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TRI-SERVICE PAVEMENTS WORKING GROUP (TSPWG) MANUAL

TESTING PROTOCOL FOR POLYMERIC SPALL REPAIR MATERIALS

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TESTING PROTOCOL FOR POLYMERIC SPALL REPAIR MATERIALS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This TSPWG Manual supersedes USAF ETL 08-4, dated 10 April 2008.

FOREWORD

This Tri-Service Pavements Working Group Manual supplements guidance found in other Unified Facilities Criteria, Unified Facility Guide Specifications, Defense Logistics Agency Specifications, and Service specific publications. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, ensure compliance with the more stringent of these documents, protocols, agreements, specification and criteria, as applicable. This manual provides guidance on acceptance testing protocol and limits to identify materials for use, with minimal risk, in partial depth spall repairs of rigid pavements in locations subject to high operations tempo, and where time to return the area to aircraft traffic is limited. This protocol and the material identified by the process are referenced in technical publications found on the Whole Building Design Guide. It is not intended to take the place of service specific doctrine, technical orders (TOs), field manuals, technical manuals, handbooks, Tactic Techniques or Procedures (TTPs) or contract specifications. Use this manual along with these other documents to help ensure pavement repairs meet mission requirements.

TSPWG Manuals are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction, maintenance, repair, or operations. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of this document. Technical content of this TSPWG Manual is the responsibility of the Tri-Service Pavements Working Group (TSPWG). Contact the preparing activity for document interpretation. Send recommended changes with supporting rationale to the respective service TSPWG member.

TSPWG Manuals are effective upon issuance and are distributed only in electronic media from the following source:

Whole Building Design Guide web site http://dod.wbdg.org/.

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TRI-SERVICE PAVEMENTS WORKING GROUP MANUAL (TSPWG M) REVISION SUMMARY SHEET

Description of Changes: This update converts USAF ETL 08-4, Testing Protocol for Polymeric Spall Repair Materials into a TSPWG Manual. Content was reorganized for ease of understanding and locating information.

Reasons for Changes: To ensure the material is available to all services.

Impact: There is no cost impact. This publication results in the following benefits:

- Supplemental information on the operation, maintenance and repair of pavements as well as airfield damage repair will be available to all services and Defense Logistics Agency.
- Maintenance and/or upgrading of this supplemental information will include inputs from all services and Defense Logistics Agency.

Note: The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Department of Defense (DOD).

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TABLES

CHAPTER 1

INTRODUCTION

1-1 **BACKGROUND**.

Prompt repair of spalls is necessary to reduce foreign object damage (FOD) potential, slow continuing pavement deterioration, and maintain riding smoothness on pavement surfaces.

A tremendous number of options are available when military personnel select a material for repairing spalls. Materials can be generalized into three categories: cementitious, asphaltic, and polymeric. Within each of these categories there are many products to choose from and some products blur the categorical boundaries (e.g., polymer-modified asphalt and polymer-modified concrete). Proprietary products often evolve over time as manufacturers attempt to address concerns or problems expressed by field personnel. The testing protocol presented herein is necessary for DOD organizations to eliminate from consideration for use those materials that have a low probability of success in the field. The field success of materials that pass this testing protocol cannot be guaranteed, but such materials are considered worthy of field testing. This testing protocol is limited to polymeric concrete repair products. This TSPWG Manual does not address specific safety concerns or the proper application of any materials in the field. Users are encouraged to practice strict adherence to manufacturers' guidelines.

1-2 **PURPOSE**.

This TSPWG Manual provides a set of laboratory tests, with their acceptable results, that can be used to evaluate polymeric materials for spall repair in portland cement concrete (PCC) pavements. Common polymeric repair materials include epoxies, methacrylates, and urethanes, supplied in liquid form, often with aggregate filler. The repair kits may include two liquid components, with or without aggregate, or one liquid and one dry component. This TSPWG Manual does not address materials that require heating or melting for application. Spalls in PCC pavements consist of damage that does not penetrate through the pavement surface to the underlying layers. Spalls may be up to 5 feet (ft) (1.5 meters [m]) in diameter. Typical pavement spalls require less than 1 cubic foot (0.028 cubic meter) of repair material, although larger spalls resulting from exploding munitions can occur in contingency environments. This TSPWG Manual provides information and guidance for inspecting pavement drainage systems. Various inspection and testing techniques and the effectiveness of each are described.

This protocol identifies materials which, based upon material and mechanical properties, will likely result in a durable partial depth spall repair in a PCC pavement subjected to aircraft traffic in a short period of time. Repairs using these materials can fail to meet the mission needs or expected performance when: the repair area is not properly prepared; the materials are not properly proportions or mixed; the materials are used in temperatures outside the manufacturers' recommended weather conditions; the materials are not properly placed, consolidated, finished, isolated or sealed; or the joints or cracks within or next to the repair are not properly re-established. Each test and limit within this protocol is intended to remove or diminish risk and uncertainty associated with the materials bond to and compatibility with the pavement being repaired as well as the repair's ability to withstand the environmentally, material and mechanically induces loads (stress and strains).

1-3 **SCOPE**.

This TSPWG Manual provides a testing protocol for the acceptance of polymeric spall repair materials intended for use on both airfield and roadway pavements that were previously constructed with Ordinary Portland cement (OPC) concrete.

1-4 **REFERENCES.**

Appendix A contains the list of references used in this TSPWG Manual.

CHAPTER 2

General Product Selection Considerations

2-1 CURE TIME.

Select polymeric materials for spall repair when rapid curing is necessary; a typical requirement is the ability to support aircraft traffic in one hour or less. Manufacturer-recommended cure times range from ten minutes to eight hours for most polymeric repair materials. The testing protocol described herein assumes that manufacturer-recommended cure times are accurate. Note that cure times are most often a function of environmental conditions, especially temperature, so cure times may vary from the laboratory to the field.

2-2 SHELF LIFE.

Some polymeric repair materials have a very limited shelf life, as reported by the manufacturer, carefully consider shelf life when selecting a material. Shelf life typically ranges from three months to two years, and depends on storage conditions such as temperature, humidity, and the integrity of packaging.

2-3 SURFACE PREPARATION.

Prepare the damaged concrete surface according to the repair material manufacturer's recommendations. Common recommendations are removing loose debris by either sandblasting or high-pressure water, followed by blowing with compressed air. Some repairs require saw-cutting to eliminate feathered edges. Many materials require the application of a primer to the concrete surface before applying the repair material. Some repairs are designed to immediately follow the priming step, while some require that the primer coat be allowed to fully cure before repairing.

2-4 FILLERS.

While some polymeric repair materials include particular aggregates or fillers that are supplied with the resin, others are designed to use local aggregates. Follow manufacturers' recommendations regarding aggregate selection and preparation.

2-5 SAFETY.

Safety hazards, such as fire/explosion hazards, toxicity, and reactivity, are associated with many polymeric repair materials. Ensure that a material safety data sheet (MSDS) from the manufacturer always accompanies the material. Before use, review and follow the MSDS guidance for personal protective equipment and other safety precautions.

CHAPTER 3

TESTING PROTOCOL

3-1 TEST SPECIMEN CURING.

Cure all test specimens at ambient laboratory conditions (i.e., 73 °F [23 °C] and 50% relative humidity). Cure times are designated for each test in paragraph 3-2.

3-2 DESCRIPTION OF TESTS.

3-2.1 Chemical Resistance.

Chemical resistance is important because some polymeric materials may be subject to softening, swelling, or erosion in the presence of certain chemicals. Depending on the field activity, potential exposure solvents in an airfield environment may include jet fuel, de-icing compounds, hydraulic oil, or other chemicals. Assess resistance to these agents using ASTM C267. Acceptable specimens for chemical resistance tests are 2-inch (in) (51-millimeter [mm]) cubes cured at 73 °F (23 °C) for seven days. Specimens are measured and weighed before being submerged in the test solvent and held at a predetermined temperature. Sets of three specimens are removed at specified time intervals and inspected, weighed, and compression tested in accordance with ASTM C579. The number of specimens needed depends on the number of test solvents, exposure temperatures, and exposure time intervals. To limit experimental effort, realistic worst-case conditions may be simulated for the given field application (e.g., exposure to JP8 fuel at 150 °F [66 °C] for 24 hours). Include the appearance of the specimens and solvent, and weight and compressive strength changes as percentages in reported observations.

3-2.2 Compressive Strength.

Compressive strength is important for ensuring the spall repair does not deform or crack under wheel loads or under stresses caused by environmentally induced pavement movements. The material's compressive strength is mobilized when the underlying parent pavement can fully support the applied load. Perform compressive strength tests in accordance with ASTM C579 procedures. Most polymeric spall repair materials can be evaluated using 2-in (51-mm) cubes, which is the preferred specimen size because the samples do not require grinding or capping. Do not use 2-in (51-mm) cubes when evaluating a material having a maximum aggregate size greater than 0.4 in (10.2 mm), though such material is rarely used to repair spalls unless they were particularly deep. Follow the guidance in the ASTM method when testing materials comprising aggregates greater than 0.4 in (10.2 mm). Test a first set of specimens after a curing period of one hour and a second set after a curing period of four hours. If a product's manufacturer reports a cure time at 73 °F (23 °C) of other than one or four hours then additionally test that product at the manufacturer-recommended cure time (e.g., the product literature for Product X indicates trafficability after two hours at 73 °F

[23 °C]; therefore, test Product X at one, two, and four hours). Results are reported as peak compressive stress (pound per square inch [lb/in2]), which equals maximum load divided by cross-sectional area, at each cure time interval.

3-2.3 Flexural Strength and Modulus of Elasticity.

The flexural strength and modulus of the repair material are important in cases where the parent concrete underlying the spall is too thin to support the entire wheel load. In such cases, some of the load has to be borne by the repair and transferred to the sound pavement via the bond. Low modulus materials may flex excessively and fail by debonding from the sides of the repair. Flexural strength and modulus of elasticity are measured by ASTM C580 procedures. Flexural test specimens are beams measuring 12 in x 2 in x 2 in (305 mm x 51 mm x 51 mm). The beams are tested in a three-point bending configuration with a 10-in (254-mm) span. Test a first set of specimens after a curing period of one hour and a second set after a curing period of four hours. If a product's manufacturer reports a cure time at 73 °F (23 °C) for other than one or four hours, then additionally test that product at the manufacturer-recommended cure time (e.g., the product literature for Product Y indicates trafficability after 20 minutes at 73 °F [23 °C]; therefore, test product Y at 20 minutes, one hour, and four hours). Report flexural strength and tangent modulus of elasticity at each cure time interval. The flexural strength is equal to the stress (lb/in2) at maximum load. The tangent modulus (lb/in2) is equal to the ratio of stress to corresponding strain within the elastic limit (i.e., the slope of the linear region of the stress-strain curve).

3-2.4 Bond Strength by Slant Shear.

Bond strength is important to ensure the spall repair does not easily become dislodged from the parent material onto which the repair was applied. Preform bond strength tests in accordance with ASTM C882 procedures, with the following modification: ASTM C882 specifies testing the bond strength of an epoxy layer sandwiched between two PCC dummies. For this repair material protocol, a single PCC dummy is inserted into the bottom of the 3-in x 6-in (76-mm x 152-mm) cylinder mold and the repair material is placed on top to fill the remaining portion of the mold. The result is a half-PCC, half-polymeric cylinder, having a bond line at approximately 30 degrees from vertical. After curing, this method requires capping the cylinder according to ASTM C617. The composite cylinder is then tested in compression, causing shearing failure at the bond line. Test a first set of specimens after a curing period of four hours and a second set after a curing period of 24 hours. Results are reported as maximum bond stress (lb/in2), which is calculated as maximum force divided by the area of the elliptical bonding surface.

3-2.5 Thermal Compatibility.

ASTM C884 is a test to determine thermal compatibility between the repair material and the parent PCC, especially under cyclic freezing conditions. If a repair material expands and contracts greatly, relative to the PCC, then delamination may occur. This test is a practical and applied method to observe the effects of complex interactions between bond strength, modulus, elongation, and the coefficient of linear thermal expansion (CLTE) of the repair material. First, two PCC blocks, each measuring 12 in x 12 in x 3 in (305 mm x 305 mm x 76 mm), are cast and cured for 28 days. A 0.5-in (13-mm) overlay of the repair material is then applied to each block and cured for seven days at 73 °F (23 °C). The completed specimens are exposed to five freeze–thaw cycles, each cycle consisting of exposure to -6 °F (-21 °C) for 24 hours, then 73 °F (23 °C) for 24 hours. Any delamination observed in either specimen constitutes failure of the test. The results are reported as pass or fail.

3-2.6 Dynamic Mechanical Analysis (DMA):

Modulus of Elasticity as a Function of Temperature. Most polymeric materials are much more susceptible to thermal effects than cementitious materials. Use ASTM D5023 to reveal any mechanical weakening, melting, degradation, glass transition, or other thermal transitions of the repair material over a selected temperature range. The recommended temperature range for testing pavement repairs is -60 °F to 400 °F (-51 °C to 204 °C), but may be adjusted to reflect actual extremes in the applied environment. In the recommended DMA technique, a sinusoidal three-point bending load is applied to the specimen at a frequency of 0.1 second and a maximum strain of 0.01%, and the temperature is linearly increased at a rate of 3 °C/minute. The storage modulus (modulus of elasticity), loss modulus, and tangent delta are recorded as a function of temperature, thus revealing temperatures corresponding to sample weakening. Note that the modulus values are relative, not absolute. Use test specimens with dimensions at or near the maximum allowable specimen size for the instrument being used. Prepare resin specimens without added aggregate when possible. Test at a specimen age of seven days. Report the temperature at which the storage modulus value decreases to 50% of the modulus value at 73 °F (23 °C). Consider this to be the maximum pavement surface temperature for which the material is suited. Use only materials where this maximum temperature exceeds 150 °F (66 °C).

Table 3-1. Requirements for Test Results

Property	ASTM	Requirement
Chemical resistance	C267	No more than 20% loss in strength or 10% change in weight after 24-hour exposure at 150 °F (66 °C). Begin test after seven-day cure at 73 °F (23 °C).
Compressive strength	C579	> 500 psi Cure at 73 °F (23 °C) for one hour and four hours.
Flexural strength and modulus of elasticity	C580	> 350 psi and > 5,000 psi, respectively. Cure at 73 °F (23 °C) for one hour and four hours.
Bond strength by slant shear	C882	> 500 psi Cure at 73 °F (23 °C) for four hours and 24 hours.
Thermal compatibility	C884	Pass = No delamination in either of two samples. Begin test after seven-day cure at 73 °F (23 °C).
Dynamic mechanical properties vs. temperature	D5023	Temp. at 50% modulus loss has to be > 150 °F (66 °C). Begin test after seven-day cure at 73 °F (23 °C).
Note: Test three replicates of each specimen unless instructed otherwise by ASTM method.		

3-2.7 Replicates.

Three replicates are required for each of the tests described as being part of this protocol unless instructed otherwise by the ASTM method. The average result, calculated from the three replicates, is compared to the requirements presented in Table 3-1. The average of only two replicates is not acceptable, so those conducting the tests are encouraged to make extra specimens in case a problem occurs during testing. . Report, with the other test results, any test results that are thrown out because they are believed to be outliers and explain the reason the data is considered invalid.

3-2.8 Product Information and Test Results.

Information on products that have undergone testing by this protocol is available at https://transportation.erdc.dren.mil/cacsites/TriService/pavement_repair.aspx.

3-3 ADDITIONAL REPORTING REQUIREMENTS.

Additional Reporting Requirements. When reporting results on a material after it has been tested in accordance with this testing protocol, include the following information to help reveal any differences between testing conducted by different testing agencies. Include information that is important for material selection, but not directly related to the test result requirements presented in Table 3-1.

- Manufacturer-reported shelf life and storage requirements.
- Curing conditions and times.
- Pot life / gel time.
- Moisture tolerance.
- Manufacturer-recommended surface preparation.
- Types and yields of packaging options.
- Any required materials not included with the repair kit.
- Mixing and application methods/equipment.
- Cleanup requirements.
- Safety hazards.
- Rate of freeze–thaw cycles (i.e., number of cycles per day)
- Selected testing conditions not defined by protocol and/or deviations from protocol.
- Notes on ease of handling and use, limitations, unexpected observations, etc.

3-4 EVOLVING PROTOCOL.

This testing protocol and the associated material requirements will evolve over time as it is put to use and material test results are compiled.

GLOSSARY

Acronyms and Abbreviations

ADR	– airfield damage repair
ASTM	– American Society for Testing and Materials
Prime BEEF	– Prime Base Engineer Emergency Force
C	– Celsius
CLTE	– coefficient of linear thermal expansion
DMA	– dynamic mechanical analysis
DOD	– Department of Defense
ETL	– engineering technical letter
F	– Fahrenheit
FOD	– foreign object damage
ft	– foot
in	– inch
lb	– pound
lb/in2	– pound per square inch
m	– meter
MAJCOM	– major command
mm	– millimeter
MSDS	– material safety data sheet
OPC	– ordinary portland cement
PCC	– portland cement concrete
psi	– pound per square inch
RED HORSE Repair Squadron	– Rapid Engineers Deployable - Heavy Operations

APPENDIX A

REFERENCES

American Society for Testing and Materials (ASTM), Annual Book of ASTM Standards, 100 Barr Harbor Drive, West Conshohocken, PA, available at http://www.astm.org.

ASTM C267, Standard Test Methods for Chemical Resistance of Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes

ASTM C579, Standard Test Method for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes

ASTM C580, Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes

ASTM C617, Standard Practice for Capping Cylindrical Concrete Specimens

ASTM C882, Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear
Note: Modification to specimen preparation is described in subparagraph 3-2.4.

ASTM C884, Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay

ASTM D4065, Standard Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures

ASTM D5023, Standard Test Method for Plastics: Dynamic Mechanical Properties: In Flexure (Three-Point Bending)