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Expeditionary Ground Rehabilitation for Military-Vehicle Traffic †

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Abstract: The research objective for this study is to identify and evaluate techniques for soil stabilization to support military-vehicle ground maneuver in contested environments. Various types of stabilizers mixed with silty sand are evaluated in the laboratory for their compressive strength at various soil moisture contents and in the field for their rutting performance. Field data are analyzed for the ability to withstand trafficking from a military ground vehicle by evaluating the rut depth and measured instrumentation data. The field testing shows that the rapid soil stabilization materials and techniques can produce repairs that withstand required traffic without traditional pavement surface materials.

Keywords: construction equipment; road repair; soil stabilizer; additive; silty sand

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1. Introduction

When the military's critical infrastructure assets do not meet mission load requirements, new materials, equipment, and techniques are required to alter the state of infrastructure and upgrade its capacity. The research objective of this project was to identify and evaluate materials for rapid soil stabilization to support military-ground-vehicle maneuvers in complex and contested environments. The target roads to be repaired are low-volume roads requiring approximately 1000 passes of military vehicles.

The chemical stabilization of soils improves quality most commonly by improving gradation, reducing plasticity index, or increasing durability or strength. Chemically stabilized layers can serve as a wearing course once curing has progressed to an adequate level for construction platforms, roads, or airfields where poor soils exist [1].

The typical design for stabilized soils in commercial applications includes detailed soil characterization such as gradation, Atterberg limits, and moisture–density relationships. Target strength and durability values are derived from detailed analysis of the number and magnitude of the loads using the structure. The design stabilizer content is the minimum dosage resulting in the desired properties. Specialized construction equipment available during construction results in thorough mixing and compaction to achieve desired properties. Military operations, however, are often limited in equipment and time to perform such tasks. Prescriptive methods for stabilizing problematic soils are needed that provide a standard recipe containing sufficient reliability to resolve the most common problems.

2. Method

Stabilization materials were studied in the laboratory and in the field. Unconfined compressive-strength (UCS) testing was completed on 13 chemical stabilizer products at moisture contents dry of optimum, optimum, and wet of optimum. The laboratory study also determined the appropriate moisture contents, dosage rates, and curing time requirements for use in field applications. Pavement repairs were then completed and subjected to military vehicle traffic in a full-scale concrete test section. Silty sand (SM) was chosen as the testing soil in the laboratory and field because it represents the most commonly found soil all over the world [2].

3. Field Testing and Results

Four downselected stabilizers and a control were tested with SM in a full-scale test section. The stabilizers included Type I/II cement, rapid-setting calcium-sulfoaluminate (CSA) cement, and xanthan gum. The rapid-setting CSA products are proprietary; no additional details are available. The control was pure SM with no additive and compacted at optimum moisture content.

The repairs were constructed within the interior of a 15-inch-thick concrete test section placed over natural lean clay subgrade. The natural subgrade had an average California bearing ratio (CBR) of 9% with a dry density of 108 lb/ft^3 and a moisture content of 18%. The repair location consisted of one confined slab, which was 12.5 ft wide by 15 ft long. Prior to the repair, the concrete slab was removed, and a geotextile was placed on top of the natural subgrade to prevent migration into the base. A 15-inch-thick heavy clay base with an in situ moisture content of approximately 35% and a CBR of 3 to 5% was compacted to a dry density of approximately 84 lb/ft^3 to provide a foundation for the repair material. Earth pressure cells (EPCs) were installed on top of the base in the wheel paths of each repair. Each of the approximate 7-inch-thick repair surfaces consisted of SM mixed with the stabilizers. The soil surfaces were compacted flush with the surrounding concrete.

The stabilizers were placed at 5% of the total dry weight of the SM. The only exception was Repair 2 where 3% of Type I/II cement was added to the SM. The moisture content of each SM stockpile before placement was approximately 10%. The preparation of each stabilizer-soil mixture occurred in batches by evenly spreading the stabilizer on top of a premeasured quantity of SM and mixing with a compact track loader (CTL) tiller attachment and flipping with a CTL bucket.

The SM mixtures were placed and compacted in two lifts approximately 4 to 5 inch thick. Compaction was completed with a vibratory drum compactor CTL attachment. The entire surfaces of each lift received two passes of the compactor—the vibrator was turned on for each second pass. Each stabilized surface material, including the control SM, was cured for 24 h after compaction before traffic was applied.

Each repair surface was subjected to nuclear-density gauge testing directly before trafficking. The nuclear gauge data showed that the moisture content of the stabilized surfaces ranged from 6 to 9%, and the dry density ranged from 101 to 118 lb/ft^3. Periodic rod and level surveys were completed to determine elevation changes with traffic applications.

Repair performance was evaluated with a four-axle common bridge transporter (CBT). The CBT weighed approximately 60,000 lb with tire pressures of 60 to 83 psi. Each repair was subjected to channelized traffic until failure, which was defined as 7 in. of rutting, or until 1000 passes. Often, repairs were trafficked beyond 7 in. of rutting.

Table 1 presents the field performance results in terms of rutting and EPC measurements. The number of passes at 7 in. of rutting is included for the north and south wheel paths. If a repair was trafficked beyond failure, the maximum rut shown in Table 1 was measured at the maximum passes applied. If the rut did not reach 7 in. in one of the wheel paths, the data were extrapolated to provide a number of passes for both wheel paths. The trafficking of each repair occurred over the course of one to two days after curing for 24 h.

As expected, the control (Repair 1) performed worst compared to the stabilized SM surfaces. The control had a rapid and steady increase in rutting with traffic in both wheel paths. Repair 5 with the rapid-setting C product had the least amount of rutting after 1000 passes of the CBT. Rutting did not exceed 1.20 in. for either wheel path.

Table 1. Field Performance results.

Repair	Additive	Passes at 7 in. of Rutting		Max Rut (in.)	Max Passes Applied	North EPC Peak (psi)	South EPC Peak (psi)
		N	S				
1	none	65	55	7.50	70	144	187
2	cement [a] (3%)	600 [b]	450	8.50	500	40	54
3	cement [a] (5%)	1050 [b]	n/a [b]	6.50	1000	23	38
4	rapid-setting cement A	385	425 [b]	7.25	400	47	48
5	rapid-setting cement C	n/a [c]	n/a [c]	1.20	1000	16	20
6	xanthan gum (3%) and cement (2%) [a]	500	450	8.25	500	--- [d]	40

[a] Type I/II cement; [b] Extrapolated data; [c] Rutting was not beyond 1.20 in.—extrapolation to 7 in. was not possible; [d] No data collected—EPC malfunctioned.

Type I/II cement (Repairs 2 and 3) was tested at different concentrations (3 and 5% cement). After 300 passes in Repair 2, a noticeable spike occurred in the rut depth data. Repair 3 performed significantly better except for the south wheel path. The rutting in the south wheel path steadily increased to a maximum of 6.50 in., while the rutting in the north wheel path remained relatively constant with rutting under 1 in. at 1000 passes.

Repair 4 failed at 400 passes. Citric acid had been added to the SM at a small dose (0.27% of the weight of rapid-setting cement) prior to mixing with the cement to help decrease the set time of the rapid-setting cement due to the high ambient temperatures. Repair 4 also had lower-than-expected dry density, and for unknown reasons, the moisture content of the SM mixture increased by 4% after trafficking.

Repair 6, consisting of 3% xanthan gum and 2% of Type I/II cement, failed at approximately 500 passes. The SM mixture appeared to be sticky to the touch and almost pliable. The dry density of Repair 6 was also lower than expected after 24 h of cure time.

The peak pressures measured from the EPCs typically occurred at or near failure for the repairs that performed poorly. The highest pressures were recorded in the control (Repair 1), which were at least three times as high as those of the other repairs. The lowest pressures were recorded in the repairs that did not develop 7 in. of rutting. This occurred in Repair 5 and the north wheel path of Repair 3. Repair 3 did achieve 1000 passes; however, the south wheel path had considerable rutting at 1000 passes. The peak pressure in the north wheel path was only 23 psi.

4. Discussion

Repairs 2 and 3, with Type I/II cement, showed that a small increase in stabilizer greatly increased the performance. Increasing the cement by two percentage points increased the performance enough to meet the objective of the study.

Some of the repairs had a much deeper rut on one wheel path compared to the other. Repair 3, stabilized with Type I/II cement, had a rut measurement difference of 5.5 in. with the south wheel path rut at 6.5 in. and the north wheel path rut at 1 in. The repairs with a large rut depth difference could be due to inconsistent mixtures or compaction.

Two of the repairs appeared not to have set; these had lower densities and worse performance. Repair 4, with the rapid-setting A product, failed earlier than expected for a cementitious product. The addition of a small amount of citric acid to decrease the set time may not have allowed the rapid-setting cement to reach final set even after curing for 24 h. Repair 6 may have had too much xanthan gum, as the material did not set after 24 h. After excavation of Repair 6, the soil-product mixture appeared to still be pliable.

It should be noted that when variability in repair performance occurred (i.e., varying rut depths with each wheel path or with each end of the wheel path), the maximum rutting occurred in the south wheel paths for each repair and on the west ends of each wheel path. This was particularly the case for Repairs 2, 3, and 6. The west end of each repair was the leading edge for trafficking and the trailing edge for compaction; traffic was applied west to east, and compaction was applied east to west.

5. Conclusions

The laboratory and field studies indicate that chemical stabilizers increase the load-carrying capabilities of repairs on low-volume roads. This was shown in the field when the rutting performance was improved from 70 passes to at least 400 passes of the CBT military vehicle. The field tests were also constructed wet of the optimum moisture content; therefore, the performance results are conservative. Additionally, chemical stabilizer types and dosages were identified that could achieve the 1000-pass target. Chemical stabilizers are an appropriate alternative for the military to use for rapid road repairs with and without surfacing with concrete or asphalt.

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