Repair and Restoration of Bomb-Damaged Airfield Pavements

G. M. Hammitt II & D. W. Pittman
U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, USA

ABSTRACT: Improved repair and restoration systems for paved surfaces is an ongoing U.S. Army responsibility. This responsibility includes evaluating equipment, materials, and procedures designed to improve the U.S. Air Force's capability for emergency airfield pavement repairs of war-damaged craters. These improvements reduce the personnel requirements and repair time and increase permanency of the repairs. The U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi evaluated the performance of four materials and construction techniques. These materials were a blend of portland cement, crushed limestone, calcium chloride and water; fibrous reinforced polyester (FRP); high-density foam slab over a low-density foam slab; compacted crushed stone over the low-density foam slab; and a compacted crushed limestone with a nylon reinforcing grid. The repaired craters were trafficked with simulated C-141 and 300 coverages of a simulated F-4 military aircraft gear. All of the repair procedures and materials performed satisfactorily, with different time and manpower requirements.

The development of improved repair and restoration systems for paved surfaces is an ongoing U.S. Army responsibility. This responsibility includes evaluating equipment, materials, and procedures that are designed to improve the U.S. Air Force capability for emergency pavement repairs. These improvements are enacted to reduce personnel requirements and repair time, as well as to improve the capability and permanency for repairs under various conditions.

The objective of this investigation was to conduct prototype traffic tests and evaluate performance of the following materials:

a. Precast foam subgrade and pavement blocks.

b. Laminated reinforced subgrades and wearing surfaces using plastic mesh and crushed limestone.

c. Sand grids overlayed with 1.3 cm FRP pallets.

d. Cement grout with 1 percent calcium chloride as an accelerator mixed with 7.6 cm maximum size crushed stone.

This investigation consisted of the construction and testing of a specially designed test section consisting of three craters. The traffic pattern over the three craters was divided into two lanes, each 3 m wide on either side of the craters. Visual observations of crater performance were recorded throughout the trafficking.

Each of the three craters were 8 m long and 8 m wide, constructed over a subgrade of selected debris. This select material was composed of a blended soil combined with crushed limestone, to obtain a gradation that would simulate debris following a blast on the pavement. The aggregates and proportions used to obtain the blended soil were as follows:

24 percent	Sandy Gravel (GW)
22 percent	Concrete Sand (SP)
25 percent	Crushed Gravel
10 percent	Campbell Swamp Sand (SW)
19 percent	Silt (ML)

A cement grout consisting of Type 1 portland cement with 1 percent calcium chloride added as an accelerator was used in construction of the test surface in Crater 1. A crushed limestone with 7.6 cm nominal aggregate size was added to the grout mixture before it hardened. The stone was mixed with the grout by use of a front-end loader and a D-4 dozer until the final thickness of the concrete was 61 cm.

Crater 1 was filled with cement grout and crushed limestone to a depth of 61 cm. The time required for this construction, from the start of mixing to the final broom finish was approximately 14 hours. A total of 10 personnel were used for construction including a supervisor, a mechanic, and an operator.

A fabric membrane was placed in the crater and along its sides to act as a barrier to water seepage during construction. A 3 m box made 5 cm by 25 cm boards with a fabric bottom was used to mix the grout.

Several hundred gallons of water was first pumped into the crater. Pumps were used to recycle this water to mix the cement and then pass through the screen of the box back into the crater. The amount of materials combined to achieve a 1 ft depth of grout was as follows:

Type 1 cement - 570 bags (258 kg per bag)
Water - approximately 14,000 liters
Calcium chloride - 317 kg

This aggregate was added by the loader until the crater had been filled. As the loader added the aggregate it also mixed the aggregate and the grout with its wheels as it drove into the crater. A steel-wheel vibratory roller was then applied to the surface.

The sand grids in Crater 2 were high-density polyethylene grids expandable to a 6.1 m by 2.4 m section, 20 cm thick. The 1.3 cm thick FRP matting was bolted to the concrete surrounding the crater with nine bolts transversely across each end and five bolts longitudinally on each side.

Before installing the first layer of sand grids, a thin leveling layer of sand was laid and covered with a layer of fabric (polypropylene). The grids were placed in three layers with each succeeding layer placed in alternate directions. Each layer of sand grids was backfilled with concrete sand compacted with a steel-wheel vibratory roller. A vibratory plate roller was used around the edges of the lifts where the vibratory roller could not reach. A final layer of sand was applied to level the surface in preparation for the FRP matting.

Two types of foam blocks used in Crater 3 were high (1.9 kPa) and low (.8 kPa) density blocks. The high-density blocks measured approximately 114 cm by 114 cm by 30 cm and four of them were used in the test section. The low density blocks measured approximately 114 cm by 114 cm by 45 cm and 8 of these were used in the test section.

Nylon reinforcing grids (3 cm by 3 cm opening) were used as reinforcement between the layers of limestone in Crater 3. This reinforcing was supplied in rolls 3 m wide and 50 m long.

Crater 3 was backfilled with combinations of foam, nylon reinforcing, and crushed limestone. Lane 1 of Crater 3 had a layer of low density foam slabs over concrete sand used as a leveling course. This lane was divided by placing a 3 m by 3 m section of high-density foam as a surface material on the eastern end of Lane 1. The remainder of the lane was filled with 30 cm compacted crushed limestone over the low density base foam. Crushed limestone was also placed around the edges of all foam wherever it did not fit smoothly to the edge of the crater. Following partial trafficking, the low-density foam was placed as a traffic surface on top of the crushed limestone.

Lane 2 of Crater 3 consisted of 75 cm of crushed limestone with nylon reinforcing placed on the subgrade and between 15 cm lifts.

The traffic applied to the test section was distributed by load carts across the traffic lanes following a normal distribution curve as might be expected under normal aircraft traffic operations. Information concerning both load carts is given below:

Type of Load Cart	C-141	F-4
Tire Size	30 x 11.5	30 x 11.5
Tire Pressure	1825 kPa	470 kPa
Test Loads (Total Load)	12,231 kg	65,232 kg

At total of 960 C-141 and 300 F-4 coverages were applied to Lane 1. Lane 2 received a total of 1,000 C-141 and 150 F-4 coverages. These coverages were applied in various stages over a time span of several weeks.

By 80 coverages of traffic, hairline cracks had developed across the corners on each end of Crater 2. These cracks appeared to be about 4 m long and ran at 45-degree angles across the corners.

The final cross-sections indicated that there had been practically no displacement of the trafficked surface. These cracks did not affect the trafficability of the crater. The condition of Lane 2 on Crater 1 prior to traffic was similar to that of Lane 1.

The initial traffic applied to Lane 1 on Crater 2 was interrupted after four F-4 coverages due to large FRP mat deflections. The mat was deflecting approximately 15 cm under the weight of the F-4 load cart. The mat was raised, and more sand was added to the crater and compacted. An additional 36 F-4 coverages for a total of 40 F-4 coverages were added before more sand was again required beneath the FRP matting. The final traffic totals were 300 F-4 coverages and 820 C-141 coverages.

The FRP mat performed well. Five bolts out of a total of 28 holding the entire mat came loose. There was no horizontal displacement of the matting.

In Lane 2, Crater 2 the FRP mat did not break or exhibit distress except for settlement which was caused by the displacement of the sand beneath it. As with Lane 1, 5 bolts along the mat edge holding the mat to the surrounding concrete surface worked loose during traffic.

Traffic was applied to Crater 3, Lane 1 with the F-4 load cart, and after a total of 250 F-4 coverages, one block of the low-density foam started to develop cracks. At 270 coverages, the surface of this block began to break up. This surface was broken off to a depth of 3 cm due to an apparent shearing of the block during the traffic. A smooth even surface was exposed after all the pieces were removed. The foam block which was broken up on the surface was then turned over and an additional 660 C-141 coverages were applied for a total of 820 C-141 coverages to this lane.

The traffic applied to Crater 3, Lane 2 consisted of 150 F-4 and 1,000 C-141 load cart coverages. Several small depressions developed in the traffic lane with the deepest depression measuring 4.5 cm from the original elevation. The traffic lane surface however, remained serviceable to traffic.

The following is a summary of the traffic data:

Summary of Traffic Data

Crater No., Traffic Lane No.	Traffic Surface and Traffic Element(s)	Element Thickness (cm)	Aircraft Load Cart Traffic	No. of Coverages Applied
1,1	Concrete	61	F-4	300
			C-141	960
1,2	Concrete	61	F-4	150
			C-141	1,000
2,1	FRP Matting	1.3	F-4	300
	3 Layers of Sand Grids	61	C-141	820
2,2	FRP Matting	1.3	C-141	1,000
	3 Layers of Sand Grids	61		
3,1	Crushed Limestone	30.5	F-4	150
	Low-Density Foam	45	C-141	80
	High-Density Foam	30	F-4	150
	Low-Density Foam	45	C-141	80
3,1A	Low-Density Foam	46	F-4	150
	Crushed Limestone	30.5	C-141	740
	High-Density Foam	30.5	F-4	300
	Low-Density Foam	46	C-141	820
3,2	4-15 cm Layers of Crushed Limestone with	15	F-4	150
	3.8 cm Nylon Fabric Reinforcing between Layers		C-141	1,000

All test surfaces used in the three craters performed satisfactorily under the applied traffic. The precast foam subgrade and pavement foam blocks, both high and low-density, performed satisfactorily when subjected to traffic, with minor maintenance. The time required to place these blocks was approximately 1-1/2 days using four laborers, an operator with a fork lift and a front end loader. The only maintenance performed was to elevate the high-density foam blocks with sand after 150 coverages of F-4 and 80 coverages of the C-141.

Laminated reinforced subgrades and wearing surfaces with crushed grout performed satisfactorily when subjected to traffic. The crushed limestone with its plastic mesh reinforcing was placed in one traffic lane of a crater in less than 8 hours by four laborers and one operator with a front end loader and vibratory roller.

The sand grids overlayed with 1.3 cm FRP pallets performed satisfactorily when subjected to traffic with minor maintenance. Constructing the sand grids for Crater 2 required a relatively long time (16 hours) compared with the time required for assembling the FRP matting (4 hours). The FRP matting had to be removed three times and more sand was placed beneath it. The cement grout with 1 percent calcium chloride as an accelerator mixed with 3-in. maximum size crushed stone performed very satisfactorily. The cement grout was successfully mixed in the crater in 12-hours using 10 laborers; one operator with a water truck, front end loader, D-4 dozer, and vibratory roller; and 2 pumps and other minor miscellaneous mixing equipment. The initial low strengths that the grout gained during the first 24-hours after construction suggested that the calcium chloride added was not properly mixed into the grout.

ACKNOWLEDGEMENT: The support of the US Army Engineer Waterways Experiment Station (WES) in gathering and preparing material for this paper is gratefully acknowledged. The material presented here represents the views of the author alone and does not reflect any official government view or policy. This paper is published with the permission of the Chief of Engineers.