MILITARY APPLICATIONS OF BLOCK PAVEMENTS IN THE UNITED STATES

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SUMMARY

The U.S. Army Corps of Engineers is responsible for the research and development of pavement systems for the Department of Defense and other federal agencies. From a military standpoint, this responsibility becomes very challenging because of the wide variety of traffic, soil, and environmental conditions associated with the U.S. military's worldwide inventory of pavements.

One of the new approaches the U.S. Army is examining for handling military tank traffic is the concrete block pavement. This paper describes a recent demonstration project where a concrete block pavement was constructed over a weak subgrade on an Army base. The concrete paving blocks were used to provide a flexible pavement surfacing which could withstand the abrasive action of tracked vehicles. After nearly two years of daily tank traffic, the block pavement continues to perform satisfactorily.

Introduction

The pavements needs of the United States Department of Defense (DOD) are the most challenging of any single agency in the world. The DOD has in its inventory over 1 billion square meters of pavements to maintain. These pavements are located in environments ranging from the arid deserts to the polar arctic regions. DOD pavements carry heavy trucks, tanks, aircraft and space shuttles. In support of the DOD's enormous pavement needs, the U.S. Army Corps of Engineers is continually seeking innovative pavement materials.

As the lead pavements research center for the U.S. Army Corps of Engineers, the Waterways Experiment Station (WES) has been involved in the research of concrete block pavements for military applications for many years. This research has included investigations of block pavement materials, designs, and construction practices. A concrete block pavement test section was constructed and analyzed in 1979 in order to develop standards suitable for the needs of the U.S. military. The lessons learned from this test section and their implications for military pavement applications are documented in a 1983 report for the U.S. Army by Rollings [I].

In the 1980's, the U.S. Army Corps of Engineers developed a technology transfer program which funded various demonstration projects involving new and innovative construction technologies. The documentation of the demonstration projects was used to introduce these new technologies to the U.S. Army facilities engineering community. One such project was undertaken by WES in 1988 for the construction of a concrete block pavement to demonstrate its effectiveness in carrying military tank traffic.

Site Conditions

The site selected for the concrete block pavement demonstration project was on a U.S. Army base in Maryland known as Aberdeen Proving Ground. As part of its military mission, this base maintained a tank training school and several large training ranges. A gravel-surfaced tank road intersection located on the outer rim of a training range brought five range roads together near a tracked vehicle motor pool area. The traffic count for this intersection was estimated at 10 M-88 (50 metric ton) Tank Retrievers and 10 M-578 (27 metric ton) tracked vehicles per day.

Approximately 1,150 square meters of the existing gravel surfaced intersection was scheduled for reconstruction using the concrete paving blocks as the new pavement surfacing. The main reason for reconstructing this intersection was that the existing gravel-surfaced system could not effectively withstand the churning action of the tank tracks. Constant regrading to eliminate severe wheelpath ruts and additions of new gravel to resurface the intersection became routine in this area. This continuing and expensive cycle of required maintenance was to be eliminated by the new concrete block pavement. The existing subgrade was a weak (Design CBR 3) clay material with varying amounts of natural sands and silts. The silty clay materials were highly frost-susceptible, thus providing the potential for differential frost heave in the subgrade. A flexible pavement design was determined to be the most economical means of addressing this potential problem. Traditional flexible pavement surfacings, such as asphalt concrete, would not have withstood the abrasive action of the turning tracked vehicles, however. The combination of a soft, frost-susceptible subgrade and tracked vehicle traffic made the Aberdeen Proving Ground site a good candidate for the concrete paving block demonstration.

Design

The design of the concrete block pavement was based on the Corps of Engineers standard flexible pavement design. The thickness requirements of the base and subbase layers were computed based on the in-situ soil properties and equating the concrete block and sand bedding layers with 165-mm of asphalt concrete surfacing. The design results indicated that the total reconstructed pavement thickness, excluding recompacted subgrade, would be approximately 685-mm. The pavement layers, from bottom to top, consisted of 305-mm of recompacted existing subgrade material, a geotextile for separation of subgrade and subbase, 490-mm of select-fill compacted in lifts as the subbase, 100-mm of crushed stone base course, 15-mm (estimated final thickness) sand bedding layer, and the 80-mm thick paving block.

ASTM C936 "Standard Specification for Solid Concrete Interlocking Paving Units" [II] was used to specify the physical requirements of the concrete paving blocks. This standard specifies minimum requirements of compressive strength, absorption, resistance to freezing and thawing damage, and abrasion resistance. The rectangular shaped paving block was specified for this project because of its local availability and low cost in comparison with other block shapes. Also, previous research indicated that rectangular shaped blocks laid in the herringbone pattern are suitable for heavy-duty applications [I, III, IV].

Construction

Construction of the demonstration project at Aberdeen Proving Ground began in May 1989. The first step in the construction process was to erect silt fence barriers around the intersection to prevent excessive silt runoff during the earthwork stage. Next, a total of 685-mm of the existing soil was removed and the existing subgrade was compacted to meet the specified density requirements. A geotextile was placed on top of the compacted subgrade and a select-fill subbase material was spread and compacted over the geotextile in several lifts. To complete the base and subbase construction, a 100-mm thick crushed stone base course was placed and compacted over the subbase.

After the final compaction and grade requirements for the base course were achieved, a cast-in-place concrete curb was built around the intersection area. A commercial slip-form type curb machine was used for this process. The concrete curb was constructed at a 85-mm height differential from the surface of the base course to match the final thickness of the paving block and sand bedding layers. The curb would act as the required edge restraint to prevent the paving blocks from shoving under traffic.

Once the concrete curbs had sufficiently cured, construction of the paving block system began. A sand bedding layer was placed over an area of the compacted base estimated to equal to one day's coverage of paving blocks. The sand used for the bedding layer was clean and well-graded, meeting the specification requirements listed in Table 1. The sand was dumped and

TABLE 1. Grading Requirements of Bedding Sand and Jointing Sand

Sieve Size (ASTM [V] E-11)	Percent Passing	
	Bedding Sand	Jointing Sand
3/8-in.	100	100
No. 4	80-100	100
No. 8	60-90	95-100
No. 16	25-70	70-100
No. 30	10-35	40-75
No. 50	5-20	10-40
No. 100	0-10	2-25
No. 200	0-5	0-10

spread over this area with the use of screeding pipes. The pipes were 25-mm outside diameter and were used along with a wooden screeding board to achieve the specified 25-mm initial depth (Figure 1). After screeding the 25-mm sand bedding layer on both sides of the screeding pipe, the pipe was carefully pulled and the resulting void in the sand layer was filled and screeded with a small piece of wood mounted on a broom handle.

The paving blocks were hand laid beginning at the center edge of one of the road entrances. A stringline was set up perpendicular to this curb edge to run from the start point through the center of the intersection. The stringline served as a reference point to begin and keep all block placement in perfect alignment. This technique was necessary since the concrete curbs surrounding the intersection area were curved and were in no particular alignment.



Figure 1. Screeding 25-mm-thick bedding sand layer

The herringbone pattern was carefully established at the beginning of the block placement phase as the alignment of the entire block pavement depended upon the initial blocks. The paving blocks were placed directly on the 25-mm sand bedding layer (Figure 2). The resulting height differential at the curb was 20-mm to allow for consolidation of the sand bedding layer during compaction and settlement of the underlying layers under traffic.

Near the end of each day's production, the newly laid paving blocks were compacted with several passes of a manually operated vibratory plate compactor (Figure 3). No compaction was allowed within 1.5 meters of the unfinished paving block edge in order to prevent the paving blocks from shoving outward. Once the paving blocks had been compacted, a fine-graded masonry sand was spread over the paving blocks and broomed into the joints. This jointing sand had a considerably finer gradation (as described in Table 1) than the bedding layer sand. Several passes of the vibratory plate compactor consolidated this jointing sand. The spreading and vibrating of the jointing sand was repeated several times until the joints were filled.

The paving blocks were trimmed in aloig the concrete curb edge restraint as the work progressed. Each block cut was measured by placing the block over the open area and marking the required cut line with chalk. A hand operated splitting device was used to break the block along the cur line. This device produced & relatively clean and straight break. A slight angle was provided on every break to make the top surface approximately 10-mm longer (or wider) than the bottom surface. This chamfered edge helped the paving block to fit into the desired space much easier. Once a length of the pavement edge had been trimmed in, the paving blocks were compacted and the joints filled in the same manner as previously described.



Figure 2. Hand placement of 80-mm rectangular paving blocks

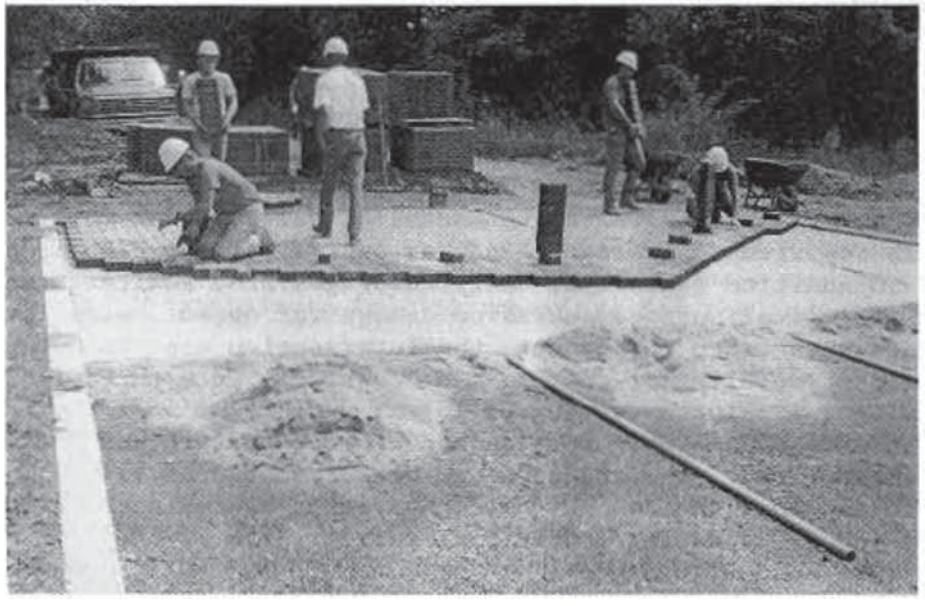

Figure 3. Initial compaction of paving blocks

By the end of each working day, all areas of screeded bedding sand were covered by paving blocks to prevent disturbance of the sand bedding layer before block placement and compaction. Tie paving block installation for the entire 1,150-sq m intersection was coupleted in approximately sixteen working days. The paving block installation crew generally consisted of one person screeding sand and trimming in the edges, two people laying the paving blocks and two people carrying the paving blocks from nearby pallet stacks to the block layers.

Initial Traffic Testing

The initial traffic testing of the block pavement took place on the same day the construction was completed. A 50-ton M-88 Tank Retriever, which was the heaviest vehicle scheduled to traffic the intersection, was used for the traffic tests. The M-88 first made several low-speed straight passes through the intersection. The tank retriever next performed high-speed breaking and acceleration maneuvers to check the block pavement's lateral stability. Since no damage occurred with the straight line maneuvers, the M-88 was allowed to make several 90-degree pivot steer turns. Again, no damage to the block pavement occurred. Finally, the M-88 was allowed to lock one track and perform several 360-degree pivot steer turns at high speed (Figure 4). This maneuver is thought to be the most severe in terms of surface abrasion from tracked vehicles. No damage to the block pavement was noticed; only scuff marks from the tracks' rubber pads were left on the pavement surface.

Performance Monitoring

The paving block demonstration site was monitored during its first year of service to evaluate its field performance capabilities. Initial communications with Aberdeen Proving Ground personnel indicated that the concrete block pavement was performing exceptionally well with no reported block failures or rutting problems. The only maintenance performed during the first few months of use resulted from the tracked vehicles carrying a considerable amount of mud onto the block pavement from the training ranges. The mud was scraped off of the pavement surface using a motor-grader or dozer blade. Although this is not a recommended practice, no damage to the paving blocks was reported as a result of this maintenance procedure.

On 30 April 1990, WES personnel visited the demonstration site to observe the pavement under traffic and to determine the general condition of the concrete block pavement after eight months of service. At this time, daily traffic was reported to average 12 passes per day of the M-88 Tank Retriever in addition to several daily coverages from smaller tracked vehicles. No visual surface abrasion damage was noted. Straightedge measurements were taken throughout the intersection area to determine if any significant settling or rutting had occurred. Only three isolated areas of slight wheelpath rutting (< 10-mm) were found near the intersection entrance areas where the tracked vehicle traffic was noted to be the most channelized. The straightedge measurements and visual observations indicated that the concrete block pavement had maintained its structural integrity during its initial service life.

WES personnel visited the demonstration site again on 22 August 1990 to observe the concrete block pavement. At this time, the pavement had been in service under daily traffic for approximately one year. Heavy rainfall before and during this site visit had caused a great deal of mud to be tracked onto the paving block intersection by the tracked vehicles. As much as 200-mm of mud covered the heavily trafficked areas (approximately 60 percent of the total block pavement surface), while most of the remaining areas were coveredwith 10- to 25-mm of mud. Local personnel reported that these muddy conditions were not uncommon and did not seem to adversely affect the block pavement's performance. A few areas of paving blocks were visible and these areas indicated that the paving blocks were in good condition. Aberdeen Proving Ground personnel reported no major

maintenance for this pavement during its first year of service, and were very satisfied with the pavement's performance to date.

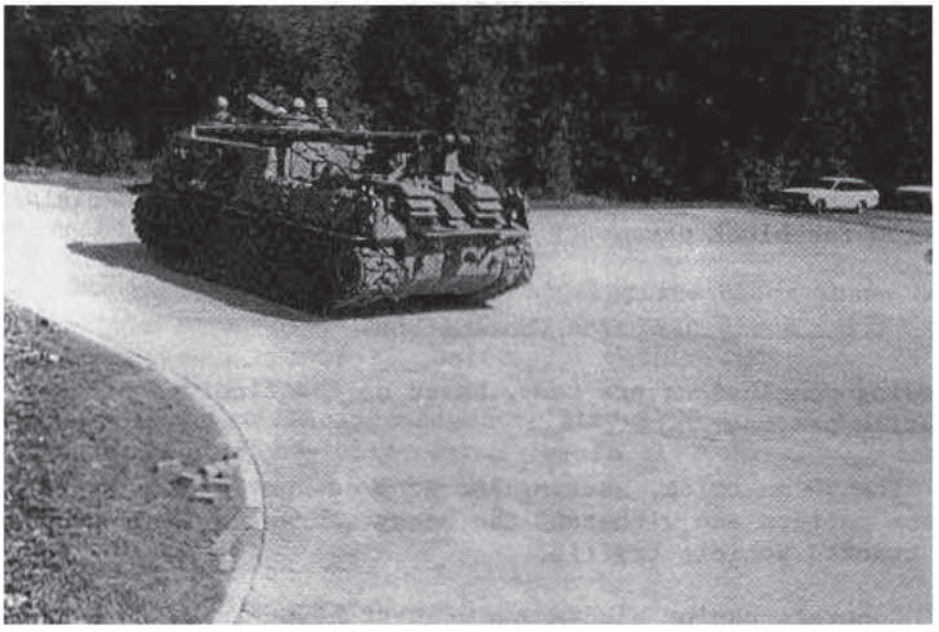

Figure 4. M-88 Tank Retriever performing initial traffic testing

Economics

The total cost of the paving block project at Aberdeen Proving Ground was $126,743. This cost included all subbase and base course work, the geotextile placed beneath the subbase, and all related incidentals and miscellaneous expenses. The cost of obtaining and placing the paving blocks, Including all block and sand materials, labor, and equipment charges, was $51,431. This translates into a cost of about 45 $/sq meter for the paving blocks on this job. The elimination of continual mainte nance on this intersection (including regrading, drainage reconstruction, and other work) will result in long-term savings for the installation.

It was estimated that it would have cost approximately the same amount to build an asphalt concrete surfaced pavement structure capable of carrying the same traffic loads at this site. Building such an asphalt concrete pavement would not have been advisable however, as the abrasive action of the turning cracked vehicles would have significantly shortened the service life of an asphalt concrete surface. Because of the relatively small surface area of the intersection, it was estimated that a portland cement concrete (PCC) pavement designed for the demonstration site would have cost between 1C and 30 percent more than the paving blocks for initial construction. Maintenance costs would likely have been high for a PCC pavement, resulting from damage due to differential frost heave of the underlying soil. The concrete block pavement is expected to require virtually no maintenance throughout its 20 year design life.

In general terms, the cost of paving blocks vary considerably due to local differences In labor, material, block quality and size, and transportation costs [I] For large scale applications in the United States, block pavements arc usually more expensive than conventional paving materials in terms of construction costs. Under some conditions, such as those of the

demonstration site, the maintenance cost savings realized by using paving blocks instead of conventional paving materials give the paving block alternative the economic advantage.

The market for concrete block pavements is currently growing in the United States. More manufacturers are producing paving blocks to meet the increasing demands, thereby reducing freight costs in many areas. The numbejf of block paving contractors is also increasing, creating a more competitive market. It is anticipated that as the concrete paving block market grows in the United States, the relative cost of materials and construction for block pavements will decrease.

Conclusions

The following conclusions are made, based on the findings of the demonstration project:

a. The 80 mm-thick, rectangular concrete paving blocks laid in the herringbone pattern can withstand the heavy, abrasive loading conditions of military tracked vehicle traffic.

b. Concrete paving blocks can support heavy loads when constructed over weak subgrades.

c. The current method of using the Corps of Engineers standard flexible pavement design with a 165-mm equivalent thickness ratio is a conservative but valid design method for concrete block pavements.

Acknowledgment

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