# Landing Mat Development at WES

*by Michael C. Robinson*

The U.S. Army Waterways Experiment Station (WES) at Vicksburg, Mississippi, made a host of contributions to American successes in World War II. The station, founded in 1929 as the Corps' hydraulics research facility, set aside most of its civil works program after Pearl Harbor and began focusing on military-related research and development. The loss of 631 employees who enlisted in various branches of the armed services aggravated this transition. With many men at war, WES hired and trained women to fill various technical and support roles. Captain Kenneth E. Fields, who became the station's director in September 1939, left to join the Manhattan Project in December 1941. Consequently, Gerard H. Matthes became the only civilian director of WES in the research facility's history.

In the midst of transition and restaffing, WES took on a broad agenda of research and support roles that included developing artificial harbors for the invasion of northern Europe, improving the trafficability of military vehicles in many types of terrain, and using its vast library resources to gather historic hydrologic data in support of Allied crossings of the Rhine River.

WES also made far-reaching contributions to the development of criteria for the design and construction of airfields including airfield drainage, soil stabilization, and flexible pavements. One phase of this work consisted of developing and testing "expedient surfacing" as the need arose for rapidly constructed airfields designed for short periods of intensive use.

Landing mats tested and developed by WES made a significant contribution to Allied victories in Europe and the Pacific. Mats saved time and building materials by offering a reliable alternative to assembling the thousands of tons of base material, sand, and asphalt required in more permanent, conventional designs. The capability to rapidly deploy these temporary landing strips was of utmost importance in maintaining air superiority. Raymond Tolbert of the Office of the Chief of Engineers described this innovation as "an engineering device of important military significance that was largely responsible for the growth and maintenance of Allied air power." WES continued to test and improve landing mats until 1975.

Work on expedient surfacing in Europe predated landing mat research and development in the United States. As air power became a central part of the military capability of the leading European powers, France and England experimented with various landing surfaces to accommodate large fleets of aircraft. Before the war began, France deployed on its airfields a "chevron grid" mat it had developed. France's agricultural practices dictated the mat's design. Since most of the country's airfields were sited on previously cultivated land, soil conditions required a rigid bar-and-grid type mat capable of withstanding heavy landing loads. The gridwork of the mat consisted of longitudinal T-sections interconnected with a zig-zag bar forming large panels that exhibited a herringbone pattern. Bolts and nuts locked the sections to one another.

Conversely, Britain developed a light, flexible-mesh mat that it deployed on its grass covered airfield sites. This design permitted the construction of airfields at locations previously considered unacceptable, and it could also be used to build temporary roads for military vehicles. Fabricated into large rolls, the mat could follow the contours of the ground. The openings in the mesh allowed vegetation to grow relatively unhampered, which provided a natural camouflage, giving the runway the appearance of a pasture from the air. Workers could lay down the mat sections at a rapid rate. On one occasion, the British constructed a landing strip measuring 150 by 3,000 feet in only 15 hours. Easy to disassemble, the mat required only the removal of connector clips for rerolling.

The U.S. Army Air Corps took a lively interest in the British and French landing mats. In December 1939, the Air Corps asked the Army Corps of Engineers to study these European mats and to select or modify one for use by American planes. The Air Corps provided $30,000 for testing. After examining the performance of the French and British mats, however, the engineers concluded that neither product was suitable. They found that both types disintegrated under heavy use and that neither could support large bombers. During testing, connectors broke, anchors failed, and furrows and depressions appeared.

The American engineers concluded that variations of the European designs geared to better meet the needs of the U.S. Army Air Corps should be sought. After beginning research at Langley Field, the Chief of Engineers in May 1940 assigned the project to the Engineer Board that operated the Corps' central military research and development laboratory at Fort Belvoir, Virginia. The Engineer Board in turn later assigned much of the work to WES due to the station's acknowledged expertise in soil mechanics. WES assumed direct responsibility for landing mat research and development only in 1954.

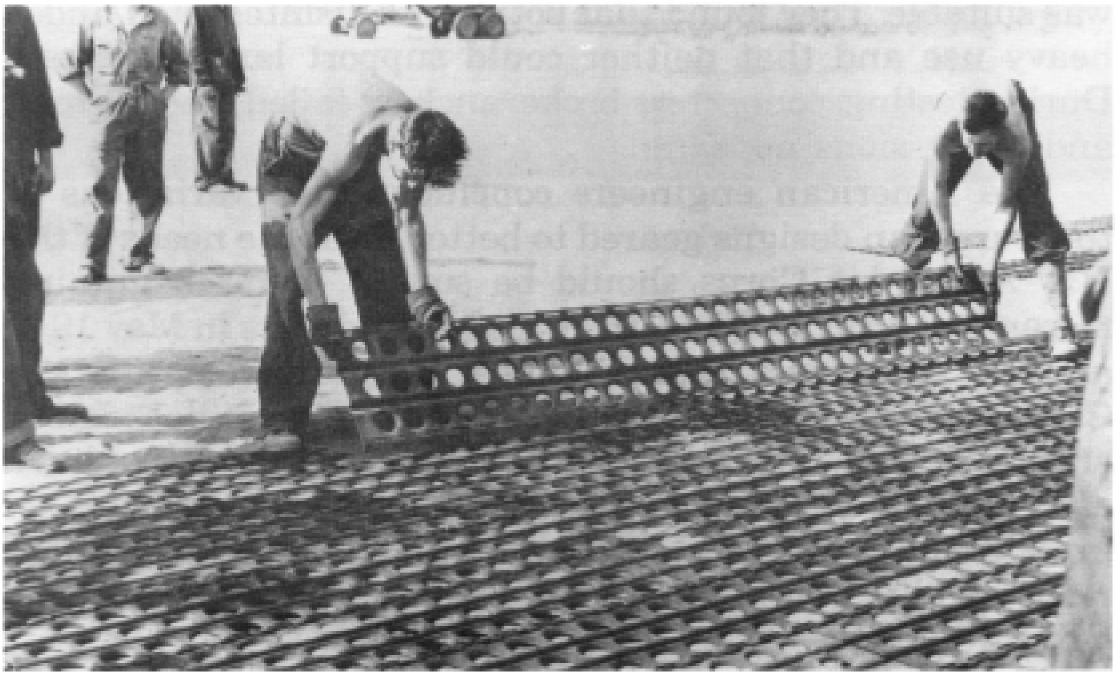
The Air Corps expected expedient surfacing to fulfill three tactical requirements:

- Hard runways that could be rapidly built.
- Standing areas and taxi strips at airfields.
- Temporary landing surfaces for use during the repair of more permanent runways damaged by the enemy.

After determining mat uses, a set of performance standards evolved. All mats had to be easy to transport, repair, camouflage, and produce.

Frequent meetings occurred between government and industry representatives to discuss landing mat testing and production. At one of these, Gerald G. Greulich of the Carnegie–Illinois Steel Corporation sketched out a rough design that evolved into the "pierced steel plank" (PSP) mat used extensively in the Pacific and European war theaters. Army Air Forces Lieutenant General Henry H. (Hap) Arnold later described Greulich's proposal as one of the "greatest contributions and achievements in aviation" during World War II.

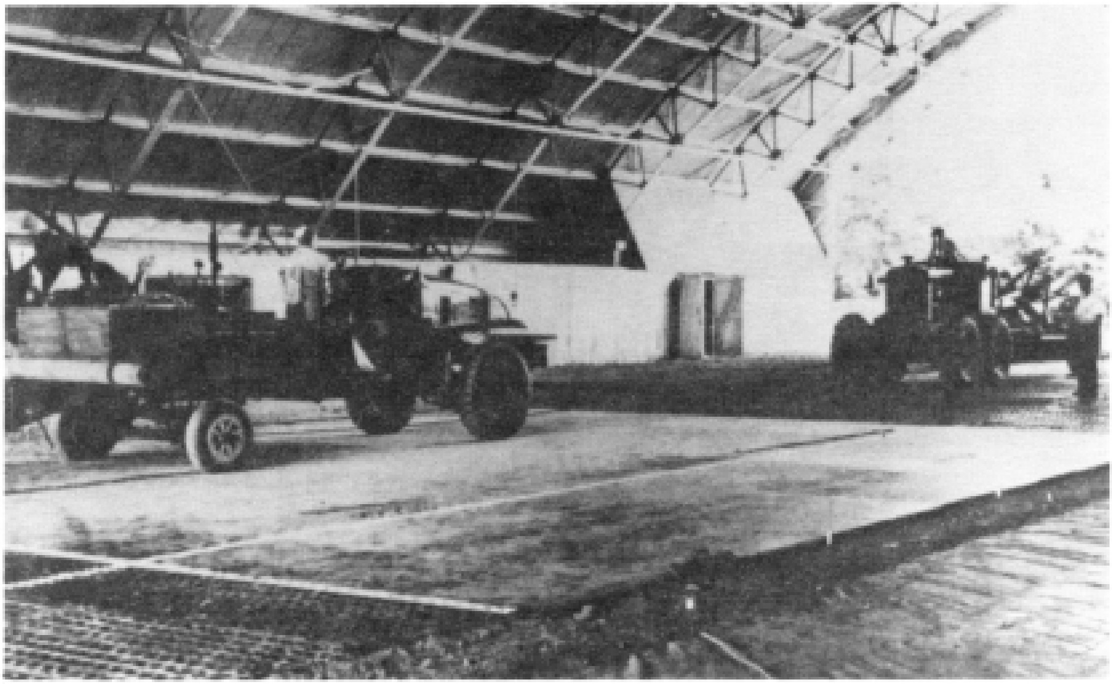
The initial steel plank design underwent many modifications. Testing revealed that the original mats weighed too much. Consequently, machines pressed holes into the steel mat sections to reduce weight, improve aircraft traction, and facilitate drainage. Flanging the holes kept the mat durable



*Expedient construction of a landing field using pierced plank mat.*

by compensating for the strength lost by removing a portion of the metal. Each steel plank was 10 feet long, 15 inches wide, and 1/4-inch thick and weighed about 70 pounds. The panels joined together by a locking mechanism consisting of alternating rows of slots on one side and sliding, interlocking projections on the other. Spring clips kept the connectors in position. Although Greulich solved the problem of mat linkage, the Army continued to test other designs proposed by manufacturers throughout the war.

To test the mats, WES engineers and scientists put in place standard procedures for conducting mat research and comparing test results. Mats selected for appraisal underwent both engineering and service testing. The engineering tests usually indicated the inherent structural adequacy or design deficiency, while the service tests examined mat behavior under airplane traffic. The laboratory phase of the engineering evaluation consisted of bending tests, shear and tensile tests of the interlocking connectors, as well as a physical and chemical analysis of the metal. Researchers compared stress-strain data from bend tests with those for other mat types. Large vehicles loaded with thousands of pounds repeatedly traversed test mat sections to evaluate mat behavior under stress and determine the strength of connectors. Many

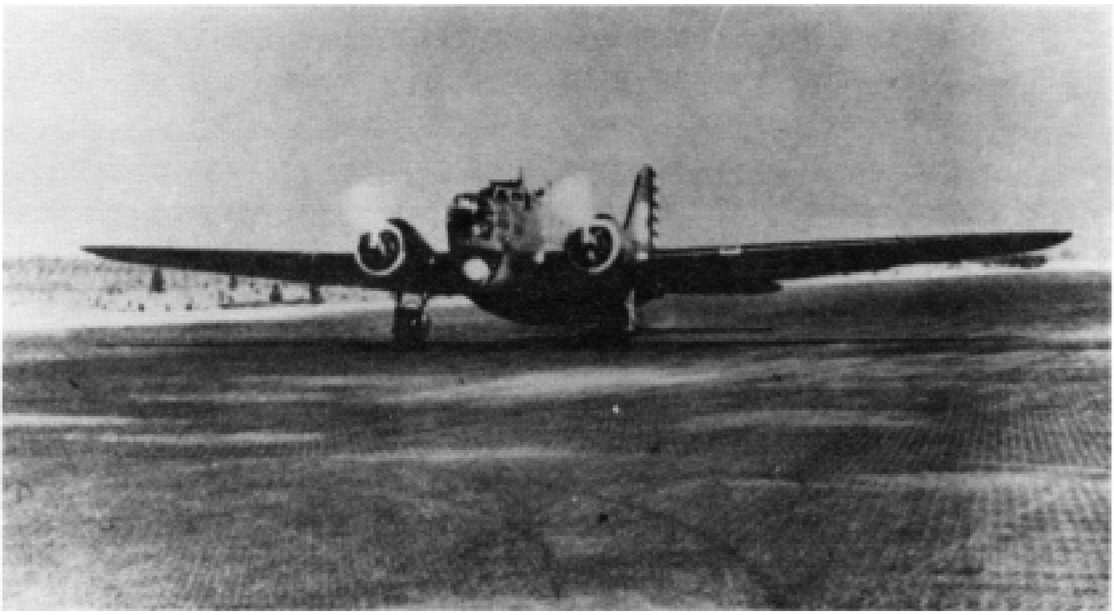


*Waterways Experiment Station researchers test experimental mat.*
*(Waterways Experiment Station)*

prototype mats failed the engineering tests and never went into production. During service testing, Corps engineers subjected mats to airplane traffic ranging in weight and size up to heavy bombers of 60,000 pounds or more. The research design included observations on:

- Structural adequacy under static and dynamic loads.
- Braking action.
- Skiddingcharacteristics.
- Tire abrasions.
- Time checks on laying operations.
- Durability.

The most extensive tests conducted at WES occurred in 1943 and 1944. By this time, the government had accepted PSP and several other types, but questions remained regarding mat performance under contrasting soil conditions. Since the armed services were deploying mats throughout Southwest Asia and Europe, these critical performance data were badly needed. Accordingly, the Office of the Chief of Engineers, in cooperation with the Engineer Board, planned an extensive research program to correlate mat performance under different loads with various soil and base courses. The



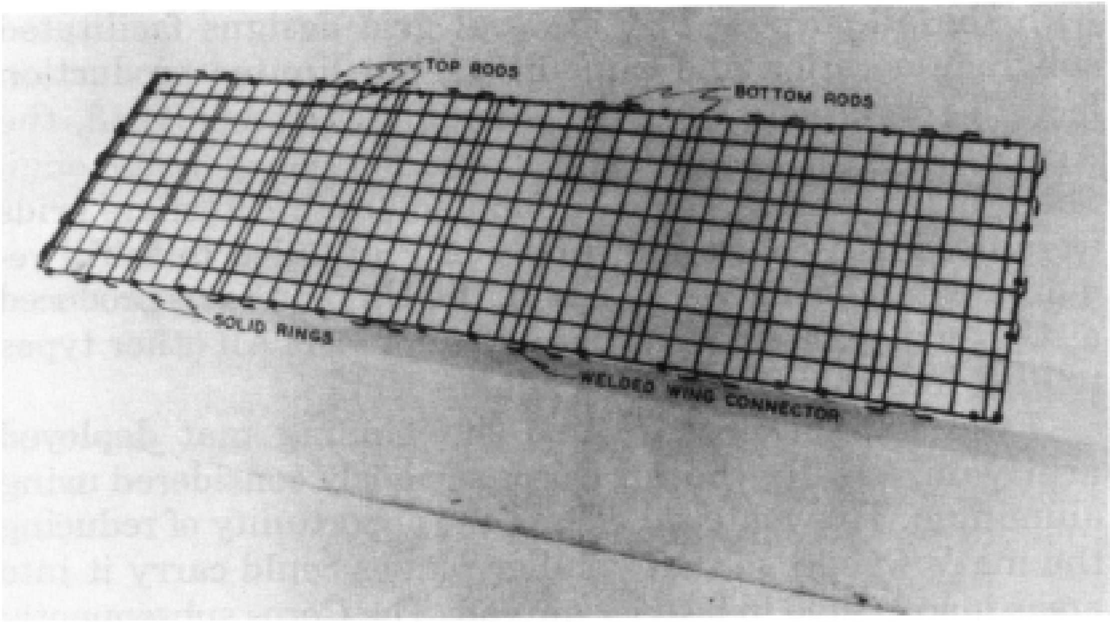
*Operational testing of pierced steel plank mat.* *(Waterways Experiment Station)*

tests included careful use of the recently developed California Bearing Ratio (CBR) to determine the penetration resistance of each soil type.

The WES Flexible Paving Laboratory received this important and complex assignment. The purposes of the investigation included determining the proper thicknesses of base courses, understanding the capabilities of landing mats placed on silt and clay, analyzing new techniques for joining sections together, and comparing the performance of various experimental mats with the standardized types already used in theaters of operations.

WES conducted most testing at two locations near Vicksburg. A site near Mounds, Louisiana, featured a fat clayey subgrade known locally as "buckshot." By contrast, the "Rifle Range" site south of Vicksburg offered a silt-loam soil. At these locations, WES conducted tests using a LeTourneau Tournapull earth-moving machine loaded progressively with 15,000, 37,000, and 60,000 pounds of weight. The research team ran tests on no less than 15 mat types, including standard steel mats, experimental steel mats, experimental aluminum alloy mats, and an array of experimental wooden mats developed by General Electric and other companies.

The tests generally vindicated deployment of PSP and a heavier bar-and-rod grid mat recently adopted. Both performed better than experimental types examined, and when




Experimental bar and rod mat. *(Waterways Experiment Station)*

laid on a thick base course of sand or gravel could support 60,000-pound wheel loads, the weight of the largest bombers. One type of laminated wood mat actually outperformed any of the steel mats tested. Its production involved building a lumber gridwork of two-by-fours and filling the interstices with subgrade material, but it was not practical for wartime conditions. The research program also determined the thickness required for aluminum mat to equal the trafficability of PSP.

The WES testing program, combined with favorable reports from airfields throughout operational theaters, reaffirmed the preeminence of PSP. The heavy bar-and-rod was relegated to a supplementary role and production of lighter types other than PSP ceased. Thereafter, research focused on refinements such as improving the durability of connectors.

Production ease and speed shaped decisions on which mat type to adopt. The plank type could be easily manufactured and steel companies readily modified their presses to quickly stamp out large quantities. However, this mat did not camouflage easily. Nevertheless, the Army decided in December 1941 to procure the PSP mat primarily because of its ease of production. It satisfied all criteria for a heavy-duty plank mat. Although the Corps of Engineers never obtained the light-duty mat sought by the Air Corps for pursuit and observation planes, field commanders were happy with the all-purpose PSP. Several grid designs facilitated subgrade aeration and camouflage, but limited production facilities retarded their deployment. In October 1943, the Army approved two types of grid mat developed by the engineers, but their role would be supplemental. Alternate grids were used only when the supply of PSP failed to fulfill requirements. During World War II, the United States produced a staggering 800 million square feet of PSP. All other types totaled less than 50 million square feet.

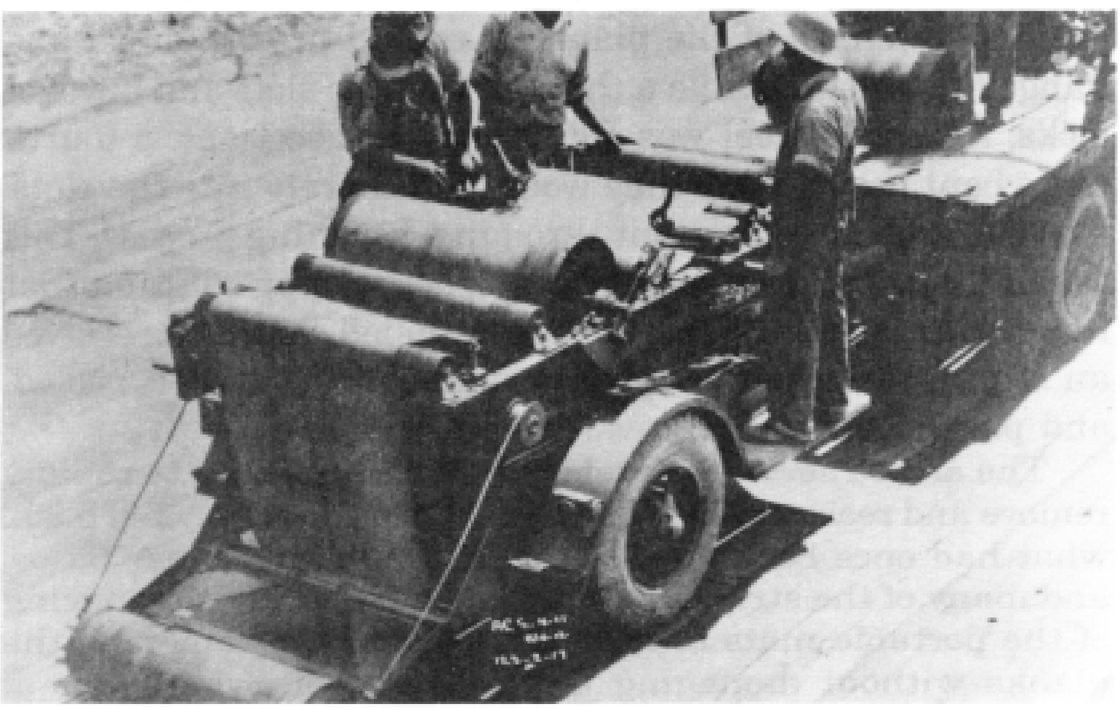
Even though PSP became the landing mat deployed nearly universally, the Air Corps seriously considered using aluminum. This material offered the opportunity of reducing the mat's weight so that smaller planes could carry it into areas inaccessible to heavier aircraft. The Corps subsequently asked the Aluminum Company of America to work with various contractors to develop the new mat. This effort resulted in the pierced aluminum plank (PAP) mat. The design of the lightweight aluminum-alloy planks mirrored the standard PSP. The PAP units measured 15 inches by 10 feet, but they weighed only 35 pounds, or about half of their steel counterparts. Although lighter, the PAP performed adequately. Designers obtained rigidity by increasing the aluminum sheet's thickness approximately 40 percent over that of steel. Since its service life was only half as long, the aluminum landing mat never replaced steel during World War II. It remained a useful supplement to PSP that facilitated airfield construction in remote areas and other locations requiring efficient use of air transportation.

WES also helped to develop prefabricated bituminous surfacing (PBS) which facilitated rapid temporary airfield construction. This technique was invented in Canada, developed by the English, and improved by the United States. Its objective was to place a waterproof fabric over graded and compacted natural soil. The fabric would provide a means of keeping the soil dry while offering a safe landing surface for aircraft traffic.

Intensive investigations at WES resulted in a membrane that could be produced in great quantities and give satisfactory results. Popularly known as "Hessian Mat," the 1/4-inch thick material went into production in early 1944. The Allies placed this relatively inexpensive mat on more than 100

*Prefabricated bituminous surfacing.*

landing strips in Europe between D-day and the crossing of the Rhine in March 1945. It provided good service under a steady stream of cargo and fighter planes as well as medium bombers. The PBS comprised nothing more than burlap that was impregnated and coated with asphalt, giving the appearance of roofing material. The relatively light PBS could be put down in strips at a rate of 2.5 to 4 miles per hour. Crews used a "stamplicker" machine that wet one side of the mat with a solvent which softened the asphalt and produced



*The* stamplicker, *a machine for laying prefabricated bituminous surfacing.*

a sticky surface. Then a second layer was applied so the bonded surface provided a thin, weatherproof, and dustproof landing strip. A fine layer of sand placed on the surface enhanced friction and reduced skidding. Alternately, the bituminous surfacing could be used in conjunction with steel landing mats when a dust palliative was required.

The prefabricated bituminous surfacing proved as easy to repair as it was to lay. Two laborers with a mop, bucket, and strip of PBS could simply repair small failures by swabbing the mat, laying it, and then just walking back and forth on it to pack it in place. Repairing larger problems caused by bombing and soft spots formed by trapped water involved peeling back the PBS, replacing the subgrade, and putting down a fresh strip. The nickname Hessian came from the fact that Hessian migrants to Dundee, Scotland, had woven Indian jute into mats more than a century before.

Once designed, tested, and ordered for procurement, the steel and aluminum landing mats had to be produced in great quantities. To meet the demands of the armed forces, steel companies retooled to accommodate landing mat production. Some 30 factories made pierced steel plank during World War II. Normally, processing facilities acquired the precut steel used for the planks. A conveyor belt carried the raw steel to a machine that impressed the metal with two ribs running the entire length of the plank. A second press pierced and flanged the metal, while a third formed the slots and bayonet locks. After the steel was cut into 10-foot sections, a fourth press bent the locks so they would fit securely into the slots. Once formed, the mat went through a finishing process. This consisted of dipping the mat into a degreasing solution that removed residues before paint was applied. The mat received an Army-green camouflage coat and was then baked, cooled, and packed for shipping.

The armed services developed field techniques to rapidly remove and reassemble PSP and PAP. As the enemy fell back, what had once been advanced airfields became rear bases, and many of the strips fell into disuse, requiring the moving of the portable mats to more forward areas. Removing the planks without damaging them for use elsewhere was of great concern. Innovation and adaptation solved the problem.

Simple railroad picks removed the locking clips and helped separate the mats.

Aircraft takeoffs and landings, as well as bombing attacks, subjected landing fields to constant stress. The need for on-the-spot repairs led to the development of portable reconditioning plants. The portable units, which weighed 60 tons each, could be carried in a cargo plane. Soldiers could recondition an entire airstrip 300 feet wide and 1/2 mile long in less than a week. The plants consisted of two main machines, a roller-leveler to straighten the mats and a brush-cleaning machine to remove soil and debris. They made a significant contribution to the war effort by making rapid repairs and reducing steel consumption through reuse.

The need for a portable landing mat arose time and again throughout the war in both Europe and the Southwest Pacific. During the New Guinea campaign, for example, enemy forces began advancing across the Owen Stanley Mountains. In response, Army engineer units constructed a PCP emergency airfield well behind enemy lines at a place called Dobodura. Cargo planes flew in the landing mats as well as all construction equipment, troops, and supplies. The fighter planes operating from this emergency runway contributed to the early Allied victories in New Guinea.

During World War II, the United States manufactured a quantity of landing mats capable of building a steel roadway around the world's equator. Some 2 million tons of mat costing in excess of $200 million accounted for enough steel to build 650 10,000-ton cargo ships. WES and other Corps elements conducted the testing that enabled the nation to develop and rapidly manufacture this essential strategic item. These pioneering efforts later redounded to the nation's benefit as heavier jet aircraft with high tire pressures evolved. Research on landing mats continued at WES for more than three decades, and especially intensified during the wars in Korea and Vietnam. The station published more than 90 technical reports on this subject, acquiring a broad institutional expertise.

WES research and development work on landing mats clearly enhanced the Allied ability to rapidly deploy and advance its air power during World War II.

## Sources for Further Reading

A discussion of the Waterways Experiment Station's wartime activities may be found in Gordon Cotton, *A History of the Waterways Experiment Station, 1929–1979* (Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station, 1979).

For technical information on the development of landing mats see W.B. Spangler, *Emergency Landing Mats for Airfields* (Fort Belvoir, VA: Engineering Research and Development Laboratory, 1954) and Raymond Tolbert, "Development of Airplane Landing Mats," *Roads and Bridges*, 83 (November 1945): 62–64, 108.