REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*

2. REPORT TYPE
Journal Article Reprint

3. DATES COVERED *(From - To)*
2003

4. TITLE AND SUBTITLE
Rapid Forward Deployment Made Easier with Composite Airfield Matting

5a. CONTRACT NUMBER
F08637-98-C-6001

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
62102F

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
4915D11A

6. AUTHOR(S)
Dean Foster and Mark Anderson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory
Airbase Technologies Division
139 Barnes Drive, Suite 2
Tyndall AFB FL 32403-5323

8. PERFORMING ORGANIZATION REPORT NUMBER
AFRL-ML-TY-TP-2003-4534

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement "A". Distribution Unlimited

13. SUPPLEMENTARY NOTES
Published in the AMPTIAC Quarterly 7(1) 2003 pp 17-22

14. ABSTRACT
To achieve the Air Force's vision of Global Vigilance, Reach, and Power, deployment and sustainment of forces are extremely important. Being able to respond quickly and decisively anywhere in the work relies on a myriad of combat support activities that occur on the ground. Many aircraft sorties are typically required to bring in equipment, supplies, and personnel when the Air Force deploys to a remote location. As the operation or conflict continues and intensifies, available parking space at these remote locations is quickly exhausted. Therefore, expanding aircraft parking aprons to increase the Maximum on Ground (MOG) requirements at airfields supporting contingency operations is critical. ... Consequently, the type of airfield and the mission requirements dictate the MOG needs, which in turn determine the amount of parking area expansion needed. These factors determine the manpower and time required for installation of the mat system.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	SAR	6	Gregg Hill
					19b. TELEPHONE NUMBER *(Include area code)* 850-283-3745

Rapid Forward Deployment Made Easier with Composite Airfield Matting

Dean Foster
Materials and Manufacturing Directorate
Air Force Research Laboratory
Wright-Patterson AFB, OH

Mark Anderson, Ph.D, P.E.
Materials and Manufacturing Directorate
Air Force Research Laboratory
Tyndall AFB, FL

BACKGROUND: MISSION REQUIREMENTS

To achieve the Air Force's vision of Global Vigilance, Reach, and Power, deployment and sustainment of forces are extremely important. Being able to respond quickly and decisively anywhere in the world relies on a myriad of combat support activities that occur on the ground. Many aircraft sorties are typically required to bring in equipment, supplies, and personnel when the Air Force deploys to a remote location. As the operation or conflict continues and intensifies, available parking space at these remote locations is quickly exhausted. Therefore, expanding aircraft parking aprons to increase the Maximum on Ground (MOG) requirements at airfields supporting contingency operations is critical. Lightweight airfield matting, rapid soil stabilization, or a combination of both will significantly increase the Air Force's contingency operation capability by providing the means to rapidly expand aircraft parking aprons and increase MOG at all types of airfields supporting contingency operations.

One major consideration for assessing airfield capabilities is the number of aircraft that can be parked at the airfield, i.e., MOG. The two categories of MOG are based on parking requirements and working requirements. The parking MOG refers to the number of aircraft that can be parked at an airfield and depends upon the specific mission. Bare base planning factors require a specific area for each type of aircraft. For example, a squadron of fighter aircraft requires more than 200,000 square feet. If these requirements are not met, there is a high probability of compromising the mission. The working MOG requirement is dependent on the available parking space and the size and type of crews and equipment available to service the aircraft. Working MOG has a significant impact on the overall speed in which a bare base can be established. The rate at which materials and equipment can be airlifted into a site is directly related to the working MOG.

The type of airfield can compound the problem of providing MOG. Airfields are typically separated into four categories: expedient airfields, temporary airfields, semi-permanent airfields, and main operating bases or commercial airfields. A wide variety of airfields are used during contingency operations and often the use of non-Air Force airfields in austere or underdeveloped locations is required. These optimally positioned airfields are selected primarily based on proximity to the theater of operations and not necessarily with regard to current airfield conditions. Therefore, these airfields often require improvements or expansion to meet mission requirements. See Table 1 for a comparison of airfield classifications.

Consequently, the type of airfield and the mission requirements dictate the MOG needs, which in turn determine the amount of parking area expansion needed. These factors determine the manpower and time required for installation of the mat system.

EXISTING SYSTEM: AM-2 AIRFIELD MAT

AM-2, the current airfield mat system, has been used by the Air Force for over 40 years. At one time AM-2 was the primary tool for rapid runway crater repairs but has now been relegated to repair and expansion of taxiways and parking aprons. It is a 1-1/2 inch thick aluminum panel fabricated from an extruded main section and extruded end connectors. (See Figures 1 and 2.) The end connectors are welded to each end of the main panel section, prongs up at one end and prongs down at the other end, forming a complete panel. The sides of the panels are manufactured to interlock in a rotating motion, as seen in Figure 3. The key features of AM-2 are summarized in Table 2.[1]

A simple rectangular area large enough to support a fighter squadron, requiring only matting, key locks, and edge clamps, requires 480 pallets of matting. This encompasses a volume of 39,066 cubic feet weighing a total of 1,274,316

Table 1. Types of Airfields.

Airfield Class (Subclass)	Typical Location	Runway Surface	Taxiways/Parking Aprons	Duration of Use	Aircraft Accommodated
Expedient Airfield (Small Austere Airfields)	Forward Tactical Areas	Soil	If Available at All, They Are Soil Surfaced	~4 Weeks or Less	C-17, C-130
Expedient Airfield (Support Area Airfields)	Forward Tactical Areas	Unpaved, Perhaps With Membrane or Mat Surfacing	If Available at All, They Are Soil Surfaced	1 - 6 Months	C-141, C-130, C-17, Various Tactical Aircraft
Temporary Airfields	Forward or Rear Areas	Asphalt or Concrete, Perhaps in Need of Improvement	Some Available, Soil Surfaced	6 - 24 Months	Most Transport and Tactical Aircraft
Semi-Permanent Airfields	Rear Areas Only	Concrete or Asphalt; Maintained	Paved and Available, but not enough for Contingency Ops	More than 2 Years	Entire Fleet of Aircraft Available for the Mission
Main Operating Bases (also Commercial Airports)	Rear Areas Only	Concrete or Asphalt; Well Maintained	Paved and Plenty Available, but Perhaps not Enough for Complete Ops	More than 2 Years	Entire Fleet of Aircraft Available for the Mission

Table 2. Features of the AM-2 Matting System.

- Panels come in two sizes, a full-length 2′ x 12′ panel and a 2′ x 6′ half-length panel; all are 1 1/2″ thick
- Panels painted Marine Corps Green; top surface is coated with nonskid of the same color
- Panels weigh 6-lbs/ft^2
- Panels cost ~ \$18/ft^2
- Several types of key locks, connector bars, locking bars, and associated hardware are needed for full assembly
- Installation requires at least a 16-person crew consisting of a supervisor, alignment leader, 2 prybar handlers, and 6, 2-person mat installation teams.
- Panels are laid in a brick pattern, building both widthwise and lengthwise away from the starting point.
- Key-locks are installed every 100′ in the longitudinal direction to facilitate the removal of panels for repair of matting or subgrade
- Ramps are used to transition from the subgrade surface to the mat
- Edges are anchored into the ground to prevent the mat from sliding and buckling.

pounds and would fill up 48 C-130 transport aircraft.[1] One crew working 12-hour shifts takes 5 days to install it, and that does not account for assembly problems due to alignment shifts, dirt, sand, and debris inside the panel connectors (AM-2 is made to fit loosely together). Another concern is damage to the panel from shipping. As can be seen in Figure 1, the end and edges are complex shapes. If damaged, the panels are rendered un-usable, thus requiring more time and material to complete the surfacing of the project area.

The AM-2 connection system between mats is also complicated, requires many additional parts, and does not allow for individual panel removal for repair or replacement. Its joint also acts as a hinge, flexing in- and out-of-plane, and does not transfer load across panels. Consequently, this "pumping" action causes subgrade repairs to be a common maintenance problem.

AM-2 matting, although robust and multifaceted, is a very heavy, complicated, time consuming, and difficult to maintain system to provide expansion of taxiways and parking areas. Not only is it cumbersome to transport, but it also requires numerous pieces of support and maintenance equipment, which reduce its ability to respond quickly and decisively anywhere in the world. The Air Force needs the capability to expand aircraft parking aprons, connecting taxiways, and maintenance areas rapidly. This could be a significant factor in the Air Force's ability to conduct contingency operations from bare bases or austere airfields.

The Department of Defense estimates that there are more than 1,200 airfields worldwide that have potential use during contingency operations. The state of these airfields ranges from extremely austere dirt strips to commercial airports and fixed military installations. Many of these airfields do not have adequate aircraft parking aprons to support large contingency operations. Compound this problem with the unknown soil types at these potential sites and the current system for providing airfield expansion to meet the vision of the Air Force is rendered obsolete.

PROPOSED SYSTEM: COMPOSITE MATERIALS

Enter the new age of materials having strengths up to ten times greater than conventional materials with unit weights less than half and we're talking about composite materials. Due to advances in manufacturing technologies, composite materials are seeing expanded use in a wide range of applications, from military and aerospace, to sporting goods. Due to these unique qualities, a project has been undertaken by the Deployed Base

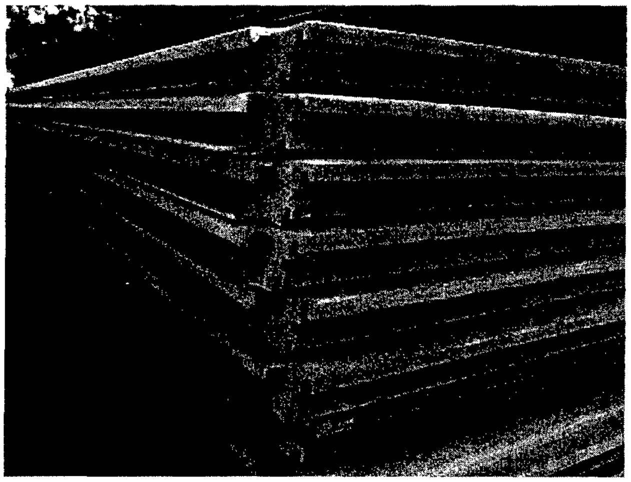


Figure 1. AM-2 Matting Stacked for Shipment.

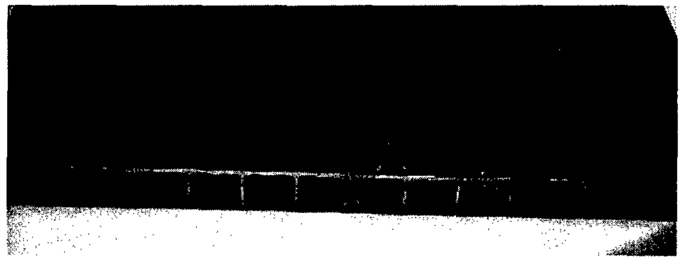


Figure 2. Extruded AM-2 Panels' Cores are Filled for Added Stiffness.

Figure 3. Deploying the AM-2 Matting Requires a 16-Person Team.

System Branch of the Air Force Research Laboratory (AFRL/MLQD) to ascertain the feasibility of a composite mat that will meet the Air Force's future requirements. (Design goals for the composite matting system are outlined in Table 3.) AFRL/MLQD is working with two contractors, Ebert Composite Corporation of Chula Vista, California and Webcore Technologies Incorporated of Dayton, Ohio, to develop the composite matting to replace the current AM-2.

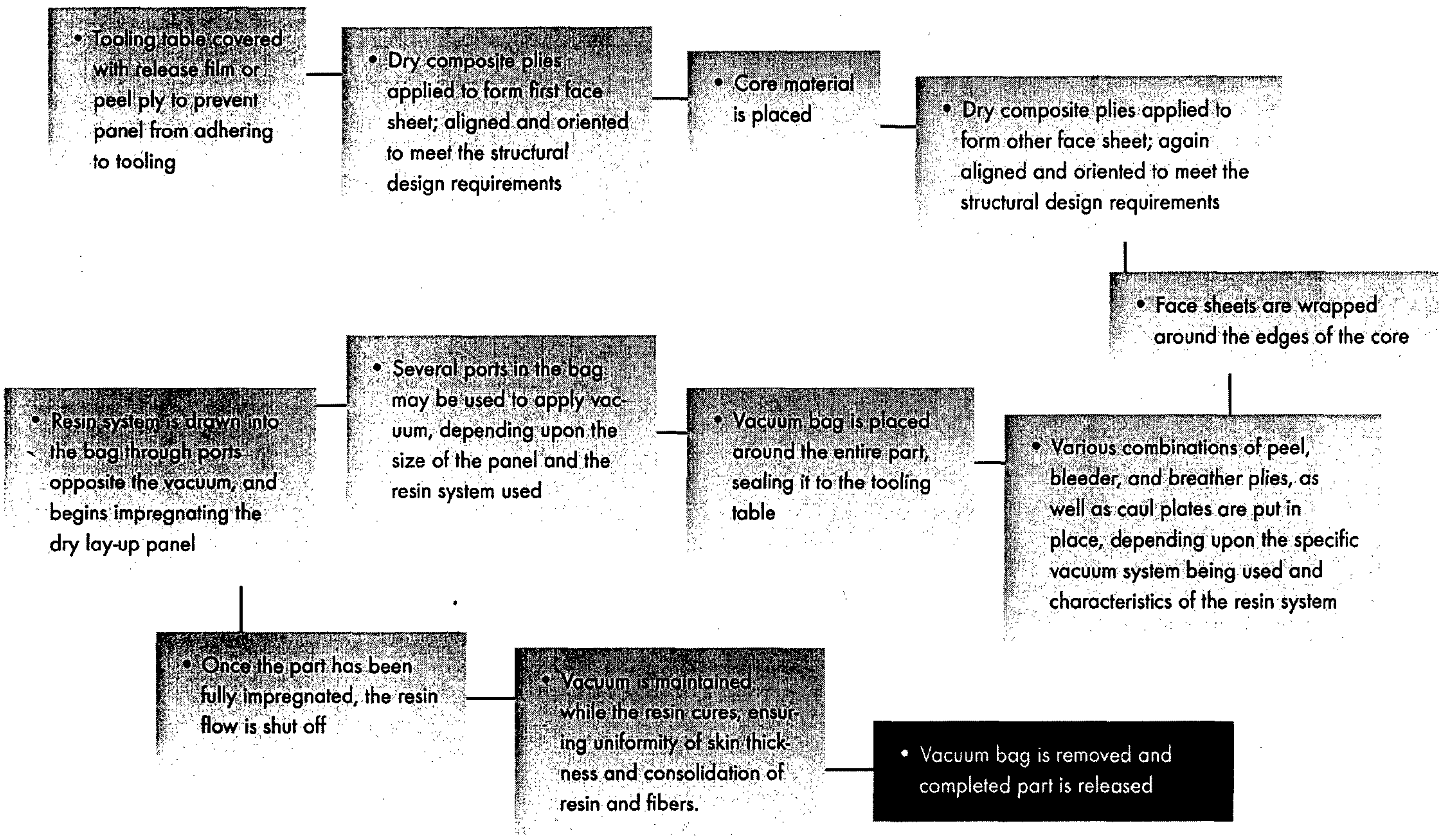
Material choices have centered on a glass fiber in a vinyl-ester matrix. Popular forms of glass fibers range from unidirectional roving to woven fabrics both in prepreg and dry states, depending on the manufacturing method used to produce the matting. A prepreg has glass fibers impregnated with resin, creating a pliable, tacky tow or fabric. It is stored below the curing temperature of the matrix and is easily formed into the desired shape or placed in the designed direction. If the fibers are bundled together in a tow or woven in a fabric with no resin, but ready for the matrix to be applied either through a resin bath process or through a resin transfer molding (RTM) process, then the material is supplied in a dry state.

The vinyl ester resin offers good corrosion resistance and excellent mechanical properties at elevated temperatures. This is because reaction sites of the vinyl ester are at the ends of its

Table 3. Goals for Composite Airfield Matting System.

- 3-lbs/ft^2
- 1 1/2" thick panels
- Cost equal or less than AM-2
- Installation rate of 800 ft^2/labor-hour
- Initial panel dimensions nominally 4' x 8', but shall be optimized later
- Connection systems shall be rugged but simple for:
  - efficient installation and breakdown
  - rapid replacement of damaged panels
  - reuse of mats and connection accessories at other deployment locations
- Capable of handling loads from present and near-future cargo and fighter aircraft operations on a low strength subgrade
- Capable of withstanding shear stress from braking and turning actions of aircraft traveling at taxiing speeds
- Performance in all weather conditions and temperatures from -25°F to 125°F
- Capability of being cleared of snow and dirt using standard airfield plows, vacuum sweepers and towed sweepers
- Resistant to ultraviolet degradation
- Ability to be anchored to restrain movement under normal operating conditions including uplift forces caused from winds or jet and propeller blast from aircraft
- Do not exceed current AM-2 transportation footprint aboard C-130 aircraft

Figure 4. VARTM Flowchart.



polymer chains resulting in fewer sites for chemical decomposition. Although vinyl ester resins have a lower cross-link density (compared to high-performance resins like epoxies,) they have improved toughness characteristics such as impact strength and interlaminar shear.

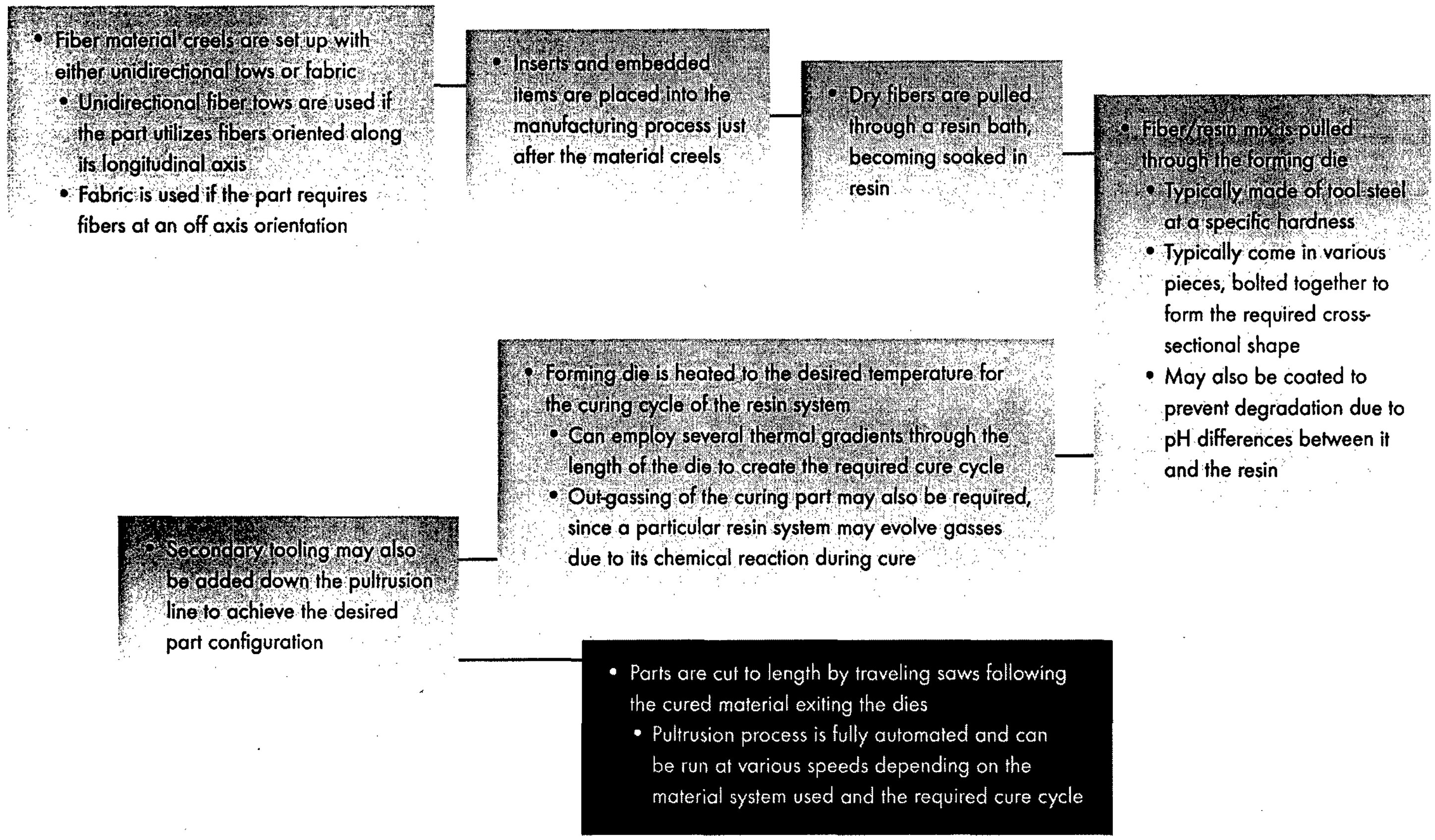
To achieve the weight reduction while maintaining the thickness requirement, the proposed matting has utilized a sandwich construction, integrating a core material in the mat's structure. Composite plies (also called skins or face sheets) are bonded completely around the core providing the required structural properties of the sandwich panel. Utilizing this concept provides greater stiffness than that of the individual pieces making up the sandwich panel. The composite skins provide the necessary means to carry the bending loads, while the core provides the means to handle the shear loading requirements. The composite plies of the skins may also be oriented to maximize the structural properties for specific loading applications, thus making the structure even more efficient.

Benefits of sandwich construction include high strength-to-weight and rigidity-to-weight ratios, good damage, impact and fatigue resistance, high durability, and the capability to imbed fasteners and other hardware into the panel. Core material choices vary widely from structural foam, non-structural foam, and balsa wood. Foams are typically polystyrene, phenolic, polyurethane, polypropylene, polyvinyl chloride, and ploymethacrylimide to name a few. Core materials also allow for different manufacturing methods such as RTM, structural reaction injection molding, vacuum infusion or vacuum assisted resin transfer molding (VARTM), and pultrusion.

This project employs two separate panel designs, each utilizing different manufacturing methods. One type of panel is made with a VARTM process, constructing the panel's fiber reinforcement in a dry state around the core material and impregnating the dry reinforcement with resin by pulling it through the panel with a vacuum, as described in the flowchart in Figure 4.[2] The other style of panel is made with a pultrusion process, where dry fiber on material creels is pulled through a resin bath, then through a die which imparts the final shape and cures the part. Cut-off saws follow the die and cut parts to the desired length. A simplified process flowchart is provided in Figure 5.[2]

An important part of the composite matting system being developed is the panel-to-panel connection and joint. The proposed connection, shown in Figure 6, is simpler than AM-2 and has the ability of transferring load. It utilizes a 3-part cam-lock system, shown in Figure 7. The bottom piece of the cam-lock can be embedded into the panel reducing the number of loose parts. This type of connection allows for removal of a minimum number of panels to facilitate subgrade and panel repairs. The joint also overlaps adjoining panels, creating a load transfer path. This joint design can minimize or possibly eliminate the need for subgrade preparation and repair.

Figure 5. Pultrusion Flowchart.



EVALUATIONS AND FUTURE EFFORTS

As mentioned before, the installation rate goal of the proposed system is double that of the existing AM-2 system. This will be achieved through a simpler installation process where the connection is incorporated into the panel and the panels are made to be independent of installation direction. The proposed panel will be manufactured with an 8" lip that is half the thickness of the overall panel and can be seen clearly in Figures 6-8. When connected together, the lips form a joint capable of transferring load. Simple cam-lock connection pieces will be embedded into the lips requiring only the mating piece to secure the panel together. The goal is to lay panels in any direction by starting with an end or edge panel with the panel lips on the bottom. Forming the first row of edge panels by mating the end lips together, the next row is placed mating the side lips together with the adjoining panel, aligning the cam-locks as shown in Figure 8. Locking the embedded cam-lock pieces together with the locking device makes the panel-to-panel connection. This procedure is repeated until the area required is covered. It's anticipated the required crew for installation will be approximately 4 to 6 people. Additional time is reduced by incorporating a ramp into the end or edge panel as opposed to installing the ramp required for the AM-2 matting. When combined, these features should reduce the installation time to the target range, as well as reducing overall weight of the system.

Initial evaluation of the proposed system will be based on a single wheel load of 30,000 pounds, a 350 psi tire pressure, and a low strength subgrade. (This loading situation is equivalent to an F-15.) Traffic will be normally distributed in a 70-inch traffic lane to simulate a taxiway traffic pattern and the panels will be laid out in a brickwork pattern over a sample subgrade. The panels and subgrade will be continuously monitored with strain gages attached to the bottom of the panels and pressure gages buried in the soil. Mat surface deflection will also be measured. The composite mats will be trafficked in line with AM-2 to compare performance. Failure criteria for AM-2 matting is a 1-inch deflection and breaks or tears in the mat that exceed 6 inches. The testing series will commence in December 2003, with results and a down-select occurring about 4 to 6 months afterward. Future evaluations will be based on loads representing C-17 aircraft over various subgrades. The proposed joint will be evaluated based on the joint's flexural strength and tensile load transfer. The flexural strength, tested according to ASTM C393, will determine the flexural properties of the bolted joint under load. If the joint is significantly more flexible than the panel, it will create rutting and pumping, resulting in subgrade failure. The tensile load transfer test in accordance with ASTM D3039 will determine the ability of

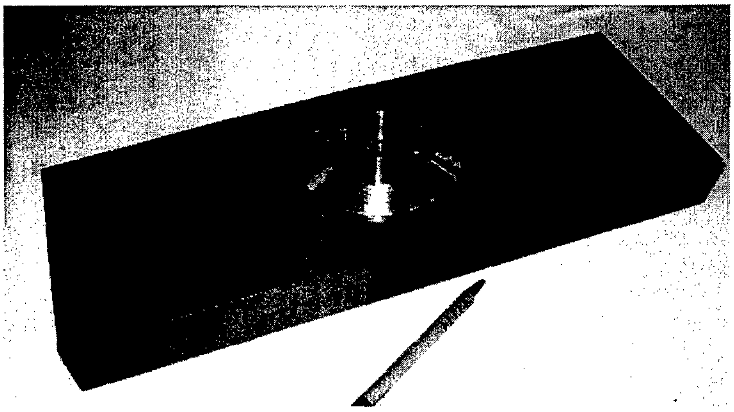


Figure 6. Section of the Proposed Composite Mat Joining Surface Showing Overlapping of Adjacent Mats.

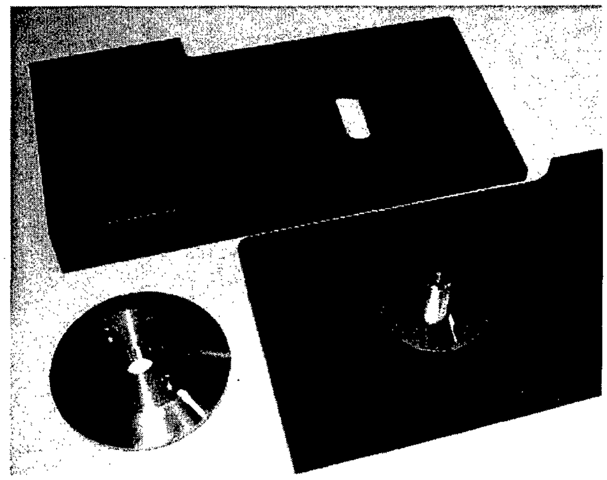


Figure 7. Lap Joint and Keylock Assembly of Proposed Composite Matting.

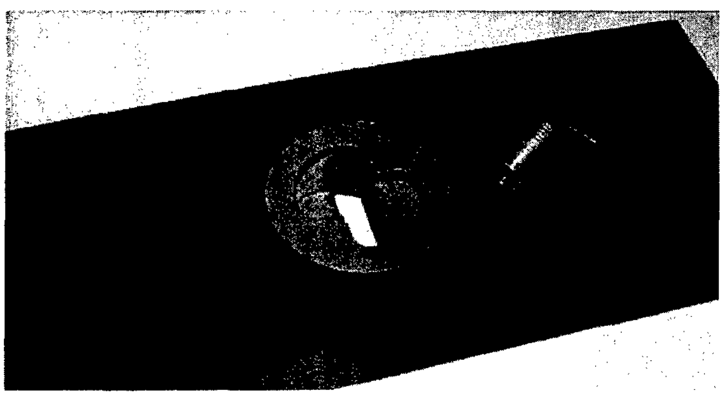


Figure 8. Close-up View of Keylock Assembly (Underside) in Proposed Composite Matting.

the joint to transfer tensile loads across the joint interface. The joint must be at least as strong as the panel itself in order to achieve adequate load transfer.

Once the down-select occurs, Phase II will focus on optimizing the panel performance against its weight. The joint and connection details will be further refined to ensure load transfer occurs under all possible conditions. The connection hardware will be scrutinized against all possible attacks from corrosion and material interaction, and appropriate material selection will be undertaken to reduce these effects. Manufacturing will also be optimized for efficiency and costs.

CONCLUSION

This project will cut across all military branches for improved mobility in adverse terrain. The Army and Navy have recently evaluated a number of mat systems under the Joint Logistics Over The Shore (JLOTS) program. This program assessed mat performance under heavy truck traffic and subgrade conditions representative of beach and marine environments. Mat systems evaluated in this program ranged from an 8 feet wide by 14 feet wide high-density polyethylene thermoplastic weighing 9 lbs/sf to a 0.35-inch thick 4-ply woven chopped fiberglass mat weighing approximately 3 lbs/sf, to engineered lumber. While many of these mats work well for truck traffic, none meet the Air Force goals of weight, installation rate, and structural capacity required for aircraft operations. The Army's Joint Rapid Airfield Construction (JRAC) program is another area where the Air Force's lightweight structural mat will be a big player. One of the main JRAC research areas is MOG expansion through improved matting technology and soil stabilization. Consequently, mobilization for future military operations will be greatly enhanced by providing a system for universal use that covers a wide range of uses without costly and complicated installation. Composite materials may provide the only realistic solution to all these considerations.

REFERENCES

[1] NAVAIR 51-60A-1, *AM-2 Airfield Landing Mat and Accessories Technical Manual: Installation, Maintenance, Repackaging and Illustrated Parts Breakdown*, Naval Air Systems Command 1993

[2] *Engineered Materials Handbook Vol 1 Composites*. ASM International Handbook Committee, Theodore J. Reinhart Technical Chairman, ASM International 1987