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US TRANSCOM JDDE Program

Full-Scale Trafficability Testing of Prototype Submersible Matting Systems

Benjamin A. Rutherford, Andrew T. Collins, Zachary J. Tyler, Patrick M. Border, Stanley J. Boc, Jr., and Timothy W. Rushing

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Benjamin A. Rutherford and Timothy W. Rushing

US Army Engineer Research and Development Center (ERDC)
Geotechnical Structures Laboratory (GSL)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Andrew T. Collins, Zachary J. Tyler, Patrick M. Border, and Stanley J. Boc, Jr.

US Army Engineer Research and Development Center (ERDC)
Coastal and Hydraulics Laboratory (CHL)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

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Abstract

This report describes the full-scale evaluation of prototype submersible matting systems (SUBMAT) at a test site at the US Army Engineer Research and Development Center's Vicksburg, Mississippi, site. The SUBMAT prototypes were designed to bridge the gap between high and low tide at a beach interface to enable 24-hour operation at an expeditionary watercraft landing site. This phase of the SUBMAT prototype development was intended to determine prototype system durability by applying military vehicle loads representing a combat brigade insertion across a littoral zone. The two mat systems evaluated in this study were the PYRACELL Road Building System (PRBS) and a basaltic rebar mat system. The results of the study showed that the PRBS system was able to sustain 1,000 Medium Tactical Vehicle Replacement, 350 Heavy Expanded Mobility Tactical Truck, and over 150 M1A1 main battle tank passes without significant damage. The basaltic rebar mat failed early in the test and was removed from further consideration for the SUBMAT application. Observations and lessons learned from this phase of the prototype PRBS development will be used to improve the PRBS design and modify its installation procedures for improved efficiency.

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Preface

This study was conducted for the US Transportation Command's Fiscal Year 21 Joint Deployment Distribution Enterprise Government Research, Development, Test and Evaluation (RDT&E) program under Submersible Matting (SUBMAT), MIPR F3ST950197G002. The technical monitor was Mr. Lou Bernstein, RDT&E program director (TCJ5-SC).

The work was performed by the Airfields and Pavements Branch (GMA) of the Engineering Systems and Materials Division, US Army Engineer Research and Development Center (ERDC), Geotechnical and Structures Laboratory (GSL), and the Coastal Engineering Branch and Field Data Collection and Analysis Branch of the Navigation Division, ERDC Coastal and Hydraulics Laboratory (CHL). At the time of publication, Ms. Anna M. Jordan was branch chief; Mr. Justin S. Strickler was division chief; and Mr. R. Nicholas Boone was the technical director for Force Projection and Maneuver support. The deputy director of ERDC-GSL was Mr. Charles W. Ertle II, and the director was Mr. Bartley P. Durst. Dr. Lauren M. Dunkin was branch chief; Mr. William C. Butler was branch chief; and Ms. Ashley E. Frey was division chief. The deputy director of ERDC-CHL was Mr. Keith Flowers, and the director was Dr. Ty V. Wamsley.

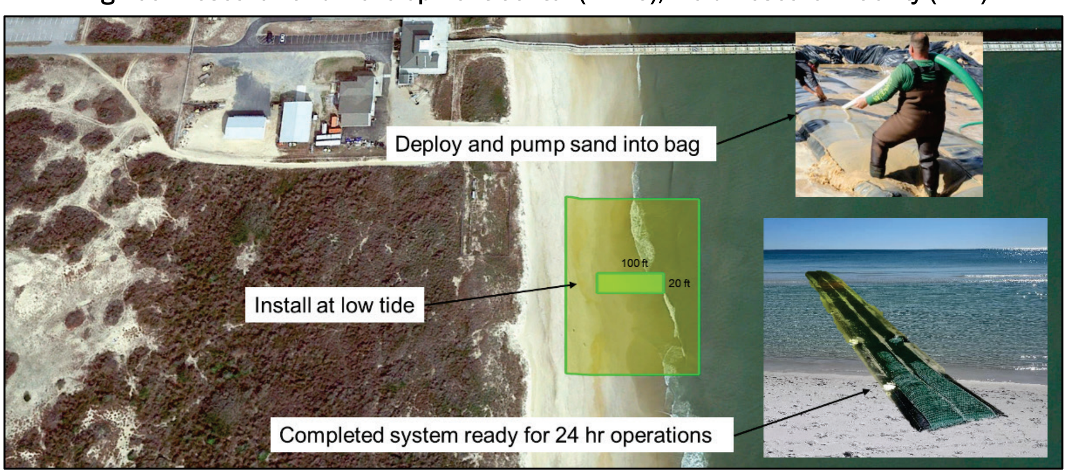
COL Christian Patterson was commander of ERDC, and the director was Dr. David W. Pittman.

1 Introduction

1.1 Background

Logistics operations in austere environments are hindered by the lack of force mobility across littoral zones, riverine shorelines, and wet/dry gaps. These environments rapidly transition between wet and dry states, present steep slopes, and have weak soils that limit vehicle weight and number of passes. These limitations will be exacerbated by emerging operational concepts, such as Program Manager Watercraft's remote lighter conveys, Navy and Marine Corps Distributed Maritime Operations and Expeditionary Advanced Base Operations, wherein ensured access is needed across lighter convey waves, bridging systems, and austere sites. The US Army Engineer Research and Development Center (ERDC) proposed to develop a submersible matting system (SUBMAT) to facilitate mobility across the shoreline and wet/dry gaps by combining current soil stability technology and mobility matting into a single product. The ERDC SUBMAT was envisioned to enable military vehicles to traverse littoral, shoreline, and wet/dry gaps by providing a collective matting technology that is easily transported and rapidly deployable from vehicles or small-craft vessels or by hand. Figure 1 shows the conceptual deployment of the SUBMAT system at ERDC's Field Research Facility (FRF) near Duck, North Carolina.

Figure 1. Concept for the submersible matting system (SUBMAT) deployment at the US Army Engineer Research and Development Center (ERDC), Field Research Facility (FRF).



1.1.1 Description of Current US Military Capabilities

The United States has many capabilities that are currently used to facilitate ship-to-shore transport of personnel and military equipment. The US Transportation Command (USTRANSCOM) Joint Deployment Distribution Enterprise (JDDE) is seeking a new connector to assist with onshore mobility in the littoral zone and especially across the water-beach interface to bridge the gap across an ever-moving tidal zone. The following sections describe some existing US capabilities and equipment to inform how they could interface with a SUBMAT system.

1.1.1.1 Joint Logistics Over-the-Shore (JLOTS)

Joint Logistics over-the-Shore (JLOTS) is a unified commander's joint employment of Army and Navy Logistics over-the-Shore (LOTS) assets to deploy and sustain a force. JLOTS operations allow US strategic sealift ships to discharge through inadequate or damaged ports or over a bare beach. JLOTS watercraft can also be used to operationally reposition units and materials within a theater.

JLOTS operations occur when Navy and Army LOTS forces conduct LOTS operations together under a Joint Forces Command. Traditionally, Navy LOTS includes the use of Marine Corps forces.

JLOTS allows the Joint Force to overcome port denial, insufficient port draft, and port congestion. The scope of JLOTS operations extends from acceptance of ships for offloading through the arrival of equipment and cargo at inland staging and marshalling areas.

1.1.1.2 Present JLOTS Methods and Technology (Bare Beach Dry Cargo)

The Elevated Causeway system (ELCAS), shown in Figure 2, provides an expeditionary Roll-On/Roll-Off (RO/RO)-capable pier at a beach. Like a commercial harbor, the pier extends beyond the beach into the water, allowing vessels to unload cargo. The elevated causeway allows unloading of sea-going vessels without lighterage.

Figure 2. Elevated Causeway system (ELCAS) piles being installed (*left*). Completed ELCAS (*right*).

The Trident pier system, shown in Figure 3, provides an expeditionary RO/RO-capable floating pier at a beach. The pier may be deployed to the construction site either by road or by ship.

Figure 3. Trident pier being assembled offshore (*left*) and landed at prepared site (*right*).

1.1.1.3 Present JLOTS Vessels (Army and Navy) of Concern

The Army and Navy Landing Craft Utility (LCU), shown in Figure 4, is capable of intratheatre transport of combat vehicles and sustainment cargo. It is ideally suited for discharge and backload from dock landing ships (e.g., landing ship docks, landing helicopter docks, and landing helicopter assaults, and the Large Medium-Speed RO/RO [LMSR]).

The LCU transports the heavy equipment and supplies ashore while able to operate independently in support of littoral maneuver, security cooperation, noncombatant evacuation, foreign humanitarian assistance, and disaster relief operations. LCUs have both bow and stern ramps for onload and offload and can conduct sustained operations at sea for up to 10 days.

Figure 4. A Landing Craft Utility (LCU) pulls away from a helicopter landing dock (*left*). Marines discharge from LCU into the swash zone (*right*).

The Improved Navy Lighterage System (INLS), shown in Figure 5, is comprised of powered and nonpowered barge-like modular platforms that are assembled into multiple configurations to satisfy mission requirements. These Causeway Ferries (CFs) are designed to discharge from the Maritime Prepositioning Force and Military Sealift Command when port facilities are damaged, inadequate, or unavailable. The RO/RO Discharge Facility is made up of nine nonpowered causeway sections and provides the at-sea Maritime Prepositioning Ship interface capability. CFs can also enter well decks of amphibious warfare ships to provide additional options to support ship-to-shore movement.

Figure 5. An assembled Improved Navy Lighterage System (INLS) and loaded from a Large Medium-Speed RO/RO (LMSR (*left*). A Causeway Ferry (CF) with powered barge and unpowered landing barge preparing to discharge vehicles (*right*).

The Landing Craft Mechanized (LCM)-8, shown in Figure 6, is a rugged, steel, displacement vessel used to transport cargo, troops, and vehicles from ship to shore or in retrograde movement. It is designed for use in rough or exposed waters, operated through breakers, and grounded on the beach and debeaches under its own power. LCMs have a bow ramp for onload and offload and can transport 100 passengers or 60 tons of cargo.

Figure 6. A Landing Craft Mechanized (LCM) beaches itself to discharge vehicles and personnel (*left*). Marines discharge from LCMs (*right*).

The Army Logistics Support Vessel (LSV), shown in Figure 7, has the capabilities of intratheatre unit deployment or relocation and the transport of supplies to support sustainment to remote, undeveloped areas along coastlines and inland waterways. The LSV has a payload of 2,000 tons and can assist in off-loading and backloading ships in a RO/RO operation. The bow and stern ramps can be used for RO/RO operations, and a bow thruster assists in docking and undocking.

Figure 7. An army unloaded Logistics Support Vessel (LSV) underway (*left*). Marines pulling a vehicle mat off the deck of an LSV to support vehicle discharge operations.

The Landing Craft Air Cushioned (LCAC), shown in Figure 8, is assumed not to be compatible with the SUBMAT system.

Figure 8. A Landing Craft Air Cushioned (LCAC) transiting the wet/dry interface (*left*). Marines struggle to discharge artillery in the swash zone from an LCAC (*right*).

1.1.1.4 Future JLOTS Vessels

The Landing Ship Medium (LSM) is under development as a maneuver and mobility ship for naval expeditionary forces in support of distributed maritime operations. The LSM will provide beachable shore-to-shore deployment, maneuver, sustainment, and redeployment options for Littoral Naval Expeditionary Forces within operational ranges.

The Maneuver Support Vessel (Light) (MSV-L) and Maneuver Support Vessel (Heavy) MSV-H are replacements in development for the LCM-8. The new vessels will have greater speed, range, and load capabilities and be capable of transporting newer generations of tanks and other combat vehicles with heavier chassis and weapons. The extended range will allow them to support both ship-to-shore and shore-to-shore operations.

1.1.1.5 Present JLOTS Vehicles of Concern

The Medium Tactical Vehicle Replacement (MTVR), shown in Figure 9, is a 6 × 6 truck with a variety of variants supporting supply and logistics missions with a 7-ton capacity. Variants include cargo truck, dump truck, gun truck, troop carrier, and fifth wheel. The MTVR has a fording depth of 5 ft.*

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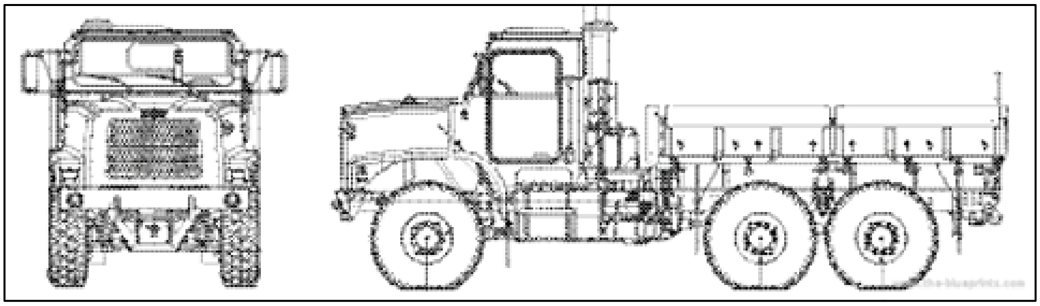
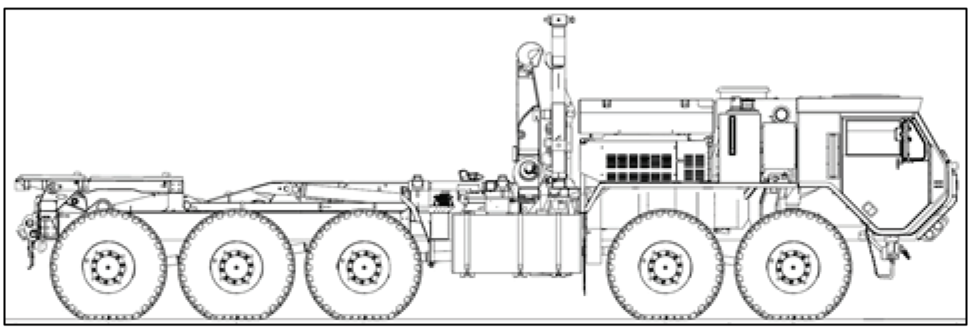
* For a full list of the spelled-out forms of the units of measure and unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248–52 and 345–347, respectively. https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

Figure 9. Front- and side-view schematics of Medium Tactical Vehicle Replacement (MTVR).



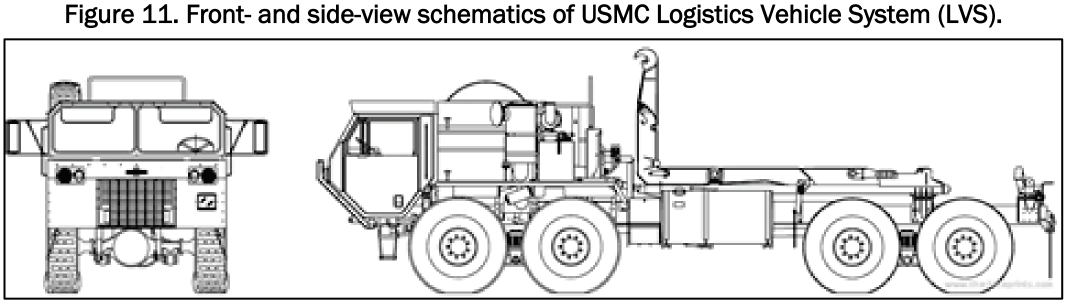
The Logistic Vehicle System Replacement (LVSR), shown in Figure 10, is a US Marine Corps (USMC) variant of the 10 × 10 Heavy Expanded Mobility Tactical Truck (HEMTT) vehicle. Payload is 16.5 tons of supplies and equipment. Variants include troop carrier, fifth wheel, Palletized Load System (PLS), wrecker, and bridger. The LVSR has a fording depth of 5 ft.

Figure 10. Side-view schematic of US Marine Corps (USMC) Logistic Vehicle System Replacement (LVSR).



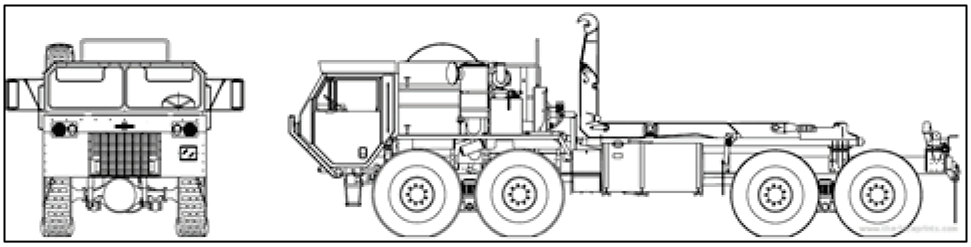
The Logistics Vehicle System (LVS), shown in Figure 11, is a USMC variant of the 8 × 8 HEMTT vehicle, outfitted with additional steering capabilities to meet stricter turning radii requirements. Variants include wrecker, flatbed, fifth wheel, bridger, crane, and cargo. Payload is 10 tons of supplies and equipment. The LVS has a fording depth of 5 ft.

Figure 11. Front- and side-view schematics of USMC Logistics Vehicle System (LVS).



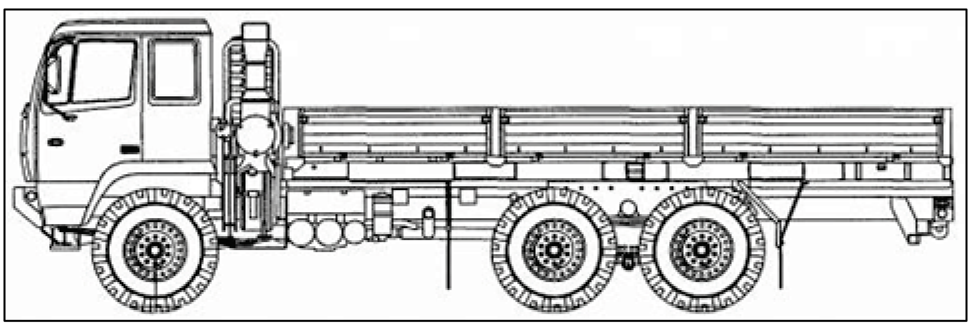
The HEMTT, shown in Figure 12, is the Army's 8 × 8 vehicle providing the backbone of off-road logistics and utility support including wrecker, fueler, cargo, bridger, and other variants. The 10 × 10 variant is known as the PLS. The payload is 10 tons of supplies and equipment. The HEMTT has a fording depth of 4 ft.

Figure 12. Front- and side-view schematics of Army Heavy Expanded Mobility Tactical Truck (HEMTT).



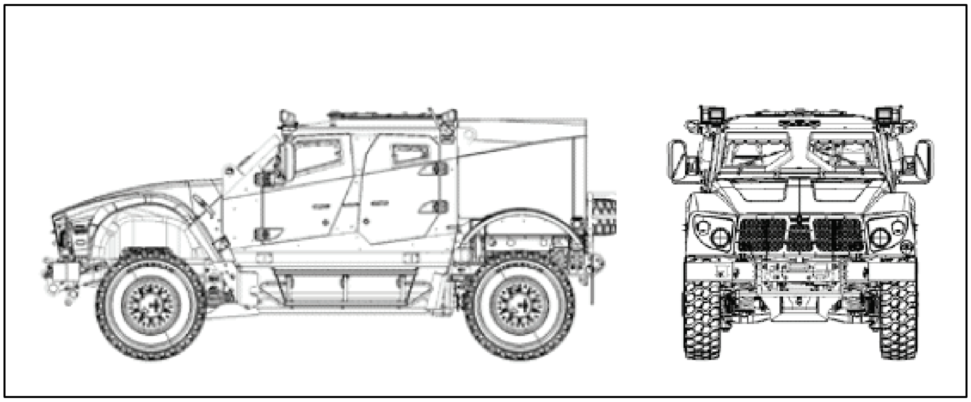
The Family of Medium Tactical Vehicles (FMTV), shown in Figure 13, is the Army's family of 4 × 4 and 6 × 6 supply and utility trucks. The payload is 2.5 or 5 tons of supplies and equipment, varying by type. The FMTV has a fording depth of 2.5 ft or 5 ft with fording kit.

Figure 13. Side-view schematic of Army Family of Medium Tactical Vehicles (FMTV).



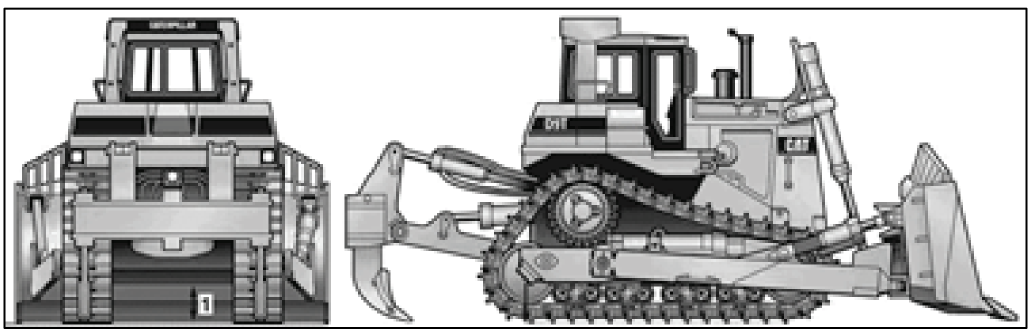
The Joint Light Tactical Vehicle (JLTV), shown in Figure 14, replaced the High Mobility Multipurpose Wheeled Vehicle for both the Marines and the Army. Variants include general purpose, utility, and weapons carrier. The JLTV can ford 5 ft without a fording kit.

Figure 14. Front- and side-view schematic of Joint Light Tactical Vehicle (JLTV).



Any military operation requires engineer support, including the use of heavy equipment. Excavators include the John Deere 230 LRC, 250G LRC, or similar models. Dozers include the John Deer 850J and the Caterpillar D9, shown in Figure 15. The construction vehicles such as dozers and excavators typically have a fording depth of 3 ft.

Figure 15. Back- and side-view schematics of Caterpillar bulldozer.



1.1.2 Submersible Matting System (SUBMAT) Project Background

In situ soil conditions within littoral zones, bare beaches, and riverbanks do not possess adequate strength to support vehicle operations in much of the world (Hull 2016). Soil with sufficient initial undisturbed strength also degrades in strength with repeated vehicle traversals as tires and tracks shift the soil. These regions further challenge mobility as they can rapidly transition from fully submerged to partially saturated and dry conditions with each state having significantly different soil strengths. However, mobility across these regions is a necessary component of force projection for JLOTS, bridging and gap crossings, emerging robotic convoy concepts, and multidomain operations (Rushing and Rowland 2012). The inability to consistently maneuver along the wet/dry interface at the shoreline due to the soil strength variability, therefore, is an existing force-projection capability gap.

Structural mediums are often utilized to enhance mobility over soft soils at the shoreline. The structural medium typically consists of a structural mat, which is a layer of stronger material over the weak layer, or a combination of a soil improvement action and a surfacing mat (Hull 2016; Rushing and Rowland 2012). Mobility matting utilized by Joint Forces is often deployed in austere dry beach environments where transiting vehicles require improved bearing capacity and traction. This type of matting is used in a variety of military and humanitarian and disaster relief operations where rapid access to otherwise inaccessible areas is essential. The matting is often designed to be self-deploying (for both heavy and light vehicles) to avoid unnecessary personnel exposure to threats of environment or circumstance.

Existing matting and site-stabilization systems cannot be readily adapted for submerged or partially submerged conditions along the shoreline. Current matting capabilities are not designed to be submersible for any length of time and cannot support traffic while under water. Commercially available roll-out aluminum mat systems, such as Faun Trackway (Faun Trackway USA; Arlington, Virginia) and Deschamps Fast Composite Roadway (Deschamps Mat Systems, Inc.; Cedar Grove, New Jersey), have not been fully tested for underwater behavior. The aluminum roll-out systems' performance during ERDC tests indicate that the systems are fully capable of surviving a significant number of military vehicle passes; however, they are not intended for deployment submerged in a dynamic tidal environment where they must maintain positive contact with the sea floor. Traditional single-panel mats are heavy and cumbersome; their assembly is slow above water and nearly impossible underwater. The Durabase (Newpark Mats and Integrated Services; Carencro, Louisiana) heavy plastic mats currently in Army's 7th Transportation Brigade inventory float; thus, they are impossible to deploy submerged without significant anchorage modifications. Flexible fabric-style mats do not provide adequate strength, and interconnected concrete block mats are cumbersome and logistically challenging to employ. Existing systems are thus unsuited to the wet/dry environment present along the shoreline, and a new matting system to ensure force projection in a multitude of environments is required.

1.2 Objectives

The objective of this study was to determine additional design changes required to improve the performance of the prototype systems prior to further full-scale technical demonstrations being coordinated at a beach environment. This report describes the first full-scale test in a series of parallel efforts for rapid prototyping (design and fabrication) and performance testing. This effort focuses specifically on durability testing of a prototype sand-filled mattress-based system called PYRACELL Road Building System (PRBS) (Propex Geosolutions; Chattanooga, Tennessee), a basalt rebar mat, and a fiberglass rebar mat. The systems were evaluated to ensure they could provide adequate bearing capacity, lateral stability, and vertical stability under applied military vehicle traffic in a wet/dry environment.

1.3 Approach

The approach utilized in this research was to simulate heavy military vehicle traffic in a saturated, sandy environment. The execution of this approach involved creating a sand bar roadway with lined, excavated traffic areas that retained water. The water was pumped into the traffic area from a local source, and military vehicle traffic was applied to instrumented traffic lanes.

1.4 Scope of Work

ERDC proposed a new Research, Development, Test and Evaluation project under the JDDE program to design, prototype, and build a premanufactured version of a SUBMAT. The SUBMAT will provide USTRANSCOM with a capability to negotiate vehicles across the wet/dry interface at shoreline where traction and bearing capacity are limiting for force projection. The small system footprint will additionally enable the system to be rapidly transported and deployed in austere locations with limited personnel. Initially, the prototype SUBMAT concept was to be a geocell hybrid matting held in place by integrated soil nails and would have the ability to stabilize the soil, stay in position once placed, and allow the required vehicle traffic under multiple sea states. However, after the research team was assembled and the problem was further studied, new concepts emerged as more viable options. Two concepts included in this study were ultimately moved into prototyping. One was based on a commercial sand-filled mattresses, and the other consisted of fiberglass or basaltic reinforcement bars woven through a semirigid geogrid structure. The SUBMAT system builds on mature ERDC soil stabilization fabric or matting and mat sinking or soil-stabilization technology to develop and provide a hybrid matting system that is specifically designed for use in wet/dry transitional environments (Floyd 2017; Webster and Tingle 1998; USACE, n.d.).

The overall research effort consists of three phases: design and fabrication of prototypes, performance testing, and deployability testing. This report documents the first design, prototyping, and testing in a laboratory setting. Descriptions of the three phases included in the work proposal are shown here for clarity.

1. Design and Fabrication–The SUBMAT system will be designed and built to meet the conditions at the wet/dry interface of the shoreline. The design phase will ensure the performance is met. Initial performance requirements include, but are not limited to the following:
    a. Bearing Capacity–The SUBMAT system should increase the bearing capacity of shoreline soils to support at least Military Load Classification (MLC) 80 tracked and 96 wheeled vehicles. This MLC supports most vehicles used during force-projection operations and is equivalent to the capacity of the Improved Ribbon Bridge.
    b. Lateral Stability–The matting should not shift from the deployed location and should eliminate lateral heave of the soil surrounding the matting due to insufficient distribution of the vehicle load. This eliminates the operational need to reset or deploy additional matting.
    c. Vertical Stability–The system should not shift vertically after initial deployment due to either buoyance forces or soft soils.
    d. Transportability–The undeployed SUBMAT system cube will be minimized for ease of transport. The undeployed matting will collapse to be transported on lighter vessels and vehicle convoys without significant modification to the cargo plans. The undeployed system will additionally allow for system stacking

within a twenty-foot equivalent unit (commonly referred to as TEU).

e. Deployability–The SUBMAT system should be simple and rapid to deploy. A SUBMAT unit will be deployable by a single soldier squad. The matting also will allow multiple SUBMAT matting units to be joined for simultaneous vehicle deployment.
f. Recoverability–While the SUBMAT system is intended to be sacrificial (i.e., to stay permanently in the deployed location), training and exercises require the system to be removed after deployment. The SUBMAT system will be designed to be quickly and safely removed.
g. Affordability–As the SUBMAT system is intended to be a single-use system, minimizing the cost of SUBMAT units is necessary to ensure that the system can be widely disseminated and frequently employed.

2. Performance Testing–Performance testing of the SUBMAT was performed under varying soil and environmental conditions to ensure performance requirements are met. This testing was sequenced to identify performance deviations early to allow iterative design and prototyping. Additionally, it consisted of both scale-model and full-scale tests.

   Strong and weak soil substrates will be evaluated to determine the systems' abilities to mitigate their respective failure modes. Strong soils (i.e., sands) fail as repeated passes over the soil cause the soil to shift, reducing traction. SUBMAT performance in strong soils will be evaluated for its ability to improve lateral confinement thereby preventing soils from shifting under tires and tracks. Weak soils (i.e., silts, clays, and organics) fail as the tires penetrate the soil surface due to a lack of localized bearing capacity. SUBMAT performance in weak soils will be evaluated for its ability to distribute vehicle loads across the SUBMAT structure to improve soil bearing capacity and prevent tire penetration. Soil heave at the edges of the mat will be monitored as an indicator of matting failure.

   Strong and weak soils will be evaluated across varying soil saturation and water conditions to confirm SUBMAT performance is maintained across all potential deployment areas.

3. Deployment Testing–Deployment testing will test the ability of the SUBMAT system to be installed by various means. Tests may be conducted to verify deployment times and ensure proper installation. The testing will demonstrate the ability of SUBMAT to expand from its collapsed state, be dragged into position along the soil, and be pressed into the soil or filled with soil. Recovery will not be explicitly tested because the system is intended to be sacrificial. Testing will include deployment of single SUBMAT units as well as multiple connected units.

   It is currently envisioned that the SUBMAT system will be deployed by one of three means, illustrated in Figure 2.

   a. Vehicle Deployment–The collapsed SUBMAT unit(s) will be connected to a vehicle capable of crossing the area of interest (AOI) via chains or cordage. As the vehicle crosses the AOI, it will expand the SUBMAT unit. This type of deployment is the anticipated mechanism during riverine, dry beach, and inland use cases.
   b. Lighter Deployment–In littoral environments, particularly during JLOTS operations, vehicles are conveyed to the beach via lighter vessels. Under these scenarios, the lighter provides a platform from which to assemble and deploy the SUBMAT system. As in the vehicle-deployment case, the leading edge of the SUBMAT unit will be taken onshore to partially deploy the matting as the vehicle leaves the lighter. As the vehicle leaves the lighter, the lighter will debark from the landing, deploying the remainder of the matting under the water surface. In this manner, the wet/dry interface of the shoreline can be stabilized. Additionally, if the dry reach of the beach requires stabilization, multiple vehicles can deploy the matting from the lighter in a similar manner.
   c. Manual Deployment–The SUBMAT system will be deployable by a squad of personnel, allowing it to be rapidly installed to cover larger areas than existing matting solutions. The collapsed unit will be carried to its installation location and extended from its collapsed state. Prior to or during installation, multiple units can be joined.

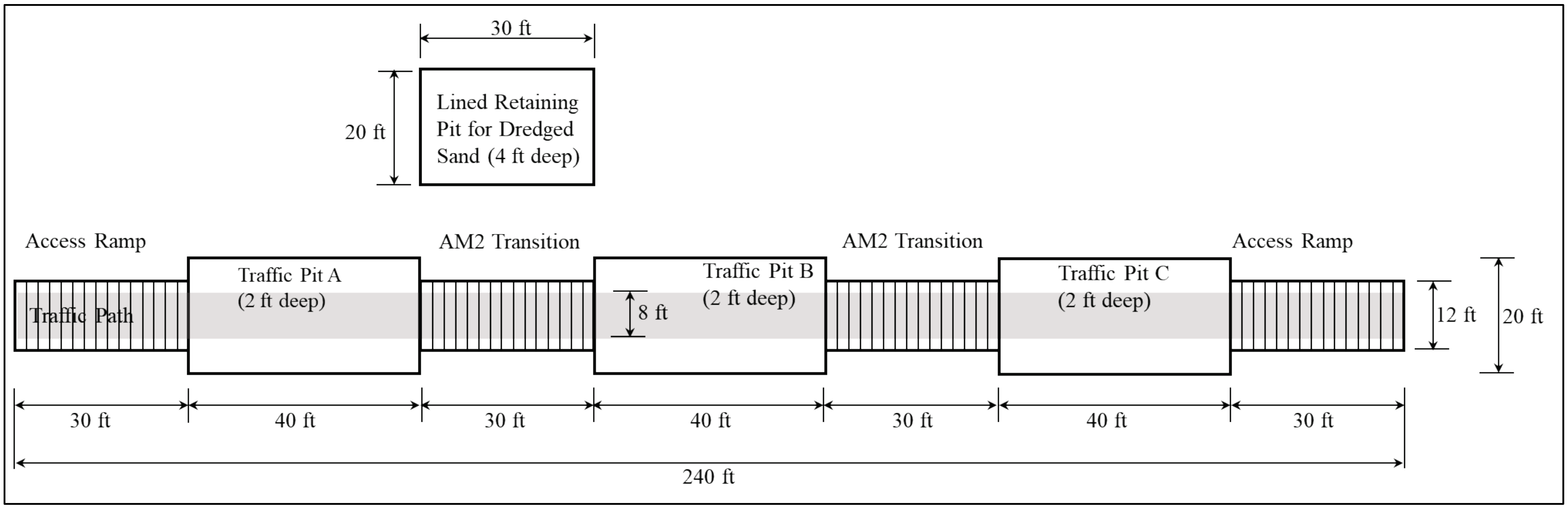
The viability of each deployment mechanism will be verified, and preliminary guidance will be formulated for each deployment mechanism. This guidance will serve as the basis for a formal technical manual when the SUBMAT goes to full production.

2 Trafficability Testing at the Ground-Vehicle Terrain-Surfacing Test Facility

A full-scale test section was constructed and evaluated during the period July through October 2021. All tasks associated with the experimentation, including the construction, testing, and analysis, were accomplished by ERDC personnel. Additionally, Fast Flow Pumps, LLC (Moss Point, Mississippi) aided in the deployment of several mat-filling systems. Construction activities were performed using conventional construction equipment and pumping systems. Plan-view schematics are provided in Figure 16.

The wet/dry gap trafficability mat test began by installing prototype matting sections over a uniform sand subgrade material in plastic-lined sand pits filled with water to simulate a military beach crossing in the littoral zone. The mat systems were aligned end-to-end with Airfield Matting 2 (AM2) (Alfab, Inc.; Enterprise, Alabama) transitions ramps between each system to form a straight, level roadway over a prepared sand subgrade. The mat road was trafficked with a 7-ton MTVR loaded with a 7-ton payload, an HEMTT with a 10-ton payload, an M1A1 Abrams tank, and several construction vehicles. The performance of each matting system was monitored at selected traffic intervals to quantify its deterioration. Performance comparisons were made between mat systems based upon rutting and wear of the mat materials. For those mat systems that performed well during the sand subgrade test, a future deployment and evaluation in a beach environment is planned. This evaluation, testing performance under full-scale beach wave and tidal conditions, will be presented in a future ERDC technical report.

Figure 16. Plan view schematic of SUBMAT traffic road.



2.1 Description of the Test Section

2.1.1 Overview

The field experiment was conducted at an outdoor test site at the ERDC Ground Vehicle Terrain Surfacing Test Facility (GVTSTF) in Vicksburg, Mississippi. The site was located on the northeast end of Brown’s Lake in a dredge-fill containment area encircled by a gravel-surfaced road (Susquehanna Circle). The soil at the site consisted of dredged material from Brown’s Lake placed in the 1980s. Local soils in the Vicksburg area are loess deposits, and subgrade sediments in the containment area are classified per the Unified Soil Classification System as low-plasticity clayey silt (Santoni 2003).

The subgrade immediately underlying the mat systems was a locally sourced sand typically used as fine aggregate in concrete. The sand was originally placed on site in 2006 for a beach-road traffic study by Rushing et al. (2007). The sand was a pit-run wash sand containing approximately 4% gravel sizes and 2% minus No. 200 US standard sieve-size material. It classified per American Society for Testing and Materials (ASTM) D 2487 as a poorly graded (SP) sand (ASTM 2017). Additional material properties for the sand are provided in Table 1. Dry unit weights were determined according to ASTM D 4253 (ASTM 1993).

Table 1. Sand properties. (Rushing et al 2007. Public domain.)

Property	Value
Specific gravity	2.65
Laboratory maximum, dry unit weight, lb/ft^3	117.7
Laboratory minimum, dry unit weight, lb/ft^3	98.2
Coefficient of uniformity, C_u	2.0
Coefficient of curvature, C_c	1.23
Plasticity Index	Nonplastic
Percent finer than No. 200 sieve	2.0
Grain size	Medium sand
Mean diameter, D_{50} (in.)	0.02
Fineness modulus	2.31

Two types of mat systems were tested and are described individually here based on the best available information at the time of this reporting.

2.1.2 Rebar-Geogrid Mat (RGM)

The Rebar-Geogrid Mat (RGM) is a combination of rebar and geogrid mat attempting to combine properties of each to create a lightweight and simple rollable roadway system. Geogrid provides a layer of strong synthetic material, the apertures of which allow confinement and interlocking of the soil media. While other patterns of geogrid offering greater strength and ground improvement are available, only the square pattern mesh allowed the rebar to be woven through the grid. This specific example was Tensar Biaxial Geogrid (Tensar; Alpharetta, Georgia), made of polypropylene. Plan dimensions were 20 ft × 40 ft.

Rebar provides durability and spreads the wheel loads over a wide area to reduce rutting. The rebar used was AIT Composites (AIT Composites; Brewer, Maine) GBar #4 basalt rebar in 20 ft bar lengths with a yield strength of 154.6 ksi. The rebar was woven into a row of geogrid every sixth cell along the length of the mat and woven through every sixth cell across as shown in Figure 17. The spacing of six cells is approximately 7 in. on center. For this test, the rebar was woven into the mat by hand and tested under the load of military vehicles at the GVTSTF. The deployed prototype can be seen in Figure 18.

Figure 17. Schematic of a section of Rebar-Geogrid Mat (RGM).

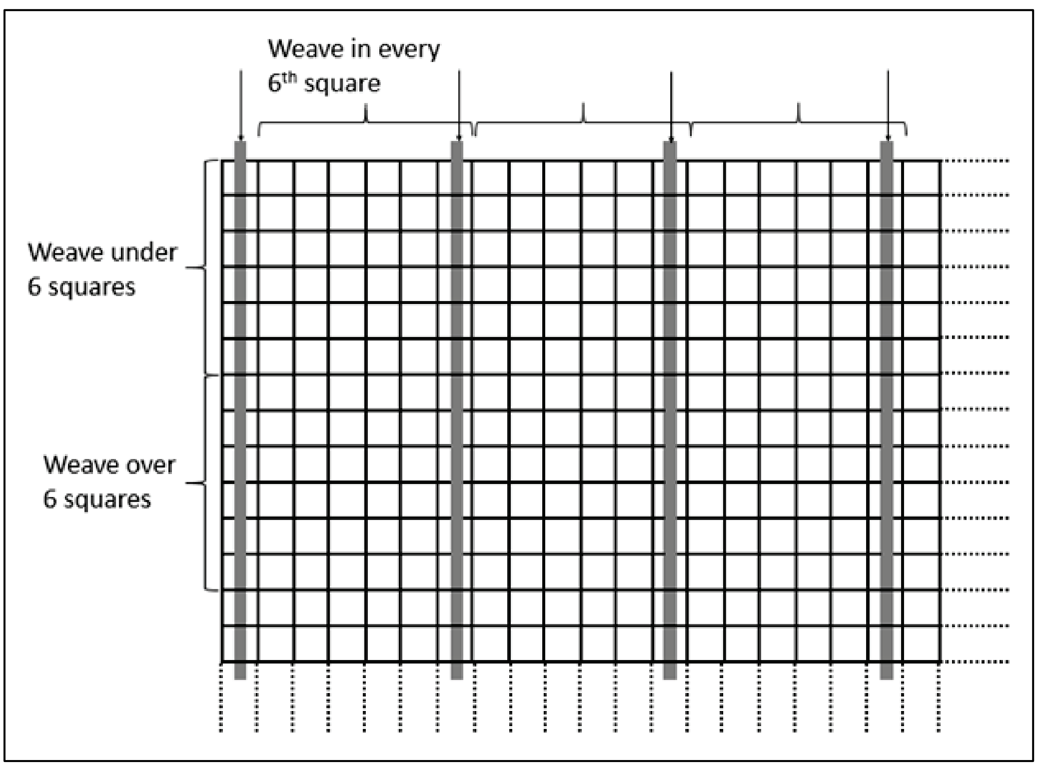


Figure 18. Deployed RGM.

2.1.3 PYRACELL Road Building System (PRBS)

The PYRACELL Road Building System (PRBS) is a novel combination of commercial technologies for defense mobility purposes. It is composed of GEOTEX (Propex Geosolutions; Chattanooga, Tennessee) 4 × 6 polypropylene geotextile with heavy woven serrated yarns, sewn into a rectangular mattress protected by an outer layer of PYRAMAT (Propex Geosolutions; Chattanooga, Tennessee), a 3D, lofty, polypropylene geotextile woven into a uniform configuration of resilient pyramid-like projections. The geotextile material and PYRAMAT material are shown in Figure 19. The seam strength of the sewing operation is greater than the strength of the geotextile. In October 2021, two slightly different PYRACELL mattress prototypes were tested at ERDC to determine performance under military vehicle wheel loading. Both prototypes were constructed by first sewing a 1 ft high by 7.5 ft wide × 40 ft long rectangular mattress with a longitudinal line of 12 in. long internal vertical braces located 3.5 ft from the mattress edge. The 12 in. long internal vertical braces were located on either a 1.5, 2.5, or 5 ft spacing. In addition, the mattress had three fill sleeves sized to accommodate a 6 in. diameter fill pipe. To complete the construction of the prototype to be tested, two of these rectangular mattresses were sewn together to form the 15 ft wide prototype. The result for the trafficking test was two 1 ft high × 15 ft wide × 40 ft long PRBS prototypes. Photographs of the two PRBS prototypes are shown in Figure 20 and Figure 21.

Figure 19. PYRAMAT (*left*) and geotextile (*right*) materials that constitute the PYRACELL Road Building System (PRBS) layers.

Figure 20. PRBS 1 rolled out and ready to be filled in test pit.

Figure 21. PRBS 2 rolled out and ready to be filled in test pit.

2.2 Test-Section Construction

The test section was constructed using an excavator and a skid steer to place the sand at the site into a roadway that was approximately 240 ft long, 30 ft wide, and 6 ft high. Once the sand was roughly leveled, three pits were dug along the length of the sand subgrade. Each pit was 40 ft long, 20 ft wide, and 2 ft deep. The pits were lined with a plastic lining to allow them to retain water. Once lined, the pits were refilled with the original sand, and an earth pressure cell (EPC) was installed in each of the traffic pits approximately 1 in. below the surface in the line of the north wheel path of the traffic. The pits were distributed such that each pit was approximately 30 ft from the next pit. Transition ramps of AM2 mat were placed over the sand subgrade to support traffic between the prototype matting systems.

To the side of the traffic lane, another pit, approximately 30 ft long, 20 ft wide, and 4 ft deep, was excavated. The bottom of this pit was lined with hexagonal plastic mats to protect the plastic liner. This pit was used as a dredging pit to create a sand slurry that could be pumped into the PRBS matting prototypes.

Each matting system was deployed within a traffic pit such that the surface of the matting system was approximately flush with the transition ramps between each traffic pit. On the outer edges of the test section, Supatrac (Mojo Rental; Manheim, Pennsylvania) ramps were placed over the sand subgrade. Figure 22 through Figure 28 show the construction of the sand road and test pits.

Figure 22. Leveling sand at test site with a compact track loader.

Figure 23. Test site prior to excavating pits for test-article installation.

Figure 24. Excavating sand pits for test-article installation.

Figure 25. Excavated dredge pit, lined with plastic and floored with hex mat to prevent pump from sucking up liner.

Figure 26. Dredge pit filled with sand and saturated with water to make a slurry fill for the PRBS mats.

Figure 27. Compacting loose sand prior to test-article installation.

Figure 28. Completed test pits prior to test-article installation.

2.3 Mat Installations

2.3.1 Mat Panel Installations

The RGM was installed by pulling the rolled-up mat to the traffic pit via a trailer. Once the mat was near the pit, a team of four lifted the mat off the trailer and placed it onto the ground near the east end of the traffic pit. The team then unrolled the mat across the 40 ft long pit and anchored it into place by using a sledgehammer to drive steel rebar anchors over the basaltic rebar reinforcements. The deployed RGM is shown in Figure 29.

Figure 29. RGM just after unrolling onto the sand test section.

The PRBS matting prototypes were taken from shipping pallets, unrolled, and carried by the corners by a team of four. Each mat prototype was placed into its own traffic pit and was ready to be filled by sand pumped from the dredge pit. A picture of PRBS 1 in the central trafficking pit is shown in Figure 30.

Figure 30. PRBS 1 after unrolling onto sand test section.

2.3.2 Filling of the PRBS

For the filling of the PRBS mats, Fast Flow Pumps, LLC, demonstrated the capability of its 3 in. Ductile Iron Twin Motor Pump (Fast Flow Pumps LLC; Moss Point, Mississippi). The pump was desirable for the compact design, 21 in. × 10 in. × 12 in., and high volumetric flow rate of up to 600 gpm. While the pump itself is physically small and relatively lightweight, 78 lbf, it requires a hydraulic power unit (HPU), which has a much larger logistical footprint. A vehicle with hydraulics (e.g., a skid steer or front-end loader) could be used to supply the hydraulic power; however, the effectiveness depends on the hydraulic capacity of the equipment. The filling process using the commercial pump is shown in Figure 31, Figure 32, and Figure 33.

The 3 in. pump from Fast Flow Pumps, LLC, experienced significant difficulties pumping the sand from the dredge pit because the concrete sand had a significant amount of aggregate of various sizes. While the larger pieces of aggregate tended to choke the pump quickly, the smaller pieces also tended to accumulate, causing slugs to form in the hose as well as choking the pump at the impellor. After a day of attempting to fill the PRBS, only approximately an eighth of the mat was filled. Thus, this pump was deemed unsatisfactory for this application, and a more appropriate pumping system for field deployment of the PRBS was required.

Figure 31. Using the Fast-Flow Pumps system to dredge sand for filling PRBS.

Figure 32. PRBS ready for filling with Fast-Flow Pump system.

Figure 33. PRBS while filling with the Fast-Flow Pumps system.

The following day, the research team utilized the Mini Robotic Submersible–Dredge (MRS-D) to fill the PRBS. The MRS-D system is shown in Figure 34. Like the previous pump, the MRS-D system requires a substantial HPU, but the system comes with a mobile HPU. Although the MRS-D proved capable of filling the PRBS, the capacity of the system was simply too powerful for the task. The system was running on the lowest possible settings, but the pressure of the dredged material going into the PRBS caused the strapping within the PRBS to fail with an audible popping during the filling operation. The internal strapping of the PRBS was meant to confine the shape of the PRBS to ensure a relatively flat surface rather than a pillowed or ballooned shape whereby too much material had settled in a local area of the PRBS. Figure 35 shows the PRBS being filled using the MRS-D.

Figure 34. Using the Mini Robotic Submersible–Dredge (MRS-D) to fill the PRBS.

Figure 35. Continuing to fill the PRBS using the MRS-D.

To reduce the effect of the overfilled sections of the PRBS mats, smaller 2 in. dredge pumps were implemented to fill in low areas and improve the overall smoothness of the surface of the PRBS mats. This proved difficult, as the aggregate that caused the issues for 3 in. twin-motor pump from

Fast Flow Pumps, LLC, resurfaced with the smaller dredge pumps. As a result, the research team settled on implementing fine sand free of aggregates, mixed with water in a metal tub and fed into a 2 in. diesel dredge pump. This set up worked well, and within several hours, the PRBS mats were made sufficiently flat for the pretraffic scans to be made and trafficking to begin. The fully filled PRBS mats are shown in Figure 36.

The research team gained a significant amount of knowledge regarding the difficulties that could be faced trying to implement this system. Although coarse aggregate is not likely to be encountered on many beaches, there are beaches with significant amounts of coral or shell content that, like the aggregate, could choke the pumps. Furthermore, the internal strapping was not robust enough to withstand the filling process. While the MRS-D was entirely too powerful for the straps to withstand, it is possible they could have failed with other dredging systems. Additionally, the straps prevented the dredge-pump filling nozzle from adequately maneuvering inside the PRBS, making evenly filling the mat difficult. Therefore, the team has proposed a new design iteration to remove the straps and instead implement a membrane wall.

Figure 36. Completed test section prior to traffic application.

2.4 Traffic Application

Channelized traffic was applied by using a series of military vehicles according to the traffic path shown in Figure 16. The vehicles included a 7-ton, 6-wheeled MTVR truck; a 10-ton, 8-wheeled HEMTT truck; and an M1A1 Abrams tank equipped with road pads. Descriptions and photographs of these vehicles are included in the following sections. The vehicles were driven alternately forward and backward over the test roadway in the same wheel paths at a steady-state condition of approximately 5 to 10 mph. All necessary accelerations and decelerations were performed on the AM2 access ramps beyond the ends of the mat systems being evaluated.

Traffic was paused intermittently to document the condition of the test roadway surface. Prior traffic data from other studies have shown that rut development is exponential in nature, so intervals were selected to have a logarithmic-like distribution. Data were collected after passes 0, 10, 20, 50, 100, 200, 500, and 1,000 for the MTVR. The traffic intervals for the HEMTT were 0, 10, 20, 50, 100, 200, and 350 passes, and the traffic intervals for the M1 Abrams were 0, 10, 30, 50, 100, and 150 passes.

2.4.1 Medium Tactical Vehicle Replacement (MTVR) (7-Ton)

In this study, a dump truck variant of the MTVR was utilized to apply traffic, as shown in Figure 37. The truck was loaded with 7 tons of uniformly distributed lead blocks. The tire pressures were set following the recommendations for cross-country driving conditions (i.e., 28 psi in the two front tires and 35 psi in the four rear tires). The front axle of the loaded truck carried a load of 15,490 lbf, and the combined load on the two rear axles was 29,450 lbf. The contact area of the tire-to-soil was estimated assuming the contact pressure is equal to the air pressure of the tires, giving a front and rear contact area of 277 in.^{2} and 210 in.^{2}, respectively. Usually, the actual contact pressure will be higher than the air pressure due to the rigidity of the tire sidewall. In previous studies using the MTVR, the contact pressures have been estimated to be approximately 28 to 32 psi for the front and 35 to 40 psi for the rear tires.

Figure 37. The MTVR trafficking over SUBMAT prototype and Airfield Matting 2 (AM2) transition ramps.

2.4.2 Heavy Expanded Mobility Tactical Truck (HEMTT) A4 Cargo Truck (8-Wheel)

The HEMTT A4, as shown in Figure 38, is a four-axle heavy cargo truck with a nominal capacity of 10 tons used by the US Army. The front axle of the HEMTT was loaded to 13,700 lbf, the second axle to 14,140 lbf, the third axle to 16,240 lbf, and the rear axle to 15,660 lbf. Based on the axle loads and the tire pressure of 70 psi, the contact areas of the tires ranged from approximately 98 in.^{2} to 116 in.^{2} with an average of 107 in.^{2}. This agrees with the nominal tire pressure for a HEMTT of 70 psi with a contact area of 113 in^2.

Figure 38. The HEMTT trafficking the test section.

2.4.3 M1A1 Abrams Tank

The M1A1 Abrams tank is an armored, tracked vehicle with a 120 mm cannon. The weight of the vehicle is nominally approximately 127,000 lbf but was not weighed at the time of testing. Its ground pressure is approximately 10 psi. This vehicle was used as a tracked vehicle for testing but was also equipped with road pads to protect paved surfaces. Figure 39 shows the M1A1 tank used in this study.

Figure 39. M1A1 Abrams tank trafficking onto test section.

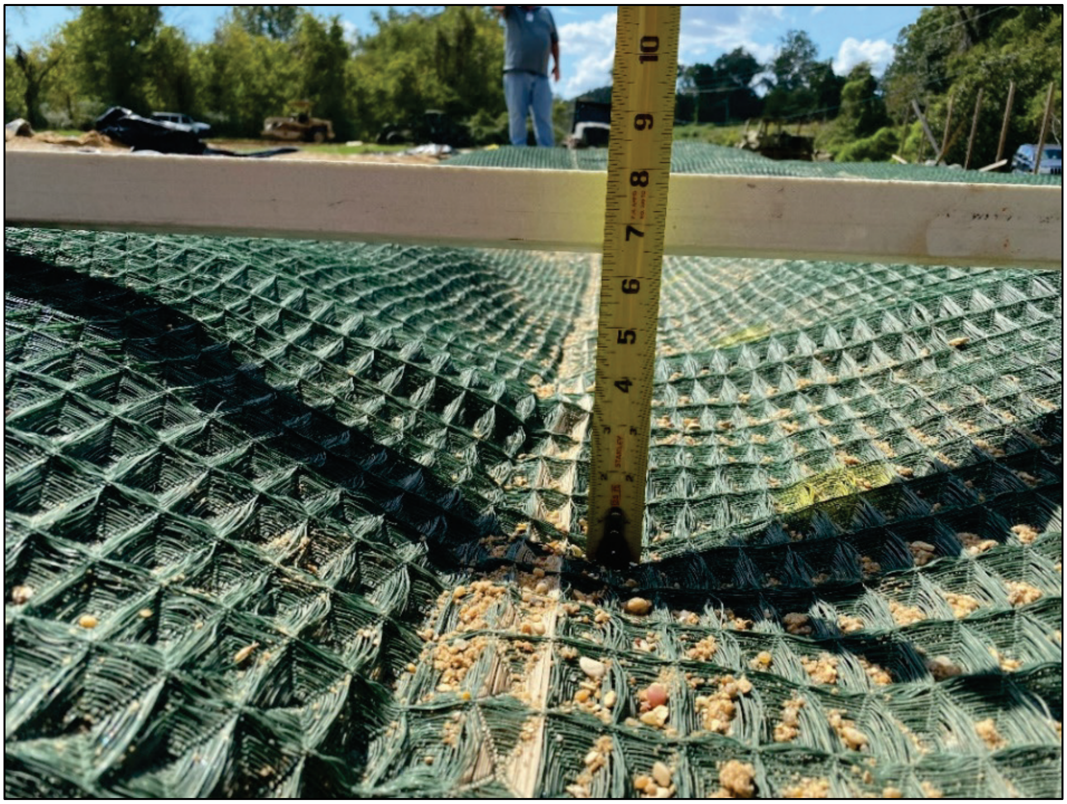
2.5 Data Collection

2.5.1 Rut Depths

Rutting in the mats was quantified and recorded via lidar. A straightedge and a ruler were also implemented at the final pass of each vehicle to supplement and validate the lidar data. The rut depth was also measured via straight edge for the RGM system since the pit was flooded and lidar data could not be collected in a timely manner. Because the matting systems in this study were filled with sand and not rigid, the rut depth was measured without a weight applied. Typically, the weight is applied to depress the mat into the rut forming in the subgrade; however, all the mats in this study experienced the deformation and rutting within the mats themselves. A metal straight edge, 6 ft long, was laid across the north wheel path at the quarter points along the length. A rigid ruler was used to measure the distance from the straight edge to the center of the rut, 1 ft left of center and 1 ft right of center, as shown in Figure 40 and Figure 41. Rut-depth data are reported in Section 4.

Figure 40. Measuring rut depth with a straight edge.

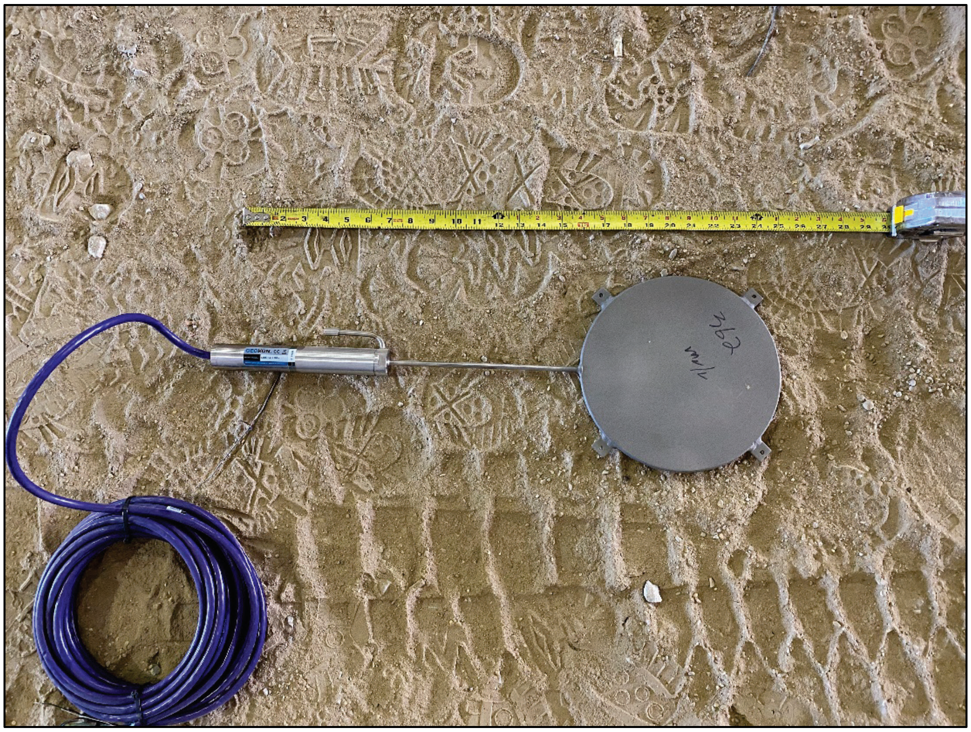
Figure 41. Rut-depth measurement from the north wheel path of PRBS 1 showing a 6.5 in. deep rut.



2.5.2 Earth Pressure Cell (EPC) Measurements

The EPCs, shown in Figure 42, were positioned approximately 1 in. below each matting system in the center of the north wheel path. They connected to a computer-controlled data-acquisition system that was manually activated before each traffic interval began. These data provided a means of assessing a given mat's ability to distribute the load of the vehicle. Results of the EPC measurements are presented and discussed in Sections 4 and 5, respectively.

Figure 42. Earth pressure cell (EPC) to be buried 1 in. below the matting systems under the north wheel path.



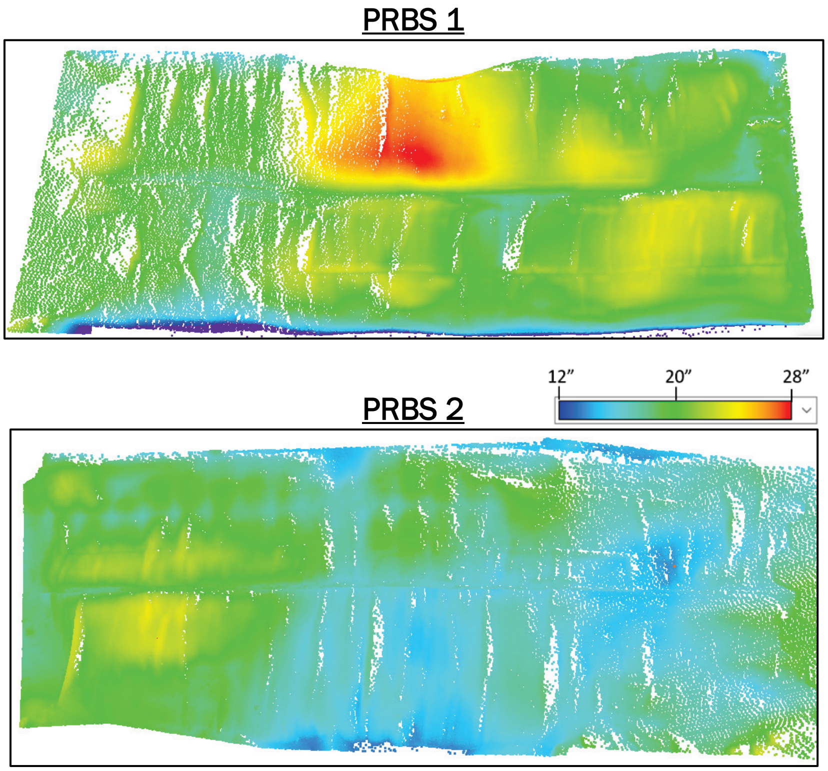
2.5.3 Lidar

A Riegl VZ-400 (Riegl; Horn, Austria) terrestrial lidar scanner was used to capture the shape of the PYRACELL PRBS prototypes postfilling and pretrafficking, as shown in Figure 43 and Figure 44. Data were collected into pointclouds using RiSCAN PRO (Riegl, Horn; Austria) collection software. The Riegl VZ-400 is a line-of-sight instrument that is unable to penetrate water, which can cause shadowing behind steep slopes and missing data points in areas of standing water. Lidar scans were also collected throughout the trafficking tests after a predetermined number of passes to track the progression of rut depths for each test vehicle. Scans were collected after 5, 10, 25, 50, 200, 500, and 1,000 passes of the MTVR; 10, 20, 50, 100, 200, 250, 350 passes of the HEMTT; and 10, 30, 50, 100, and 150 passes of the M1A1. The first scan, taken after the deployment of the mats and prior to any traffic, is shown in Figure 45. These data are presented and discussed in Sections 3 and 4, respectively.

Figure 43. Lidar scanner mounted on tripod well above the trafficking lanes.

Figure 44. Lidar targets on the west end of the trafficking lane: one near the pile of AM2 mats and the other near the bulldozer.

Figure 45. Initial lidar scans of each filled PRBS mat.



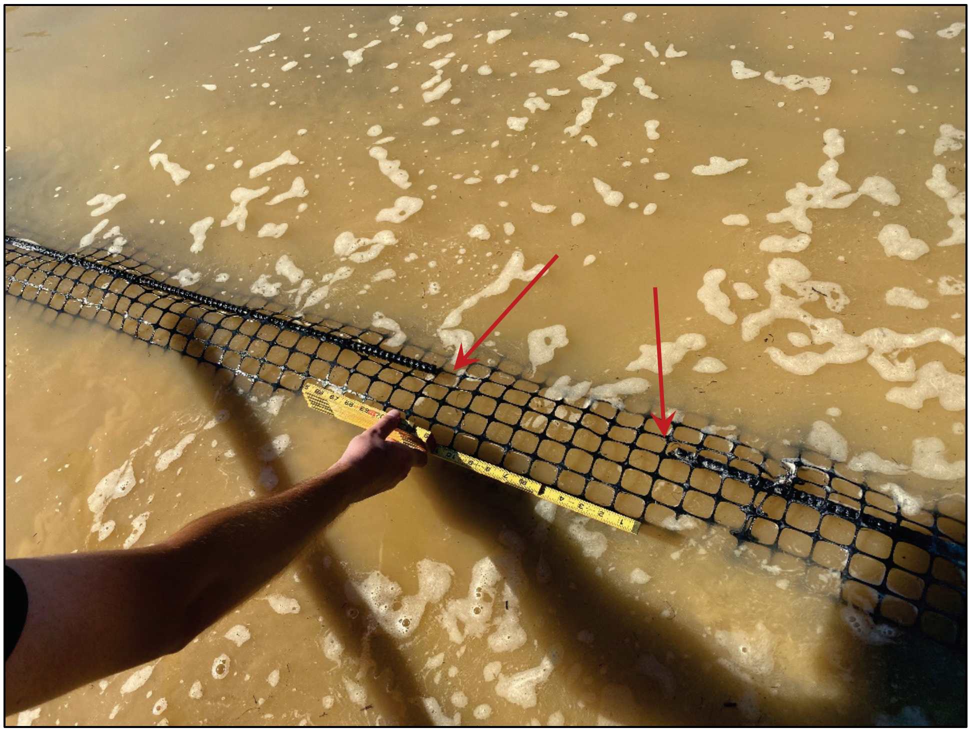
2.6 Failure Criteria

A test item was considered failed when it reached one of the following failure criteria: (1) the rut depth in the wheel path reached a critical limit or (2) the mat reached a critical point of physical damage. Note that in many cases, especially in the case of rutting failure, traffic could be sustained beyond the failure point of the mat. Although a matting system may have failed, traffic in the study continued until the mat could no longer be reasonably repaired, the mat posed a tire hazard, or rutting became severe enough to cause the differential of the vehicle to come into contact with the mat.

2.6.1 Mat Breakage

The critical point for mat breakage has been defined as 20% of the surface area in previous studies (Santoni et al. 2001; Rushing et al. 2007; Rushing and Rowland 2012), so that criterion was used in this case for direct comparisons. Physical damage and breakage for the rebar mat included fracture of the basaltic rebar or movement of the rebar out of the geogrid, as shown in Figure 46. Physical damage for the PRBS included wearing and tearing holes in the surface of the PRBS system.

Figure 46. Initial rebar breakage in the Rebar-Geogrid Mat (RGM) shown by the *red* arrows.



2.6.2 Permanent Subgrade or Mat Deformation

The overall failure of the matting due to permanent subgrade or mat deformation is vehicle dependent. The failure occurs when the vehicle is physically hindered from traversing the mat. To this end, rutting, which is a measure of subgrade or mat deformation, was used to quantify failure. In previous studies (Santoni et al. 2001; Rushing et al. 2007; Rushing and Rowland 2012), a critical limit of 3 in. deep ruts was used as the failure criterion; however, in this study that criterion is used only as a comparative value since the vehicles used in this study could still traffic the mat through 3 in. deep ruts. Also worth noting, the rut depth in this study was measured in such a way that upheaval from shear flow induced by rutting is included in the rut-depth value. The rut would need to be at least 8 in. deep for the differential of the MTVR or HEMTT to begin dragging on the mat surface and cause failure.

3 Test Results

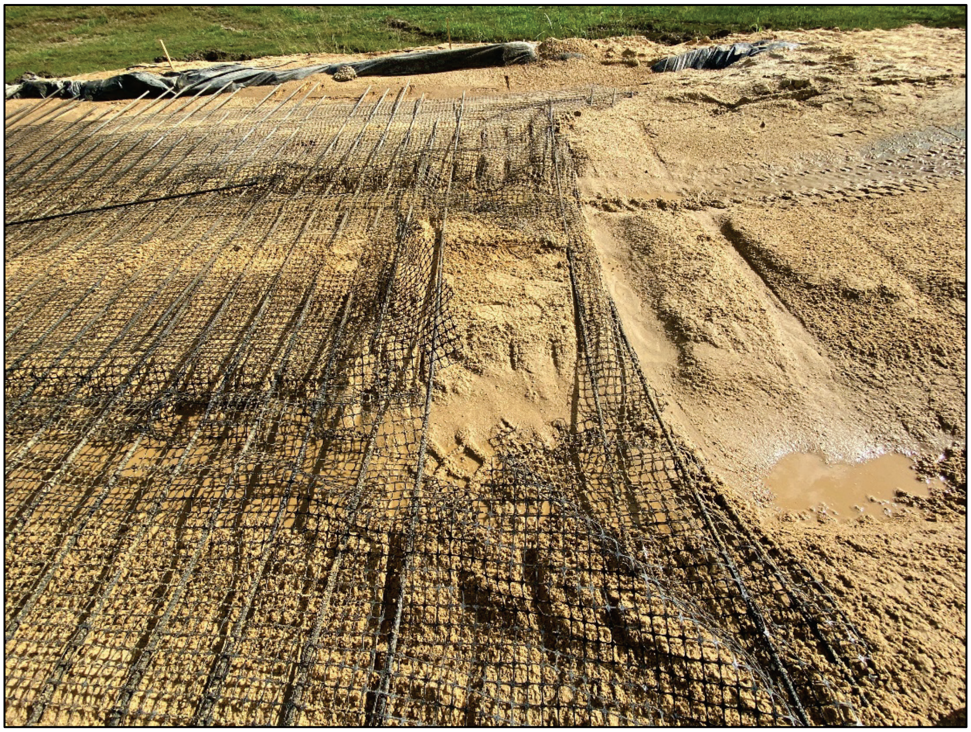
3.1 Mat Performance

3.1.1 Rebar Mat

The basaltic rebar mat performed well for the initial traffic intervals under the MTVR. However, after 50 passes with the 7-ton truck, the basaltic rebar pieces were observed to be shifting laterally through the geogrid as shown in Figure 47. Also, four pieces of rebar were fractured. Trafficking continued on the rebar mat with several more fractured rebar pieces observed at each traffic interval. Finally, at 268 passes of the 7-ton MTVR, a chunk of rebar mat approximately 1.5 ft long and 4 ft wide got caught on the underside of the truck, ripping it out of the mat. Between the torn section of the rebar and the number of fractured basaltic rebar pieces, the mat was considered to have failed at 268 passes. The damage that caused failure is shown in Figure 48.

Figure 47. RGM with rebar reinforcement shifting in the geogrid mat as trafficking progressed.

Figure 48. Final failure of RGM when a sizeable piece of the mat was ripped away by the MTVR.



3.1.2 PRBS Mats

The PRBS mat system prototypes performed well under the applied traffic. The wearing surface of the mats held up with negligible observable damage throughout the trafficking of each the 1,000 passes of the 7-ton MTVR and the 350 passes of the 10-ton HEMTT. Rutting developed in each mat deep enough to reach the 3 in. criteria, but the wearing surface held up exceptionally well, and vehicle traffic was not hindered in any significant manner. The wearing surface also held up with some minor observable damage after 50 passes of the M1A1 Abrams tank. The observed damage was tearing along the outside of the track path near the transition ramps as shown in Figure 49. Figure 50 shows the area near the transition ramp on one of the PRBS mats after 150 passes of the M1A1. The tear in the matting is a little shorter than 3 ft long. Continued trafficking with the M1 Abrams tank resulted in further tearing in the locations where damage was already observed, but the damage was not significant enough to be considered failure by mat breakage.

Figure 49. Damage to the PRBS from the M1A1 near the transition ramp.

Figure 50. Total accumulation of damage near the transition ramps on PRBS mats after 150 passes of the M1A1 tank.

After completion of the MTVR, HEMTT, and M1A1 tank traffic, the PRBS mat system exhibited only minor damage. Therefore, the team decided to traffic the excavator on site on the mat. The excavator is shown in Figure 51. The goal of the additional traffic was to evaluate the effect of tracked vehicle traffic without any protective pads (recall the M1A1 had protective road pads on the tracks). After 26 passes of the excavator, only minor tearing of the wearing surface was observed with no major structural damage to the confining geosynthetic material underneath the wearing surface. The research team then decided to use a nearby D8 bulldozer (Figure 52 and Figure 53) with more aggressive tracks to gain better traction. Some significant damage was observed after 24 passes in which the tracks gouged slits through the geosynthetic material and began to tear the wearing surface completely away in other locations. Some of the preliminary damage can be seen in Figure 54. With the slits in the geosynthetic, the capability of the PRBS system to completely confine the sand material was compromised leading to degradation in performance, especially in a littoral environment. However, the damage was relatively small, so it is possible the matting system would be able to complete the mission with a limited number of passes of vehicles with tracks like the bulldozer, but the team recommends avoiding that type of vehicle tracks, if possible.

Figure 51. Excavator used to apply additional traffic on PRBS mats.

Figure 52. Army D8 bulldozer used for additional traffic on PRBS mats.

Figure 53. Trafficking with the D8 bulldozer.

Figure 54. Damage accumulated from the additional traffic caused tearing in the wearing surface and punctured the geosynthetic material underneath.

3.2 Rut Depths

Figure 55 is a plot of the rut depth versus number of traffic passes for the MTVR. Recall from Section 2 that rut depths were measured using lidar and verified with a straight edge and a ruler. Figure 56 and Figure 57 show the normalized average rut depth for the HEMTT and M1A1, respectively. These data sets were normalized to show the evolution of the rutting strictly due to the new vehicle traffic, without respect to how deep the rut was prior to trafficking with the new vehicle. The non-normalized average rut depth data are presented in Appendix B. Note that the normalized average rut depths for the HEMTT and the M1A1 are generally negative, meaning that the ruts became less deep. This phenomenon is further discussed in Section 4.

Figure 55. Average rut depth data for MTVR across PRBS 1 and 2.

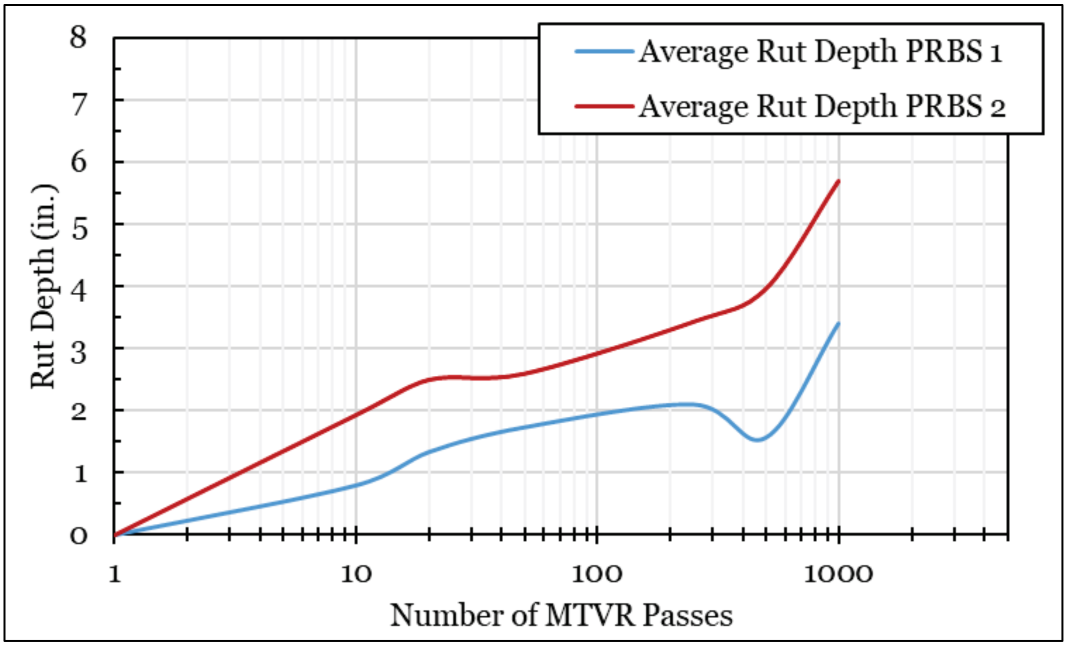


Figure 56. Normalized average rut depth for HEMTT across PRBS 1 and 2.

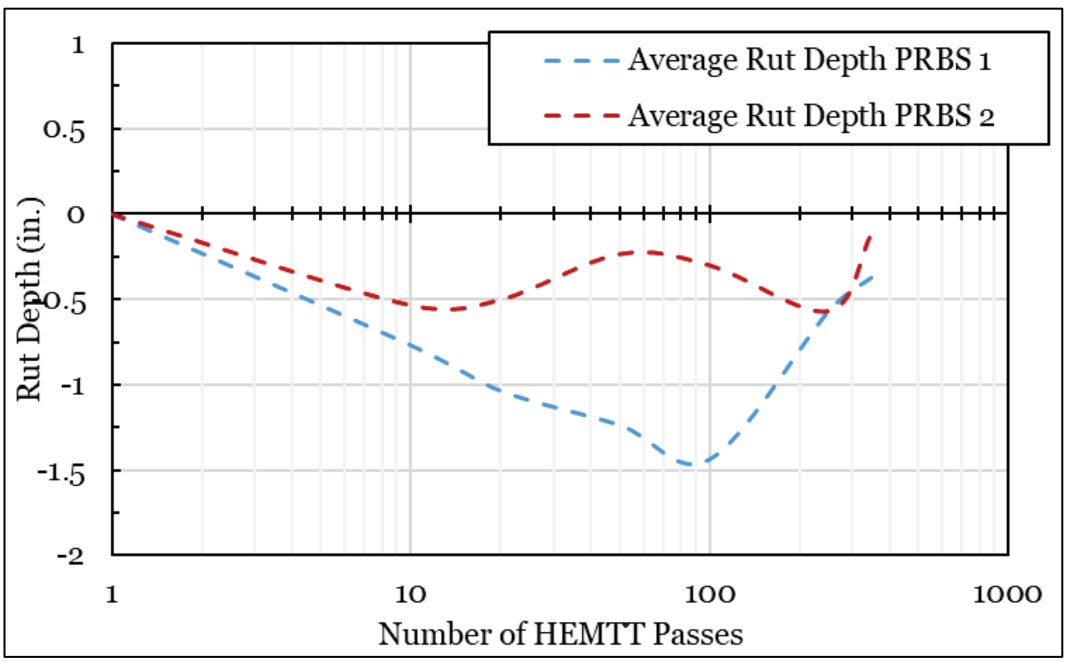
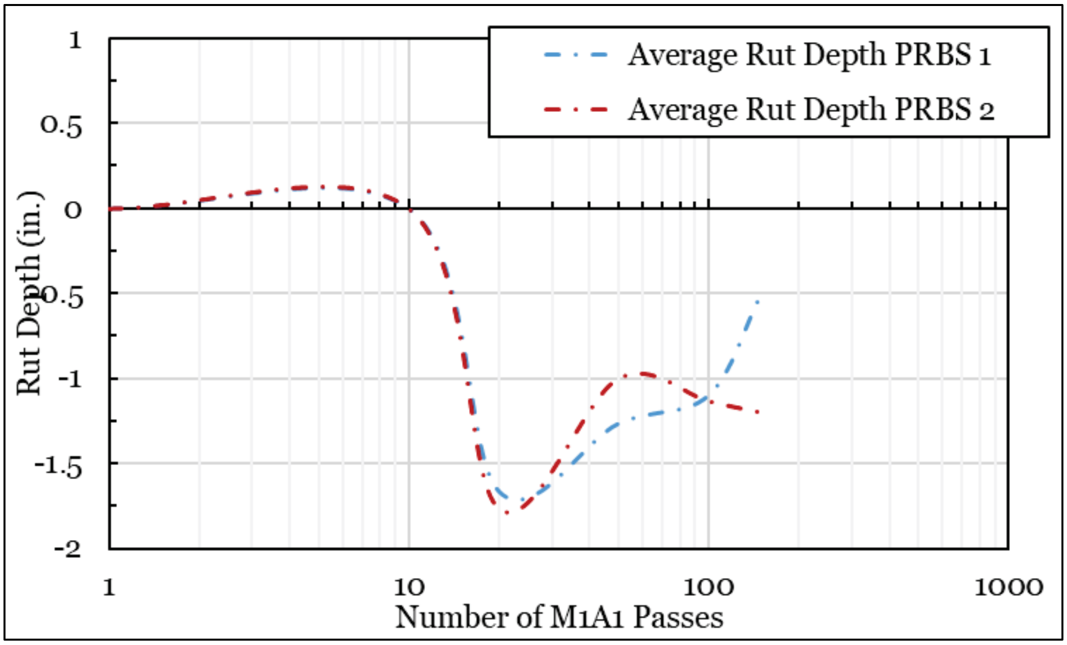


Figure 57. Normalized average rut depth for M1A1 across PRBS 1 and 2.



3.3 EPCs

EPCs were deployed underneath each mat item at a 1 in. depth to measure each mat's ability to distribute the applied load. EPC data for the PRBS 1 and 2 mat systems are reported in Figure 58 and Figure 59, respectively. The raw data were greatly reduced due to their variability. Rather than the imprecision of the instruments, experimental error associated with the speed and steering of the vehicles was thought to be the cause of the inconsistencies in the data. Very slight deviations in the wheel path resulted in large differences in the measured pressures. While a false high pressure is unlikely, a false low pressure resulted if the vehicle tire or track did not pass directly over the center of the EPC. Therefore, a peak-picking software was implemented to find the peaks in each traffic interval, and the maximum peak of each interval was recorded. The raw data of pressure peaks are included in Appendix C. Also, the traffic intervals for each vehicle type are tabulated in Table 2.

Figure 58. Peak pressures observed during each traffic interval for each vehicle type on PRBS 1.

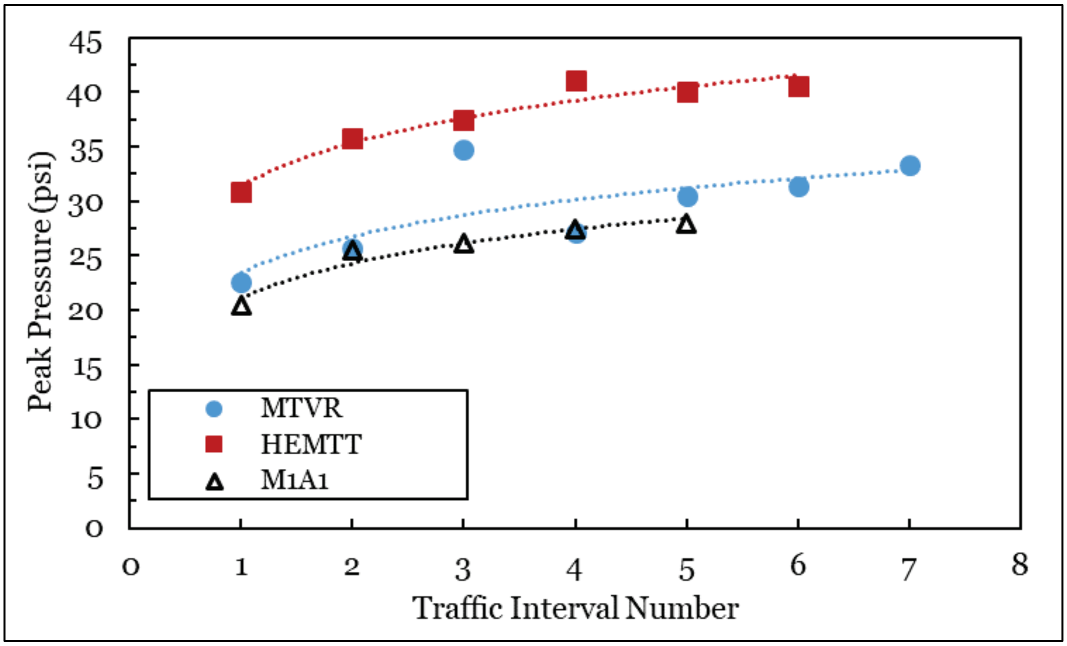


Figure 59. Peak pressures observed during each traffic interval for each vehicle type on PRBS 2.

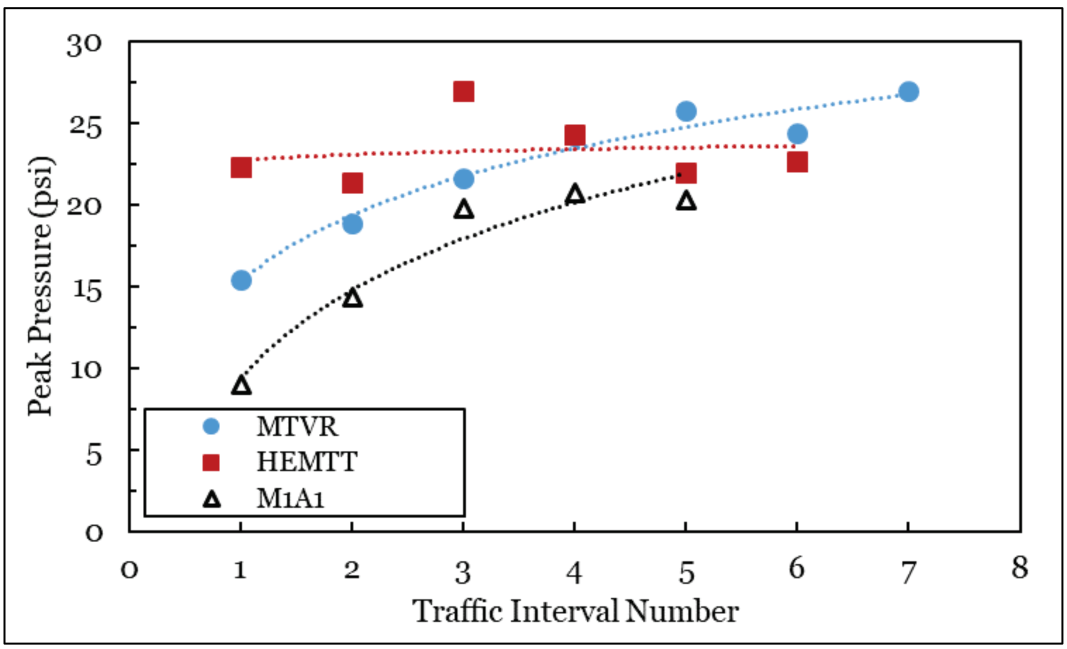


Table 2. Traffic intervals by vehicle.

Traffic Interval	Number of Passes at the End of the Interval		
Number	MTVR	HEMTT	M1A1
1	1–10	1–10	1–10
2	11–20	11–20	11–20
3	21–50	21–50	21–50
4	51–100	51–100	51–100
5	101–200	101–200	101–150
6	201–500	201–351	—
7	501–1000	—	—

The researchers also note that the peak pressures are not plotted for the RGM because it failed very early in the testing. The maximum pressure experienced by the rebar mat for the MTVR was 90.6 psi. This value is substantially greater than the vehicle tire pressure (i.e., 28 to 32 psi in the front tires and 35 to 40 psi on the back tires). This shows that the assumption of uniform pressure distribution in the tires for trafficking on unconfined, saturated sand does not hold. It is likely that during the traffic pass that resulted in the 90.6 psi reading, the sidewall of the tire passed directly over the EPC causing a much larger pressure than would have been otherwise expected.

3.4 Lidar

Recall from Section 2 that lidar scans were collected throughout the trafficking tests after a predetermined number of passes. Scans were collected after 5, 10, 25, 50, 200, 500, and 1,000 passes of the MTVR; 10, 20, 50, 100, 200, 250, and 350 HEMTT passes; and 10, 30, 50, 100, and 150 passes of the M1A1. These scans produced dense point clouds used to map the overall shape of each PRBS prototype as well as to track the progression of rut depths for each test vehicle. While this collection method allows rut depth measurements for both wheel paths along the entire length of mat, only measurements at the quarter-point locations along the north wheel path, shown in Figure 60, are presented in Table 3.

Figure 60. Quarter points for PRBS 1 and 2.

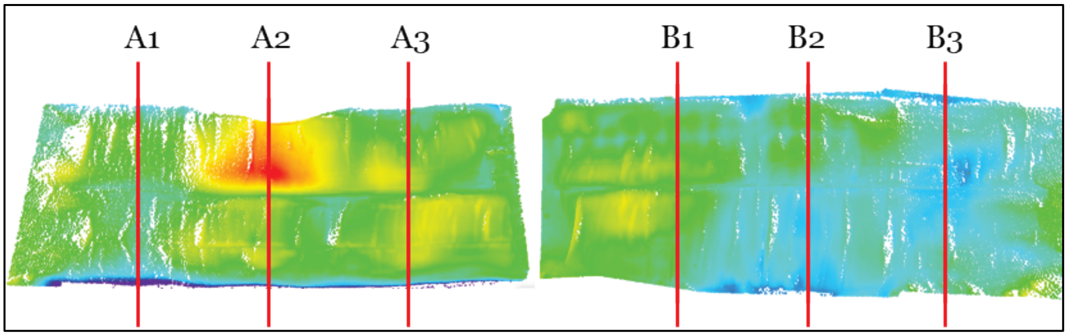


Table 3. Rut depth measurements from PRBS quarter points at the traffic intervals for each vehicle.

Vehicle	Passes	Rut Depths (in.)					
		PRBS 1			PRBS 2		
		A1	A2	A3	B1	B2	B3
MTVR	5	1.1	2.2	2	4.9	2.6	2.4
	10	1.6	2	4	3.9	3.2	2.9
	20	1.9	2.4	4.9	4.5	3.9	3.3
	50	2.4	3.1	4.9	5.1	3.5	3.4
	200	3.1	3.1	5.3	5.5	4.5	4.5
	500	3.2	2.4	4.3	4.5	5.7	5.9
	1,000	5.9	3.8	5.7	5.9	8.5	6.9
HEMTT	10	5.1	2.7	5.3	5.3	7.7	6.7
	20	4.9	2.3	5.1	5.3	7.6	6.9
	50	4.1	2.7	4.9	5.7	7.8	7.1
	100	3.9	2.4	4.8	5.7	7.8	6.9
	200	5.5	2.9	5.3	5.7	7.2	6.7
	250	5.3	3.1	5.9	5.7	7.9	7.4
	350	5.5	3.4	6	6.5	7.9	7.9
M1A1	10	1.6	3.7	4.6	3.7	7.2	6.1
	30	2.8	3.3	5	5	8	6.3
	50	3	3.2	5.4	4.9	7.5	6.5
	100	3.8	3.9	5.7	5	7.6	6.1
	150	3.7	4.5	6.2	5.3	7.9	6.4

4 Analysis of Results

4.1 Mat Performance

4.1.1 RGM

The performance of the basaltic rebar-reinforced geogrid mat was poor under trafficking conditions. The rebar was not sufficiently durable to hold up for 300 passes of the MTVR with some 15 pieces fracturing during the test. This is likely due to the severe rutting observed under the rebar mat.

The severe rutting rate of the rebar mat is a result of several factors: (1) the nature of the sand subgrade, (2) the lack of long-range rigidity of the rebar mat, and (3) the water-saturated conditions of the test. When subjected to shear stress, sand particles can shift or flow; however, if confined by the surrounding environment, such as berms, sandbags, etc., the capacity to shift and flow is reduced. Sand particles at the surface of the subgrade can move laterally with ease due to lack of confinement, resulting in weak load-bearing capacity near the surface. Under traffic, ruts form as the sand shifts away from the wheel path on the surface of the subgrade. As the surface sand is displaced and the rut grows deeper, the subsurface sand is better confined and capable of bearing greater loads.

In previous studies (Rushing et al. 2007; Floyd 2017, 2018), researchers noted that matting placed on a sand subgrade further confines sand, improving rutting resistance. In the case of this study, this added benefit was not fully realized as the geogrid mat and rebar reinforcement do not act as a rigid body and leave the surface sand exposed to air. The rebar reinforcement acts as a load-distribution mechanism, which reduces rutting. However, the mat was designed to deploy as a roll, making it highly flexible in the trafficking direction, and long-range flexibility is a liability in terms of rutting performance.

The saturation of the sand pit also negatively impacted the rutting resistance of the rebar mat. With the lined pit unable to quickly drain water, the sand subgrade remained in a state of suspension near the surface. Deep in the pit, the weight of the sand and water may have helped compact the sand, but the surface bearing capacity was undoubtedly reduced by the presence of water. This resulted in lower bearing capacity than dry sand and, therefore, even faster rutting than dry sand.

As a result of these three factors, the onset of rutting occurred quickly, and the deeper the rutting became, the more the load and deformation experienced by the rebar. This led to fracture of the rebar reinforcement, which resulted in less load-bearing capacity in the area near the fracture. As a result, a negative feedback loop was created where rutting led to fracture of the rebar, which led to greater rutting in the area causing more deformation and eventual fracture of the neighboring pieces of rebar. Combined, all these factors led to a total failure of the rebar mat in 268 passes.

4.1.2 PRBS Mats

The performance of the PRBS mat under conditions of this study was excellent in terms of serviceability of the system. While significant rutting was observed well beyond the 3 in. criterion, none of the vehicles were hindered by the ruts. The PRBS wearing surface proved capable of withstanding 1,000 passes of the MTVR and an additional 350 passes of the HEMTT without showing any significant damage. Although the M1A1 Abrams caused some minor tearing at the edges of the two PRBS prototypes at 150 passes, the damage was not sufficient to cause catastrophic failure in a field deployment. The only concern for the tearing in a beach environment would be the transport of sediment out of the PRBS during shifting tidal zones throughout the deployment of the system.

Note that while trafficking, the M1A1 Abrams tank was equipped with road pads on the track, which are designed to protect paved roadways from being damaged by the tank tracks. These road pads may have also served to reduce the wear and tear on the surface of the PRBS mat systems. After trafficking with the M1A1 Abrams was completed, another 50 passes were made using tracked vehicles that were not equipped with any type of padding. Half of the passes were with an excavator used at the jobsite, and the other half of the passes were done by a bulldozer equipped with bog tracks for greater traction in unstable soil environments. The unprotected tracked vehicles caused significant damage to the matting surface, resulting in fraying and tearing across the surface of the mat. Despite the surface damage, the sand remained largely confined, and the mat remained trafficable, but in a tidal environment with wave action on the surface of the mat, sediment transport out of the PRBS would be a concern.

4.2 Rut Depth

As mentioned, the RGM did not act as a confining surface, resulting in rapid rut development.

For the PRBS prototype, the rut profile changed notably when the trafficking vehicle changed; however, this phenomenon was not easily seen in the averaged data. This can be seen in Figure 56 where the normalized average rut depth at the beginning of HEMTT traffic goes negative. This is likely due to the changes in tire shape and pressure. As a result, the initial passes of a new vehicle tended to flatten out the channelized rut formed under the previous vehicle's tires. The same phenomenon was observed when traffic changed from HEMTT to M1A1 Abrams tank.

It is also worth noting that the primary difference between the PRBS 1 and PRBS 2 was the amount of sediment filling each mat. The internal strapping of the two prototypes failed due to the water pressure during the filling process resulting in the two prototypes being essentially identical in that respect. However, the PRBS 1 prototype was filled with more sediment than PRBS 2. This resulted in noticeably less rutting in PRBS 1, so it is believed that with a better, more evenly distributed filling method, greater resistance to rutting can be achieved. This is attributed to effective confinement of the sand. By filling the PRBS more completely, the sediment inside the mat was more confined with less space to move around. As a direct result, the bearing strength of the sediment inside the PRBS was significantly improved leading to slower rut formation.

After the removal of the prototype PRBS mats post trafficking, the research team observed that the sand beneath the prototypes showed no signs of rutting. This was expected because the sand-filled PRBS mats were capable of accommodating the deformation within the mat itself rather than acting like a rigid mat that disperses pressure across the subgrade. By containing the deformation, the PBRS mats effectively protected the subgrade soil.

4.3 EPCs

In general, the peak ground pressure just below the PRBS matting increased as the traffic intervals increased. One reason for this is that there were simply more passes in the later traffic intervals increasing the likelihood of the tire passing directly over the EPC. The second reason is that, as the ruts developed, less sand was present to transmit the pressure through the PRBS. The latter reason is further supported by the logarithmic nature of the increasing pressure. The rutting tends to increase logarithmically with increasing traffic passes, and, similarly, the observed peak ground pressure increased logarithmically with traffic intervals as well.

4.4 Lidar

During the filling process, PRBS 1 was slightly overfilled in some areas while PRBS 2 was slightly underfilled in others, as seen by the high and low spots in Figure 61. Significant rut development occurred rather quickly as vehicle traffic was applied but appeared to reach a steady-state depth over time for each vehicle trafficked as seen in the lidar data and Table 3.

Figure 61. Lidar results from postfill, pretraffic, PRBS 1 and PRBS 2

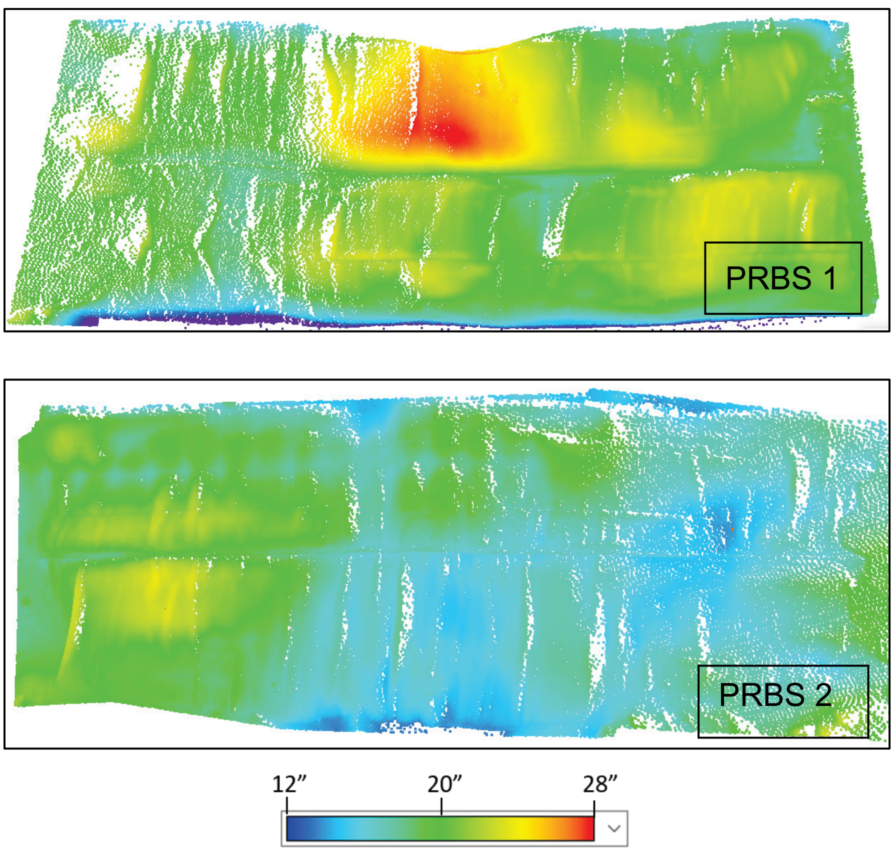


Figure 62 shows the fully developed ruts after 1,000 MTVR passes across both PRBS prototypes. Rut depth is much greater in the areas of the mats that were underfilled due to less localized confinement of sand in these areas.

Figure 62. Lidar scan results after 1,000 MTVR passes.

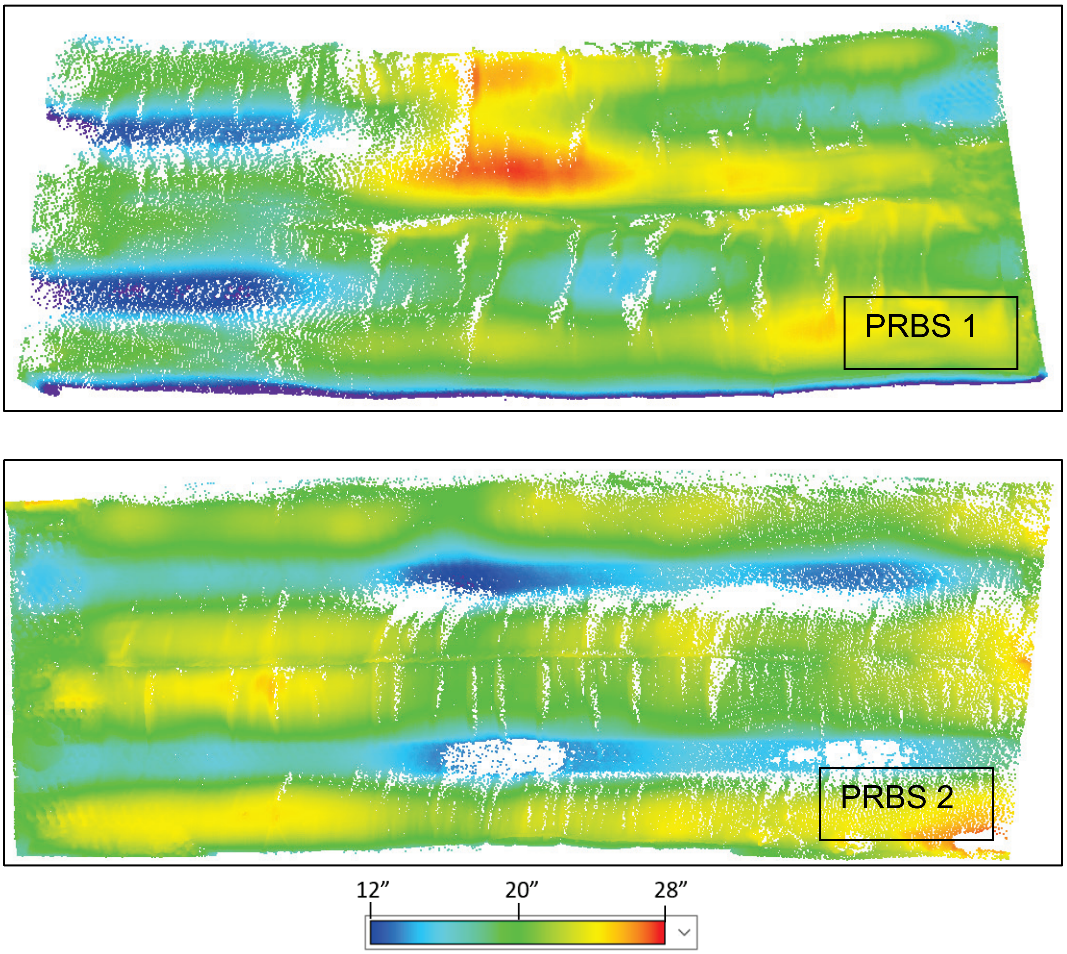


Figure 63 shows the progression of rut-depth development from the pretraffic state to 25 MTVR passes at the quarter points of both PRBS prototypes. After 25 MTVR passes, significant rutting had developed in the underfilled areas of PRBS 2, as seen in cross-sections *B2* and *B3*.

Figure 63. Cross sections from 5 to 25 MTVR passes.

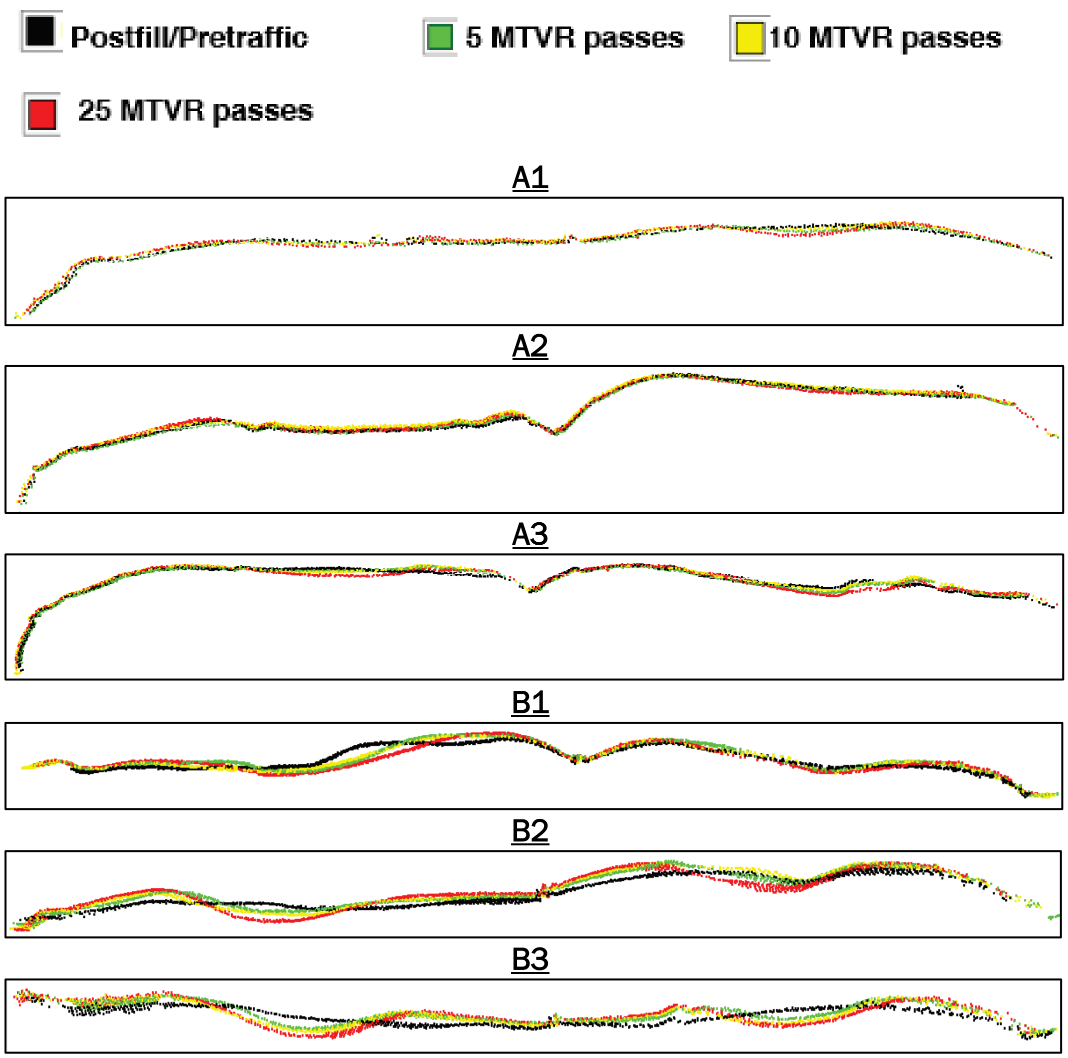


Figure 64 shows the change in rut depth and shape between 50 and 200 MTVR passes at the quarter points of PRBS 1 and PRBS 2. At 50 MTVR passes the rut is almost fully developed, and there is little change in rut shape or depth after 200 MTVR passes. Cross sections *B2* and *B3* show a shift in the rut locations due to the wander of the vehicle path during trafficking.

Figure 64. Cross sections from 50 to 200 MTVR passes.

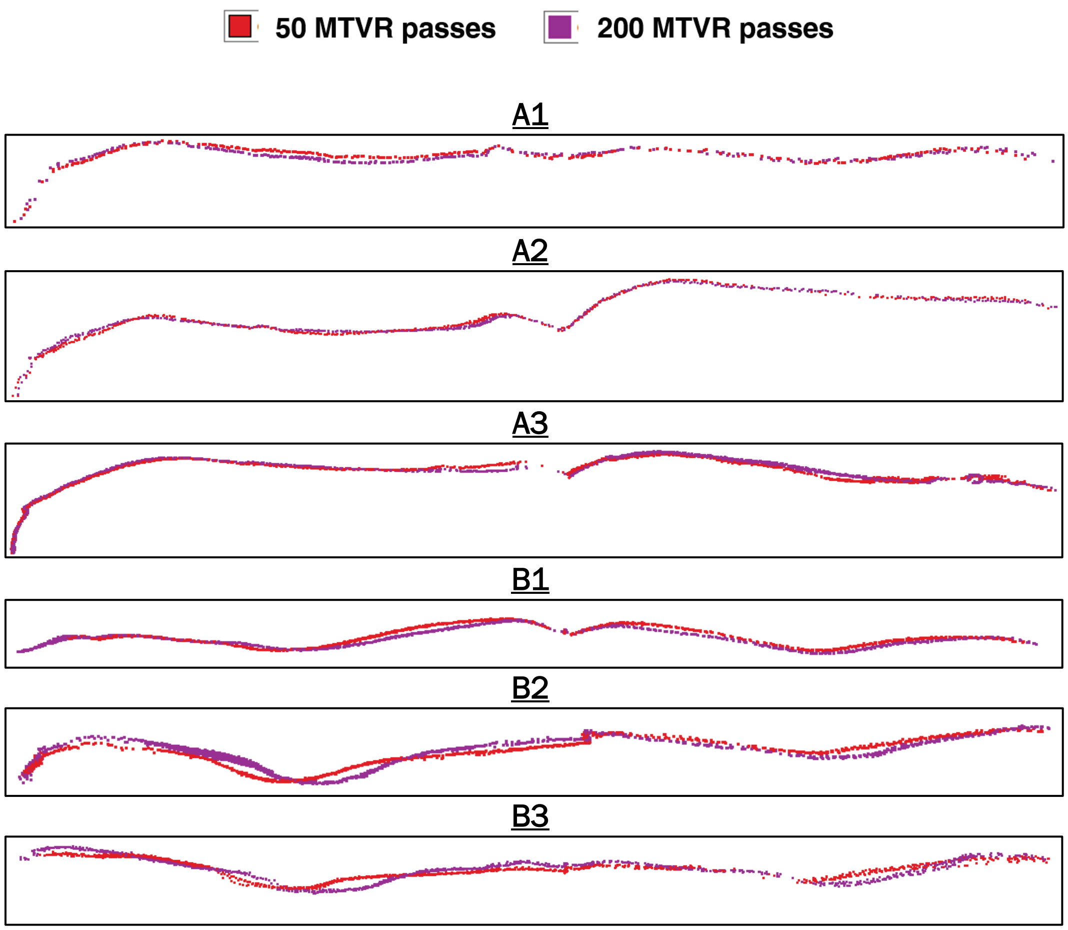


Figure 65 and Figure 66 show the cross sections at the quarter points of PRBS 1 and PRBS 2 after 500 and 1,000 MTVR passes, respectively.

Figure 65. Cross sections at 500 MTVR passes.

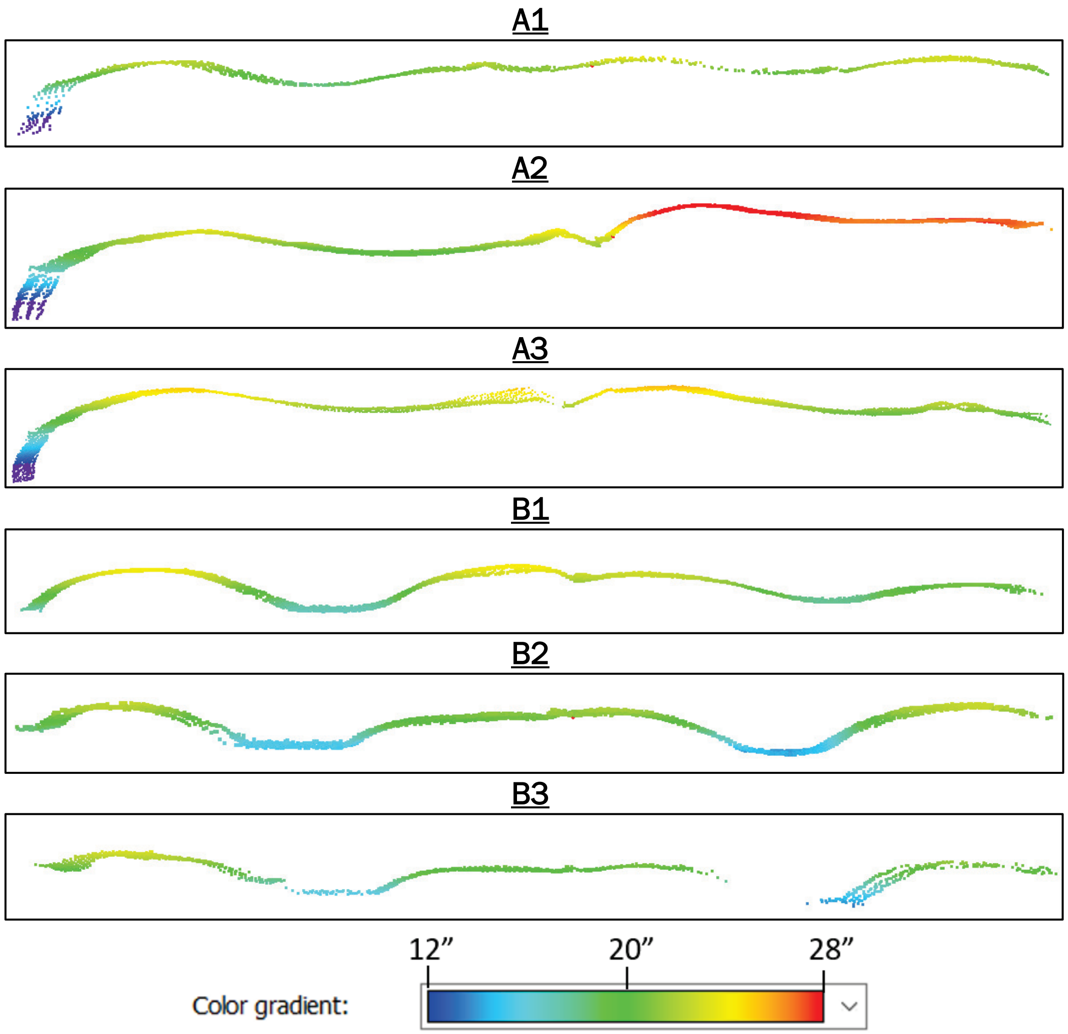


Figure 66. Cross sections at 1,000 MTVR passes.

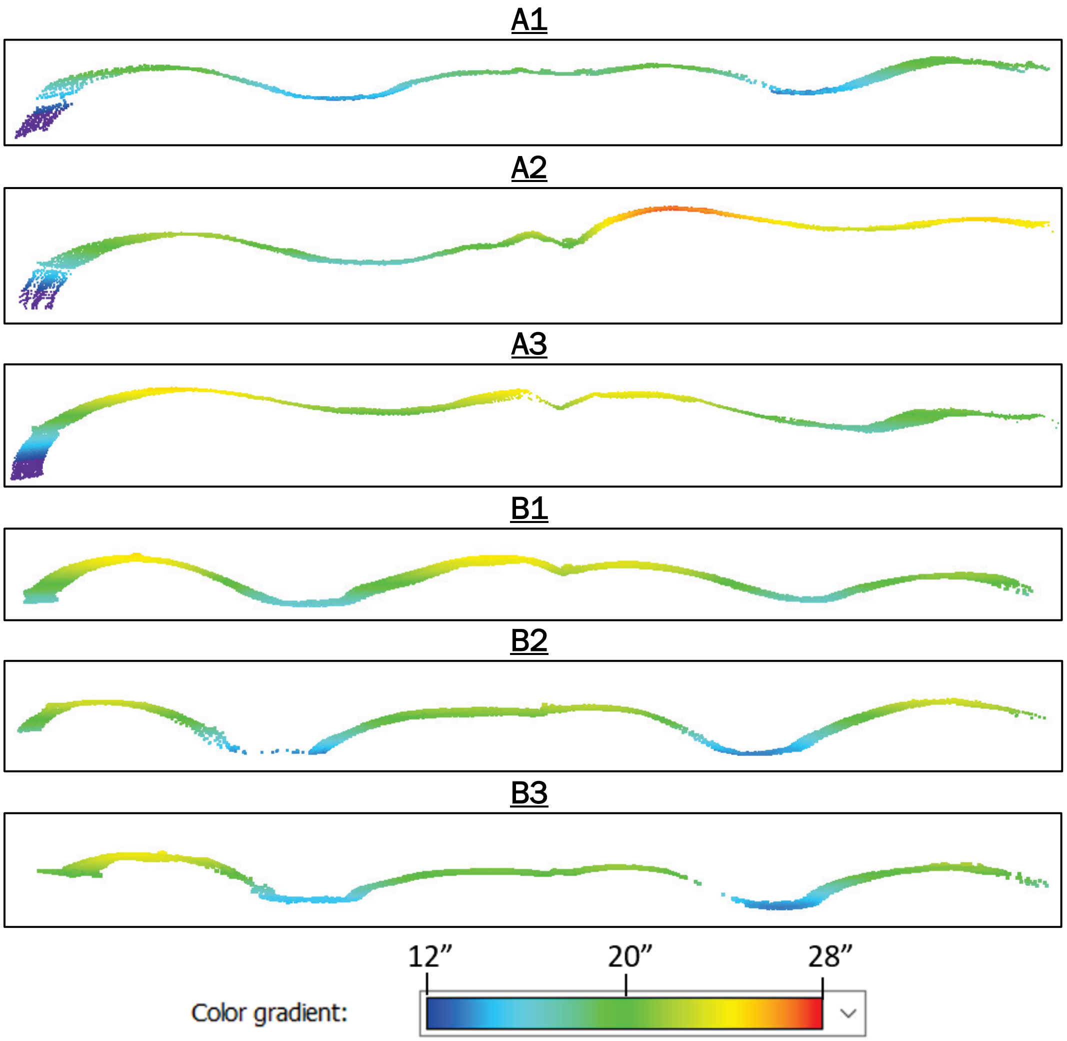


Figure 67 shows the fully developed ruts after 1,000 MTVR and 350 HEMTT passes across each PRBS prototypes. After 350 HEMTT passes, the rut depths and shapes have completely adjusted to accommodate the vehicle's tire shape and wheel loads.

Figure 67. The 1000 MTVR, plus 350 HEMTT passes for PRBS 1 and PRBS 2.

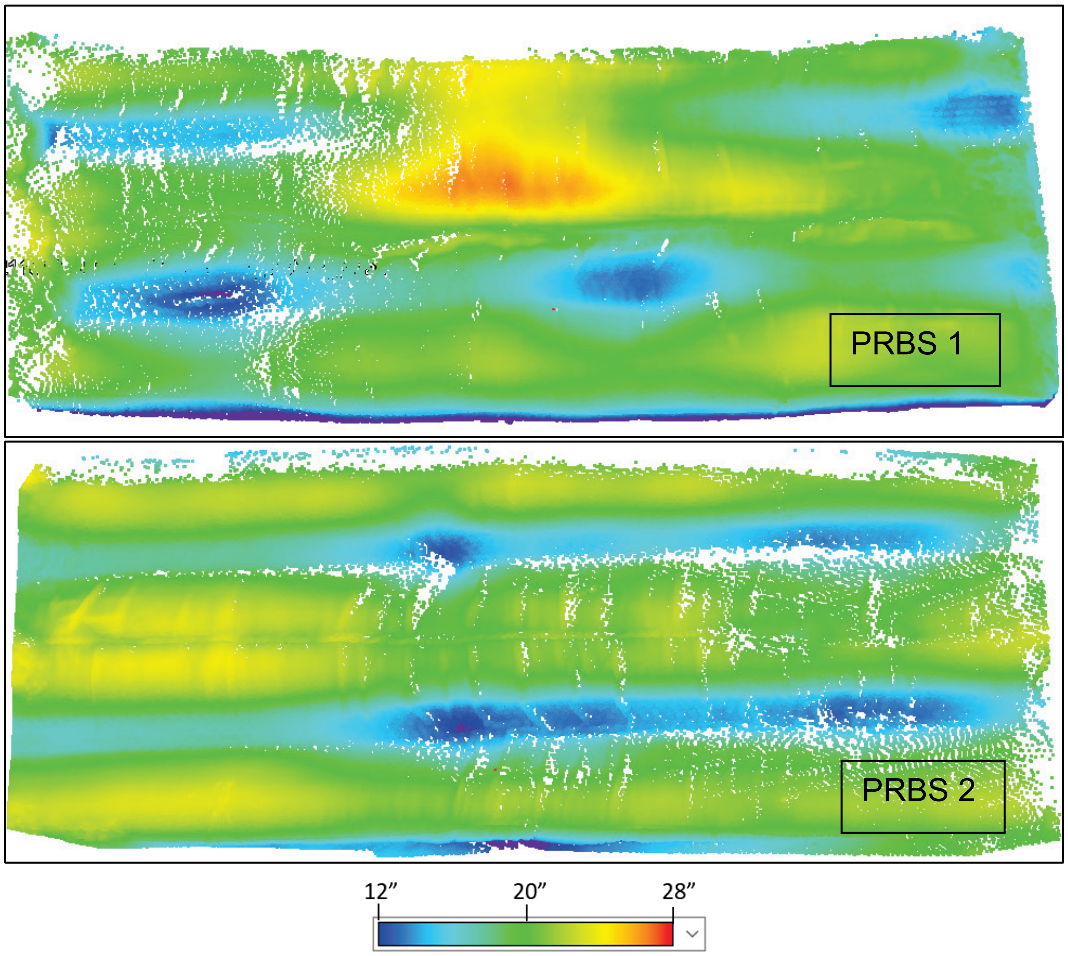


Figure 68 shows the progression of rut depth development from 10 to 350 HEMTT passes at the quarter points of PRBS 1 and PRBS 2. These cross sections show the gradual change in rut shape, depth, and location as HEMTT trafficking progressed. Notice the general change in shape as the rut progresses to match the HEMTT wheel shape.

Figure 68. Cross sections from 10 to 350 HEMTT passes.

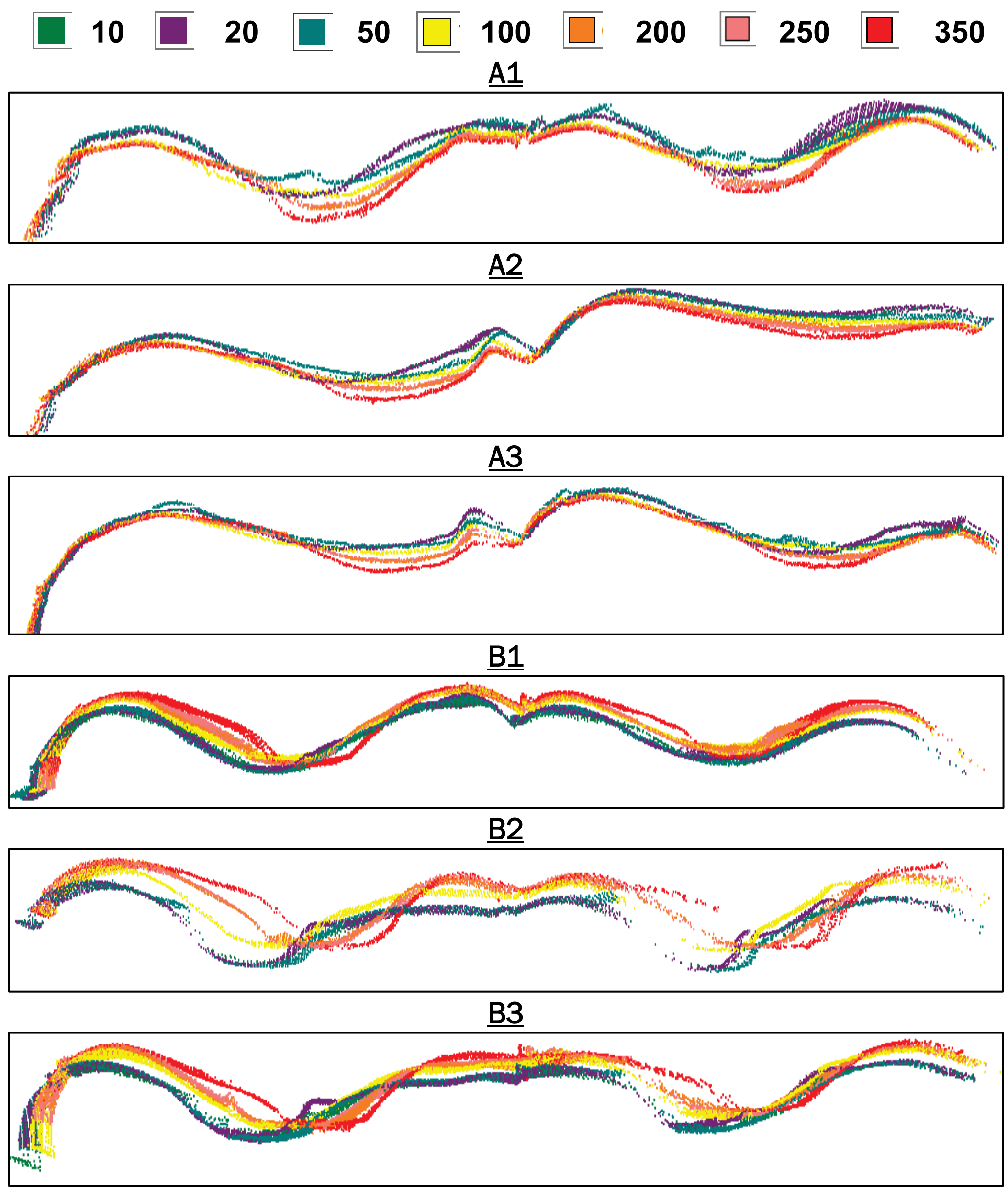


Figure 69 shows the fully developed ruts at the conclusion of the trafficking tests after 1,000 MTVR, 350 HEMTT, and 150 M1A1 passes across both PRBS prototypes. The M1A1 has a wide track footprint and a wider wheelbase than both the MTVR and the HEMTT. This resulted in the flattening out of the PRBS mats as sand was displaced from areas of overfilling and upheaval from the MTVR and the HEMTT passes into the ruts from those vehicles.

Figure 69. The 1,000 MTVR, plus 350 HEMTT, plus 150 M1A1 passes.

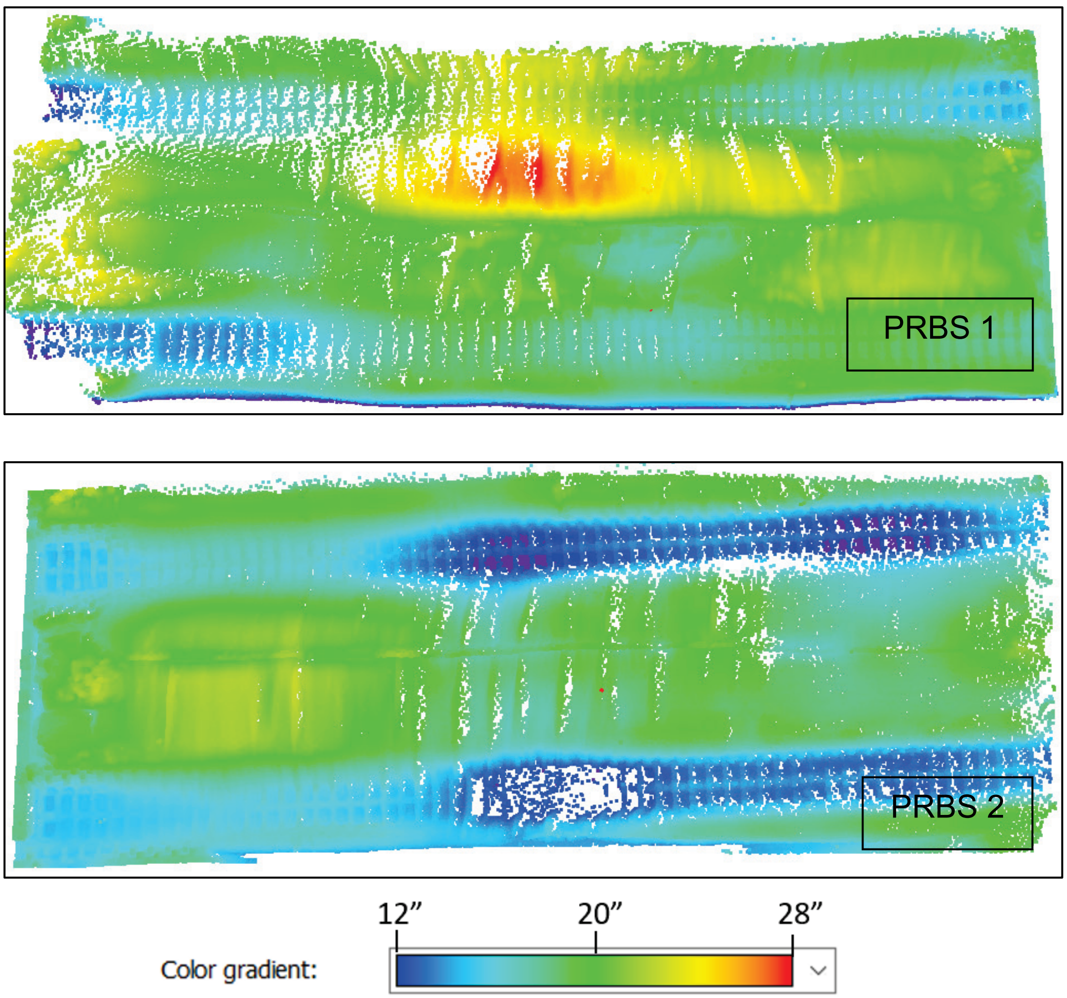
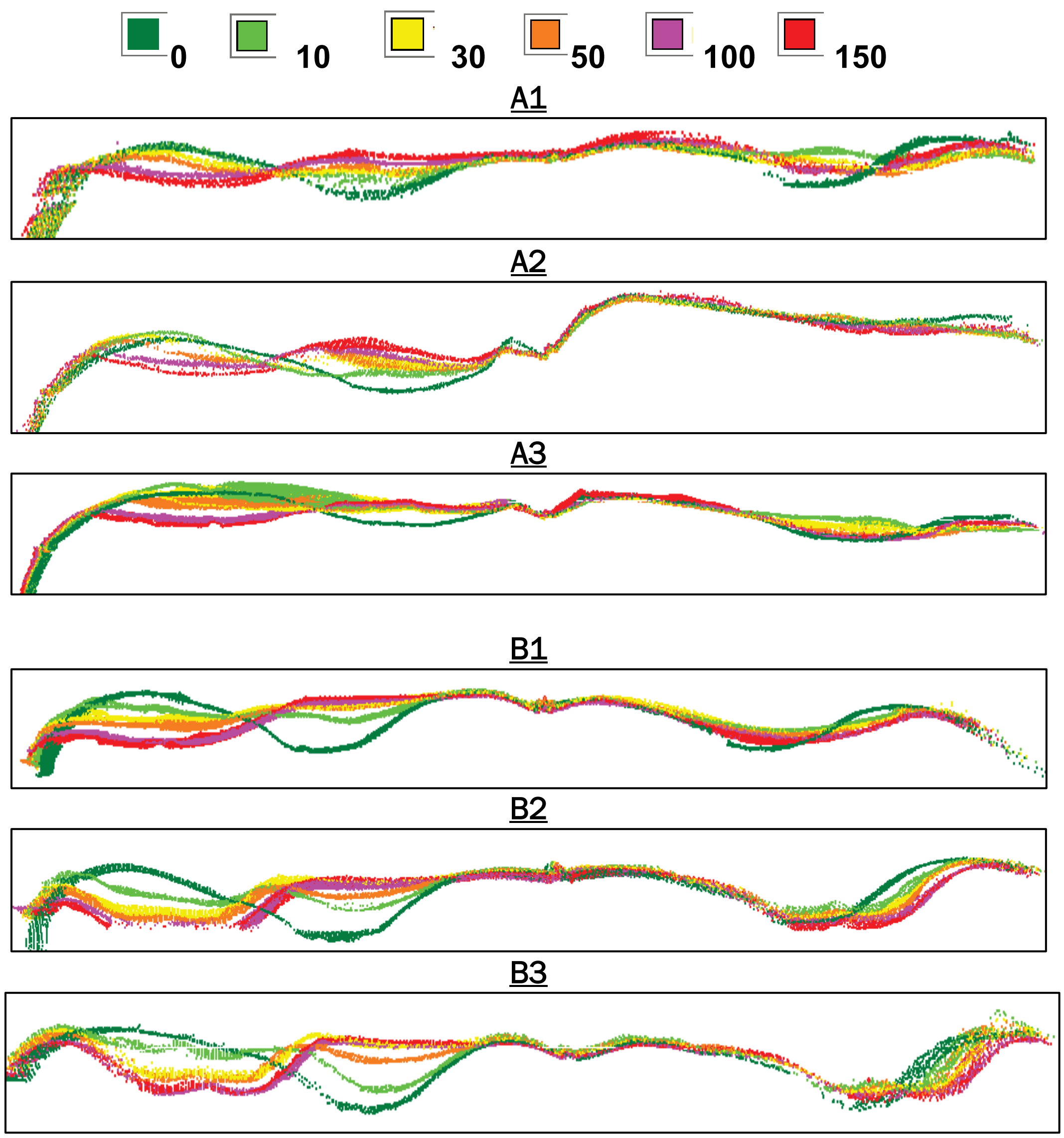


Figure 70 shows the progression of rut depth development from 350 HEMTT passes to 150 M1A1 passes at the quarter points of each PRBS prototypes. Notice as the number of passes increases, the ruts widen and decrease in depth to match the M1A1 track shape as the areas of overfilling and upheaval from MTVR and HEMTT traffic are flattened by the M1A1 traffic. As there is little change from 100 to 150 passes, it appears the ruts were approaching a steady-state condition for M1A1 traffic.

Figure 70. Cross sections at M1A1 passes.



5 Conclusions and Recommendations

5.1 Conclusions

The submersible matting trafficking evaluation reported herein suggested the following conclusions regarding the individual items tested:

- The RGM test item performed poorly. The deployment of the mat was relatively quick, but reliably anchoring the mat in saturated sand proved difficult. The trafficking durability was insufficient.
- The PRBS performed above expectation. The PRBS withstood 1,000 MTVR passes, an additional 350 HEMTT passes, and 150 more passes with a M1A1 Abrams tank while experiencing only minor damage.
- Additional traffic was applied to the PRBS with 26 passes of a tracked excavator and 24 passes of a bulldozer. The tracked vehicles did not have protective padding, and both vehicles caused some minor damage. The tracks on the bulldozer, with protrusions for better traction, caused significant damage including tearing small holes in the geosynthetic material and completely pulling away the wearing surface in some areas.
- The rut formation in the PRBS was significantly deep. However, with a mat filled more evenly and fully, the PRBS offers sufficient confinement to protect against rut formation. Once the ruts reached a critical depth, there was enough confinement to prevent any further deterioration of the PRBS. Furthermore, when heavy vehicles trafficked the same path, the ruts did not get deeper. Rather, the rut profile shifted to match the profile of the new vehicle's tire or tracks.
- Filling the PRBS in a timely manner proved to be more difficult than expected. Further research on the appropriate size and type of dredging system is needed.
- The internal strapping of the PRBS was unable to hold up to the filling pressure of the sand slurry during the deployment process. It is unlikely the current design will be able to hold up in a field deployment.
- The lidar data were comparable to rut depth data measured by a straight edge and a ruler potentially allowing faster surveying between traffic intervals in appropriate conditions.

5.2 Recommendations

The PRBS prototypes proved to be durable and robust in holding up to a wide variety of vehicle traffic in austere conditions. However, it is recommended that there should be a redesign of the internal structure of the PRBS. Rather than having a network of internal straps holding the PRBS to a rough shape, it is thought that a system of several large membranes with continuous seams down the length of the PRBS to provide stronger structure. This design change may also enable easier filling of the mat.

The recommendation is that a more appropriate dredging and pumping method be identified to rapidly and efficiently fill the PRBS. It was identified that the ability to fill the PRBS with native material wherever the system is deployed as a key advantage of the PRBS system. This benefit reduces the transportation logistics burden to only the mat and the pumping equipment eliminating the need to transport the filler material, as well. However, fully achieving this benefit may require a sizeable pumping system to overcome the challenges of dredge pumping a wide range of geotechnical materials.

While the PRBS matting system can support wheeled traffic as well as some tracked vehicle traffic without experiencing significant damage, the recommendation is that the quantity of tracked vehicles be limited to only that necessary. For heavy, aggressive-tracked vehicles, the mat could be compromised in as few as 30 passes. If tracked vehicle traffic is necessary, it is further recommended that wheeled vehicle traffic proceed before the tracked vehicle traffic to optimize the service life of the matting system.

References

ASTM (American Society for Testing and Materials International). 1993. *Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*. ASTM D4253-00. West Conshohocken, PA: ASTM International.

ASTM (American Society for Testing and Materials International). 2017. *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*. ASTM D2487-17e1. West Conshohocken, PA: ASTM International.

Floyd, W. C. 2017. *Evaluation of the WavTrac Expeditionary Mobility Matting System*. ERDC/GSL TR-17-4. Vicksburg, MS: US Army Engineer Research and Development Center, Geotechnical and Structures Laboratory.

Floyd, W. C. 2018. *Evaluation of the WavTrac Expeditionary Mobility Matting System: Supplementary Testing*. ERDC/GSL TR-18-18. Vicksburg, MS: US Army Engineer Research and Development Center, Geotechnical and Structures Laboratory.

Hull, J. 2016. *Bragg Engineers Test Airfield Repair Innovations at Sicily Drop Zone*. https://www.army.mil/article/164559/bragg_engineers_test_airfield_repair_innovations_at_sicily_drop_zone.

Rushing, T. W., and J. F. Rowland. 2012. *Comparison of Original MO-Mat and Prototype Replicas for Expeditionary Roads*. ERDC/GSL TR-12-18. Vicksburg, MS: US Army Engineer Research and Development Center, Geotechnical and Structures Laboratory.

Rushing, T. S., J. S. Tingle, and Q. S. Mason. 2007. *Evaluation of Expeditionary Mat Surfacings for Beach Roads*. ERDC/GSL TR-07-1. Vicksburg, MS: US Army Engineer Research and Development Center, Geotechnical and Structures Laboratory.

Santoni, R. L. 2003. *Enhanced Coastal Trafficability: Road Construction Over Sandy Soils*. ERDC/GSL TR-03-7. Vicksburg, MS: US Army Engineer Research and Development Center, Geotechnical and Structures Laboratory.

Santoni, R. L., C. J. Smith, J. S. Tingle, and S. L. Webster. 2001. *Expedient Road Construction Over Soft Soils*. ERDC/GSL TR-01-7. Vicksburg, MS: US Army Engineer Research and Development Center, Geotechnical and Structures Laboratory.

UASCE (United States Army Corps of Engineers). *Mat Sinking Unit*. n.d. Accessed: 23 June 2019. https://www.mvk.usace.army.mil/Missions/Operations-Division/River-Operations/Mat-Sinking-unit/.

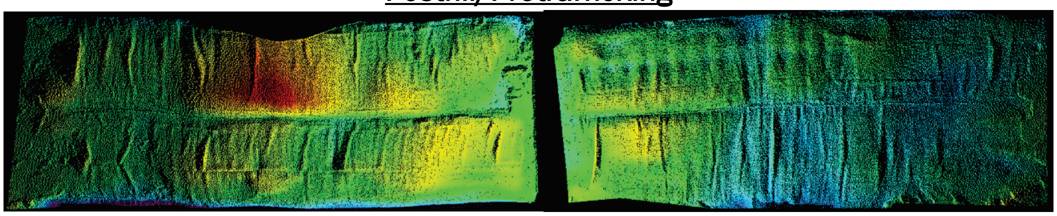
Webster, S. L., and J. S. Tingle. 1998. *Expedient Road Construction over Sands Using Lightweight Mats*. WES/GL TR-98-10. Vicksburg, MS: US Army Engineer Waterways Experiment Station, Geotechnical Laboratory.

Appendix A: Supplemental Lidar Data

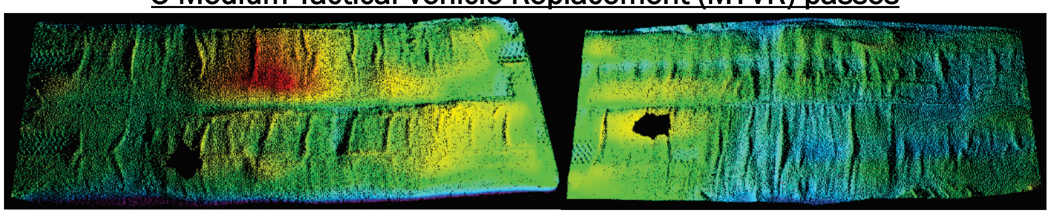
Figure A-1 shows lidar scans from testing that are not included in the body of the report.

Figure A-1. Lidar scans of each PYRACELL Road Building System (PRBS) at every traffic interval.

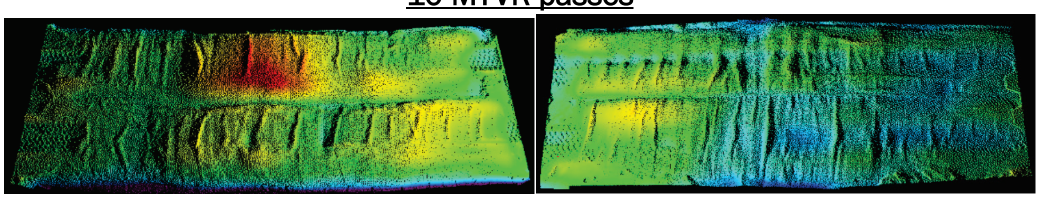
Postfill/Pretrafficking



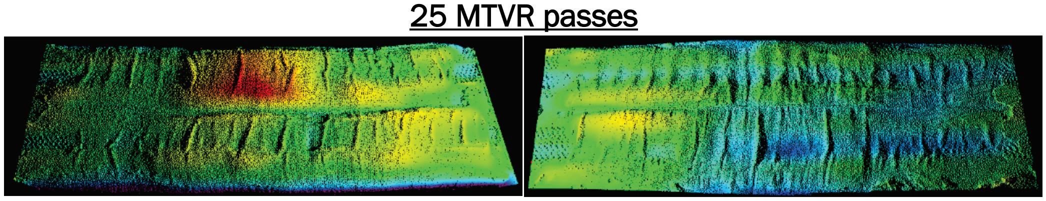
5 Medium Tactical Vehicle Replacement (MTVR) passes



10 MTVR passes



25 MTVR passes



50 MTVR passes

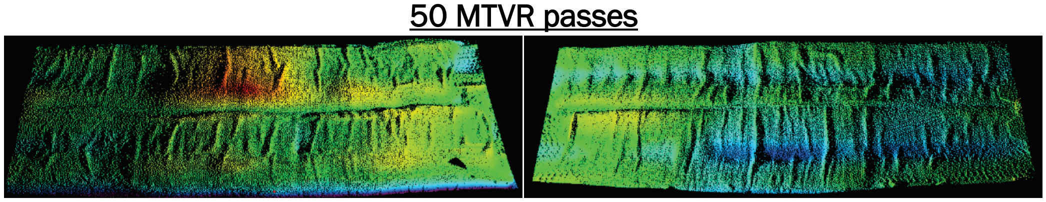
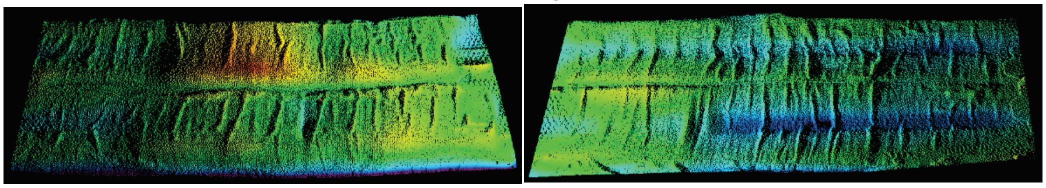
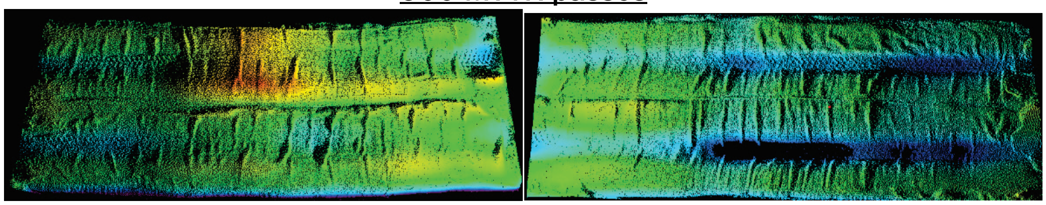


Figure A-1 (cont.). Lidar scans of each PYRACELL Road Building System (PRBS) at every traffic interval.

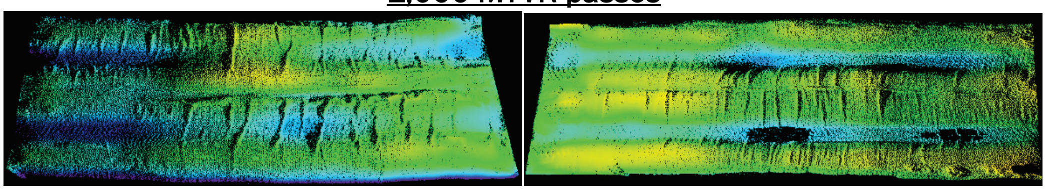
200 MTVR passes



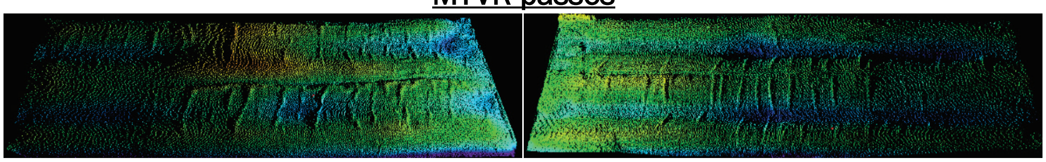
500 MTVR passes



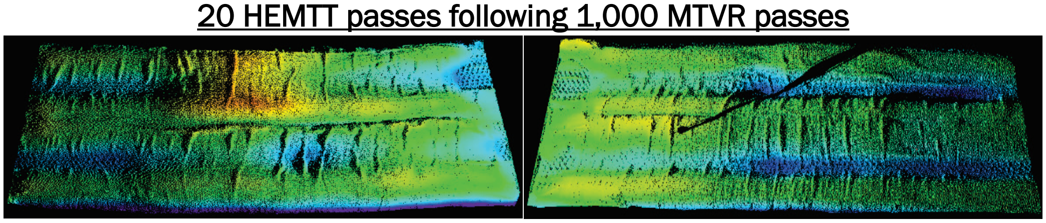
1,000 MTVR passes



10 Heavy Expanded Mobility Tactical Truck (HEMTT) passes following 1,000 MTVR passes



20 HEMTT passes following 1,000 MTVR passes



50 HEMTT passes following 1,000 MTVR passes

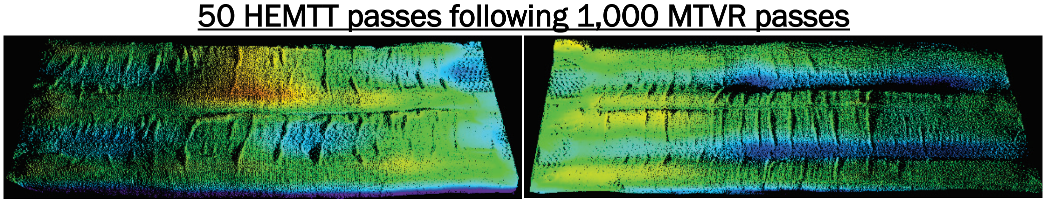
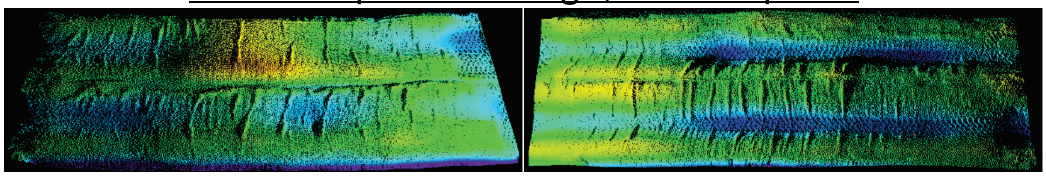
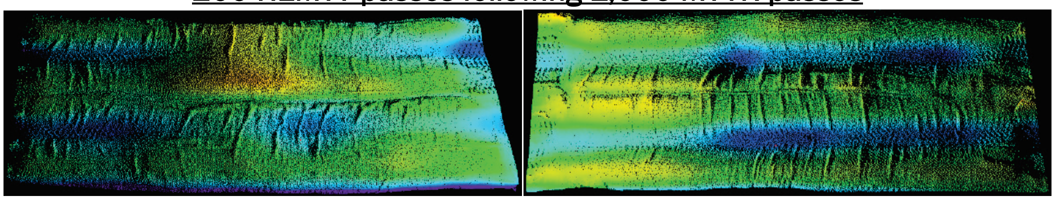


Figure A-1 (cont.). Lidar scans of each PYRACELL Road Building System (PRBS) at every traffic interval.

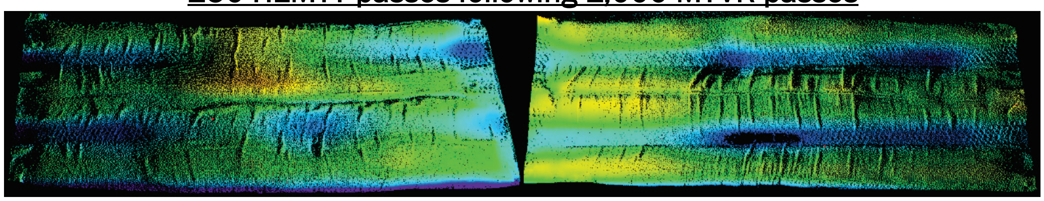
100 HEMTT passes following 1,000 MTVR passes



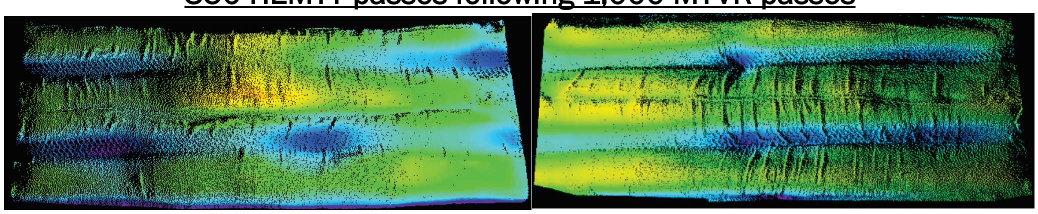
200 HEMTT passes following 1,000 MTVR passes



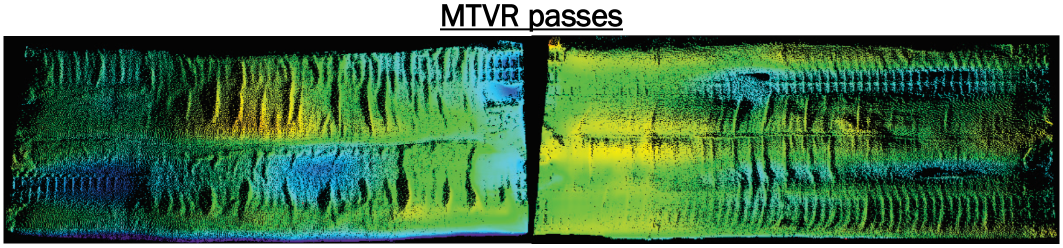
250 HEMTT passes following 1,000 MTVR passes



350 HEMTT passes following 1,000 MTVR passes



10 M1A1 Abrams tank (M1A1) passes following 350 HEMTT and 1,000 MTVR passes



30 M1A1 passes following 350 HEMTT and 1,000 MTVR passes

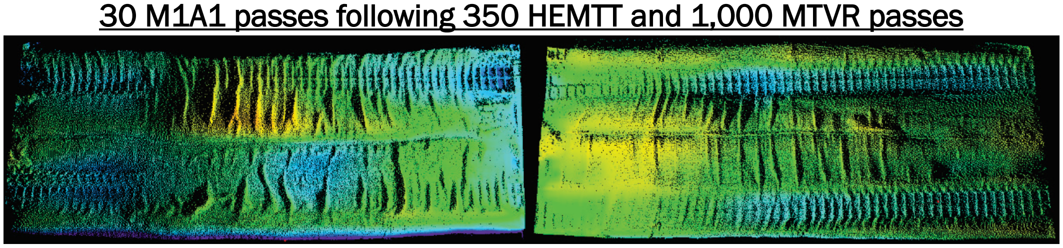
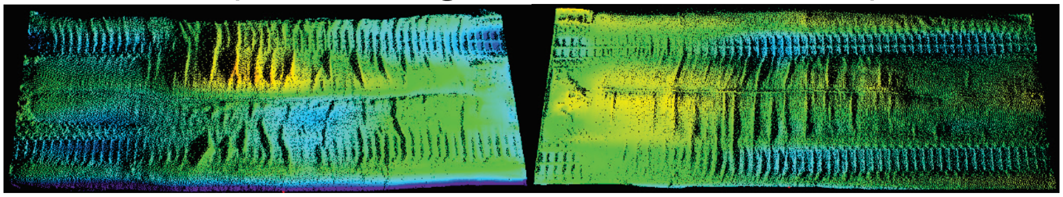
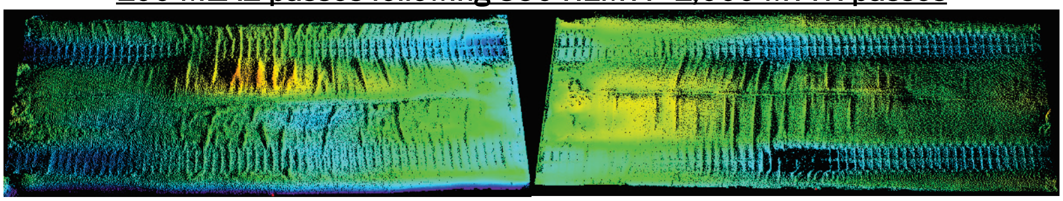


Figure A-1 (cont.). Lidar scans of each PYRACELL Road Building System (PRBS) at every traffic interval.

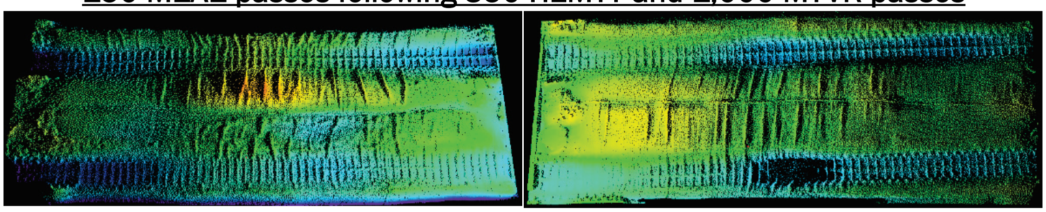
50 M1A1 passes following 350 HEMTT and 1,000 MTVR passes



100 M1A1 passes following 350 HEMTT 1,000 MTVR passes



150 M1A1 passes following 350 HEMTT and 1,000 MTVR passes



Appendix B: Supplemental Rut Depth Data

Figure B-1 and Figure B-2 present the non-normalized average rut depth data for the Heavy Expanded Mobility Tactical Truck (HEMTT) and M1A1 Abrams tank traffic intervals.

Figure B-1. Non-normalized average rut depth data for Heavy Expanded Mobility Tactical Truck (HEMTT) traffic.

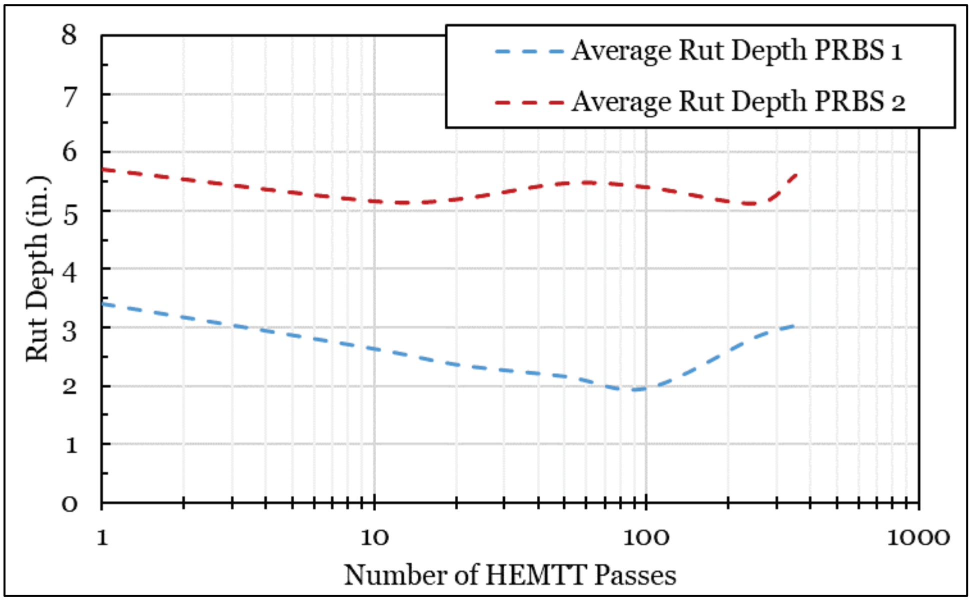
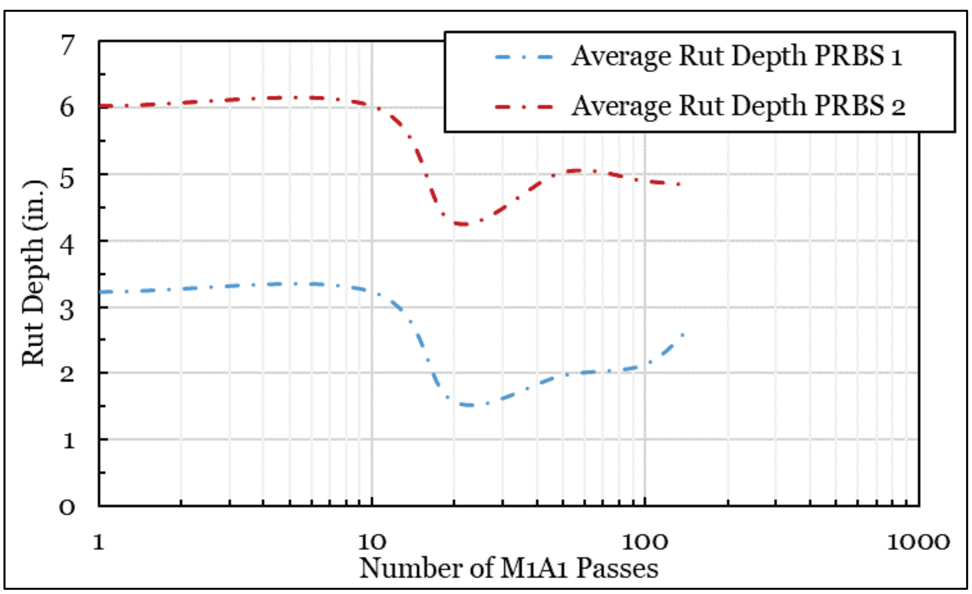


Figure B-2. Non-normalized average rut depth data for M1A1 traffic.



Appendix C: Supplemental Earth Pressure Cell (EPC) Data

Figure C-1 through Figure C-3 present select raw EPC data from vehicle traffic on each of the three matting systems in this report. The sample reference number plotted on the *x*-axis of each figure is essentially time. The data are a running counter of each time data are collected, which occurred at a frequency of 200 Hz.

Figure C-1. Sample raw earth pressure cell (EPC) data for Rebar-Geogrid Mat (RGM).

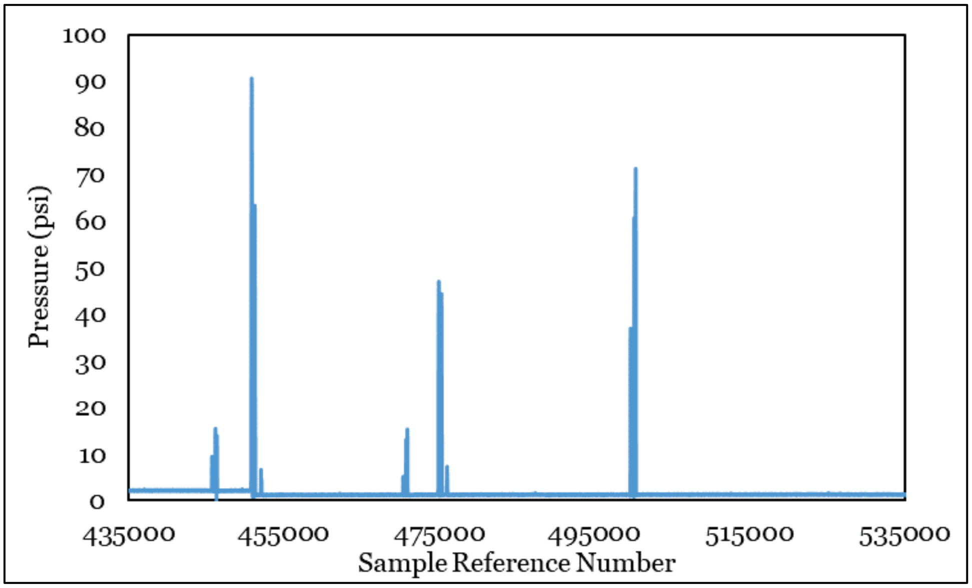


Figure C-2. Sample raw EPC data for PRBS 1.

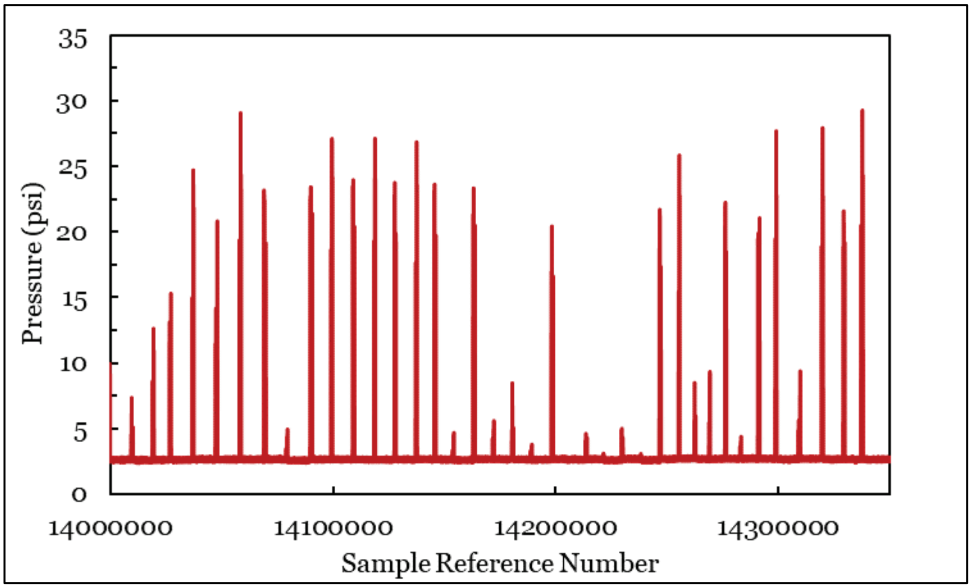
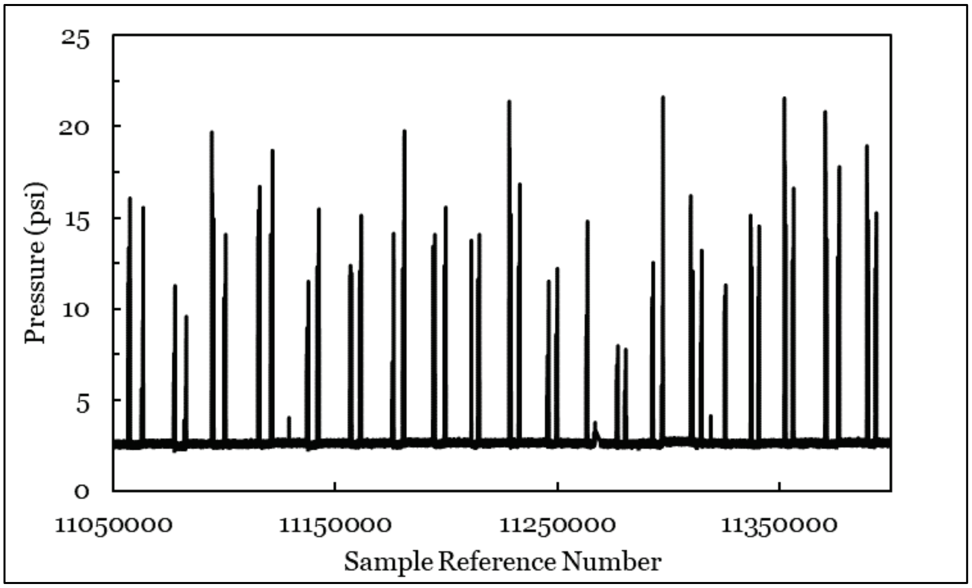


Figure C-3. Sample raw EPC data for PRBS 2.



Abbreviations

AM2	Airfield Matting 2
AOI	Area of interest
ASTM	American Society for Testing and Materials
CF	Causeway Ferry
ELCAS	Elevated Causeway system
EPC	Earth pressure cell
ERDC	US Army Engineer Research and Development Center
FMTV	Family of Medium Tactical Vehicles
FRF	Field Research Facility
GVTSTF	Ground Vehicle Terrain Surfacing Test Facility
HEMTT	Heavy Expanded Mobility Tactical Truck
HPU	Hydraulic power unit
INLS	Improved Navy Lighterage System
JDDE	Joint Deployment Distribution Enterprise
JLOTS	Joint Logistics Over-the-Shore
JLTV	Joint Light Tactical Vehicle
LCAC	Landing Craft Air Cushioned
LCM	Landing Craft Mechanized
LCU	Landing Craft Utility
LMSR	Large Medium-Speed RO/RO
LOTS	Logistics over-the-Shore
LSM	Landing Ship Medium
LSV	Logistics Support Vessel
LVS	Logistics Vehicle System

LVSR	Logistic Vehicle System Replacement
MLC	Military Load Classification
MRS-D	Mini Robotic Submersible–Dredge
MSV-H	Maneuver Support Vessel (Heavy)
MSV-L	Maneuver Support Vessel (Light)
MTVR	Medium Tactical Vehicle Replacement
PLS	Palletized Load System
PRBS	PYRACELL Road Building System
RGM	Rebar-Geogrid Mat
RO/RO	Roll-On/Roll-Off
SUBMAT	Submersible matting system
USMC	United States Marine Corps
USTRANSCOM	US Transportation Command

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Benjamin A. Rutherford, Andrew T. Collins, Zachary J. Tyler, Patrick M. Border, Stanley J. Boc, Jr., and Timothy W. Rushing

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Engineer Research and Development Center (ERDC)
Geotechnical Structures Laboratory (GSL)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

US Army Engineer Research and Development Center (ERDC)
Coastal and Hydraulics Laboratory (CHL)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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14. ABSTRACT
This report describes the full-scale evaluation of prototype submersible matting systems (SUBMAT) at a test site at the US Army Engineer Research and Development Center's Vicksburg, Mississippi, site. The SUBMAT prototypes were designed to bridge the gap between high and low tide at a beach interface to enable 24-hour operation at an expeditionary watercraft landing site. This phase of the SUBMAT prototype development was intended to determine prototype system durability by applying military vehicle loads representing a combat brigade insertion across a littoral zone. The two mat systems evaluated in this study were the PYRACELL Road Building System (PRBS) and a basaltic rebar mat system. The results of the study showed that the PRBS system was able to sustain 1,000 Medium Tactical Vehicle Replacement, 350 Heavy Expanded Mobility Tactical Truck, and over 150 M1A1 main battle tank passes without significant damage. The basaltic rebar mat failed early in the test and was removed from further consideration for the SUBMAT application. Observations and lessons learned from this phase of the prototype PRBS development will be used to improve the PRBS design and modify its installation procedures for improved efficiency.

15. SUBJECT TERMS
Amphibious operations; Beaches; Landing mats--Evaluation; Landing operations; Trafficability

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19a. NAME OF RESPONSIBLE PERSON	19b. TELEPHONE NUMBER (include area code)
Benjamin A. Rutherford	601-634-4225