, slippery when wet, and impossible to work for two days after a short rain. Its depth varied from one to three feet. The subsoil was a type of clay, very hard when dry, and when wet, worse to handle than "bad" clay. This had to be ripped out and, even then, it came out in large slabs which were difficult to handle. A sheeps-

Fig. 33. Campsite hidden in trees.

foot roller was used to break up the larger chunks, and to compact the runway subgrade.

While the grading was being done, other crews assisted by native laborers set about surfacing the finished portions. River gravel, the only available material was used for the surfacing. Plans called for two 4-inch layers of compacted and stabilized gravel. Binder for the gravel had to be obtained locally, and a deposit of a sand, silt, and clay mixture found along the river bank served the purpose. The binder was incorporated into the gravel by windrowing with power graders and the surface was compacted by a multiwheeled rubber-tired trailer weighted down by pierced steel planks.

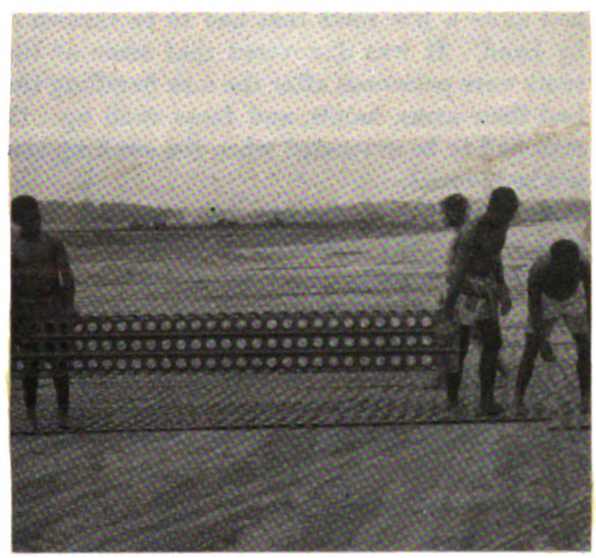

Fig. 34. Laying pierced steel plank.

After the gravel surfacing was in place, it was decided to top this with a layer of pierced steel plank. First was laid a blanket of steel mesh, then the plank. As the latter was placed, the ends of the steel mesh were bent up and the entire surface was grouted. The bent up mesh provided a good measure of reinforcement. All of the taxiways and hardstands were finished in the same manner as described above for the runway.

Coral island airfields were much less difficult to construct than the foregoing, in that the native coral proved to be a very desirable surfacing material, while providing at the same time an extremely stable subbase. The principal difficulty was the hardness of the substance when it

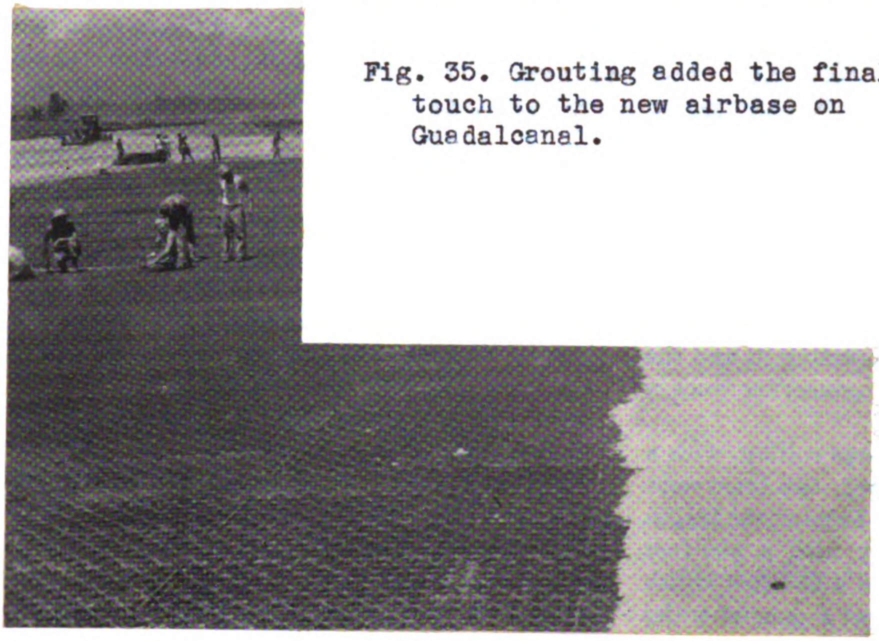

Fig. 35. Grouting added the final touch to the new airbase on Guadalcanal.

was not in the loose state. This, as stated before, called for extensive blasting operations.

One of the most effective units for building this type of airfield was the Aviation Engineering Battalion of the Corps of Engineers. This ubiquitous group consisted of 777 men and had an impressive table of equipment which included 20 bulldozers, 12 carryalls, 3 power shovels, 8 motor graders, 42 dump trucks, and 5 to 10 tournapulls. In addition to the above, each unit had an asphalt-mixing plant with an output capacity of 200 tons per hour, and a rock-crushing plant capable of handling 150 tons per hour. With 'round-the-clock construction, it is not difficult to imagine the speed with which one of these units could construct a base. The standard procedure was to land on an island as soon as possible after the beaches had been cleared, and to go to work as soon as the equipment could be brought ashore from the landing craft. Coral was then blasted out or scooped up, brought to the crusher by truck, returned to the construction site, and spread and graded. After this had been accomplished, the asphalt plant was ready to deliver coral asphalt at a rapid rate. Since speed was the essential factor, the niceties of engineering were frequently overlooked. The completed project, however, served very well the purpose for which it was designed.

Water Supply

In the islands of the Pacific, the problem of securing drinking water was one of converting the sea water into fresh. This was accomplished through the use of portable distilling units operating on diesel fuel. One such still could produce twenty gallons of fresh water to one gallon of fuel consumed.

The disposal of sewage was not frequently dealt with, since the digging of latrines was almost the universal practice, even in hospitals. Shown here is one method of producing a disposal system using only available items.

Fig. 36. Sewer line of welded empty gas drums.

Buildings

Practically all of the buildings erected for the housing of troops, for the hospitalization of the wounded, and for the storage of supplies, as well as those serving as hangars, shops, and other necessary structures were of the prefabricated type; and most of them were the familiar Quonset hut. A Quonset consisted merely of a corrugated skin of sheet steel or galvanized iron fastened to a steel framework. These units were, whenever possible, set on concrete floors. Metal construction was used rather than wood, because of the latter's inability to withstand the rigors of the tropical climate.

Engineer Depots

Both in the Pacific and in the European theaters of operation, the setting up of engineer depots for the receiving, storing, and issuing of engineering equipment and materiel was a large project in itself. The layout of such a depot had to be such that it could expedite the receipt and issue of goods with a minimum of confusion and time consumption. Thus, roads, entrances and exits, and the location of stock piles had to be carefully planned. This was evidenced by the fact that an average depot carried more than 10,000 standard items, as well as about 300,000 spare parts items.

Part 3

Zone of the Interior

Since this report deals primarily with the problems of the overseas military engineer and construction man, the work of these people in the United States during the war will not be highly emphasized. Although their contribution to the victory was as tangible as was that of the units abroad, it was not beset from beginning to end by critical shortages of equipment, replacement parts, and raw materials.

When it became evident that the United States would be required to build a war machine and to provide training facilities for millions of troops, the government enlisted the aid of the nations contractors and construction engineers. The task that they accomplished was not as colorful as that performed overseas, but the alacrity with which it was done deserves mention.

The first task undertaken by these men was the construction of housing and training facilities for the armies. This construction included such items as barracks and other buildings, roads, water supply and sewage disposal, and special installations depending upon the type of camp to be built. For instance, an air base would require landing strips, hangers and shops, and gas and bomb storage; camps for heavy vehicles needed heavy-duty roads; navy installations lacked sufficient dock facilities; precise surveying was a requisite for the placement of coast artillery positions.

With the troops taken care of, these men turned to other projects. Defense plants sprang up almost overnight; the Big Inch pipeline from Texas northward was begun; the Alcan highway approximated overseas construction methods; an extra boat lock was installed at Sault Ste. Marie, Michigan. The list is endless. To give an account of the building of these would be only to write a library of standard engineering practice and construction methods.

Perhaps a few statistics would present a clearer picture of the total amount of work undertaken by the construction men and engineers in the United States.

Military construction involved the building of 2,973 command installations, and 300 major industrial plants, at a total cost of almost eleven billion dollars. The acquisition of property found the U.S. in possession of an additional 38 million acres. Troop camps provided facilities for the housing of 5½ million men (and women). Maintenance was carried on for 13,000 miles of sewers, 4,300 miles of railroads, 13,000 miles of water lines, 63,000 miles of roads, 23,000 miles of power lines, 3000 miles of gas lines, and 1600 miles of steam lines, to mention a few. In addition to the above, the Engineers provided 480 million maps of active and potential battle areas.

Conclusion

The field of engineering and construction in World War II consisted of so many diverse factors, influences, and circumstances, that it is difficult to think of it as a unit, and even more difficult to tell about it without consuming more time and effort than is represented here.

Many improvisations which were made by desparate engineers during the war have definite peacetime values. Many techniques which were used as last-ditch emergency measures are now rewriting the account of some accepted standards in the books on engineering and construction.

The agencies which were responsible for the carrying out of the overall construction plan for wartime were these: The Corps of Engineers (including the Combat Engineers), the Civil Engineer Corps (including the Seabees), special units of the Marine Corps, and the private contracting business of the United States under the supervision of men from the above units.

The countless installations still in use throughout the world stand silent testimony to American ability to get the job done, and to do it well. The spirit behind this ability is written in the words "contract completed" at the end of project reports, and in the blood of the men who gave their lives that the task could be completed.