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Aircraft Arrestor System Panel Joint Improvement

Jesse D. Doyle, Nolan R. Hoffman, and M. Kevin Taylor

July 2021

Geotechnical and Structures Laboratory

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Jesse D. Doyle, Nolan R. Hoffman, and M. Kevin Taylor

Geotechnical and Structures Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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Abstract

Aircraft Arresting Systems (AAS) for military applications utilize sacrificial panels made of Ultra-High Molecular Weight polyethylene (UHMWPE) that are embedded into the pavement beneath the AAS cable to protect the pavement from cable damage. Problems have been observed with the materials and practices used to seal the UHMWPE panel joints from water and debris. Data obtained from laboratory and field studies were used make improvements to current practice for sealing UHMWPE panel joints. The study evaluated four joint-sealant materials, eight alternative surface treatment and preparation techniques to promote adhesion to UHMWPE, and seven joint-edge geometries. Bond-strength testing of joint-sealant specimens was conducted in the laboratory, followed by field evaluation of construction techniques. Field performance of the joint systems was monitored for 24 months after installation. Additionally, a thermal response model was developed to refine the joint design dimensions. Results confirmed that the best material to use was self-leveling silicone joint sealant. It was recommended that a dovetail groove be cut into the edge of UHMW panels to provide positive mechanical interlock and to reduce adhesive failures of the sealant. It was also recommended that the panel-to-panel joint-sealant reservoir be widened to prevent sealant compression damage.

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Contents

Abstract ii

Figures and Tables v

Preface viii

1 Introduction 1

1.1 Background 1
1.2 Research need 3
1.3 Objective and scope 3

2 Experimental Program 4

2.1 Research approach 4
2.2 Materials 5
2.2.1 Ultra-high molecular weight polyethylene (UHMWPE) 5
2.2.2 Sealants 6
2.3 Experimental treatments 8
2.3.1 Surface treatments 8
2.3.2 Panel-edge geometries 10
2.4 Specimen preparation, test methods and experimental design 12
2.4.1 Sealant material properties 12
2.4.2 Laboratory Phase 1 13
2.4.3 Laboratory Phase 2 14
2.4.4 UHMWPE strength 14

3 Laboratory Results and Analysis 16

3.1 Sealant material properties 16
3.2 Laboratory Phase 1 17
3.3 Laboratory Phase 2 21
3.4 UHMWPE strength 27
3.5 Panel-edge geometry analysis 30

4 Field Installation and Monitoring 32

4.1 AAS panel system construction 32
4.2 Sealant installation 33
4.3 Observations during 21-day sealant curing period 36
4.4 Observations 1 yr after sealant curing 38
4.5 Observations 2 yr after sealant curing 39

5 Joint Thermal Movement 41

5.1 One-dimensional thermal model for joint movement 41
5.2 Thermal model results 43

6 Conclusions and Recommendations 47

6.1 Conclusions 47
6.2 Recommendations 48

References **49**

Appendix A: Laboratory Test Data **51**

Appendix B: Material Datasheets **69**

Acronyms **98**

Unit Conversion Factors **99**

Report Documentation Page

Figures and Tables

Figures

Figure 1. F-16 aircraft stopped by an arresting cable. 1
Figure 2. Pavement beneath arresting system with cable removed. 2
Figure 3. UHMWPE panel-to-panel and panel-to-adjacent-pavement joint geometry. 10
Figure 4. Modified UHMWPE panel-edge geometries. 11
Figure 5. Specimen orientation (from ASTM D638 2014). 15
Figure 6. Sealant 1 cure evaluation with PCC and UHMWPE substrates. 17
Figure 7. Load-strain plot for Sealant 1, no surface treatment and flat edge. 25
Figure 8. Load-strain plot for Sealant 1, Primer 1, and flat edge. 25
Figure 9. Load-strain plot for Sealant 1, Adhesive 3, and flat edge 26
Figure 10. Load-strain plot for Sealant 1, no surface treatment and dovetail edge. 26
Figure 11. AAS panel installation procedure. 33
Figure 12. Sealant installation procedure. 35
Figure 13. Observations during 21-day sealant curing period. 37
Figure 14. Diagram of one-dimensional thermal model for panel expansion joints. 41
Figure 15. Effects of installation temperature on differential joint movement. 44
Figure 16. Effect of varying joint width on joint-sealant material. 45
Figure 17. Intensity plot of hot weather maximum joint closure percentage as function of installation temperature and nominal joint width. 46
Figure 18. Intensity plot of cold weather maximum joint opening percentage as function of installation temperature and nominal joint width. 46
Figure A1. Load-strain plot for Sealant 1, no surface treatment, flat edge. 52
Figure A2. Load-strain plot for Sealant 1, no surface treatment, flat edge + concrete. 52
Figure A3. Load-strain plot for Sealant 1, no surface treatment, flat edge + asphalt 53
Figure A4. Load-strain plot for Sealant 5, no surface treatment, flat edge or concrete. 53
Figure A5. Load-strain plot for Sealant 1, Adhesive 3, flat edge. 54
Figure A6. Load-strain plot for Sealant 1, Primer 1, flat edge. 54
Figure A7. Load-strain plot for Sealant 1, Primer 3, flat edge. 55
Figure A8. Load-strain plot for Sealant 1, Primer 3 + flame treatment, flat edge. 55
Figure A9. Load-strain plot for Sealant 1, sanded surface, flat edge. 56
Figure A10. Load-strain plot for Sealant 1, flame treatment, flat edge 56
Figure A11. Load-strain plot for Sealant 1, no surface treatment, stepped groove. 57

Figure A12. Load-strain plot for Sealant 1, no surface treatment, radius groove. 57
Figure A13. Load-strain plot for Sealant 1, no surface treatment, single groove. 58
Figure A14. Load-strain plot for Sealant 1, no surface treatment, dovetail groove. 58
Figure A15. Load-strain plot for Sealant 1, no surface treatment, notch groove. 59
Figure A16. Load-strain plot for Sealant 1, no surface treatment, multi-groove. 59
Figure A17. Load-strain plot for Sealant 1, no surface treatment, flat edge, control. 60
Figure A18. Load-strain plot for Sealant 1, sanded surface, single groove. 60
Figure A19. Load-strain plot for Sealant 1, sanded surface, dovetail groove. 61
Figure A20. Load-strain plot for Sealant 1, Adhesive 3, flat edge. 61
Figure A21. Load-strain plot for Sealant 1, Primer 1, flat edge. 62
Figure A22. Load-strain plot for Sealant 1, Primer 1 + sanded surface, flat edge. 62
Figure A23. Load-strain plot for Sealant 1, Primer 1 + sanded surface, single groove. 63
Figure A24. Load-strain plot for Sealant 1, Primer 1 +sanded surface, dovetail groove. 63
Figure A25. Load-strain plot for Sealant 1, Primer 2, flat edge. 64
Figure A26. Load-strain plot for Sealant 1, Primer 2 +sanded surface, dovetail groove. 64

Tables

Table 1. Physical requirements of UHMWPE for AAS panels (USAF 2012). 5
Table 2. Sealant material testing. 12
Table 3. Sealant hardness testing results and modulus estimates. 16
Table 4. Bond strength test results for sealants alone. 18
Table 5. Bond strength test results for sealants and surface treatments. 20
Table 6. Bond strength test results for Sealant 1 and panel-edge geometries. 21
Table 7. Phase 2 bond strength test results. 22
Table 8. Summary of UHMWPE testing at 23°C. 27
Table 9. Statistical ANOVA summary for yield strength at 23°C. 28
Table 10. Multiple comparison procedure results, 23°C yield strength for material. 28
Table 11. Multiple comparison procedure results, 23°C yield strength for direction. 29
Table 12. Summary of UHMWPE testing at 75°C. 29
Table 13. Statistical ANOVA summary for yield strength at 75°C. 29
Table 14. Multiple comparison procedure results, 75°C yield strength for material. 30
Table A1. Tivar® UV Resistant UHMWPE tensile test data at 23°C. 65
Table A2. Tivar® UV Resistant UHMWPE tensile test data at 75°C. 66
Table A3. Polystone® M UV Stabilized UHMWPE tensile test data at 23°C. 67

Table A4. Polystone® M UV Stabilized UHMWPE tensile test data at 75°C. 67
Table A5. Polyslick® UV Stabilized UHMWPE tensile test data at 23°C. 68
Table A6. Polyslick® UV Stabilized UHMWPE tensile test data at 75°C. 68

Preface

This study was conducted for the U.S. Air Force Civil Engineer Center (AFCEC) under MIPR Number F4ATA44136J001, "Aircraft Arrestor System UHMW Panel Joint Sealant." The technical monitor was Dr. Barry Mines, AFCEC.

The work was performed by the Airfields and Pavements Branch (GMA) of the Engineering Systems and Materials Division (GM), U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory (ERDC-GSL). At the time of publication, Ms. Anna M. Jordan was Chief, GMA; Mr. Justin S. Strickler was Chief, GM; and Mr. R. Nicholas Boone, GZT, 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.

COL Teresa A. Schlosser was the Commander of ERDC, and Dr. David W. Pittman was the Director.

1 Introduction

1.1 Background

On airfield runways, aircraft arresting systems (AASs) are used to stop aircraft in emergency situations. There are three primary types of AASs: engineered materials arresting systems (EMASs), aircraft arresting barriers, and aircraft arresting cables (Bachtel 2001). EMASs are primarily used at civilian airports to safely stop aircraft that have overrun the end of a runway (FAA 2012). EMASs are similar in concept to a runaway truck ramp, and they consist of a material, such as lightweight cellular concrete, that is designed to collapse in a controlled fashion under the weight of a runaway aircraft, thus safely bringing it to a stop. Arresting barriers and arresting cables are primarily used by military aircraft and are typically found on military airfields but can also be found on some joint-use civilian-military airports (Bachtel 2001). Arresting barriers consist of net devices and are typically used for lightweight aircraft, such as surveillance drones. The focus of this report is on aircraft arresting cable systems' construction and materials issues.

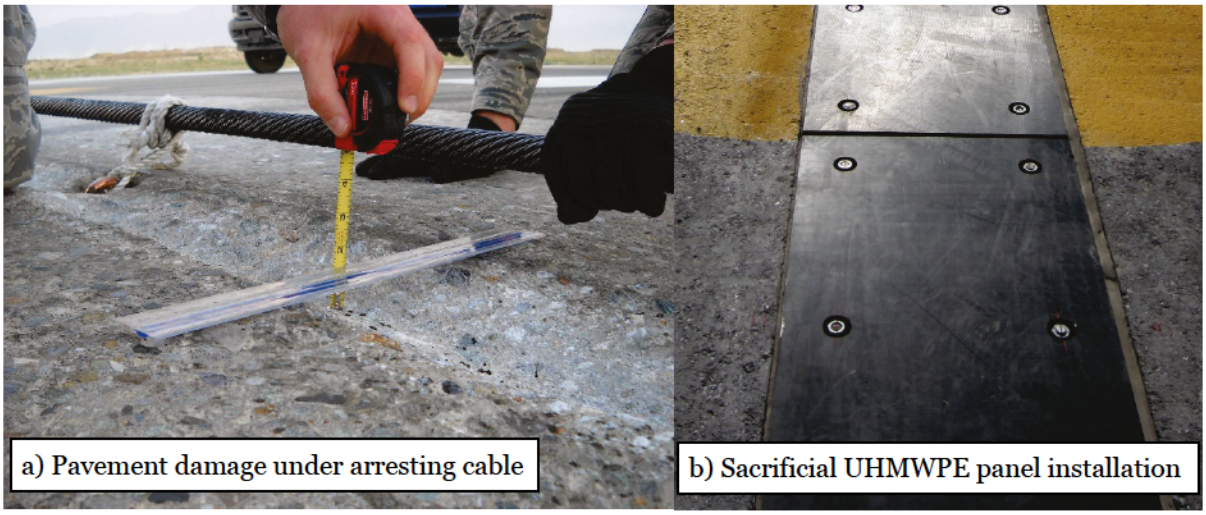
Arresting cable systems consist of a thick, wire-cable pendent stretched across a runway and attached to a braking system (USAF 2012). In an emergency situation, a tail-hook mechanism on the aircraft is lowered to engage the cable, whereupon the braking system will dissipate the forward momentum of the aircraft, bringing it to a safe stop (Figure 1).

Figure 1. F-16 aircraft stopped by an arresting cable.



During normal operations, the repeated passage of aircraft over the arresting cable stretched across the runway will quickly cause damage to the underlying pavement surface (Figure 2a). To mitigate this damage, sacrificial panels are installed directly beneath the arresting cable in a recess made in the pavement (Figure 2b). The sacrificial panels are made of ultra-high molecular-weight polyethylene (UHMWPE) plastic because of its excellent abrasion and impact resistance. The UHMWPE panels can be installed directly into a Portland cement concrete (PCC) pavement or into an asphalt pavement by use of a concrete foundation.

Figure 2. Pavement beneath arresting system with cable removed.



a) Pavement damage under arresting cable

b) Sacrificial UHMWPE panel installation

UHMWPE plastic consists of very long polymer chains with a high degree of cross-linking. A consequence of this is that it also has a high coefficient of thermal expansion, on the order of 198 µm/m/°C (110 x 10^{-6} in./in./°F). By comparison, the coefficient of thermal expansion for PCC is on the order of 9.9 µm/m /°C (5.5 x 10^{-6} in./in./°F); the UHMWPE coefficient of thermal expansion is about 20 times higher than that for PCC. This high coefficient of thermal expansion for UHMWPE necessitates that multiple short panels be installed to provide strain relief and to prevent buckling of the panels in hot weather. For a standard 45.7-m (150-ft)-wide runway, between 42 and 48 UHMWPE panels are installed, depending on the configuration (USAF 2012). This requires numerous joints between individual panels as well as joints between panels and the adjacent pavement surface. The joints are sealed to prevent the intrusion of water and debris that would accelerate deterioration of the pavement and panels.

1.2 Research need

A survey of existing AASs at 18 airfields where military aircraft operate revealed that most of the installations had problems with the sealant used in the joints both between the UHMWPE panels and between the panels and the adjacent pavement (Brown 2009). Typically, this was adhesion failure of the sealant to the UHMWPE panels. It was noted that not all types of sealants bonded well to the UHMWPE panels; however, self-leveling silicone sealant generally provided the best relative performance. At Shaw Air Force Base (AFB), a coal-tar modified polyurethane sealant (Gardox®) that had potentially superior performance to silicone was used. Also at Shaw AFB, a keyway was milled into the edge of the UHMWPE panels. The shape or dimensions of the keyway were not provided, but it was observed that the mechanical interlock between sealant and panel kept the sealant in place even if the adhesive bond deteriorated or failed. Brown (2009) recommended that research be performed to determine the best type of sealant for AAS panel joints, that the use of primers to improve sealant bond be investigated, and that a keyway in the UHMWPE panels to improve sealant performance be studied.

1.3 Objective and scope

The objective of this research project was to build upon the observations of Brown (2009) and to determine the best overall solution to improve performance of sealants in AAS panel joints relative to current practice. The scope of possible evaluated solutions included multiple sealant material types, surface primers to improve sealant bond, UHMWPE panel surface preparation techniques to improve sealant bond, and keyways or grooves in the UHMWPE panel edge to provide mechanical interlock with the sealant. A laboratory investigation evaluated many options, followed by a field installation to trial the best combinations and observe performance over time under ambient weather conditions.

2 Experimental Program

2.1 Research approach

To accomplish the research objective, a two-phase laboratory testing program was conducted. Results from Phase 1 were used to down select for Phase 2 testing. Finally, the most viable options from laboratory results were evaluated in a field experiment to determine the feasibility of utilizing them in full-scale AAS construction. The field experimental sections were left in place to monitor their performance over time under ambient weather thermal cycling in the absence of traffic loading.

In Phase 1 of the laboratory testing, five sealant materials, eight surface treatments, and seven panel-edge geometries were tested. Not every experimental treatment combination was tested; instead, an iterative approach was taken. The focus of Phase 1 testing was on different sealant materials in combination with a surface treatment or an alternative panel-edge geometry. Current best practice, as recommended by Brown (2009), to use a self-leveling silicone joint sealant was considered the baseline of performance for a sealant material. If the performance of a sealant material could not match or exceed that of the baseline, it was generally eliminated from further testing with surface treatments or alternative-edge geometries. In total, 28 different combinations were tested in Phase 1.

In Phase 2 of the laboratory testing, a selection of the best performing treatments from Phase 1 was subjected to further testing. In addition, combinations of surface treatments and panel-edge geometries were explored to see whether the beneficial effects observed in Phase 1 results were additive. In total, ten different combinations were tested in Phase 2.

For the field experiment, an 18.3-m (60-ft)-long segment of UHMWPE panels was constructed on an existing PCC pavement at ERDC's outdoor pavement test facility. Installation of the panels was performed in accordance with standard USAF (2012) guidance. Performance of the joint sealants was monitored periodically for 24 months to assess the sealant performance over time under thermal cycling in the absence of aircraft traffic loading. In total, four different combinations were tested in the field experiment.

2.2 Materials

2.2.1 Ultra-high molecular weight polyethylene (UHMWPE)

The required physical properties of UHMWPE for AAS are given in Air Force Instruction (AFI) 32-1043 (USAF 2012) and are provided in Table 1. In addition, AFI 32-1043 states that "the panels will be fabricated from virgin and/or recycled UHMW polyethylene and will be black in color and UV-stabilized." However, elsewhere AFI 32-1043 states that "it is desirable to use light-gray-colored panels to help minimize thermal expansion and contraction." Both of these requirements likely cannot be simultaneously met since UV-stabilization is most frequently accomplished by the addition of carbon black to the UHMWPE, resulting in a black color. Obtaining UHMWPE in any colors other than black or natural white (especially with UV-stabilization) can incur significant extra cost for special manufacturing runs. Since UV-stabilization will extend the life of UHMWPE panels exposed to sunlight and every AAS inspected by Brown (2009) had black-colored panels, it was decided for this study to use the UV-stabilized black panels.

Table 1. Physical requirements of UHMWPE for AAS panels (USAF 2012).

Property	Test Method	Requirement
Density	ASTM D1505	0.92 – 0.94 g/cm
Tensile elongation at break	ASTM D638	300 – 400 percent
Tensile yield strength	ASTM D638	2800 – 4000 psi
Shore hardness "D"	ASTM C886[a]	60 – 70
Coefficient of friction	ASTM D3028	0.2
Izod impact strength	ASTM D256, Method A	>20 ft-lb/in.

[a]This reference appears to be inaccurate. Shore hardness is ASTM D2240.

From a previous study to optimize construction techniques for AAS panel installation (Bly 2020), a large quantity of UHMWPE panels was available that met the geometric requirements of AFI 32-1043. Details of the material source were not readily available; however, they were black in color, UV-stabilized, and made from recycled UHMWPE. One of these panels was cut up for use in laboratory sealant testing. The remaining panels were used for the field experiment.

To investigate material strength variability of UHMPE, samples were obtained from three different manufacturers. The first sample was

Quadrant®'s Tivar® UV Resistant UHMWPE. The material was obtained from Nationwide Plastics and was 3.2 mm by 0.61 m by 1.2 m (0.125 by 24 by 48 in.). The second sample was Rochling®'s Polystone® M UV Stabilized UHMWPE. Material was acquired through ThyssenKrupp Engineer Plastics and measured 6.4 mm by 1.2 m by 3.0 m (0.25 by 48 by 120 in.). Typically, the suppliers offer 3.2-mm (0.125-in.)-thick sheets of UHMWPE; however, ThyssenKrupp did not have any in stock. According to ThyssenKrupp, the as-molded sheets are usually skived, or sliced, into the lower thickness sheets. The third sample was Polymer Industries' Polyslick® UV Stabilized UHMWPE. The material was obtained directly through Polymer Industries and was 3.2 mm by 1.2 m by 3.0 m (0.25 by 48 by 120 in.).

2.2.2 Sealants

Based on the observations of Brown (2009), self-leveling silicone as well as Gardox® sealants were considered for this study. Discussion with the manufacturer of Gardox® revealed that its production had been discontinued (coal-tar has been largely eliminated in the United States due to carcinogenic effects); an alternative polyurethane sealant was recommended as a replacement. Hot-poured sealants were observed to perform poorly in climates with large annual temperature variations but were somewhat successful in locations with less variation in annual temperature (Brown 2009).

Temperature reductions cause shrinkage of UHMWPE panels and opening of the joints. This results in stress at the joint sealant to UHMWPE panel interface. If the sealant-panel interface stress exceeds the adhesion strength of the sealant, the sealant will fail. The amount of stress at the interface is controlled by the sealant modulus. For a given joint opening movement, a lower modulus sealant will result in lower interface stress than a higher modulus sealant. Since UHMWPE has a low surface free energy, materials do not bond well to it. Minimizing the sealant-panel interface stress is considered critical to joint-sealant performance for AAS panels.

Five joint-sealant materials were selected, and samples of each were obtained for testing: three silicone materials with a range of moduli, one polyurethane material, and one asphalt-based material. Details of each sealant and relevant material properties provided by suppliers are listed below, and manufacturer's datasheets are located in Appendix B.

- **Sealant 1:** 890-SL, manufactured by Dow Corning® (since changed to Dowsil™), is a one-component silicone joint sealant for pavements. It is a moisture-cure sealant and has a self-leveling consistency. It is an ultra-low modulus material that generally provided the best relative performance for AAS applications according to Brown (2009). The manufacturer's data sheet indicates that it develops a tensile stress of 31-kPa (19 psi) at 150% elongation measured in accordance with ASTM D412 (2016), an ultimate elongation of 1,000% measured in accordance with ASTM D412, and a durometer hardness of 41 (Shore OO scale) measured in accordance with ASTM C661 (2015). The manufacturer's data sheet states that the product meets or exceeds the requirements of ASTM D5893 (2010).

- **Sealant 2:** 888-NS, manufactured by Dow Corning® (since changed to Dowsil™), is a one-component silicone joint sealant for pavements. It is a moisture-cure sealant and has a non-sag consistency. It is a low-modulus material, and the manufacturer's data sheet indicates that it develops a tensile stress of 193-kPa (28 psi) at 150% elongation measured in accordance with ASTM D412, has an ultimate elongation of at least 1,000% measured in accordance with ASTM D412, and has a durometer hardness of 15 (Shore A-2 scale) measured in accordance with ASTM C661. The manufacturer's data sheet states that the product meets or exceeds the requirements of ASTM D5893.

- **Sealant 3:** 832-Multi Surface Adhesive Sealant, manufactured by Dow Corning® (since changed to Dowsil™), is a one-component silicone joint sealant. It is a moisture-cure sealant and has a non-sag consistency. It is designed to adhere to many substrate materials, including concrete and most plastics. The manufacturer's data sheet indicates that it has a tensile strength of 2.41-MPa (350 psi), an elongation of 420%, and a durometer hardness of 35 (Shore A scale). Details of the test methods were not provided but appeared to be similar to those of ultimate tensile strength and ultimate elongation by ASTM D412, as well as hardness by ASTM D2240.

- **Sealant 4:** Pourthane® SL, manufactured by W.R. Meadows®, is a one-component polyurethane joint sealant. It is a moisture-cure sealant and has a self-leveling consistency. According to the manufacturer's technical representative, it is similar to the discontinued Gardox® sealant referenced by Brown (2009). The

manufacturer's data sheet indicates that it has a modulus at failure greater than 600-kPa (87 psi) measured in accordance with ASTM D412, has an ultimate elongation greater than 800% measured in accordance with ASTM D412, and has a durometer hardness of 35 (Shore A scale) measured in accordance with ASTM D2240.

- **Sealant 5:** Roadsaver 231, manufactured by Crafco®, is a hot-applied, asphalt-based joint sealant. It is a thermoplastic material that has a self-leveling consistency at the application temperature of 193-204°C (380-400°F). It is a low-modulus material intended for very cold climates. The manufacturer's data sheet states that the product meets all requirements of ASTM D6690 (2012) Type IV.

2.3 Experimental treatments

2.3.1 Surface treatments

UHMWPE has a very low surface free energy that makes it difficult for other materials, such as sealants and adhesives, to adhere well (Zhang et al. 2010; Chaoting et al. 1993). A number of surface-treatment techniques have been developed in other industries to improve the bonding characteristics of UHMWPE. These include various plasma treatments (Zhang et al. 2010; Chaoting et al. 1993; Li et al. 1992; Teodoru et al. 2009), solvents (Gao and Mackley 1992), ultraviolet exposure (Lanfranconi et al. 2012), flame treatment (Lanfranconi et al. 2012), and abrasion (Lanfranconi et al. 2012). Plasma treatments and ultraviolet exposure were deemed impractical for the current project because they require specialized equipment and sophisticated treatment techniques that would be difficult to implement for a real-world military construction application. Solvent-based primers, flame treatment, and abrasion were selected for this study.

Various primer and adhesive products were examined in this study. Eight surface treatments were selected and applied to the UHMWPE panels to enhance the bonding of sealant to the plastic. These were three chemical surface primers, three adhesives, and two UHMWPE surface modifications. Details of each surface treatment method are provided below, and manufacturer's datasheets are located in Appendix B.

- **Primer 1:** PR-1204, manufactured by Dow Corning® (since changed to Dowsil™), is a silane-based liquid prime coat intended to improve

the adhesion of moisture-cure RTV silicone sealants to a variety of substrates. Manufacturer-provided datasheet indicates adhesion 180° peel strength of 45.5 N/cm² (66 ppi) on aluminum substrate.

- **Primer 2:** PR-1205, manufactured by Dow Corning® (since changed to Dowsil™), is a silane-based liquid prime coat intended to improve the adhesion of RTV silicone sealants to a variety of substrates. Manufacturer-provided datasheet indicates adhesion 180° peel strength of 23.4 N/cm² (34 ppi); substrate not specified.

- **Primer 3:** BONDiT™ A-43, manufactured by Reltek LLC, is a silane-based liquid primer intended to promote adhesion to a variety of materials such as cross-linked polyethylene, urethane, and silicone rubber. In addition to ambient temperature, the manufacturer also suggests using a thermal curing regime of 75°C for 15 min.

- **Adhesive 1:** Loctite® 3035, manufactured by Henkel Technologies, is a two-part acrylic adhesive for bonding low surface energy plastics.

- **Adhesive 2:** BONDiT™ B-45TH, manufactured by Reltek LLC, is a two-part epoxy adhesive intended for difficult-to-bond substrates and dissimilar materials, including low surface energy plastics such as UHMWPE.

- **Adhesive 3:** 300LSE, manufactured by 3M, is an acrylic adhesive provided as a two-sided transfer tape with a 5.2-mil thickness. It bonds to many substrates, including to low surface energy plastics.

- **Sanding:** Mechanical abrasion of the UHMWPE surface was done by using a belt sander with 50-grit sandpaper for about 1 min. This provided a roughened surface. Mechanical abrasion using a handheld angle grinder with a twisted wire cup brush was also tried, but it did not roughen the UHMWPE surface adequately and was not used further.

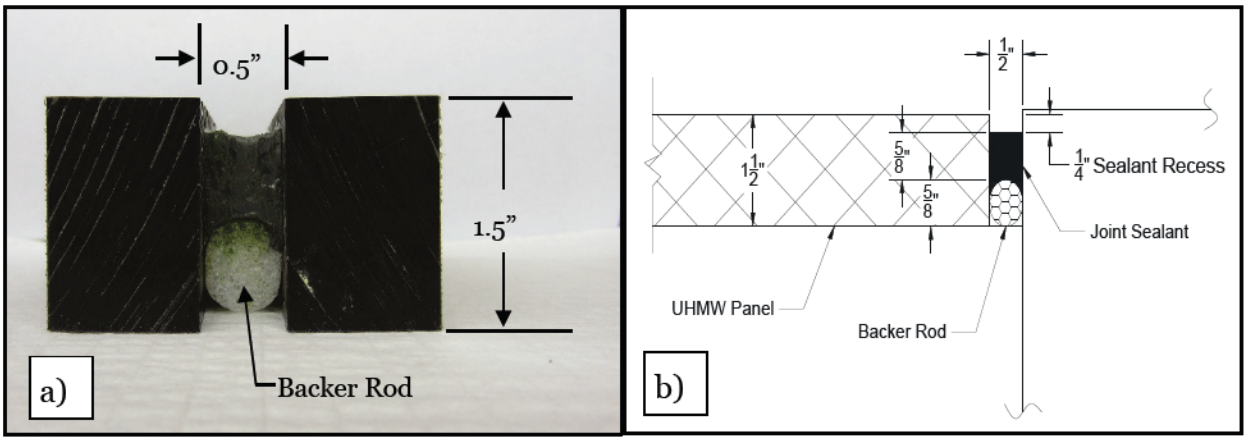
- **Flame:** Flame treatment of the UHMWPE surface was done by using a handheld propane torch (maximum flame temperature of 1,995°C). Heat was applied until the UHMWPE surface was slightly charred but not completely melted. Trial and error was required to find a technique of about 5 sec of heating until the plastic surface temperature was

about 160°C (320°F). For reference, the melting point of standard UHMWPE is about 138°C (280°F).

2.3.2 Panel-edge geometries

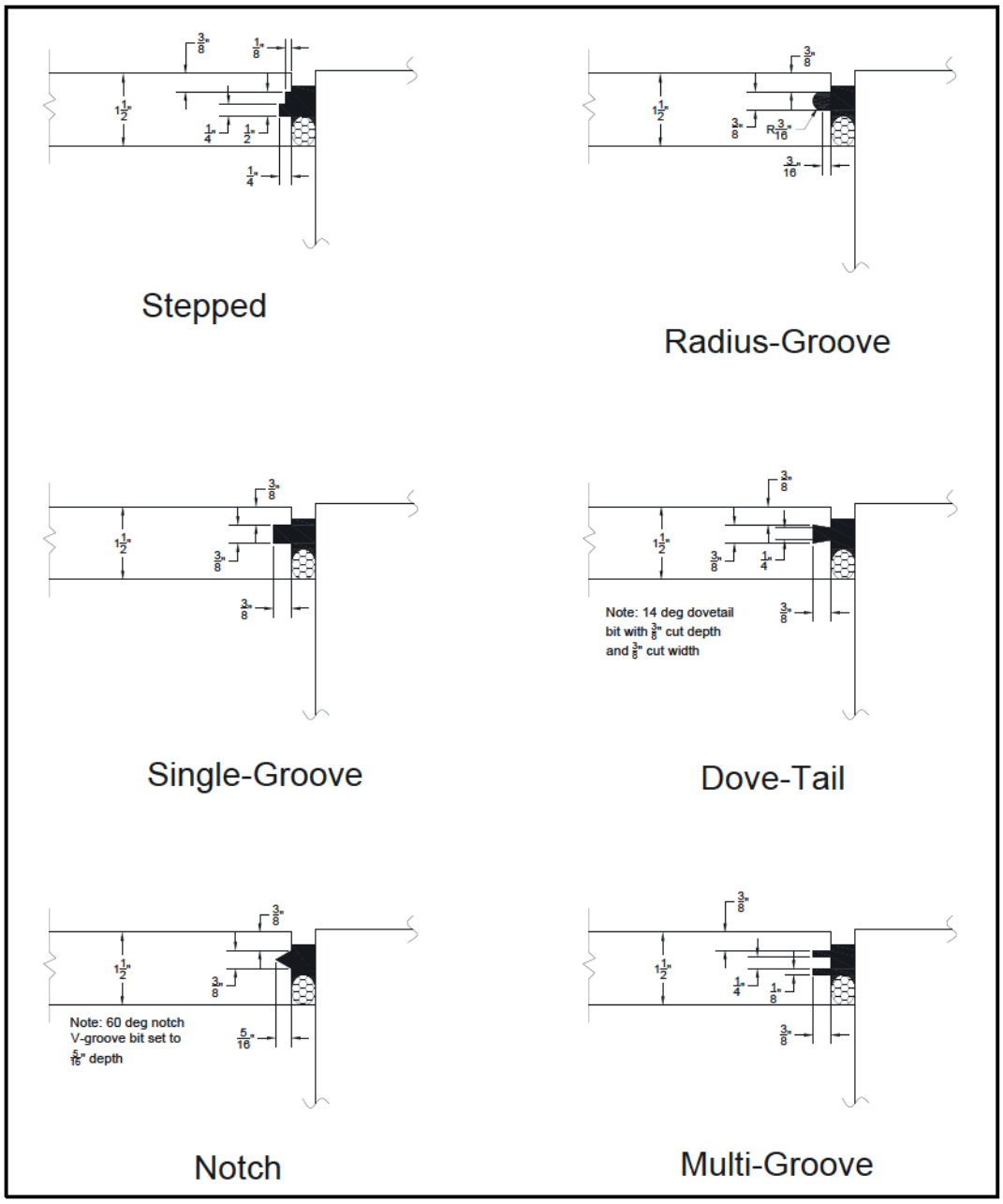
In total, seven panel-edge geometries were tested. All of these consisted of the standard joint configuration and either standard practice flat panel edges or one of six modified panel-edge geometries. Details of the standard joint configuration between a UHMWPE panel and adjacent pavement, according to the design dimensions of AFI 32-1043 (USAF 2012), are shown in Figure 3b. The same joint dimensions are used between adjacent UHMWPE panels with the exception of the slight elevation change between adjacent pavement and the UHMWPE panel. The UHMWPE panel edges are flat in this standard joint configuration.

Figure 3. UHMWPE panel-to-panel and panel-to-adjacent-pavement joint geometry.



An additional six panel-edge configurations were designed that maintained the overall joint dimensions while incorporating various keyway grooves into the UHMWPE panel edge. Dimensions of these configurations are provided in Figure 4. The goal was to provide greater surface area for adhesion of sealant to the UHMWPE and to also provide some additional mechanical interlock between the sealant and the panel edge when adhesive sealant failure starts to occur. Standard woodworking tools can be used to fabricate these edge shapes into UHMWPE. The ability to effectively construct and seal joints with edge shapes other than flat was further investigated as part of the field experiment.

Figure 4. Modified UHMWPE panel-edge geometries.



All shapes in Figure 4 are designed in such a way that the minimum thickness of UHMWPE above the groove is 9.5 mm (0.375 in.). The maximum depth of grooving is also 9.5 mm (0.375 in.). This results in a cantilevered segment of UHMWPE above the grooves that will be directly impacted by aircraft traffic. The peak stresses in this cantilevered segment were calculated via structural mechanics principles with the assumption of a worst-case loading condition of 2.24-MPa (325-psi) applied tire

pressure. Results are that the maximum stress condition in the UHMWPE is 6.72 MPa (975 psi) in both tension and compression.

2.4 Specimen preparation, test methods and experimental design

2.4.1 Sealant material properties

All sealant material testing is summarized in Table 2. Hardness testing was performed for all materials for information and compared to manufacturer's data. Flame-resistance testing was also performed for all materials to evaluate relative resistance to simulated jet blast. Cure evaluation was performed on Sealant 1 only. Testing parameters are described in the following paragraphs.

Table 2. Sealant material testing.

Sealant	Test Method		
	Hardness D 2240	Flame SS-S-200E	Cure Evaluation
1	X	X	X
2	X	X	Not tested
3	X	X	Not tested
4	X	X	Not tested
5	X	X	Not applicable

Hardness testing of samples of each sealant material was performed in accordance with ASTM D 2240-15 (2015) at standard laboratory temperature of 23°C. Two specimens of each material were tested, and five hardness determinations were made on each specimen for a total of ten measurements per sealant. Hardness data were used to calculate estimates of elastic modulus by using the procedure of Mix and Giacomin (2011).

Flame-resistance testing of all sealants was performed in accordance with Federal Specifications SS-S-200E (2009). This consists of exposure of the sealant to an open flame temperature of 260°C (500°F) for 120 sec. The material must "not show any evidence of ignition, support of combustion, hardening or loss of flexibility, flow, or separation during heat exposure, or upon examination after cooling, or any separation or loss of adhesive strength."

A small experiment was performed to evaluate potential effects of different material substrates on sealant curing rate. Specifically, bond test

specimens were prepared by using standard PCC substrates and UHMWPE substrates with moisture curing silicone Sealant 1. The level of sealant curing was evaluated in accordance with ASTM D5893-10 (2010) paragraph 9.1 at curing time periods of 7, 14, and 21 days.

2.4.2 Laboratory Phase 1

Phase 1 laboratory testing for bond strength consisted of preparing joint-sealant test specimens and subjecting them to the non-immersed bond test. For sealants 1 through 4, the bond test requirements of ASTM D5893-10 (2010) for silicone joint sealants were followed. For sealant 5, the bond test requirements of ASTM D6690-12 (2012), Type IV for hot-applied sealants were followed. Specimens of silicone and polyurethane sealants were cured at standard conditions for 21 days. Four replicate sealant specimens were then tested. For sealants 1 through 4, specimens were expected to pass five cycles of 100% extension at -29°C (-20°F) at a loading rate of 3.18 mm/hr (0.125 in./hr) followed by recompression (ASTM D5893-10). For sealant 5, specimens were expected to pass 3 cycles of 200% extension at the same temperature and loading rate followed by recompression (ASTM D6990-12, Type IV). Specimens are considered to pass if no crack, separation, or other opening in the sealant or between the sealant and the test blocks developed.

The test specimens varied from those required by ASTM D5893-10 and D6990-12 in that UHMWPE test blocks 25 mm by 38 mm by 76 mm (1.0 in. by 1.5 in. by 3.0 in.) were used instead of concrete test blocks, and the depth of sealant was that of the standard AAS panel joint geometry. A 15.9-mm (0.625-in.)-diam backer rod was used to create the correct depth of sealant, and the sealant was recessed approximately 3.2 mm (0.125 in.) below the surface of the test blocks. A completed test specimen is shown in Figure 3a. This specimen fabrication procedure was selected to replicate the joints between AAS panels. This was considered a worst case, based on the observation of Brown (2009) that most sealant failures in the field occurred from loss of adhesion of sealant to the UHMWPE. Additionally, a few specimens were fabricated by using one UHMWPE test block and one test block made of either PCC or asphalt. This was done to replicate the AAS panel to adjacent pavement joint.

If the specimens successfully passed five cycles of extension without complete separation, they were then tested to sealant rupture or adhesive failure by additional extension at a higher loading rate of 51 mm/min (2.0 in./min). Strain was measured with a non-contact camera system,

and load was recorded from the load-frame-equipment load cell. For this testing, an environmental chamber capable of maintaining -29°C (-20°F) was not available for the high extension load frame required to test the specimens to failure. Test specimens were preconditioned in a separate freezer, removed one at a time, immediately placed into the load frame, and tested to failure. The specimens warmed up somewhat during testing, but all specimens were handled the same way, making relative comparison of the results reasonable. In addition, the modulus of silicone sealant does not vary dramatically at the test temperatures used, which also makes relative comparison of the results a reasonable approach. For sealant 5, these conditions are not as reasonable; consequences of this are discussed in the results section of this report.

2.4.3 Laboratory Phase 2

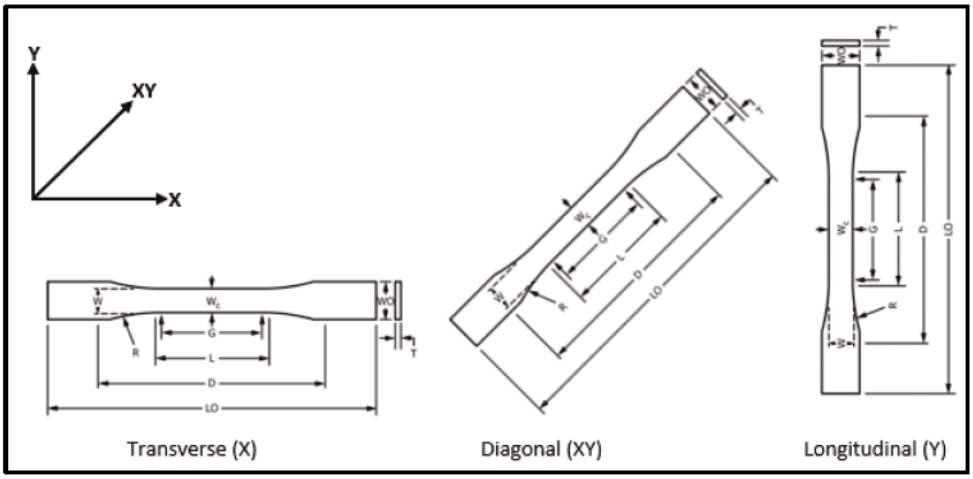
Phase 2 laboratory testing utilized the results of Phase 1 testing to select ten combinations of surface treatments and panel-edge configurations. These test specimens were prepared in the same fashion as for Phase 1 and cured at standard conditions for 21 days. Subsequently, four replicate specimens were tested to ultimate sealant rupture or adhesive failure in the same manner as for Phase 1. The non-immersed bond test was not performed on these specimens, as they all were anticipated to pass the requirement. Phase 2 test results were used to select four combinations of surface treatments and panel-edge configurations for field testing.

2.4.4 UHMWPE strength

For tensile strength testing of UHMWPE, dog-bone specimens were fabricated with a thickness of 3.2 mm (0.125 in.). Prior to testing, the Polystone® M was first milled down to 3.2 mm (0.125 in.) in order to be consistent with the other two samples. Specimens were cut from each of the three materials by using a waterjet, with specimens oriented in the transverse (X) direction, in the diagonal (XY) direction, and in the longitudinal (Y) direction, as shown in Figure 5. The longitudinal direction of the panels was parallel to the grooves along the length of the panels from their original processing. One important consideration is the roughness of the specimen surfaces and the effect that it can have on the tensile testing results. The surfaces of the tested specimens were not modified in any way. Testing was performed in accordance with ASTM D638-14 (2014); the rate of loading was 51 mm/min (2 in./min). Testing was conducted at the standard temperature of 23°C (73°F) using

specimen *Type I* dimensions listed in ASTM D638-14. Five replicate specimens were tested in the X, Y, and XY directions.

Figure 5. Specimen orientation (from ASTM D638 2014).



Further testing was conducted at an elevated temperature of 75°C (167°F) using specimen *Type V* dimensions listed in ASTM D638-14 (2014). Ten replicate specimens were tested in the Y direction for each material and an additional ten replicate specimens were tested in the X direction for the Tivar® UV Resistant.

The elevated test temperature was selected as follows. A standard panel of UHMWPE, 38 mm (1.5 in.) thick, was placed in the direct sunlight on a concrete parking area for several hours on a clear summer day (15 August in Vicksburg), and the temperature was measured periodically during the afternoon. Six measurements were made over a 45-min. period. The average air temperature was 35.4°C (95.7°F). The average surface temperature of the panel was 73.9°C (165°F). The bottom of the panel had an average temperature of 54.9°C (131°F). Assuming a linear temperature distribution in the panel, the mid-depth average temperature would be 64.5°C (148°F). In a desert climate at lower latitude (higher air temperature and more direct solar radiation), the panel mid-depth temperature will likely be somewhat higher than this. Also, the critical stress location in the grooved panels is within 9.5 mm (0.375 in.) of the panel surface. Therefore, a high-test temperature of 75°C (167°F) was selected as a near-worst-case summer temperature scenario for UHMWPE panels. For reference, the concrete parking area had an average surface temperature of 50.6°C (123°F). An asphalt specimen (dark black, unweathered surface) had an average surface temperature of 58.8°C (138°F).

3 Laboratory Results and Analysis

3.1 Sealant material properties

Results of ASTM D2240-15 (2015) hardness testing of sealants are presented in Table 3. Relative to the manufacturers' provided data, measured values for Sealant 1 were softer, measured values for Sealant 2 were considerably harder, and measured values for Sealant 3 and Sealant 4 were similar. Differences between measured data and manufacturers' data were not investigated further. A range of sealant properties from ultra-low modulus to moderately high modulus was observed. When a UHMW panel joint opens in cold temperatures, sealants with higher moduli create a higher stress at the surface, which can lead to greater likelihood of adhesive failure. Note that testing of Sealant 5 at room temperature provides a very different hardness than would be observed at lower temperature due to the high temperature dependence of asphalt-based sealant. It is anticipated that this material is several orders of magnitude harder at very low temperatures. Further, the modulus estimation procedure of Mix and Giacomin (2011) would not be appropriate to apply to this material.

Table 3. Sealant hardness testing results and modulus estimates.

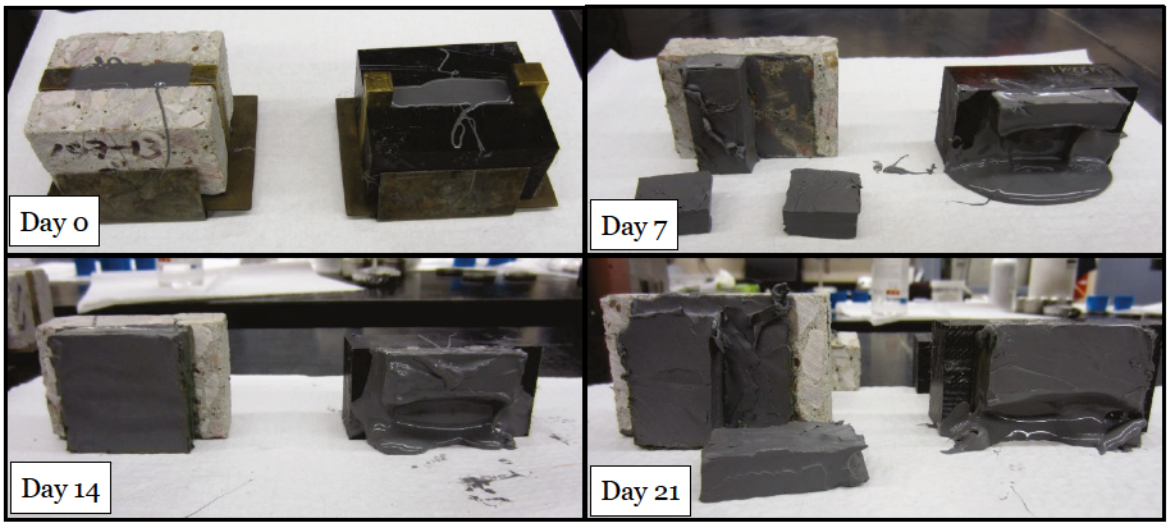
Product	Sealant 1	Sealant 2	Sealant 3	Sealant 4	Sealant 5
Durometer Type	00	A	A	A	00
Mean Hardness	27.8	38.3	31.8	30.5	29.9
Std. Dev.	0.900	1.40	3.14	1.54	1.46
COV	3.2%	3.7%	9.9%	5.1%	4.9%
Est. Modulus, kPa (psi)	96.5 (14.0)	2,110 (306)	1,634 (237)	1,551 (225)	—

Flame-resistance test results for each sealant were as follows. Sealants 1 through 4 exhibited no change upon exposure to flame. They all passed the SS-S-200E requirement. Sealant 5 exhibited melting and bubbling of the sealant and some separation at the surface exposed to the flame. This sealant did not pass the requirement of SS-S-200E. This is an expected result, since hot-applied, asphalt-based sealants are not intended for use in areas with exposure to jet-engine exhaust.

Results of the cure-evaluation experiment are presented in Figure 6. Sealant 1 on the PCC substrate was entirely cured at 14 days, while Sealant 1 on the

UHMWPE substrate was not fully cured even at 21 days. On the UHMWPE, the sealant cures from the top down, and the areas without access to the air do not cure as quickly. This result is likely due to lack of moisture in the UHMWPE and inability of moisture to migrate through the UHMWPE into contact with the sealant. This experiment indicates that curing of sealants on AAS panels is inhibited compared to normal behavior. Recall that Sealants 1 through 4 are all moisture-cure materials and would be affected by this; Sealant 5 is hot-applied and would not have an issue.

Figure 6. Sealant 1 cure evaluation with PCC and UHMWPE substrates.



3.2 Laboratory Phase 1

Test results for sealants alone with no surface treatment and the standard flat panel-edge configuration are presented in Table 4 and in Figure A1 to Figure A4 of the appendix. Comparing performances of silicone Sealants 1, 2, and 3 reveals that Sealant 1 completed five cycles with minimal separation, whereas the other sealants had complete or nearly complete separation after as little as one cycle. The failure mode was observed to be loss of adhesion to the UHMWPE in all failed specimens. This suggests that the higher modulus for Sealants 2 and 3, resulting in higher interface stress, results in greater failure of the joint sealant. Further testing of Sealants 2 and 3 was not conducted.

Table 4. Bond strength test results for sealants alone.

Sealant	Surface Treatment	Panel Edge	Non-Immersed Bond		Ultimate Failure	
			Cycles	Separation, %	Load, N (lbf)	Strain, %
1	None	Flat	5	10	128 (28.8)	754
1	None + Concrete	Flat	5	0	130 (29.1)	457
1	None + Asphalt	Flat	5	0	131 (29.5)	515
2	None	Flat	5	95-100	—[a]	—[a]
3	None	Flat	1	100	—[a]	—[a]
4	None	Flat	1	100	—[a]	—[a]
5	None	Flat	3	0	1,659 (373)	24.9
5	Concrete + Concrete	Flat	3	0	2,594 (583)	26.3
5	Concrete + Concrete	Flat	3	0	1,513 (340)[b]	26.2[b]

[a] Not tested

[b] Tested at 12.7-mm/min (0.5-in./min) loading rate.

Sealant 1 generally passed the non-immersed bond requirements and was tested to ultimate failure at the higher loading rate. For the all UHMWPE test blocks, the failure mode observed was adhesion loss (sealant pulling away from substrate) from the plastic for all specimens. For UHMWPE and concrete test blocks, adhesive failure from the concrete was observed for all specimens. For UHMWPE and asphalt concrete test blocks, adhesive failure from the asphalt concrete portion of the block occurred with 50% of the specimens and adhesive failure from the plastic occurred with the other 50% of the specimens. The load (interface stress) at failure was approximately the same for all combinations; however, the plastic-plastic test specimens failed at a higher strain level.

For Sealant 5, all specimens passed the non-immersed bond requirements at 200% elongation. Specimens were then tested to failure at the higher strain rate. This higher strain rate for an asphalt-based sealant will result in a higher effective modulus at the test temperature; however, a low temperature environmental chamber was not available for this load frame to perform slower speed tests. Cohesive failure of the sealant (tearing of sealant material while still adhered to substrate) was observed for the plastic test blocks. The application temperature for this sealant was 193°C (380°F); it is possible that the high heat improved the surface adhesion of the UHMWPE similarly to the flame surface treatment technique discovered in literature.

Specimens of Sealant 5 with concrete test blocks were tested at the 51-mm/min (2-in./min) rate and also at a lower 12.7-mm/min (0.5-in./min) rate. Interestingly, while the peak load was reduced by about 40% for the lower test speed, the failure strain was the same. Based on the high interface stresses and laboratory confirmation of the observation by Brown (2009) that hot-applied sealant did not perform well in the field at locations with large temperature variations, no further testing with Sealant 5 was conducted for this study.

After analysis of the performance of different sealant types, Sealant 1 with no surface treatment and the standard flat panel-edge configuration was selected as the control for this data set and all subsequent analysis. It is considered to be representative of the best-performing sealant combination observed in the field by Brown (2009). Any material-surface treatment-panel edge configuration would need to have greater performance than this control to be considered for additional testing.

Test data for combinations of sealants and surface treatments are provided in Table 5 and Figure A5 to Figure A10 of the appendix. Combining polyurethane Sealant 4 with Adhesives 1 through 3 and Primer 3 showed minimal improvement compared to Sealant 4 alone. None of the combinations passed the non-immersed bond requirements. No further testing with Sealant 4 was conducted in this study.

For Sealant 1 combinations, the performances of the material with Adhesives 1 and 2 applied were less than the control, and they were not tested any further. Adhesive 3 demonstrated better performance than the control with about 60% higher failure strain. It was selected for further testing in Phase 2.

Primer 1 performed better than the control with approximately 80% higher failure strain. It was selected for further testing in Phase 2. Primer 2 was not tested in Phase 1 but was added to Phase 2 part-way through the project, so no test data are available. Primer 3 performed similarly to the control. Primer 3 with a heat-curing regime recommended by the manufacturer did not perform well. Primer 3 combined with the flame surface treatment did not perform as well as the control. No further testing was conducted for Primer 3.

Table 5. Bond strength test results for sealants and surface treatments.

Sealant	Surface Treatment	Panel Edge	Non-Immersed Bond		Ultimate Failure		Treatment/ Control (Strain%)
			Cycles	Separation, %	Load, N (lbf)	Strain, %	
1	None	Flat	5	10	128 (28.8)	754	1.00
1	Adhesive 1	Flat	5	95	—[a]	—[a]	—[a]
1	Adhesive 2	Flat	1	100	—[a]	—[a]	—[a]
1	Adhesive 3	Flat	5	0	202 (45.4)	1221	1.62
1	Primer 1	Flat	5	0	223 (50.2)	1381	1.83
1	Primer 2	Flat	—[a]	—[a]	—[a]	—[a]	—[a]
1	Primer 3	Flat	5	0	110 (24.8)	713	0.95
1	Primer 3 + Heat Cure	Flat	5	60-90	—[a]	—[a]	—[a]
1	Primer 3 + Flame	Flat	5	0	68.5 (15.4)	357	0.47
1	Sanded	Flat	5	0	157 (35.3)	950	1.26
1	Flame	Flat	5	0	100 (22.5)	445	0.59
4	Adhesive 1	Flat	3	100	—[a]	—[a]	—[a]
4	Adhesive 2	Flat	1	100	—[a]	—[a]	—[a]
4	Adhesive 3	Flat	1	100	—[a]	—[a]	—[a]
4	Primer 3	Flat	5	80-100	—[a]	—[a]	—[a]

[a] Not tested

Sanding with 50-grit sandpaper of the UHMWPE panel surface improved the performance of Sealant 1 in terms of failure strain by about 25%. This technique was selected for further evaluation in Phase 2 since it could easily be combined with other surface treatments or panel-edge configurations. The flame surface treatment did not improve on the performance of the control, and no further testing was done with this technique.

Test data for Sealant 1 and panel-edge geometries are provided in Table 6 and in Figure A11 to Figure A16 of the appendix. Of the six panel-edge configurations tested, stepped, radius, notch, and multi-groove did not improve on the performance of the control. The single groove and dovetail groove both provided an improvement over the control in ultimate failure strain. During testing it was observed that failure of these specimens occurred incrementally. At around 400 to 500% strain, the sealant began to lose adhesion on the surface adjacent to the groove while the sealant remained bonded to the UHMW within the groove. Final failure occurred at a much higher strain than the initial loss of

adhesion. For some of the dovetail specimens, cohesive failure of the sealant actually occurred instead of the adhesion failure observed in all other test specimens. This difference indicates that these panel-edge configurations provide some positive mechanical interlock to the sealant that was not observed with the other groove types. Dovetail and single groove panel-edge geometries were selected for further testing.

Table 6. Bond strength test results for Sealant 1 and panel-edge geometries.

Sealant	Surface Treatment	Panel Edge	Non-Immersed Bond		Ultimate Failure		Treatment / Control (Strain%)
			Cycles	Separation, %	Load, N (lbf)	Strain, %	
1	None	Flat	5	10	128 (28.8)	754	1.00
1	None	Stepped	5	0	88.9 (20.0)	291	0.39
1	None	Radius	5	0	98.8 (22.2)	410	0.54
1	None	Single	5	0	107 (24.0)	990	1.31
1	None	Dovetail	5	0	95.1 (21.4)	1356	1.80
1	None	Notch	5	0	23.9 (5.4)	319	0.42
1	None	Multi	5	0	104 (23.3)	536	0.71

3.3 Laboratory Phase 2

Phase 2 test results are presented in Table 7 and Figure A17 to Figure A26 of the appendix. Sealant 1 with no surface treatment and the standard flat panel-edge configuration was considered the control to which other treatment combinations would be compared. The ultimate strain for control specimens tested in Phase 2 (762%) was very close to that for specimens tested in Phase 1 (754%), which indicated repeatability of results for this test method.

Table 7. Phase 2 bond strength test results.

Sealant	Surface Treatment	Panel Edge	Ultimate Failure		Treatment/ Control (Strain%)
			Load, N (lbf)	Strain, %	
1	None	Flat	113 (25.5)	762	1.00
1	Sanded	Single Groove	103 (23.2)	1105	1.45
1	Sanded	Dovetail	110 (24.8)	936	1.23
1	Adhesive 3	Flat	160 (36.0)	1068	1.40
1	Primer 1	Flat	184 (41.3)	1351	1.77
1	Primer 1 + Sanded	Flat	166 (37.1)	1281	1.68
1	Primer 1 + Sanded	Single Groove	108 (24.4)	1321	1.73
1	Primer 1 +Sanded	Dovetail	144 (32.4)	1254	1.65
1	Primer 2	Flat	119 (26.8)	805	1.06
1	Primer 2+ Sanded	Dovetail	94.6 (21.2)	850	1.12

Use of the single and dovetail grooves in combination with surface sanding (outside of the groove on the vertical face of plastic) had mixed results compared to Phase 1 (Table 6): for single groove the performance was improved, but for dovetail groove the performance was reduced. This was an unexpected result. Single groove outperformed dovetail groove, the opposite ranking as Phase 1.

Adhesive 3 with the flat edge demonstrated an improvement to the control and somewhat reduced performance of the test specimens compared to this combination in Phase 1 data (Table 5).

Primer 1 with a flat surface was much better than the control -- about 77% improvement -- and was also similar to Phase 1 results (Table 5); Primer 1 plus sanding of the surface slightly decreased failure load and strain but did not produce a large change in performance. Primer 1 combined with edge grooving (single and dovetail) and surface sanding demonstrated similar performance to Primer 1 on a flat edge (sanded or un-sanded). The use of Primer 1 with single and dovetail grooves improved performance compared to grooves alone (for all for sanded surfaces). However, the use of grooves did not improve performance compared to Primer 1 alone (with or without sanding).

Primer 2 was added to the project at this stage, as it was a similar silane-based material to Primer 1, both from the same manufacturer. It

performed similarly to the control with a flat edge and worse with combined dovetail groove and surface sanding. Primer 2 did not offer any useful improvements to performance, and no further testing was conducted with it. The results suggest that merely being a silane-based primer is not adequate to ensure better performance. The exact combination of primer and sealant should be tested to verify performance.

The use of Primer 1 in combination with edge grooving without surface sanding was not tested; it could conceivably offer some performance gains as a "belt and suspenders" approach. However, as discussed previously, the failure mode for dovetail grooving actually begins to transition from adhesive failure to a cohesive failure of the sealant. In other words, the sealant tears before pulling away from the plastic. In Phase 1 results, dovetail grooving without primer (Table 6) had an ultimate failure strain of 80% higher than the control, while Primer 1 without grooving (Table 5) had a similar ultimate failure strain of 83% higher than the control. In Phase 2 results (Table 7), use of Primer 1 improved performance of the grooves, but sanding inhibited them. Viewed the other way, the use of grooves did not noticeably change the performance of Primer 1. To summarize, use of Primer 1 in addition to single or dovetail grooves is likely redundant since sealant strength becomes the controlling factor and not adhesion to the UHMWPW surface. Either Primer 1 or edge grooving improves adhesive performance, but a change in failure mode to sealant cohesive failure prevents the combination from offering any additional improvement.

Four combinations were selected for field testing. As discussed previously, combinations of Primer 1 and edge grooving were not expected to provide any improvement over those treatments on their own and were not used in field testing. Based on Phase 1 results (Table 6), dovetail groove was selected instead of single groove. Figure 7 through Figure 10 provide plots of load versus strain for tested specimens of the selected combinations, which were

- Sealant 1 with no surface treatment and flat edge (control),
- Sealant 1 with Primer 1 and flat edge,
- Sealant 1 with Adhesive 3 and flat edge, and
- Sealant 1 with no surface treatment and dovetail groove.

The use of Primer 1 (Figure 8) is seen to increase both failure load and failure strain relative to the control (Figure 7) with the same general shape of the graph. For the control, the average failure point was 113 N

(25.5 lbf) at 762% strain. For Primer 1 at 762% strain, the average load was 110 N (24.8 lbf), which is very similar to the control failure point. This indicates that Primer 1 is effective at promoting adhesion of Sealant 1 to low surface free energy UHMWPE.

Adhesive 3 (Figure 9) also increases failure strain relative to the control, but the shape of the graph indicates the mechanism may be different from Primer 1. There is an initial peak in stress, average of 138 N (31.0 lbf), at very low strain, average of 26.4%, followed by a reduction in load to about 67 N (15 lbf), followed by a large accumulation of strain before ultimate failure at an average load of 160 N (36.0 lbf) and average strain of 1,068%. The reason for this initial peak is not clear, but in general, the data indicate that Adhesive 3 creates a strong bond to the UHMW panel and can also be adhered to by the sealant.

The dovetail groove (Figure 10) shows two distinct peaks. The first occurs at an average load of 96.2 N (21.6 lbf) at an average strain of 494%. This corresponds to adhesive failure of the sealant on the surface of the plastic adjacent to the groove. Only the sealant inside the groove remains attached, reducing the contact area and consequently reducing the measured load to an average of 47.4 N (10.6 lbf) at an average strain of 618%. Final failure occurred at an average load of 95.1 N (21.4 lbf) and average strain of 1,356%. Test specimen 2 was observed to fail by tearing of the sealant at the narrow entrance to the dovetail groove; a gradual reduction in load at the end of the test is apparent in Figure 10. The other test specimens exhibited sealant pulling out of the dovetail groove intact; a sudden reduction in load at the end of the test is visible in Figure 10.

Figure 7. Load-strain plot for Sealant 1, no surface treatment and flat edge.

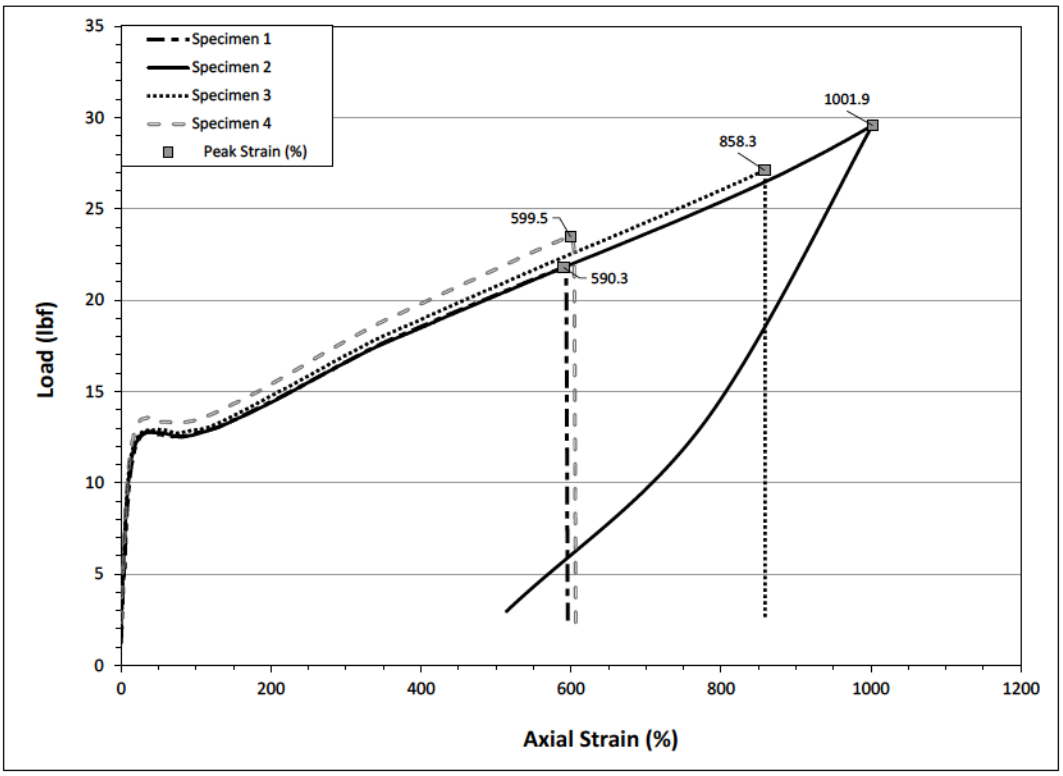


Figure 8. Load-strain plot for Sealant 1, Primer 1, and flat edge.

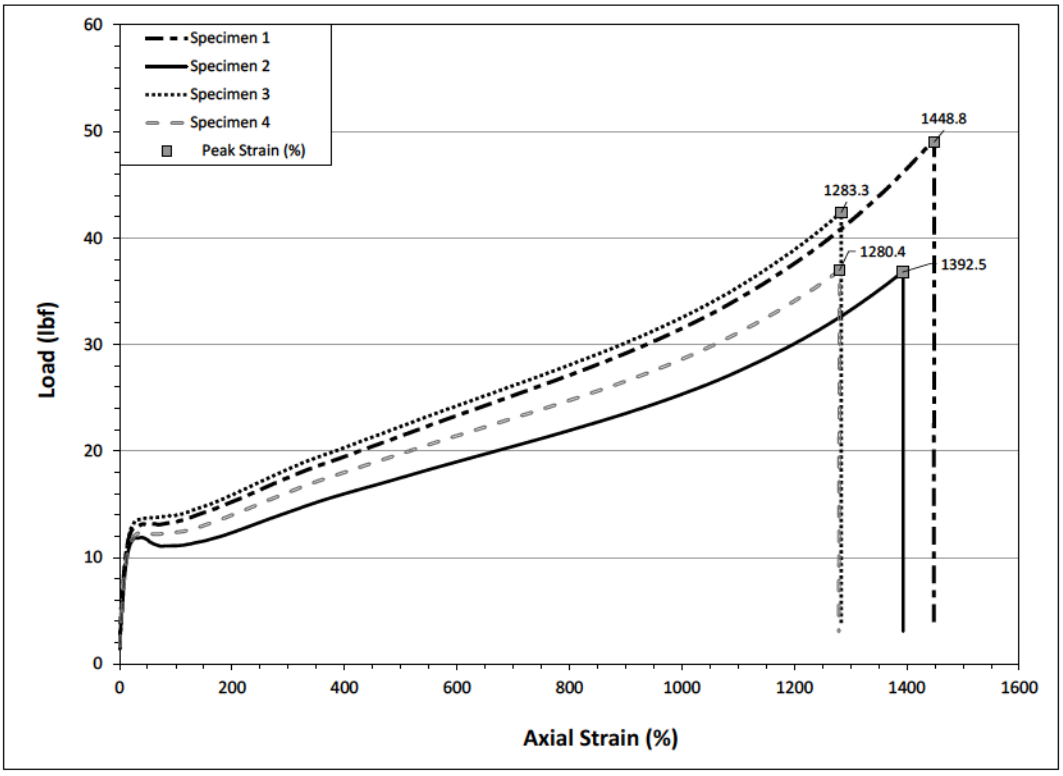


Figure 9. Load-strain plot for Sealant 1, Adhesive 3, and flat edge.

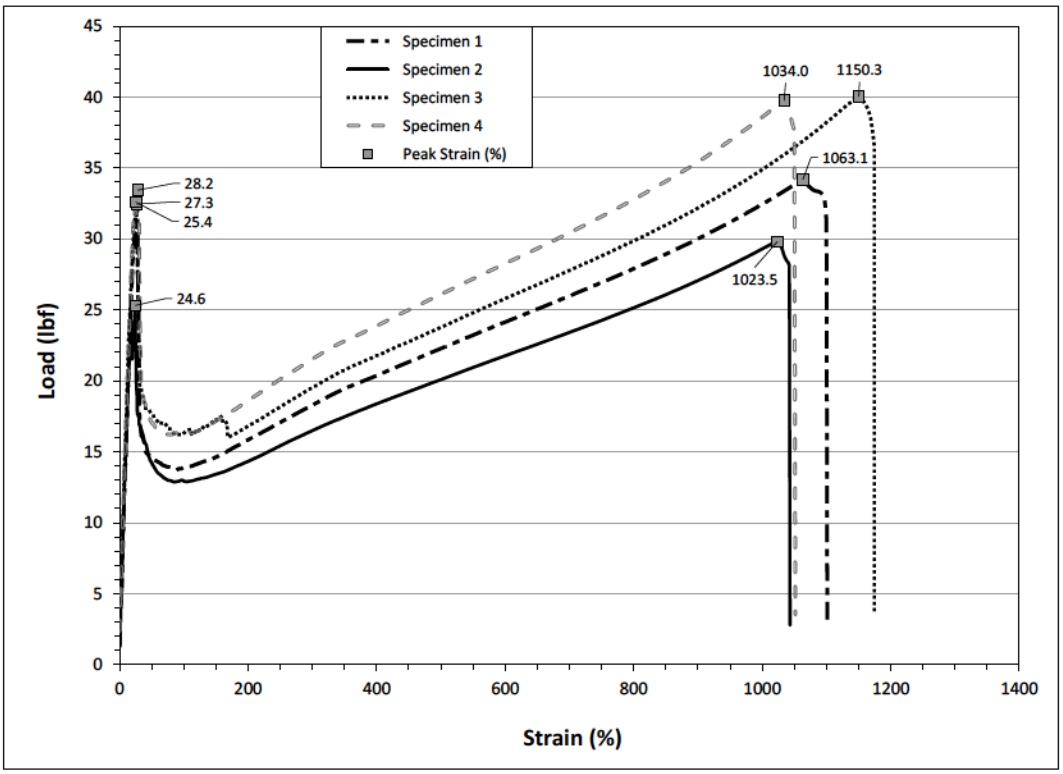
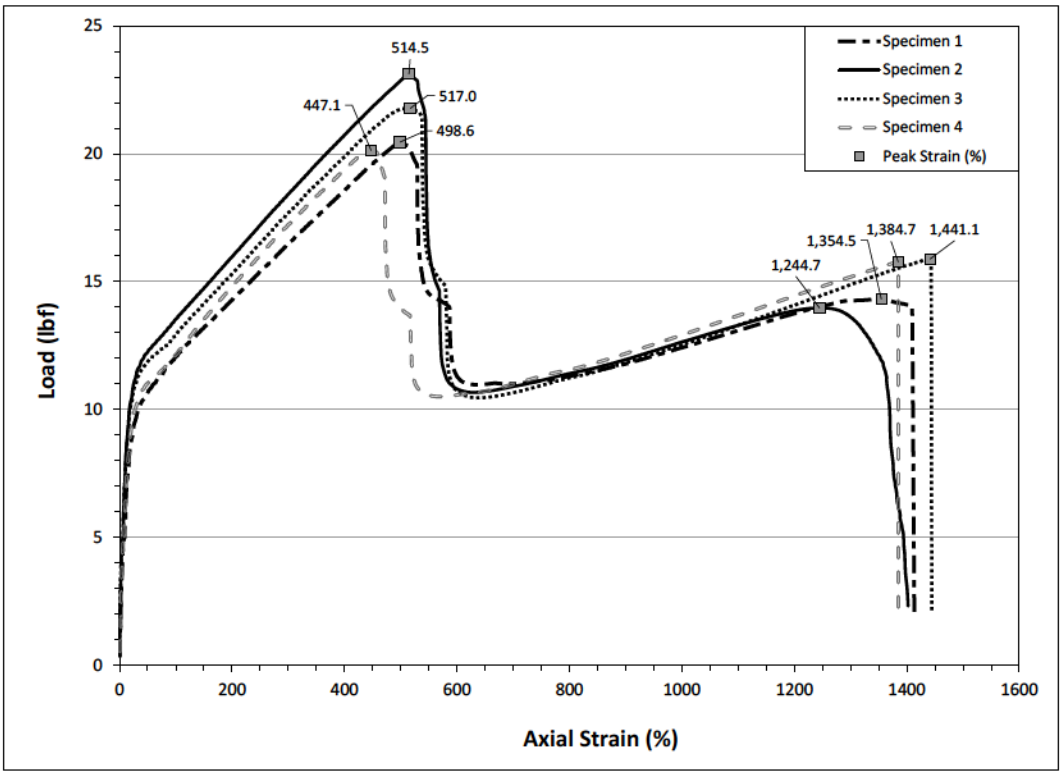


Figure 10. Load-strain plot for Sealant 1, no surface treatment and dovetail edge.



3.4 UHMWPE strength

Specimens of UHMWPE were tested for tensile strength; raw data are located in Table A1 to Table A6 of the Appendix. A summary of the 23°C test data is provided in Table 8, where each value is the average of five replicate test specimens. All of the yield-strength values meet the requirements of AF 32-1043 (USAF 2012; Table 1). However, all of the tensile elongation at break values are lower than the Table 1 requirement of 300-400%. The specimens oriented in the X direction revealed the highest strengths for all three materials, while the specimens oriented in the Y direction (extrusion direction) showed the weakest strengths for all three materials. Additionally, Tivar® UV Resistant was the strongest of the three, with Polystone® M UV Stabilized and Polyslick® UV Stabilized being the second and third strongest, respectively.

Table 8. Summary of UHMWPE testing at 23 °C.

Material	Direc-tion	Modulus MPa (ksi)	Yield MPa (psi)	Ultimate Fracture	
				MPa (psi)	Strain (%)
Tivar®	X	772 (112)	24.8 (3602)	32.4 (4703)	237
	XY	683 (99.1)	23.2 (3362)	30.5 (4417)	234
	Y	530 (76.8)	21.3 (3083)	27.3 (3966)	225
Polystone®	X	630 (91.4)	23.2 (3365)	33.3 (4832)	216
	XY	519 (75.2)	21.2 (3077)	28.2 (4088)	218
	Y	485 (70.3)	20.6 (2982)	27.4 (3974)	188
Polyslick®	X	529 (76.7)	22.6 (3283)	29.0 (4201)	197
	XY	403 (58.4)	20.8 (3020)	27.0 (3917)	219
	Y	379 (54.9)	20.3 (2942)	26.0 (3768)	220

Statistical analysis of the 23°C test data was performed by using an analysis of variance (ANOVA) technique. The experimental treatment factors were material type and specimen direction. The response variables were modulus of elasticity, yield strength, ultimate strength, and elongation at ultimate strength. A generalized linear model was fit to the data. The results for modulus of elasticity, ultimate strength, and elongation were inconclusive, since either the interaction terms (material type with specimen direction) were statistically significant or the quality of the statistical model was poor. For yield strength, the ANOVA results are presented in Table 9; the adjusted R^2 for the model

was 78%. The results indicate that the interaction term is not statistically significant, while both material type and specimen direction were statistically significant at the 95% confidence level.

Table 9. Statistical ANOVA summary for yield strength at 23 °C.

Source	df	Adj. SS	Adj. MS	F-value	P-value
Material	2	590,842	295,421	24.16	<0.000
Direction	2	1,320,744	660,372	54.00	<0.000
Mat. * Dir.	4	71,824	17,956	1.47	0.232
Error	36	440,287	12,230		
Total	44	2,423,698			

Fisher least significant difference (LSD) and Tukey multiple comparison procedures at the 95% confidence level were applied to the statistical model of the data; results are presented in Table 10 and Table 11. For material type, the Tivar ® material was found to be statistically stronger than the other materials, which were not significantly different (Table 10).

For specimen direction (Table 11), each direction is statistically significantly different from the others. This indicates that UHMWPE is anisotropic and significantly weaker in the direction that the material is extruded during manufacturing (Y-direction). The implications of this are that the specification for AAS panel materials should be modified to specify a direction of tensile strength testing. The conservative course of action would be to specify a test direction parallel to that which the material extruded during manufacturing.

Table 10. Multiple comparison procedure results, 23 °C yield strength for material.

Material	N	Mean	Tukey			Fisher LSD		
Tivar®	15	3,349	A			A		
Polystone®	15	3,141		B			B	
Polyslick®	15	3,082		B			B	

Note: Means with different letters are significantly different.

Table 11. Multiple comparison procedure results, 23°C yield strength for direction.

Direction	N	Mean	Tukey			Fisher LSD		
X	15	3,417	A			A		
XY	15	3,153		B			B	
Y	15	3,002			C			C

Note: Means with different letters are significantly different.

A summary of the 75°C test data is provided in Table 12, where each value is the average of ten replicate test specimens. Due to testing equipment constraints, the specimens could not be tested to ultimate fracture. Based on the identical average yield strength results for the Tivar® material, material direction is not an important factor at elevated temperature.

Table 12. Summary of UHMWPE testing at 75°C.

Material	Direc-tion	Modulus MPa (ksi)	Yield MPa (psi)	Ultimate Fracture	
				MPa (psi)	Strain (%)
Tivar®	Y	99.9 (14.8)	7.65 (1109)	---[a]	---[a]
	X	108 (15.7)	7.65 (1109)	---[a]	---[a]
Polystone®	Y	122 (17.8)	7.94 (1151)	---[a]	---[a]
Polyslick®	Y	78.6 (11.4)	7.31 (1060)	---[a]	---[a]

[a]Not tested due to equipment limitations.

Statistical analysis of the 75°C test data in the y-direction was performed using an ANOVA in which the experimental treatment factor was material type and the response variable was yield strength. A generalized linear model was fit to the data, and results are presented in Table 13; the adjusted R^2 for the model was 65%. The results indicate that material type was statistically significant at the 95% confidence level.

Table 13. Statistical ANOVA summary for yield strength at 75°C.

Source	df	Adj. SS	Adj. MS	F-value	P-value
Material	2	41,212	20,606	27.96	<0.000
Error	27	19,895	736.8		
Total	29	61,107			

Fisher LSD and Tukey multiple comparison procedures at the 95% confidence level were applied to the statistical model of the data; results are presented in Table 14. Each material had a significantly different strength from the others. In this case, Tivar® was in the middle of the results compared to being the strongest material when tested at room temperature. For all the UHMWPE materials tested, the reduction in tensile yield strength at 75°C compared to 23°C was 61-64%.

Table 14. Multiple comparison procedure results, 75 °C yield strength for material.

Material	N	Mean	Tukey			Fisher LSD		
Tivar®	10	1,109		B			B	
Polystone®	10	1,151	A			A		
Polyslick®	10	1,060			C			C

Note: Means with different letters are significantly different.

3.5 Panel-edge geometry analysis

For the modified panel-edge geometries, such as dovetail groove, there is concern that the overhanging plastic between the slot and the panel surface could be damaged by aircraft during use. The required material strength in this location is a function of the applied load and the panel groove geometry. An applied load of 2.24 MPa (325 psi) was assumed as a worst-case scenario for fighter aircraft tire pressure. For the worst-case panel-edge geometries tested in this study (Figure 4) of dovetail, single-groove, and multi-groove, the minimum depth of material above the grooves was 9.5 mm (0.375 in.), and the depth of grooves was 9.5 mm (0.375 in.). This overhanging plastic can be treated as a cantilever beam for structural analysis with length and depth of 9.5 mm (0.375 in.). The maximum shear stress for this situation is calculated to be 3.36 MPa (488 psi), and the maximum tensile bending stress is calculated to be 6.72 MPa (975 psi).

For UHMWPE, the service temperature range for arresting system panels is well above the material's glass transition temperature (-120 to -150°C depending on the degree of cross-linking), below which brittle failure would be a problem. On the other hand, strength of UHMWPE is reduced at elevated temperatures as can occur in hot climates. The black color of UV stabilized UHMWPE can result in material temperatures much higher than ambient air temperatures. As described in Section 2.4, measurements of material temperature on a summer day showed material temperatures of 65°C in direct sun. As described in Section 3.4,

tensile strength testing of UHMWPE was performed at 75°C, and the weakest material had a yield strength of 7.31 MPa (1060 psi). Based on ten test replicates, the standard deviation of this measurement is 0.110 MPa (16.0 psi); this indicates that the average measured tensile yield strength at conservative worst-case field conditions is more than five standard deviations higher than the calculated maximum tensile stress for this geometry. This could also be considered in terms of safety factor (S.F.), where S.F. for this scenario would be 7.31/6.72 MPa (1060/975 psi) = 1.09 for UHMWPE yield strength. However, the ultimate fracture stress of UHMWPE is some higher value than the yield stress, providing an additional margin of safety in the design calculation. Therefore, research concludes that failure of the overhanging plastic on grooved panel-edge configurations is unlikely to occur in service, provided that the groove geometry is properly constructed.

4 Field Installation and Monitoring

4.1 AAS panel system construction

A segment of AAS sacrificial panel system was constructed at the ERDC outdoor pavement test facility on pre-existing PCC slabs. The slabs were 4.6 m (15 ft) wide and 33 cm (13 in.) thick and had been in place for several years at the time of AAS panel system construction. Mixture properties were not readily available, but the material would generally meet requirements for airfield concrete, as they were originally constructed for a structural test of airfield pavement. UHMWPE panels were installed in four slabs for a total distance of 18.3 m (60 ft). This was done in two segments to fit the test area into the available space.

Figure 11 demonstrates the process used to construct the segment of AAS sacrificial panels. Installation followed the guidance of AFI 32-1043, Attachment 8 (USAF 2012) with a few exceptions as follows (additional details are available in Bly 2020). Anchor studs were made from standard threaded rod cut to length instead of the Hilti® anchors. Also, the pre-packaged Hilti® adhesive anchor capsule system was not readily available, so a different adhesive anchoring material, the Powers® AC100+ Gold® two-component adhesive anchoring system, was substituted. Finally, a standard eye-bolt was used for cable tie-down points (one tie-down point was installed per slab) instead of the custom-fabricated anchor-point hardware required by the AFI. Since this AAS system would not receive aircraft traffic or actual use, these small variations in installation are not thought to impact the results of this experiment.

During construction, temperature changes causing panel expansion created problems with aligning the panels prior to drilling anchor bolt locations and with installing the panels. During hot afternoon temperatures, panels could not be installed on anchor points that were located and installed during cooler morning temperatures. To overcome this, temperature variation of the panels was minimized by working between sunrise and the sun's first appearing over the trees and falling onto the construction area.

Figure 11. AAS panel installation procedure.



4.2 Sealant installation

Once the panel slot construction was complete, sealant installation could proceed. Based on the laboratory test results, Sealant 1 in combination with four joint configurations was selected for field testing. The combinations

were a control of no surface treatment and flat edge, Primer 1 with flat edge, Adhesive 3 with flat edge, and no surface treatment with dovetail groove edge. No surface sanding was utilized for any of these combinations. Each of the four PCC slabs was considered a test area for one of the four joint configurations to be tested. Each PCC slab had four UHMWPE panels, resulting in 9.1 m (30 ft) of panel to adjacent concrete joint on the long edges, and 1.8 m (6 ft) of panel-to-panel joint in three segments.

The installation procedure is shown in Figure 12. Primer 1 and Adhesive 3 were applied to the panel edges prior to final installation and bolt down. A closed-cell foam backer rod was installed into the joints (Figure 12c) followed by joint sealant (Figure 12d). During sealant installation, the weather was partly cloudy to slightly overcast, and air temperatures ranged about 24-29°C (75-85°F). Construction feasibility observations for each joint configuration are as follows. The control section of Sealant 1 with no surface preparation and a flat panel edge was easy to build and apply joint sealant, and no issues were noted.

Primer 1 was applied to the edge of UHMWPE panels by using a clean cloth and allowed to dry before the final anchoring of the panels. Primer 1 was easy to use, and no issues were encountered during application; it dries to the touch quickly and does not leave a sticky residue to collect dust. Joint sealant was applied in the same manner as the control section, and no issues were noted.

Adhesive 3 was also applied to the edge of UHMWPE panels before final anchoring of the panels. Double-sided tape was applied to the panel edge and the layer of paper backing was left in place, then removed just prior to installation of the sealant (Figure 12a). Adhesive 3 was somewhat difficult to install. If the paper was removed first, the backer rod would become stuck at the top of the joint and could not be inserted full depth without disrupting the adhesive. However, if the paper tape was left in place, the backer rod was wedged tight enough into the joint that the paper backing could not be removed effectively. The solution to this problem was to cut through the paper-backing tape at the bottom of the panel (Figure 12b). This narrow strip of paper was removed, the panels were bolted down, and the backer rod was inserted immediately to full depth. The paper tape at the top of the joint was left in place until just prior to sealant installation. After the paper tape was removed, the sticky surface attracted dust, which may have resulted in contamination before

the sealant could be placed. Joint sealant was applied in the same manner as the control section, and no issues were noted.

Figure 12. Sealant installation procedure.



Dovetail grooving was cut into the edges of UHMWPE panels by using a handheld router with an appropriate cutting bit before final installation of the panels. Applying the joint sealant required a modification to the

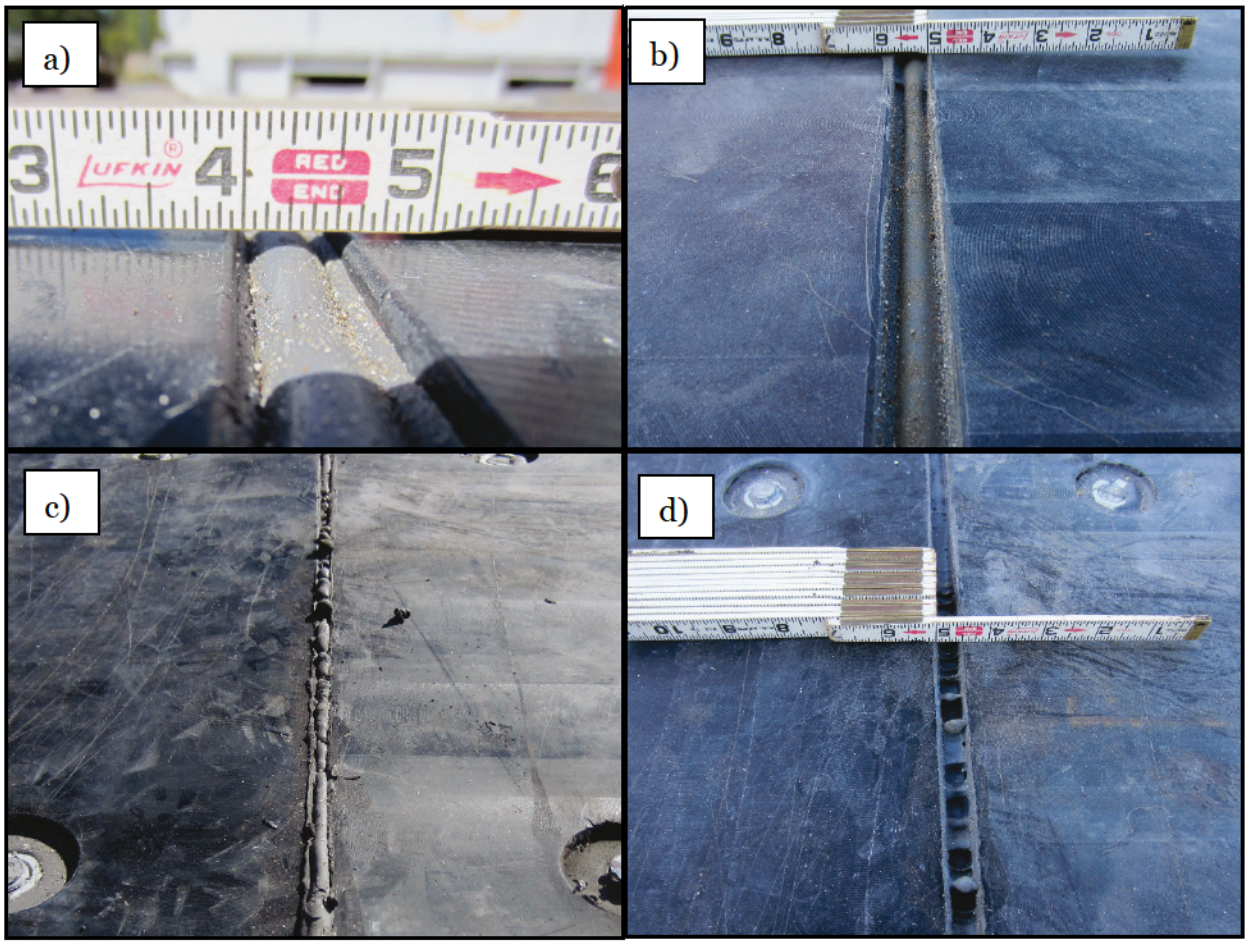
normal technique, as it took some time for the self-leveling sealant to flow horizontally and enter the dovetail recess properly. It was necessary to partially fill the joint in an area (Figure 12e), and then return two or three more times to apply additional sealant before the surface skinned over (Figure 12f). It was possible to fill the dovetail groove effectively, but the sealant application process was slowed down considerably compared to that of the control. Approximately 30-50% more sealant was used for this section than for the others with a flat panel edge. This is reasonable, since calculation of the sealant reservoir cross-sectional area (Figure 4) indicates approximately 40% more sealant would be needed per unit length of joint reservoir for dovetail compared to flat configuration.

4.3 Observations during 21-day sealant curing period

After sealant was installed, observations were made periodically during the 21 days following. This is the standard time period to ensure full cure for silicone sealants and, in most cases, full cure happens in less time. However, the laboratory cure-evaluation results (Figure 6) suggest that sealant in a UHMWPE joint may not cure as quickly as would normally be expected. Figure 13a shows a close-up of the sealant in a panel-to-panel joint five days after sealant installation. The sealant has a domed shape in the middle of the joint. It is hypothesized that this is due to the panel joint closing during a warm day soon after the sealant was installed and skinned over but while the sealant was still partially uncured liquid underneath the surface. The sealant is not fully cured through due to a lack of moisture in the plastic panel that is required to cure the sealant. Figure 13b shows this same domed sealant phenomenon on a cool morning seven days after sealant installation. The joint opening is wider at this time, but the sealant dome is still visible, suggesting that the dome is a permanent shape of the sealant. This causes some extra tension at the top of the sealant-panel interface. There appears to be a little bit of strain in the sealant even when the joint is at its normal 12.7-mm (0.5-in.) opening width.

Adhesive 3 began to show deterioration of the joint very soon after installation. Figure 13c shows a panel-to-panel joint on a warm afternoon six days after sealant installation. The sealant is squishing out of the joint and appears damaged. Figure 13d shows the same joint on the following morning (seven days after sealant installation). The areas where sealant was squishing out of the joint show voids in the sealant. This significant early deterioration was not observed with any of the other joint configurations.

Figure 13. Observations during 21-day sealant curing period.



On day 21 after sealant installation, an overall inspection was made of each joint configuration. Observations were as follows.

Control Section

- Panel-to-concrete joints looked good overall.
- Panel-to-panel joints looked good overall; some sealant was domed.

Primer 1 Section

- Panel-to-concrete joints looked good overall.
- Panel-to-panel joints looked good overall; some sealant was domed.

Adhesive 3 Section

- Panel-to-concrete joints looked good overall.
- Two of the three panel-to-panel joint segments had noticeable early deterioration. The third had some domed sealant.

Dovetail Section

- Panel-to-concrete joints looked good overall.
- Panel-to-panel joints looked good overall; some sealant was domed.

4.4 Observations 1 yr after sealant curing

An inspection was made approximately 1 yr after the sealant curing period was complete (409 days after sealant installation). Observations were as follows.

Control Section

- Panel-to-concrete joints looked good overall.
- One of the panel-to-panel joint segments was partially deteriorated by cohesive tearing in the sealant at the surface, but sealant was not completely separated. This was in an area where the sealant was domed. The other two segments looked good overall.

Primer 1 Section

- Panel-to-concrete joints looked good overall.
- Two of the panel-to-panel segments were partially deteriorated by cohesive tearing in the sealant at the surface, but sealant was not completely separated. This was also in an area where the sealant was domed. The third segment was good overall.

Adhesive 3 Section

- Panel-to-concrete joints looked good overall.
- All three segments had significant amounts of adhesive failure, in many cases full depth such that backer rod was visible (crushed very thin). Sealant was deteriorated to completely fail and even missing in a small area.

Dovetail Section

- Panel-to-concrete joints looked good overall.
- Two of the panel-to-panel segments were partially deteriorated by cohesive tearing in the sealant at the surface, but sealant was not completely separated. The tearing was not deep enough to expose the dovetail groove. This was also in an area where the sealant was domed. Sealant appeared to be fully inside the groove. The third segment was good overall.

4.5 Observations 2 yr after sealant curing

Two years after the sealant curing period was complete (752 days after sealant installation), a final inspection was made. Air temperature was on the order of 5.5°C (42°F), permitting inspection of the joints when they were under some amount of opening strain. Observations were as follows.

Control Section

- All of the panel-to-concrete joints looked good with no deterioration.
- Panel-to-panel joints for about 30% of the length had partial-depth cohesive failure in the sealant. The sealant tearing did not go all the way through but was nearly full depth in some areas. Backer rod was not visible. The joints appeared to be watertight, but barely.

Primer 1 Section

- All of the panel-to-concrete joints looked good with no deterioration.
- Panel-to-panel joints for about 25% of the length had some partial-depth cohesive tearing in the sealant that did not penetrate very deeply (less than for the dovetail and control sections). The joints appeared to still be watertight.

Adhesive 3 Section

- Most of the panel-to-concrete joint looked good. There was a small amount of deterioration.
- Panel-to-panel joints had complete adhesive failure for greater than 90% of the length. Sealant was missing in a number of areas, and the joint was full of debris; near total failure of the joint sealant.

Dovetail Section

- All of the panel-to-concrete joints looked good with no deterioration.
- Panel-to-panel joints for about 15% of the length had some partial-depth cohesive tearing in the sealant that did not penetrate very deeply (less than for control section but more than for the Primer 1 section). The tearing was not deep enough to expose the dovetail groove. The joints appeared to still be watertight.

An overall ranking of the joint configurations based on the 2-yr observations is that the Adhesive 3 section was completely failed, and it performed the worst overall. The control section was the next best performer; it was still holding up at the end of the observation period but was getting close to failure of the joint sealant. The Primer 1 and dovetail sections both performed better than the control. There was some deterioration, but both were still holding up well. The Primer 1 section had more length of sealant tearing, and the cracks in the sealant were shallow in depth. The dovetail section had less overall length of sealant tearing, but cracking was a bit deeper. The dovetail groove appeared to be functioning as intended (i.e., helping to hold the sealant in place through mechanical interlock).

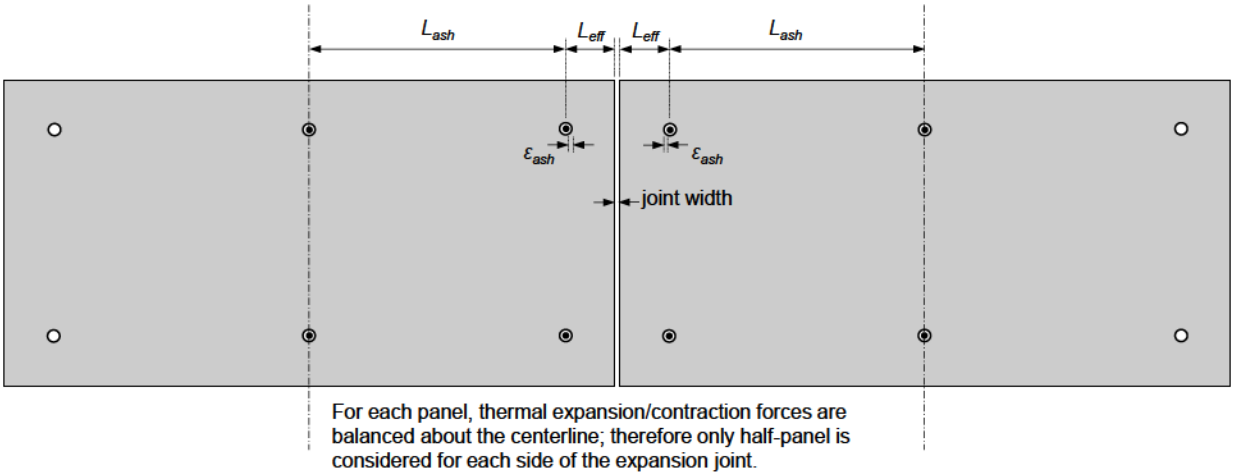
The width of panel-to-panel joints varied somewhat due to construction tolerances. A general observation from the field installation experiment was that the areas with a wider joint in the cool temperatures at the time of inspection (about 25 mm [1.0 in.]) performed very well with no distress in the control, Primer 1, or dovetail sections. The areas with the worst damage generally had a narrower joint at time of inspection (12.7-15.9 mm [0.5-0.625 in.]). This suggests that making the panel-to-panel joints a little bit wider may be advisable to improve joint-sealant performance. A joint opening and closing calculation for the UHMWPE panels was performed as follows to investigate this further.

5 Joint Thermal Movement

5.1 One-dimensional thermal model for joint movement

A one-dimensional model of the thermal behavior of UHMWPE panels was developed to calculate movement of the panel-to-panel expansion joints. Thermal movement was considered perpendicular only to the runway centerline. Figure 14 diagrams the situation of a panel-to-panel expansion joint. Since thermal expansion/contraction forces are balanced about the panel centerline, only one-half of each panel needs to be considered. The maximum joint movement is limited by the anchor studs to the anchor hole size gap (ε_{ash}) on either side of the joint plus the thermal length change of only the UHMWPE at the ends of the panels only from panel edge to outside anchor stud (L_{eff}). Further, the allowable anchor stud hole movement (ε_{ash}) is a function of thermal length change for the panel distance between center anchors and edge anchors (L_{ash}).

Figure 14. Diagram of one-dimensional thermal model for panel expansion joints.



Neglecting any frictional restraint between UHMWPE panels and the underlying PCC, estimates for the differential movement of an expansion joint between UHMWPE panels in response to temperature changes are calculated with Equation 1. The first term ($2\ \alpha\ L_{eff}\ dT$) is the thermal length change associated with UHMWPE between the outside anchor studs and the panel edge; the second term ($2\ \alpha\ L_{ash}\ dT$) is thermal length change associated with UHMWPE between the outside anchor studs and the interior anchor studs, and it is limited to a maximum value of $\pm 2\varepsilon_{ash}$.

$$dL = 2\alpha L_{eff} dT + \begin{cases} 2\alpha L_{ash} dT & \text{for } -2\varepsilon_{ash} \le 2\alpha L_{ash} dT \le 2\varepsilon_{ash} \\ \pm 2\varepsilon_{ash} & \text{otherwise} \end{cases} \quad (1)$$

Where
dL = differential joint movement caused by temperature differential dT;
dT = temperature differential of interest;
α = thermal coefficient of contraction for UHMWPE;
L_{eff} = effective panel joint spacing;
L_{ash} = anchor stud hole thermal movement length;
ε_{ash} = anchor stud hole allowable movement.

The temperature differential used to estimate differential joint movement for any given UHMWPE panel temperature is given by Equation 2.

$$dT = T_{install} - T_{panel} \quad (2)$$

Where
$T_{install}$ = temperature of the UHMWPE panel at time of installation;
T_{panel} = temperature of the UHMWPE panel.

For purposes of joint design, the temperature differential of interest is the difference between installation temperature and the relative maximum and minimum temperatures experienced by the panel over its desired service life and is given by Equation 3.

$$dT = T_{install} - T_{\boldsymbol{max/min}} \quad (3)$$

Where
T_{max} = maximum anticipated panel temperature over service life;
T_{min} = minimum anticipated panel temperature over service life.

Finally, the relative expansion or contraction of joint-sealant material is given by Equation 4. For joint design and selection of an appropriate joint-sealant material, joint differential movement (dL) would be calculated by using Equations 1 and 3. The recommended maximum allowable material movement is provided by the respective joint-sealant manufacturer.

$$Material\ Movement\ (\%) = \frac{dL}{Joint\ Width} 100 \quad (4)$$

According to the AFI 32-1043 (USAF 2012), panels range in length from 1.067 to 1.207 m (42 to 47.5 in.), depending on the slab configuration. The diameter of anchor stud holes in the UHMWPE panels is 25.4±1.6 mm (1±0.0625 in.); they are centered 102 mm (4 in.) from the panel edges and are also located at the center of each panel. The anchor studs themselves have a diameter of 19.1 mm (0.75 in.). Upon installation, spacing between the panels (nominal joint width) is to be set at 12.7 mm (0.5 in.).

Based on the panel dimensions from AFI 32-1043 (USAF 2012) and neglecting the machining tolerance, ε_{ash} = [25.4 mm (1 in.) – 19.1 mm (0.75 in.)]/2 = 3.2 mm (0.125 in.). The effective panel-to-panel joint length, L_{eff} is 102 mm (4 in.). The development length associated with anchor stud hole movement, L_{ash}, is a maximum case of 1207/2-102 = 502 mm (47.5/2 – 4 = 19.75 in.). In current practice, nominal joint width at installation is 12.7 mm (0.5 in.).

UHMWPE has a coefficient of thermal expansion on the order of 198 µm/m/°C (110 x 10^{-6} in./in./°F). For comparison, PCC has a coefficient of thermal expansion on the order of 9.9 µm/m/°C (5.5 x 10^{-6} in./in./°F), which is about 20 times lower than for UHMWPE. This means that UHMWPE will move (expand/contract) 20 times more than concrete for a given temperature change. For that reason, thermal expansion/contraction of the PCC to which the panels are anchored is neglected for these calculations.

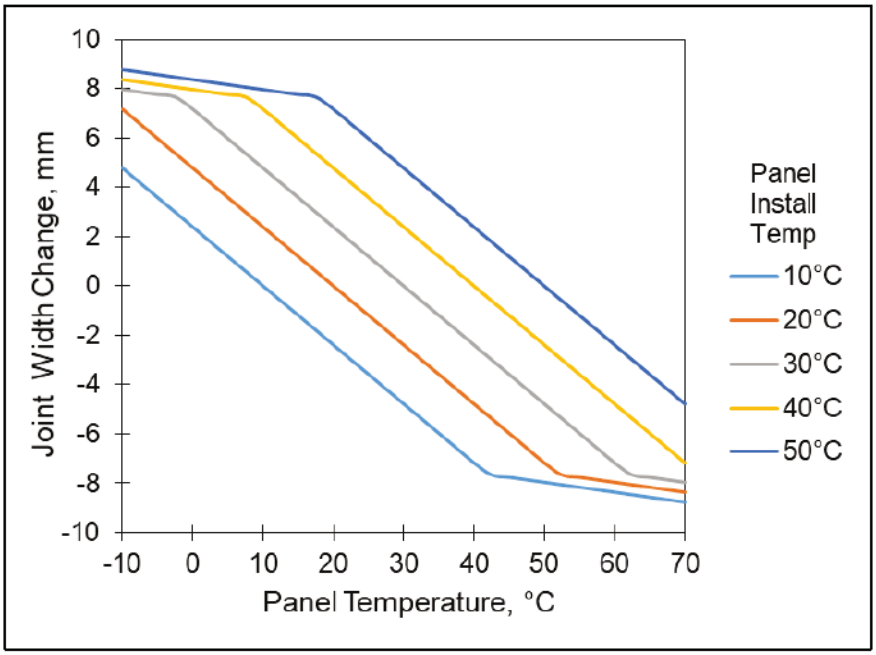
As described previously in Section 2.4 of this report, the thermal characteristics of UHMWPE cause it to have surface temperatures around 40°C (72°F) hotter than air temperature during peak summer conditions; panel mid-depth temperatures are around 30°C (54°F) hotter than air temperature. A reasonable estimate for summer high temperature (T_{max}) for UHMWPE panels at mid-depth is on the order of 70°C (167°F), corresponding to air temperature of around 40°C (104°F). For an estimate of low temperature (T_{min}), -10°C (14°F) is a reasonable estimate for a temperate climate with hot summers since panel temperature will be approximately equal to air temperature at minimum conditions (i.e., winter overnight temperatures).

5.2 Thermal model results

The thermal model developed in the previous section was used to investigate movement of a panel-to-panel joint over a range of conditions. Using Equations 1 and 2, the effect of varying panel installation

temperatures on joint differential movement was explored, and the results are provided in Figure 15. This family of curves for various panel installation temperatures clearly shows the effect of the anchor stud hole movement. Using the $T_{install}$ = 30°C curve for an example, as the panel temperature increases or decreases relative to $T_{install}$, the joint width changes at a relative steep slope until it reaches $\pm 2\varepsilon_{ash}$ (i.e., ±6.4 mm or ±0.25 in.), whereupon the anchor stud hole movement capacity is reached, and the anchor studs restrict movement of the panel interior area. At that point, only the effective length of panel (L_{eff}) can continue to expand or contract with additional thermal changes. For other installation temperatures, this behavior is the same, but the response is shifted along the temperature scale. For $T_{install}$ of 10° or 50°C, the largest movements are -8.9 mm (-0.345 in.) or 8.9 mm (0.345 in.), respectively.

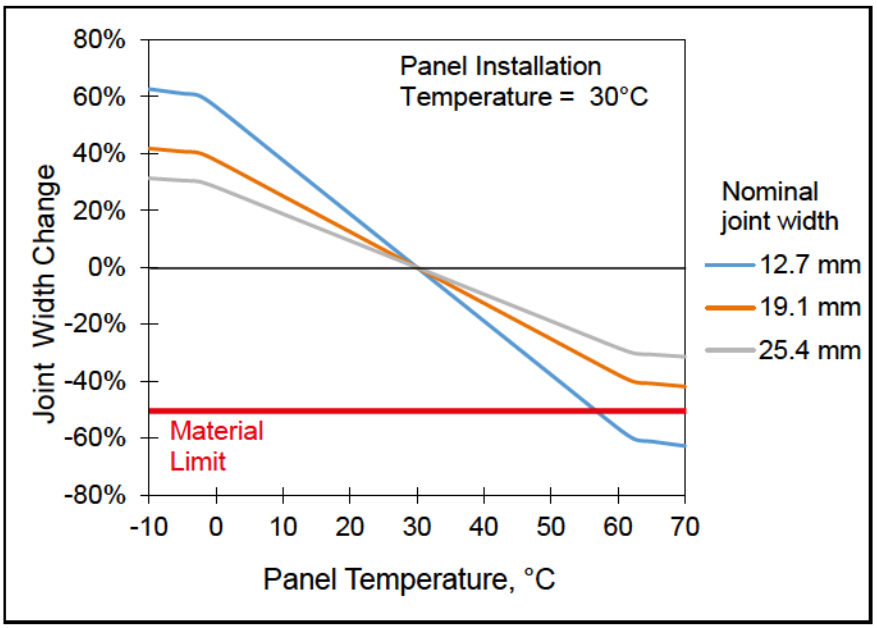
Figure 15. Effects of installation temperature on differential joint movement.



The effect of this amount of panel movement on material behavior was explored by using Equations 1, 2, and 4 with $T_{install}$ = 30°C and for nominal joint widths of 12.7 mm (0.5 in.), 19.1 mm (0.75 in.) and 25.4 mm (1.0 in.); the results are presented in Figure 16. For silicone pavement joint sealants such as Sealant 1, the recommended maximum movement range is -50% and +100%. Recall that current practice in AFI 32-1043 (USAF 2012) is for a nominal joint width of 12.7 mm (0.5 in.). It is apparent that the current joint width recommendations will result in over compression of silicone joint sealant during summer temperatures.

Conversely, by using a wider initial joint width at installation, the material capacity will not be exceeded during summer temperatures.

Figure 16. Effect of varying joint width on joint-sealant material.



To further explore the parameter space as relates to selecting an initial joint width not to exceed joint-sealant material limits, Equations 1, 3, and 4 were used to compute joint movement percentage at $T_{max/min}$ for varying $T_{install}$ temperatures and nominal joint widths. Results are presented in Figure 17 and Figure 18 for hot and cold weather conditions, respectively.

For hot weather conditions (Figure 17), the material limits (-50%) are frequently exceeded for relatively narrow joint widths but are safely avoided for relatively wider joint widths. At the midpoint joint width of 19.1 mm (0.75 in.), joint movement is within material limits for all but the coldest installation temperature. However, sources of error in the real world (e.g., construction variability) require that a factor of safety be considered for design. For this scenario, a S.F. of 1.25 is suggested. This implies that the design joint movement should be less than the joint-sealant material failure criteria. For hot weather conditions, the design allowable joint movement would therefore be -50%/1.25 = -40%. Using a nominal joint width of 25.4 mm (1.0 in.) at installation would result in joint movements within the S.F. for all installation temperatures.

For cold weather conditions (Figure 18), material limits (100%) are never exceeded. Applying a S.F. of 1.25, the design allowable joint movement would

be 100%/1.25 = 80%, and this value is also not exceeded for any combination of installation temperature and nominal joint width. Therefore, the hot-weather joint closure criteria control the design decision.

Figure 17. Intensity plot of hot weather maximum joint closure percentage as function of installation temperature and nominal joint width.

Install Temp	Joint Width, nominal at installation				
	1/2" 12.7 mm	5/8" 15.9 mm	3/4" 19.1 mm	7/8" 22.2 mm	1" 25.4 mm
-10°C	-75%	-60%	-50%	-43%	-38%
0°C	-72%	-58%	-48%	-41%	-36%
10°C	-69%	-55%	-46%	-39%	-35%
20°C	-66%	-53%	-44%	-38%	-33%
30°C	-63%	-50%	-42%	-36%	-31%
40°C	-56%	-45%	-38%	-32%	-28%
50°C	-38%	-30%	-25%	-22%	-19%
60°C	-19%	-15%	-13%	-11%	-9%
70°C	0%	0%	0%	0%	0%
Using T_{max} = 70°C					

Figure 18. Intensity plot of cold weather maximum joint opening percentage as function of installation temperature and nominal joint width.

Install Temp	Joint Width, nominal at installation				
	1/2" 12.7 mm	5/8" 15.9 mm	3/4" 19.1 mm	7/8" 22.2 mm	1" 25.4 mm
-10°C	0%	0%	0%	0%	0%
0°C	19%	15%	13%	11%	9%
10°C	38%	30%	25%	22%	19%
20°C	56%	45%	38%	32%	28%
30°C	63%	50%	42%	36%	31%
40°C	66%	53%	44%	38%	33%
50°C	69%	55%	46%	39%	35%
60°C	72%	58%	48%	41%	36%
70°C	75%	60%	50%	43%	38%
Using T_{min} = -10°C					

6 Conclusions and Recommendations

6.1 Conclusions

Based on the results of this study, some general conclusions are drawn.

- Among the five sealant materials tested, laboratory results indicated that Sealant 1, a self-leveling silicone for pavements, had the best comparative performance. Other self-leveling silicone pavement sealants meeting ASTM D5893 (2010) requirements were not tested in this study but can reasonably be expected to function as approximate substitutes for Sealant 1 and be a valid alternative material selection.

- Among the seven panel-edge geometries tested, a dovetail groove performed the best in laboratory testing, and the failure strain level was improved by around 75% relative to the flat panel-edge geometry used in current practice. The other panel-edge geometries did not provide much improvement.

- Among the eight surface treatments tested, laboratory results indicated that Primer 1, a silane-based adhesion promoter, and Adhesive 3, an acrylic adhesive two-sided transfer tape, provided the best improvement, on the order of 60 to 80%, relative to the control. The other surface treatments tested did not provide much improvement.

- Another silane-based adhesion promoter, Primer 2, was also tested but did not provide nearly the benefits observed with Primer 1. Since the chemical formulations of these products are not readily available, an alternative method to differentiate them may be the 180° Adhesion in Peel test. However, it is not clear what criteria would be most appropriate for a general requirement, and further research would be necessary to determine appropriate purchase specification criteria to ensure adequate performance is obtained from a primer.

- Strength testing of UHMWPE at elevated temperatures showed that tensile strength is likely adequate to withstand aircraft tire forces on a grooved panel-edge geometry. Strength variation between manufacturers was statistically significant.

- Field installation and monitoring of response to environmental factors for a period of 2 yr for the best performing laboratory treatment combinations indicated that Primer 1 on a flat surface and also dovetail groove edge performed better than the control and are reasonable alternatives to improve performance of AAS panel joint performance relative to current practice. Adhesive 3 was difficult to construct, performed poorly in field testing, and should not be used.

- Thermal model results indicate that the current practice of using 12.7 mm (0.5 in.) as the nominal width for panel-to-panel joints can result in over-compression of the joint-sealant material during hot weather. A wider joint would eliminate this problem.

6.2 Recommendations

Some recommendations to improve the performance of AAS panel joints include the following.

- Self-leveling silicone joint sealants meeting requirements of ASTM D5893 (2010) continue to be specified and used for sealing joints of UHMWPE panels in AAS cable systems.

- A dovetail groove be installed into the UHMWPE panel edges to improve sealant performance. Suggested dimensions of the groove are provided in Figure 4. For upgrading AAS installations, the existing UHMWPE panels can be reused by cutting a dovetail groove onsite using a handheld router and edge guide.

- If dovetail grooving is implemented, then criteria for tensile strength testing of UHMWPE at elevated temperature should be added to the material requirements. Testing performed at 75°C (167°F) in accordance with ASTM D638 (2014) on specimens cut parallel to the direction of material extrusion is suggested with a minimum value for tensile yield strength of 7 MPa (1000 psi) being required.

- The nominal joint width between adjacent UHMWPE panels (i.e., joint parallel to runway direction) should be widened to 25.4 mm (1.0 in.) to prevent over-compression of the sealant in hot weather. The joint between UHMWPE panels and concrete (i.e., joint perpendicular to runway direction) should not be changed.

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Appendix A: Laboratory Test Data

Figure A1. Load-strain plot for Sealant 1, no surface treatment, flat edge.

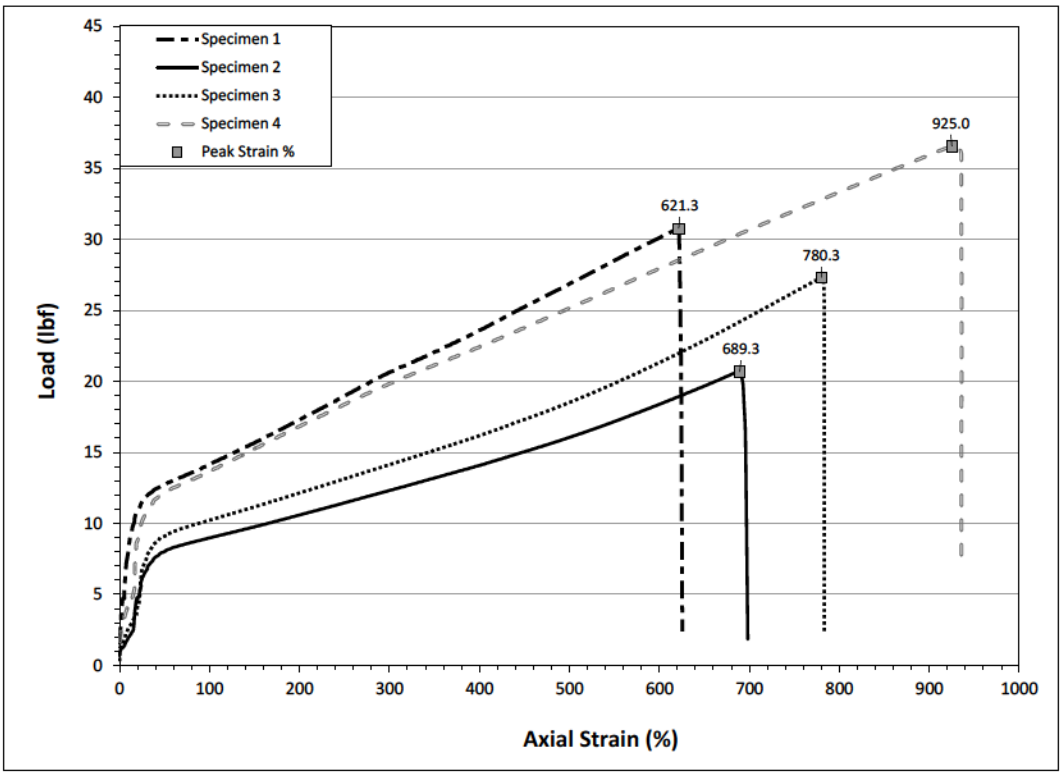


Figure A2. Load-strain plot for Sealant 1, no surface treatment, flat edge + concrete.

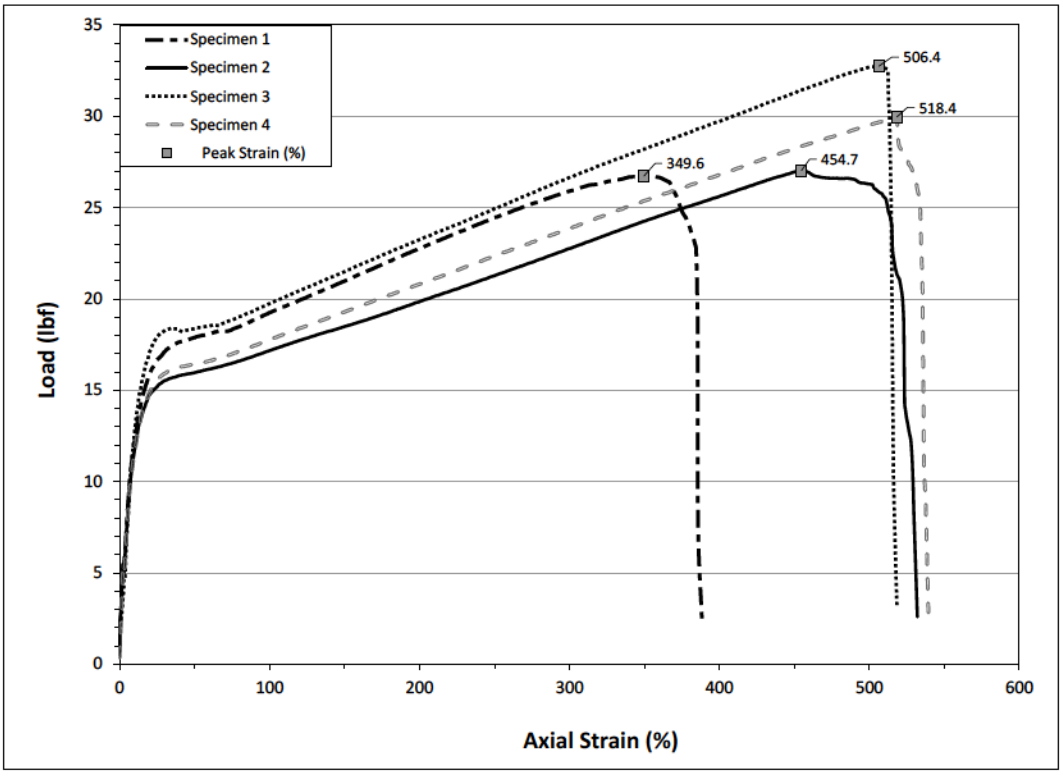


Figure A3. Load-strain plot for Sealant 1, no surface treatment, flat edge + asphalt.

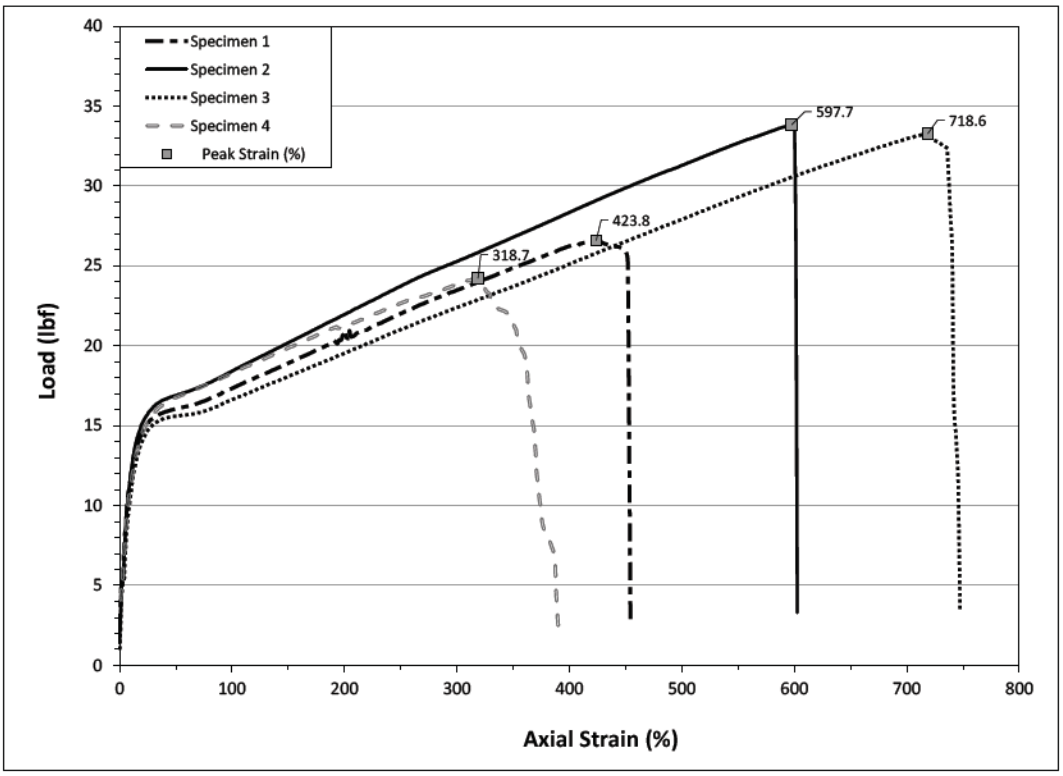


Figure A4. Load-strain plot for Sealant 5, no surface treatment, flat edge or concrete.

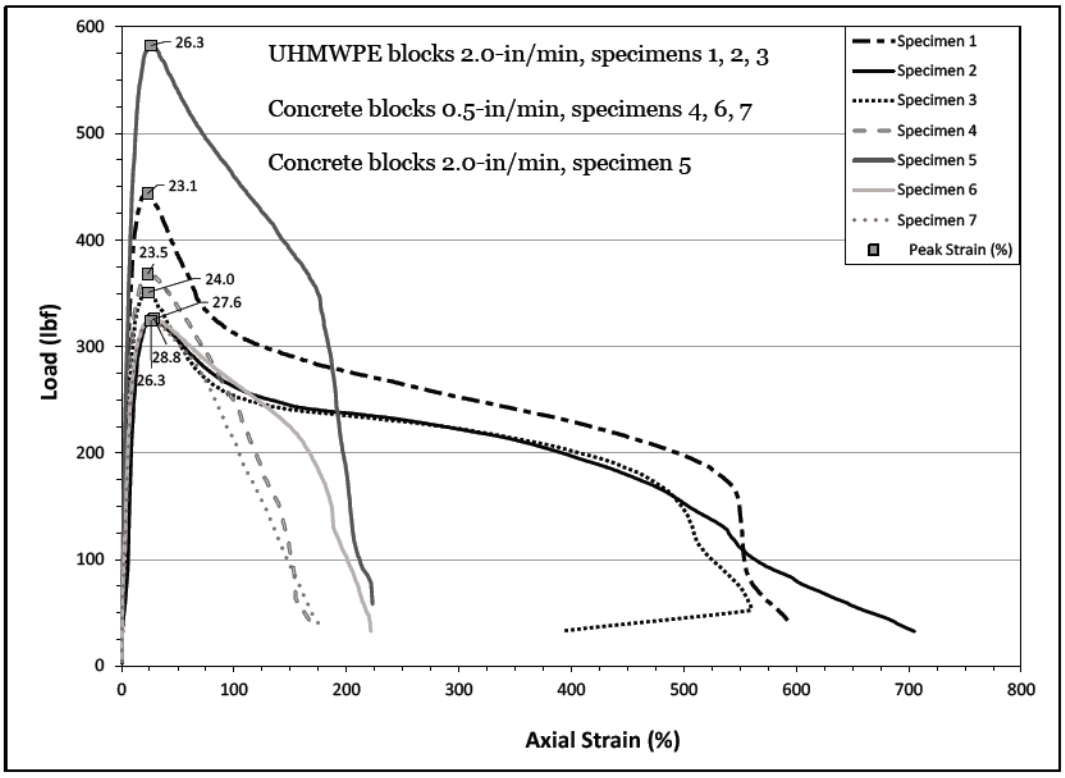


Figure A5. Load-strain plot for Sealant 1, Adhesive 3, flat edge.

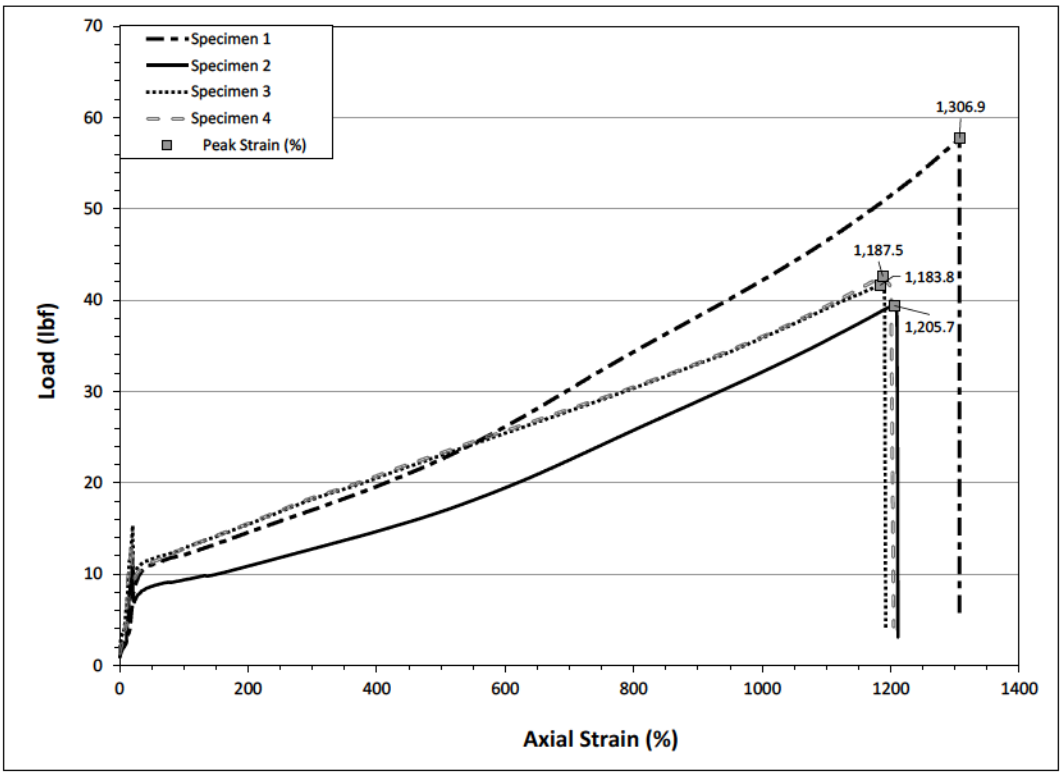


Figure A6. Load-strain plot for Sealant 1, Primer 1, flat edge.

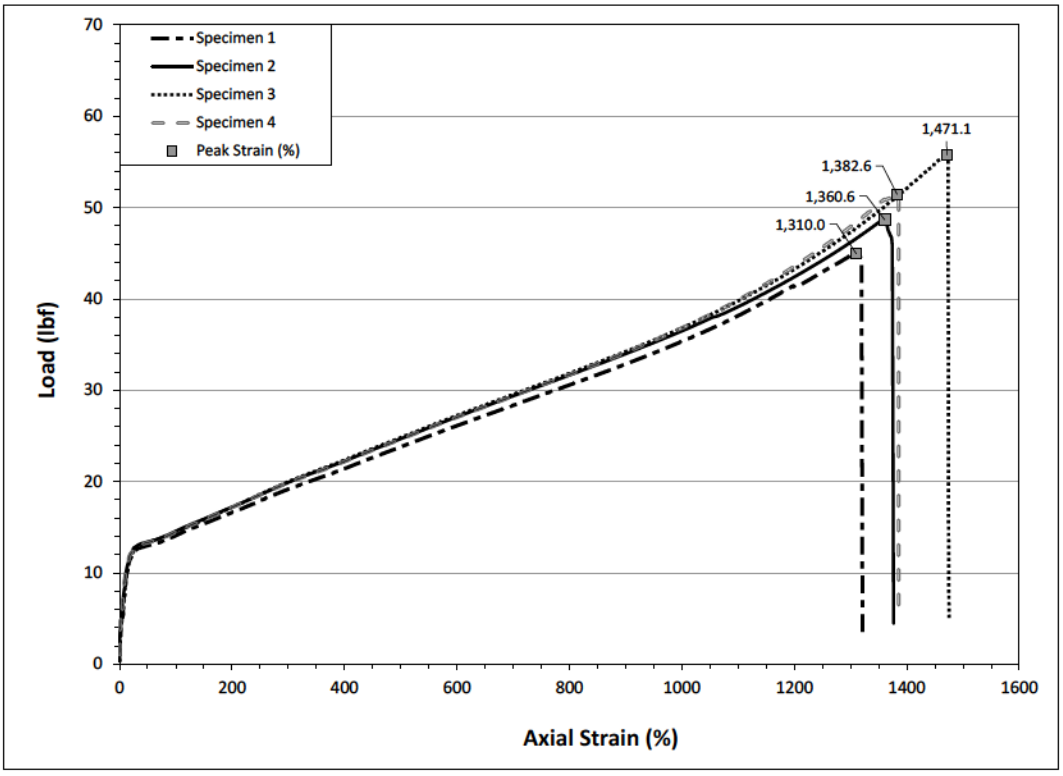


Figure A7. Load-strain plot for Sealant 1, Primer 3, flat edge.

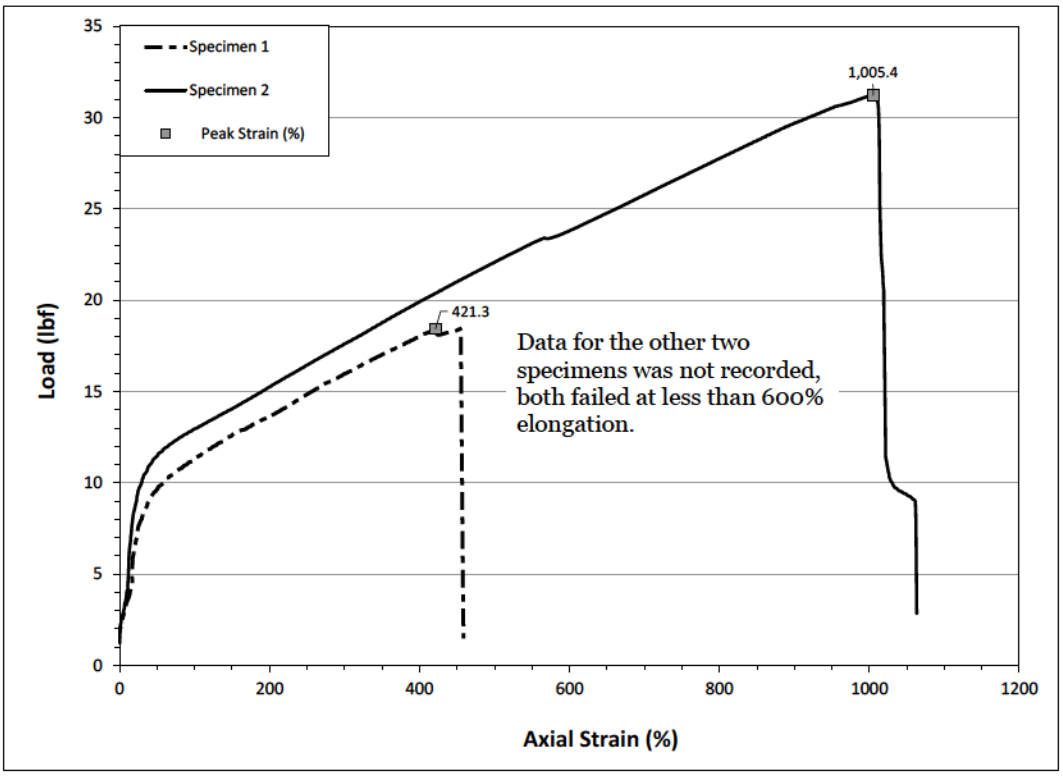


Figure A8. Load-strain plot for Sealant 1, Primer 3 + flame treatment, flat edge.

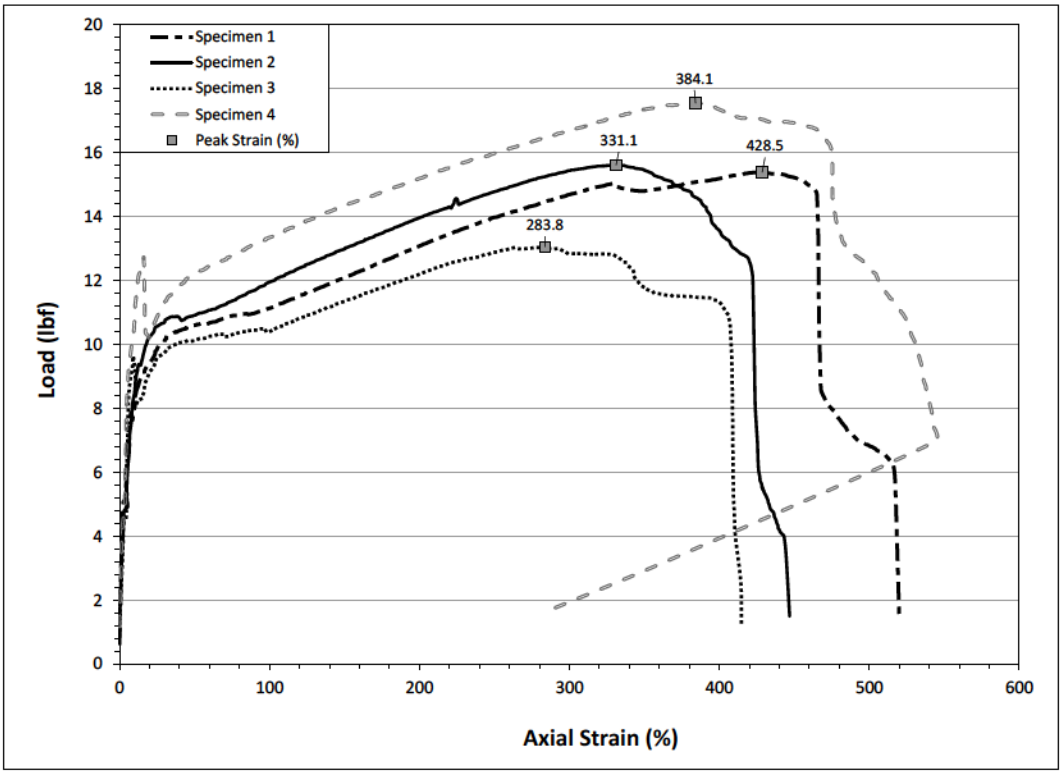


Figure A9. Load-strain plot for Sealant 1, sanded surface, flat edge.

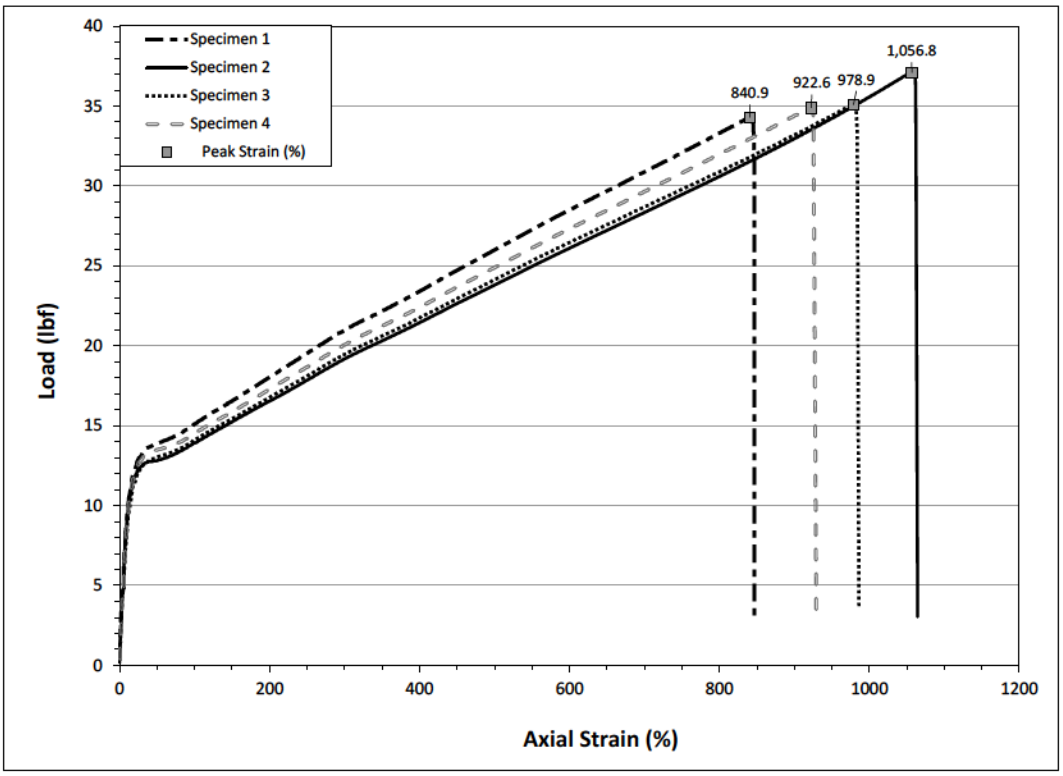


Figure A10. Load-strain plot for Sealant 1, flame treatment, flat edge.

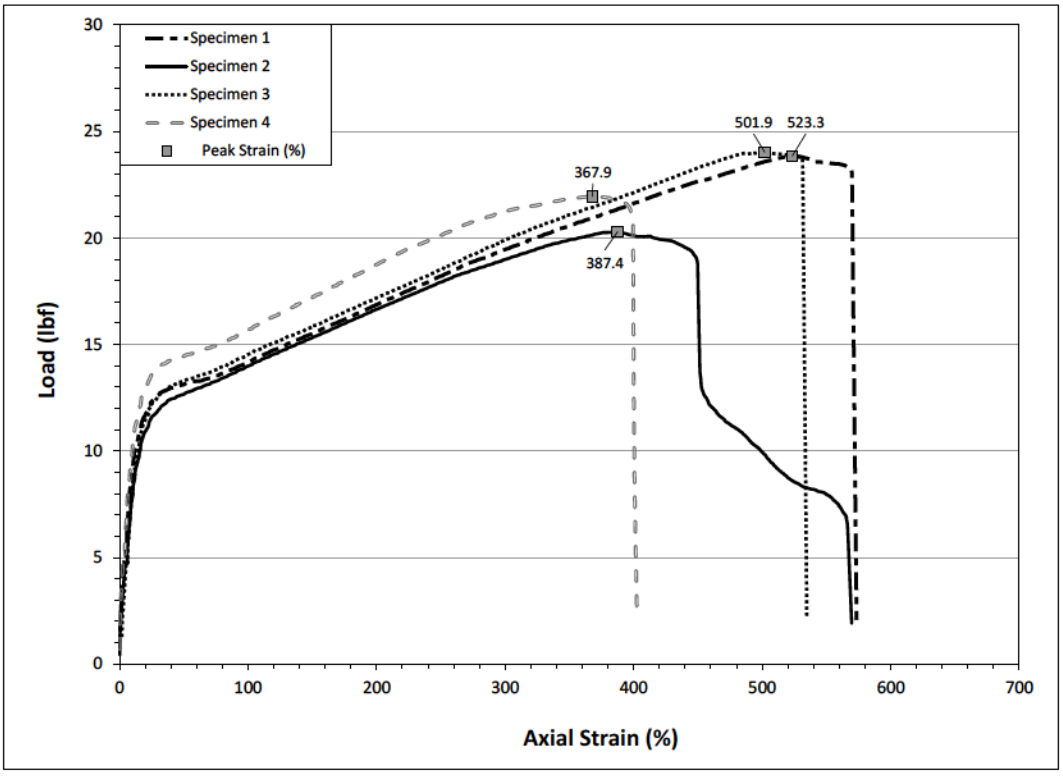


Figure A11. Load-strain plot for Sealant 1, no surface treatment, stepped groove.

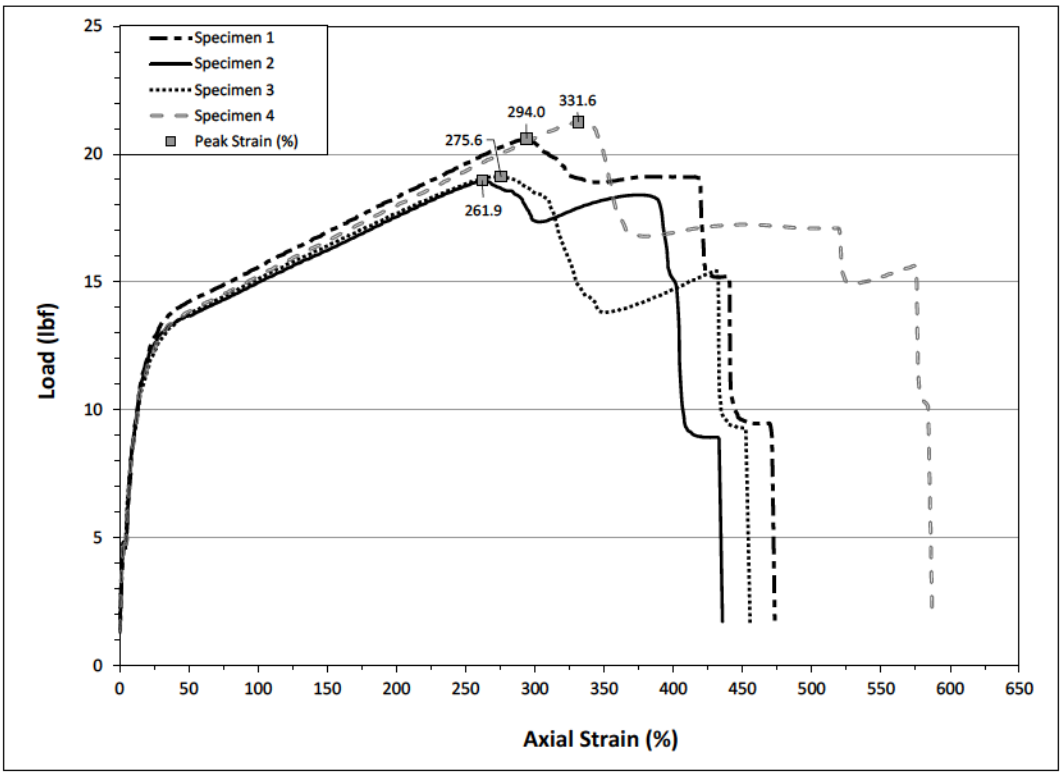


Figure A12. Load-strain plot for Sealant 1, no surface treatment, radius groove.

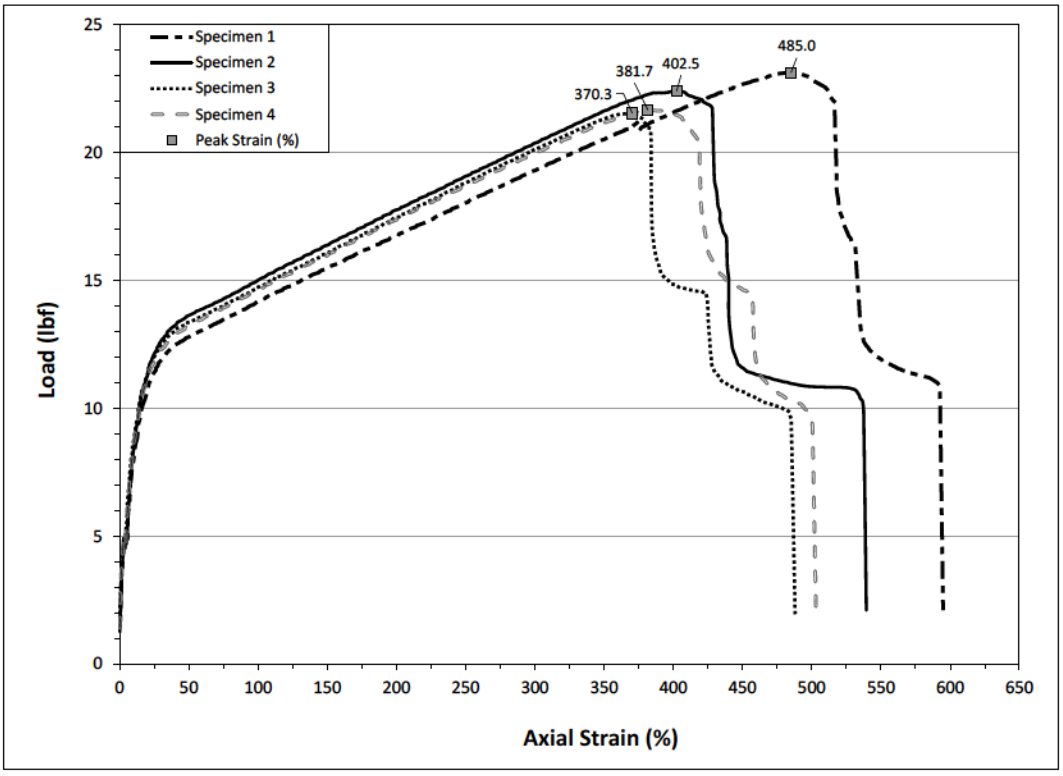


Figure A13. Load-strain plot for Sealant 1, no surface treatment, single groove.

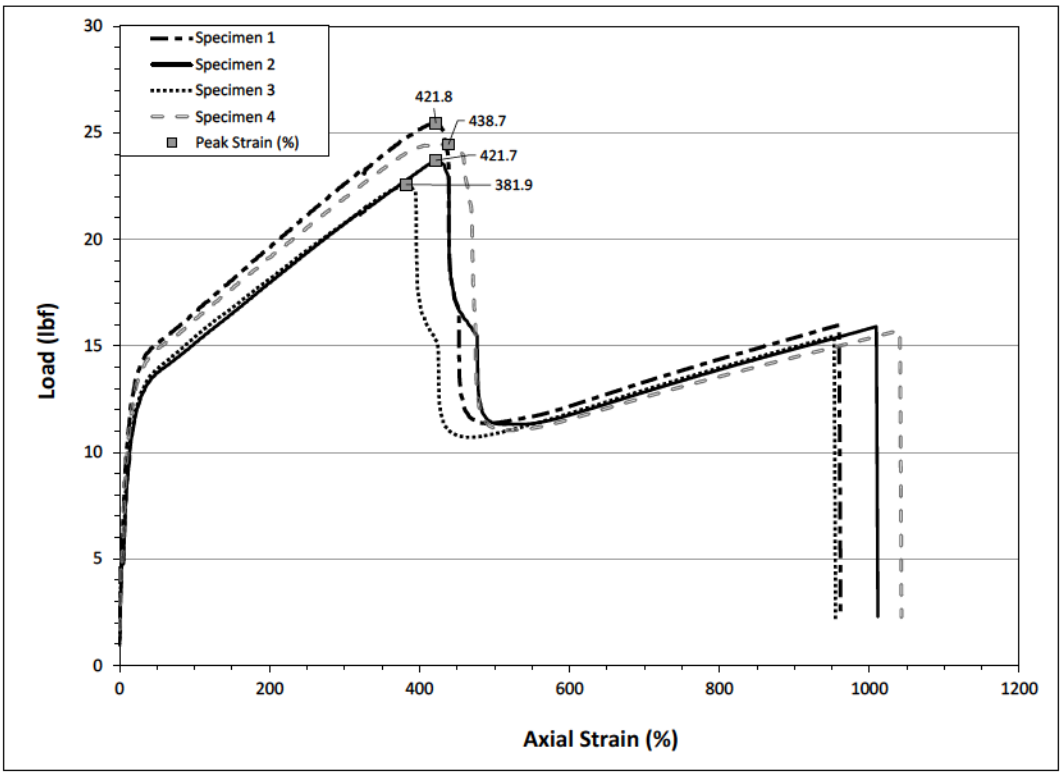


Figure A14. Load-strain plot for Sealant 1, no surface treatment, dovetail groove.

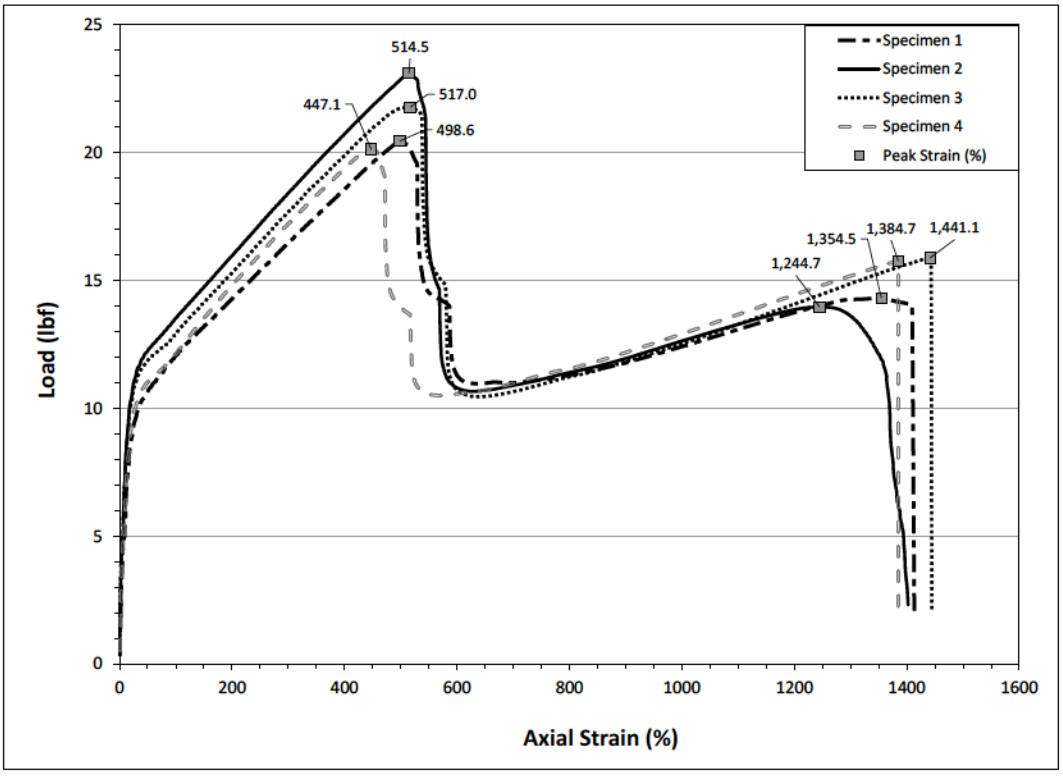


Figure A15. Load-strain plot for Sealant 1, no surface treatment, notch groove.

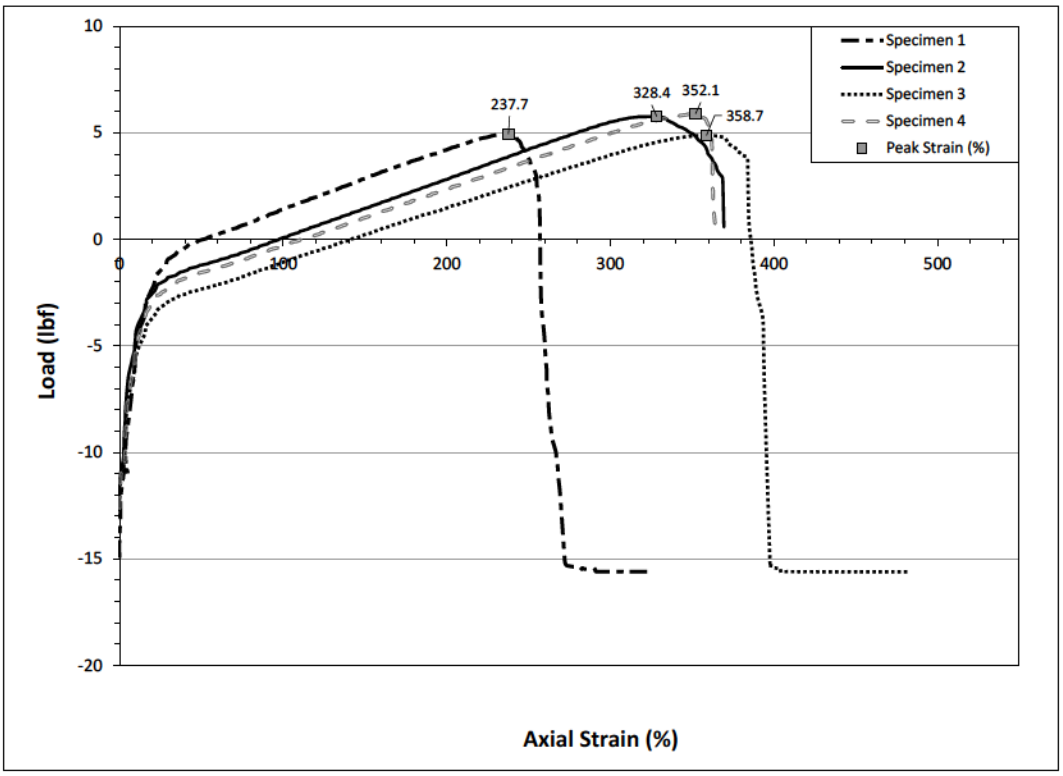


Figure A16. Load-strain plot for Sealant 1, no surface treatment, multi-groove.

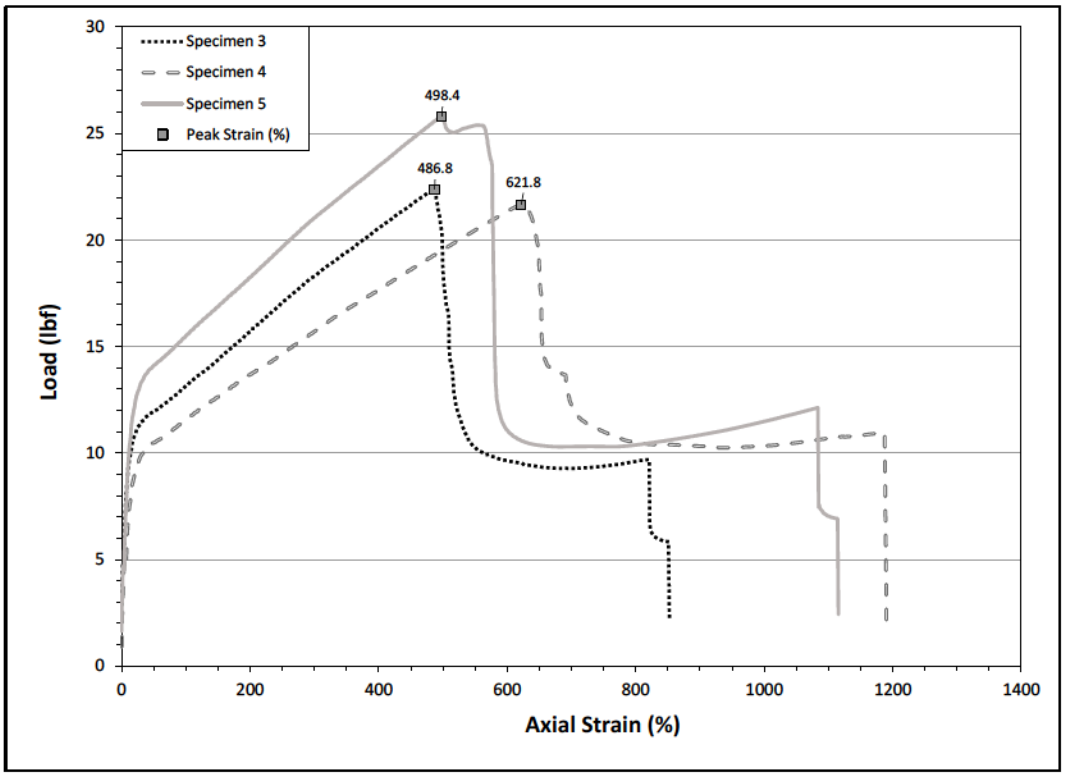


Figure A17. Load-strain plot for Sealant 1, no surface treatment, flat edge, control.

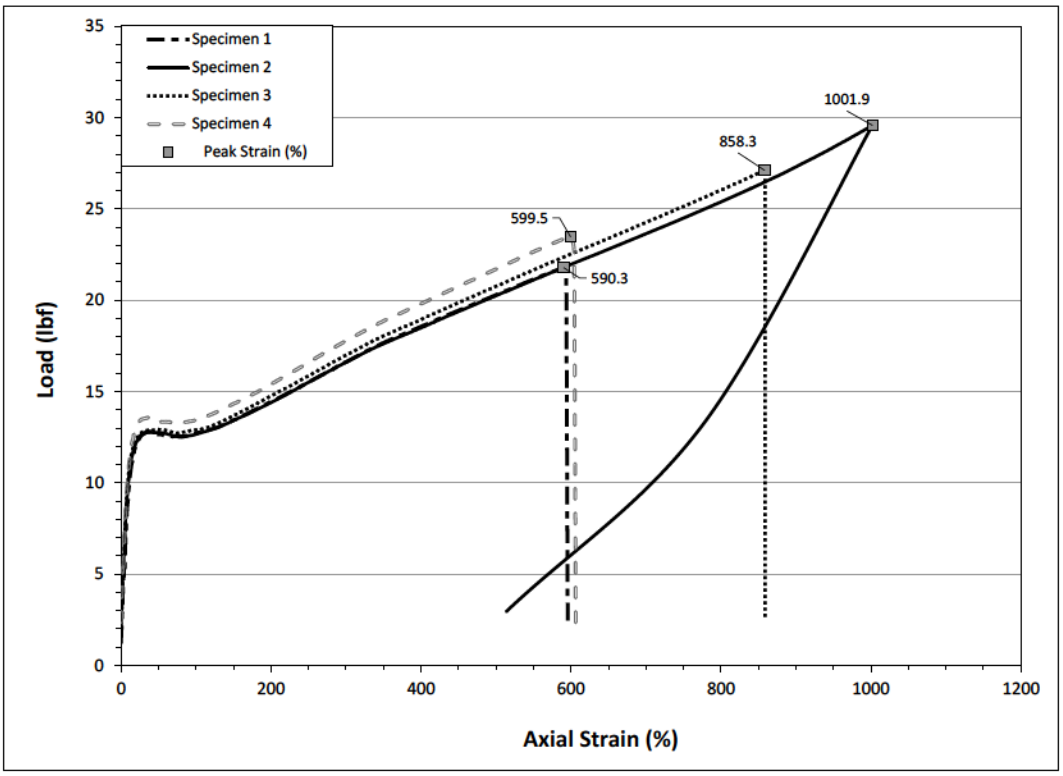


Figure A18. Load-strain plot for Sealant 1, sanded surface, single groove.

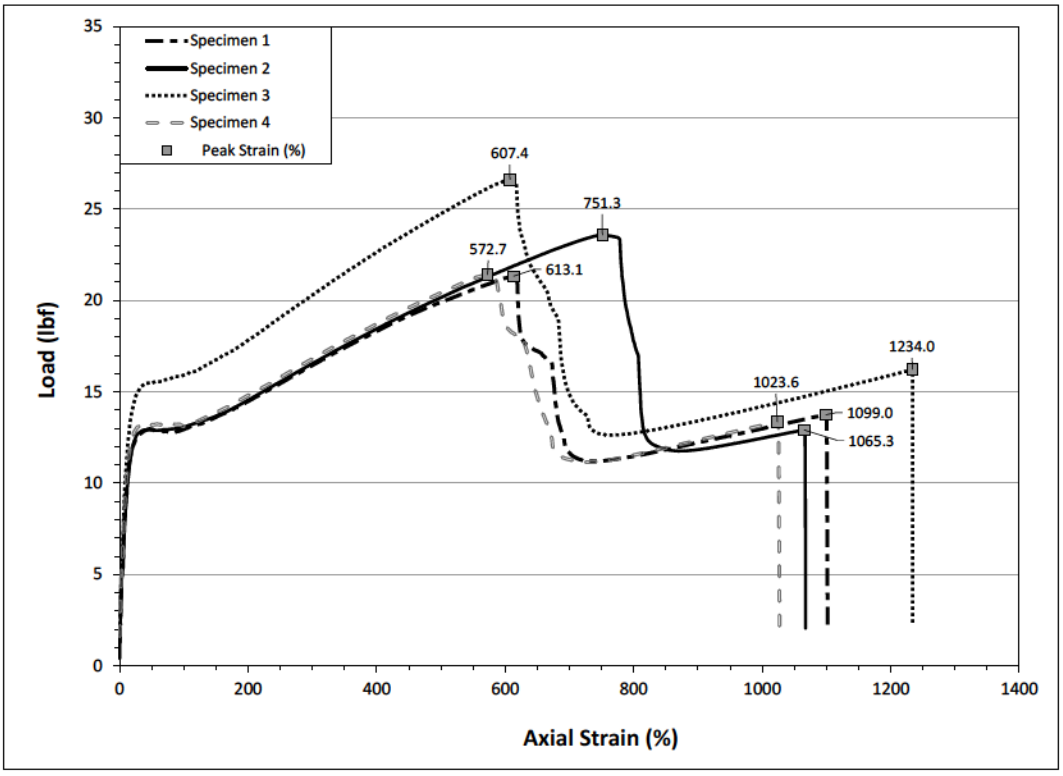


Figure A19. Load-strain plot for Sealant 1, sanded surface, dovetail groove.

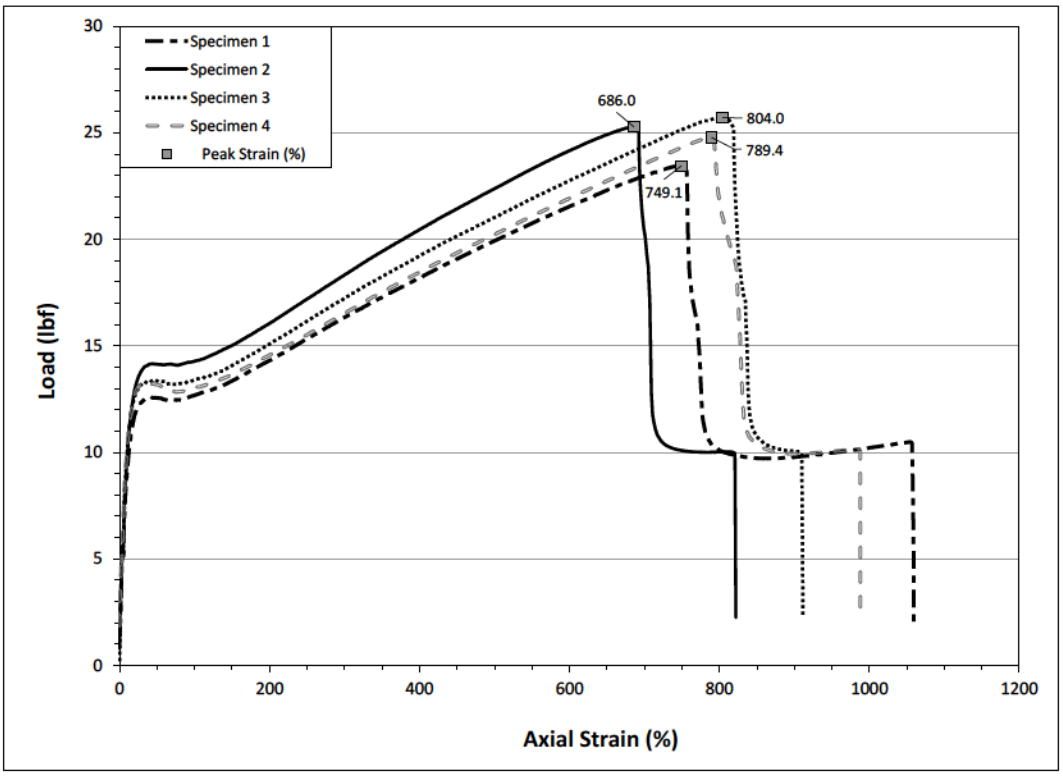


Figure A20. Load-strain plot for Sealant 1, Adhesive 3, flat edge.

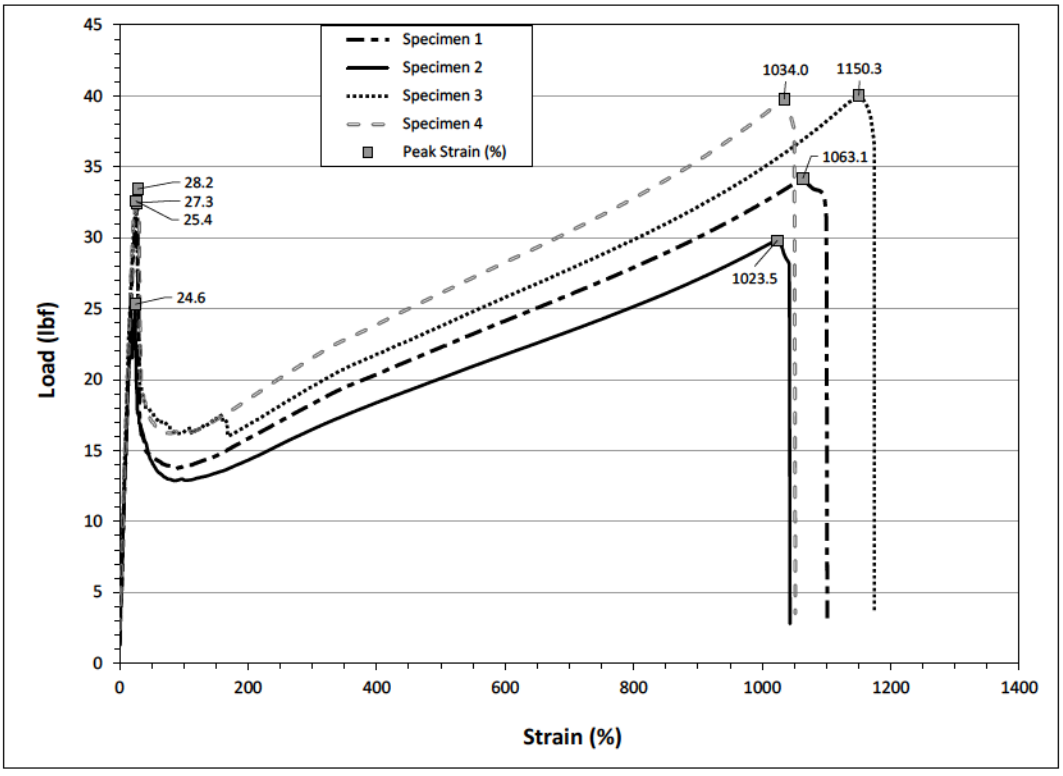


Figure A21. Load-strain plot for Sealant 1, Primer 1, flat edge.

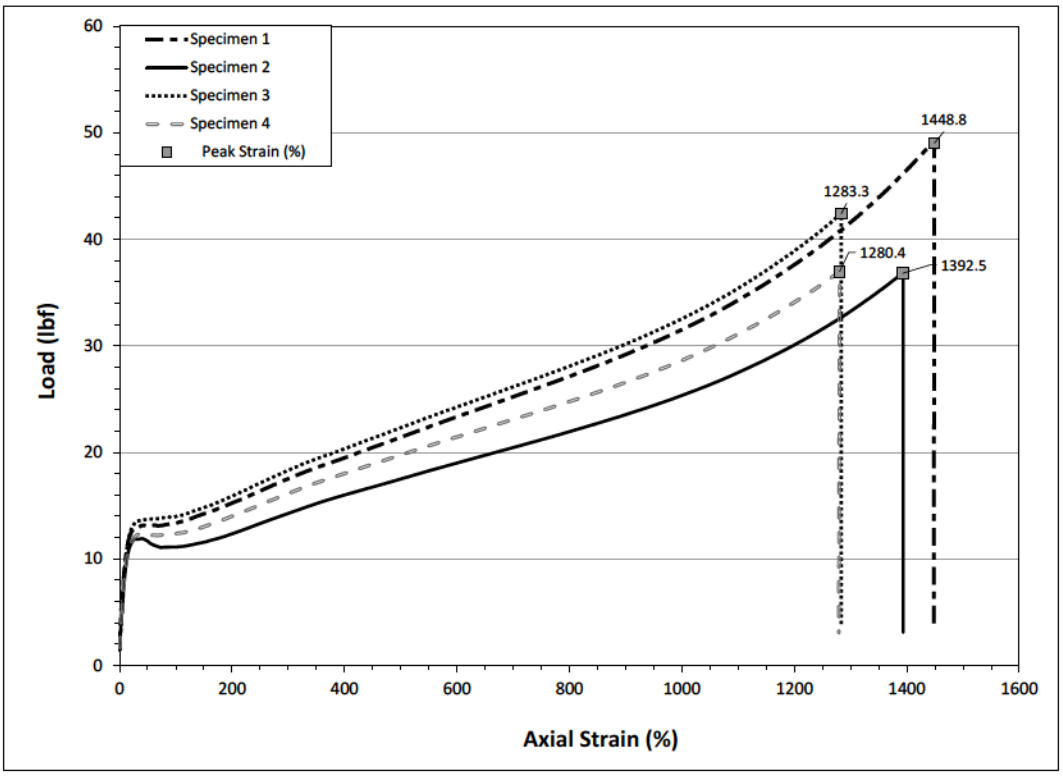


Figure A22. Load-strain plot for Sealant 1, Primer 1 + sanded surface, flat edge.

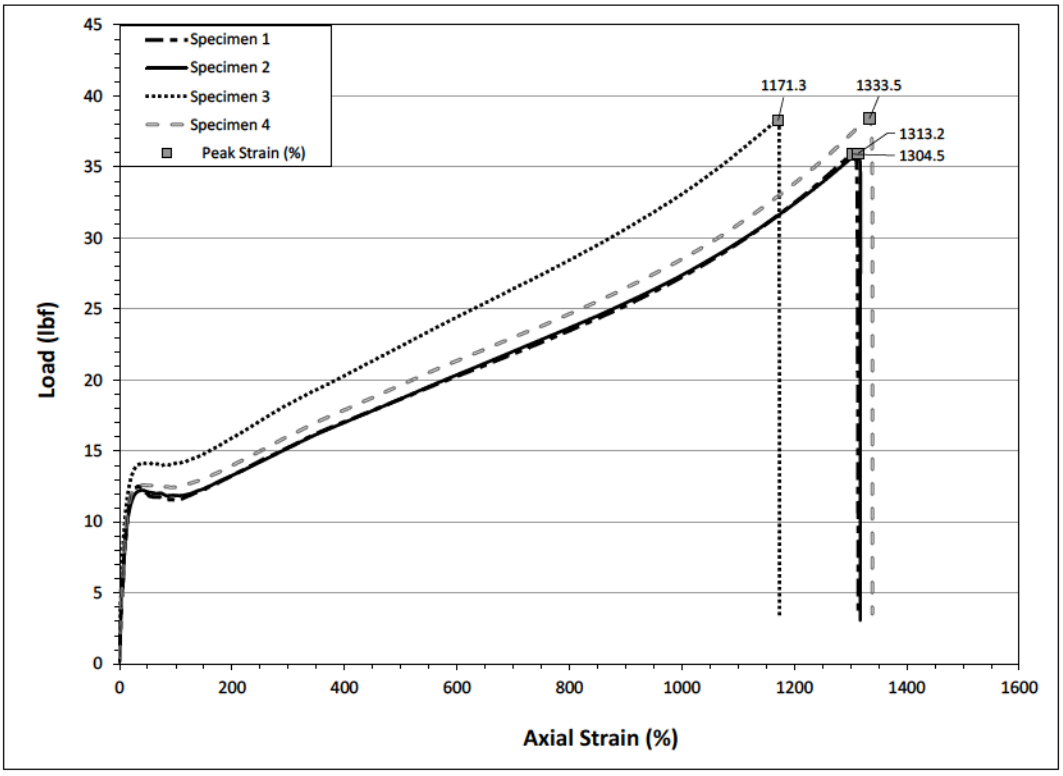


Figure A23. Load-strain plot for Sealant 1, Primer 1 + sanded surface, single groove.

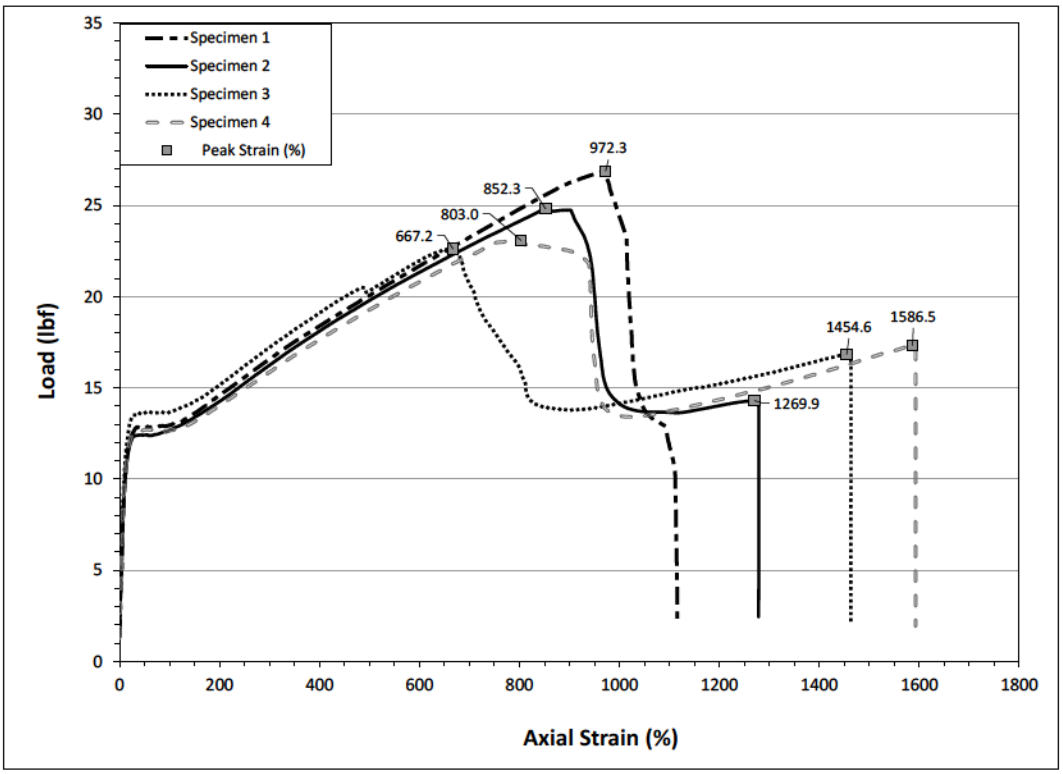


Figure A24. Load-strain plot for Sealant 1, Primer 1 +sanded surface, dovetail groove.

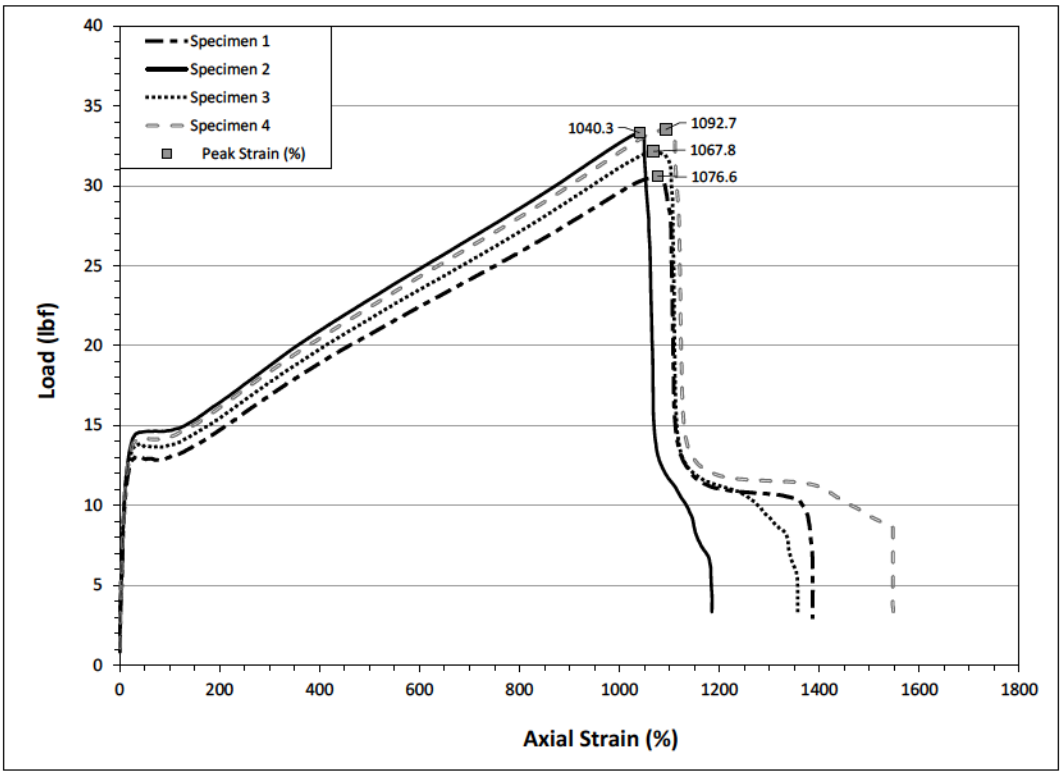


Figure A25. Load-strain plot for Sealant 1, Primer 2, flat edge.

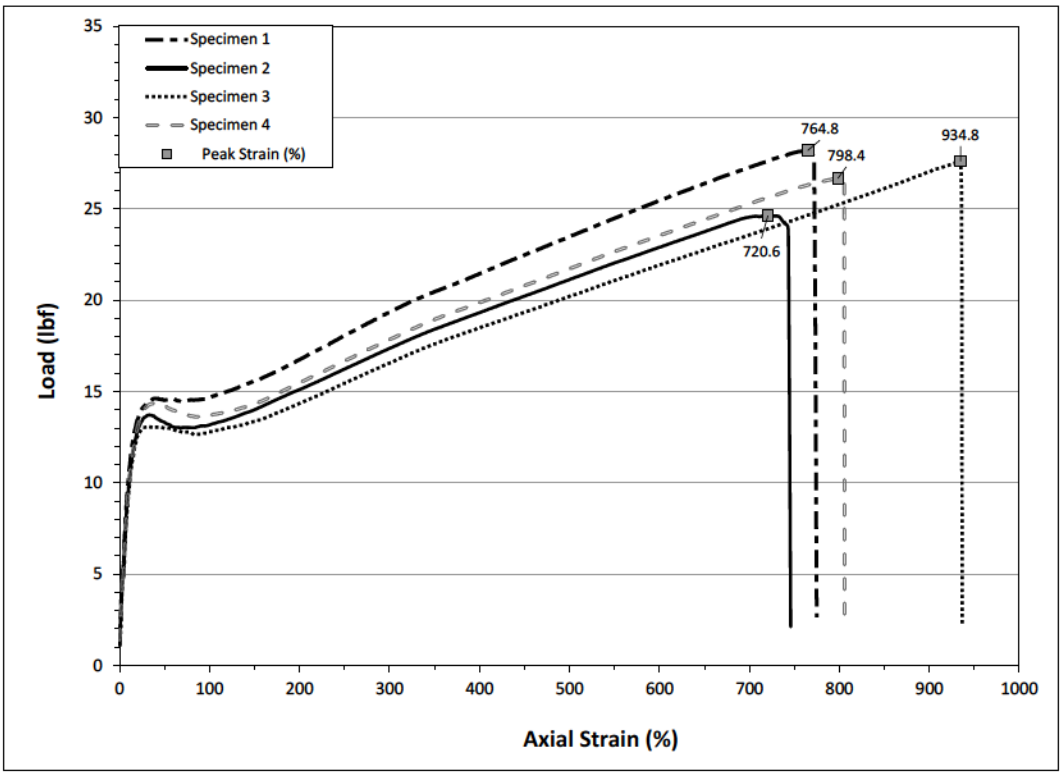


Figure A26. Load-strain plot for Sealant 1, Primer 2 +sanded surface, dovetail groove.

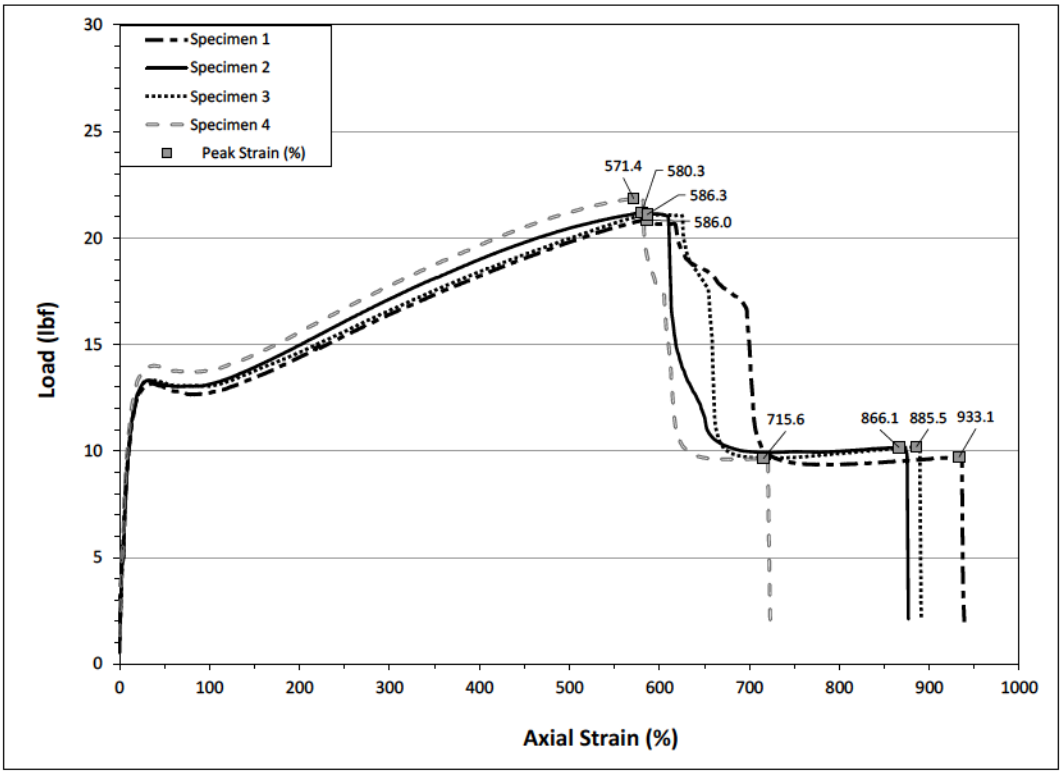


Table A1. Tivar® UV Resistant UHMWPE tensile test data at 23°C.

Direction	Rep	Modulus of Elasticity (ksi)	Yield Strength @2% strain (psi)	Fracture	
				Stress (psi)	Elongation (%)
X	1	1,276	3,662	4,697	236
	2	1,136	3,546	4,805	243
	3	1,068	3,624	4,719	239
	4	962	3,593	4,765	245
	5	1,173	3,585	4,530	221
Y	1	694	2,950	3,919	240
	2	715	3,049	3,986	226
	3	832	3,182	3,847	204
	4	782	3,103	4,069	233
	5	819	3,132	4,007	221
XY	1	1,178	3,651	4,697	209
	2	956	3,304	4,409	246
	3	892	3,250	4,240	230
	4	994	3,402	4,517	249
	5	938	3,203	4,221	234

Table A2. Tivar® UV Resistant UHMWPE tensile test data at 75°C.

Direction	Rep	Modulus of Elasticity (ksi)	Yield Strength @2% strain (psi)	Fracture	
				Stress (psi)	Elongation (%)
Y	1	13.4	1,083	---[a]	---[a]
	2	13.0	1,095	---[a]	---[a]
	3	13.9	1,112	---[a]	---[a]
	4	14.6	1,118	---[a]	---[a]
	5	14.5	1,121	---[a]	---[a]
	6	13.4	1,072	---[a]	---[a]
	7	13.9	1,095	---[a]	---[a]
	8	14.4	1,102	---[a]	---[a]
	9	17.2	1,160	---[a]	---[a]
	10	16.5	1,134	---[a]	---[a]
X	1	16.3	1,096	---[a]	---[a]
	2	14.7	1,072	---[a]	---[a]
	3	14.9	1,112	---[a]	---[a]
	4	19.7	1,155	---[a]	---[a]
	5	17.5	1,141	---[a]	---[a]
	6	13.2	1,127	---[a]	---[a]
	7	14.4	1,107	---[a]	---[a]
	8	16.7	1,082	---[a]	---[a]
	9	15.5	1,159	---[a]	---[a]
	10	14.4	1,043	---[a]	---[a]

[a]Not tested due to equipment limitations.

Table A3. Polystone® M UV Stabilized UHMWPE tensile test data at 23°C.

Direction	Rep	Modulus of Elasticity (ksi)	Yield Strength @2% strain (psi)	Fracture	
				Stress (psi)	Elongation (%)
X	1	871	3,322	4,878	237
	2	952	3,377	4,831	209
	3	914	3,380	4,938	225
	4	914	3,368	4,791	206
	5	922	3,378	4,723	204
Y	1	780	3,076	4,096	203
	2	558	2,748	3,672	210
	3	719	2,930	4,083	196
	4	728	3,064	4,135	164
	5	730	3,090	3,882	165
XY	1	809	3,152	4,234	215
	2	823	3,172	4,322	222
	3	562	2,820	3,735	229
	4	803	3,130	3,877	171
	5	764	3,111	4,272	251

Table A4. Polystone® M UV Stabilized UHMWPE tensile test data at 75°C.

Direction	Rep	Modulus of Elasticity (ksi)	Yield Strength @2% strain (psi)	Fracture	
				Stress (psi)	Elongation (%)
Y	1	17.4	1,130	---[a]	---[a]
	2	16.3	1,114	---[a]	---[a]
	3	16.9	1,136	---[a]	---[a]
	4	17.2	1,153	---[a]	---[a]
	5	17.7	1,147	---[a]	---[a]
	6	21.4	1,227	---[a]	---[a]
	7	19.4	1,199	---[a]	---[a]
	8	18.0	1,155	---[a]	---[a]
	9	15.6	1,117	---[a]	---[a]
	10	17.7	1,133	---[a]	---[a]

[a]Not tested due to equipment limitations.

Table A5. Polyslick® UV Stabilized UHMWPE tensile test data at 23°C.

Direction	Rep	Modulus of Elasticity (ksi)	Yield Strength @2% strain (psi)	Fracture	
				Stress (psi)	Elongation (%)
X	1	753	3,320	4,338	227
	2	718	3,210	3,950	191
	3	767	3,321	4,159	205
	4	769	3,276	4,290	145
	5	827	3,290	4,269	218
Y	1	593	3,010	3,964	236
	2	571	2,958	3,838	225
	3	594	3,040	3,911	227
	4	578	3,021	3,708	199
	5	407	2,681	3,417	206
XY	1	645	3,078	3,835	201
	2	573	3,034	3,801	207
	3	572	3,018	4,006	233
	4	548	2,992	4,005	233
	5	584	2,978	3,937	225

Table A6. Polyslick® UV Stabilized UHMWPE tensile test data at 75°C.

Direction	Rep	Modulus of Elasticity (ksi)	Yield Strength @2% strain (psi)	Fracture	
				Stress (psi)	Elongation (%)
Y	1	12.9	1,094	---[a]	---[a]
	2	11.5	1,052	---[a]	---[a]
	3	9.9	1,041	---[a]	---[a]
	4	11.5	1,069	---[a]	---[a]
	5	12.0	1,078	---[a]	---[a]
	6	11.1	1,056	---[a]	---[a]
	7	10.8	1,046	---[a]	---[a]
	8	11.1	1,049	---[a]	---[a]
	9	11.9	1,060	---[a]	---[a]
	10	11.3	1,059	---[a]	---[a]

[a]Not tested due to equipment limitations.

Appendix B: Material Datasheets

Product Information
Silicone
Sealants

DOW CORNING

Dow Corning® 890-SL Silicone Joint Sealant

FEATURES

- Self-leveling, no tooling required
- Can be extruded from -20 to 120°F
- Unprimed adhesion to Portland cement concrete and asphalt
- Seals irregular surfaces and joint widths
- Movement capability +100% extension and 50% compression
- Ultra-low modulus
- Weather and UV resistant
- Meets or exceeds the requirements of ASTM D5893

BENEFITS

- Self-leveling (no tooling, one component, cold applied, ready-to-use as supplied; dispensed directly from the bulk container into the joint by hand or with an air-powered pump
- Unprimed adhesion – primer is not required for bonding to asphalt or Portland cement concrete. For optimum adhesion, the surface must be clean, dry and frost-free
- Seals irregular surfaces and joint widths
- High movement capability – 100% extension and 50% compression.
- Ultra low modulus
- Weather and UV resistant
- Cure time – typically, the sealant will have a skin-over time of one hour or less at standard conditions

COMPOSITION

- One-part, cold applied, self-leveling silicone

Self-leveling silicone sealant for concrete and concrete to asphalt pavement joints.

APPLICATIONS

- *Dow Corning*® 890-SL Silicone Joint Sealant can be used for concrete to concrete and concrete to asphalt pavement joints.
- For use in new construction, repair or remedial applications. *Dow Corning* 890-SL Silicone Joint Sealant can be used to seal irregularly shaped and spalled joints.

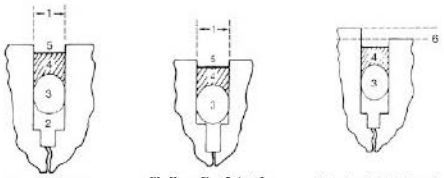
TYPICAL PROPERTIES

Specification Writers: These values are not intended for use in preparing specifications. Please contact your local Dow Corning sales office or your Global Dow Corning Connection before writing specifications on this product.

Test	Property	Result	D5893 Requirement
As Supplied			
	Color	Dark gray	
ASTM[1] C639	Flow	Pass	Smooth, level
ASTM C 1183	Extrusion Rate, minimum	231 mL/min	20 mL/min
ASTM C 679	Tack Free Time	Pass	5 hours max
ASTM C 792	Heat Aging	0.97%	10% loss max
ASTM C 661	Durometer Shore 00	41	30 minimum
ASTM D 792	Specific Gravity	1.26 - 1.34	
	Cure Time, 1/2" x1/2"x2" (73F, 50% R.H.)	Pass	21 day Cure
As Cured – 21 days at 25°C (77°F) and 50% RH			
	Bond, Non-Immersed	Pass	No cracks or separation
	Bond, Water Immersed	Pass	No cracks or separation
	Bond, Oven Aged	Pass	No cracks or separation
ASTM D 412 (Die C)	Ultimate Elongation	1000%	600% min
ASTM D 412 (Die C)	Tensile Stress @ 150%	19 psi	45 psi max
ASTM C 793	Effects of Accelerate Weathering	Pass	5,000 hours
	Resilience	77%	75% min
	Joint Movement Capability, +100/-50 percent, 10 cycles	No failure	

[1]ASTM: American Society for Testing and Materials.

Figure 1: Good Joint Design



1. Joint width wide enough to accommodate movement. (For additional information on joint width, see papers by Spells and Klosowski, "Silicone Sealants for Use in Concrete Construction," Vol. 1, No. 1, American Concrete Institute, SP-70, 1981; J.B. Cook, "Construction Sealants and Adhesives," Wiley-Interscience, 1970; and J.M Klosowski, "Sealants in Construction," Marcel Dekker, 1989.)
2. Joint sawed deep enough to allow backer rod/sealant placement and space for pumping of old sealant compounds. NOTE: This applies to standard joints only; void space beneath backer rod in new construction is not needed.
3. Proper backer rod placement to prevent three-sided adhesion.
4. Sealant installed to proper depth and width.
5. Sealant recessed a minimum of 3/8 inch to 1 /2 inch (9.53 mm to 12.7 mm) below pavement surface.
6. Depth of lowest slab determines the amount of recess required if grinding is anticipated; once grinding is complete, the sealant will have proper recess below the pavement surface.

DESCRIPTION

Dow Corning 890-SL Self-Leveling Silicone Joint Sealant is a one-part, self-leveling silicone material that cures to an ultra-low-modulus silicone rubber upon exposure to atmospheric moisture. The cured silicone rubber remains flexible from -20 to 300° F.

Asphaltic paving materials have low tensile strengths. It is important to use an ultra-low modulus material when sealing these substrates to ensure minimal strain is placed on the asphaltic joint face.

HOW TO USE

Please refer to the Dow Corning Silicone Pavement Sealants Installation Guide 61-507N-01.

HANDLING PRECAUTIONS

Caution: Before handling sealant, read product and material safety data sheets for detailed use and health information.

This product contains a proprietary acetamidosilane that liberates N-ethyl acetamide (N-EA) during cure. N-EA may cause birth defects based on animal data. Toxicology studies indicate that repeated, pro-longed overexposure to N-EA causes an adverse reproductive effect in lab-oratory animals. Avoid breathing vapors. Do not use in poorly ventilated spaces. Avoid prolonged skin contact. KEEP OUT OF REACH OF CHILDREN.

Fully cured sealant is nonhazardous.

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USABLE LIFE AND STORAGE

Keep stored in original, unopened containers at or below 32°C (90°F). Refer to product packaging for "Use By" date. Keep containers tightly closed.

PACKAGING INFORMATION

Dow Corning 890-SL Self-Leveling Silicone Joint Sealant is supplied in 29-fl oz (857-mL) dispos-able plastic cartridges, 4.5-gal (17-L) bulk pails, and 50-gal (189-L) bulk drums.

LIMITATIONS

Dow Corning 890-SL Self-Leveling Silicone Joint Sealant is not recommended for continuous

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2012, February 14
Form No. 62017-01

water immersion. It should not be applied in totally confined spaces where the sealant is not exposed to atmospheric moisture.

The sealant should never be applied to wet or damp asphalt or concrete pavements or installed during inclement weather.

Dow Corning does not encourage, warrant, or pursue the use of *Dow Corning* 890-SL Self-Leveling Silicone Joint Sealant for airfield runway applications, except for shoulder joints. Taxiways and aprons are approved applications for this product.

Dow Corning does not promote or warrant the use of *Dow Corning*® brand sealants in applications associated with spill containment areas of any kind.

This product is neither tested nor represented as suitable for medical or pharmaceutical uses.

SHIPPING LIMITATIONS

None.

HEALTH AND ENVIRONMENTAL INFORMATION

To support customers in their product safety needs, Dow Corning has an extensive Product Stewardship organization and a team of Product Safety and Regulatory Compliance (PS&RC) specialists available in each area.

For further information, please see our website, dowcorning.com or consult your local Dow Corning representative.

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Your exclusive remedy for breach of such warranty is limited to refund of purchase price or replacement of any product shown to be other than as warranted.

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DOW CORNING DISCLAIMS LIABILITY FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES.

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[1]Highway & Heavy Construction, June 1988, p. 53.

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Table 1: Recommended Backer Rod Installation (Shallow Cut)[1]

Measured in Inches						
Joint Width	1/4	3/8	1/2	3/4	1	>1
Recessed Below Surface	3/8	3/8	3/8 to ½"	3/8 to 1/2"	½"+	Contact
Sealant Thickness	1/4	1/4	1/4	3/8	1/2	Dow
Backer Rod Diameter	3/8	1/2	5/8	7/8	$1^{1}/_{4}$	Corning
Total Joint Depth	$1 - 1^{1}/_{8}$	$1^{1}/_{8} - 1^{1}/_{4}$	$1^{1}/_{4} - 1^{3}/_{8}$	$1^{5}/_{8} - 1^{3}/_{4}$	$2^{1}/_{4} - 2^{3}/_{8}$	
Measured in Millimeters						
Joint Width	6	9	13	19	25	
Recessed Below Surface	9	9	9 to 13	9 to 13	13+	
Sealant Thickness	6	6	6	9	13	
Backer Rod Diameter	9	13	16	22	32	
Total Joint Depth	25 - 29	29 - 32	32 - 35	41 - 45	57 - 60	

[1]On road surfaces where grinding is planned at a later date, the sealant and backer rod should be installed so that sealant is approximately 3/8 inch (9.35 mm) below the road surface after grinding is complete. An additional small amount should be added to allow for surface imperfections on the bottom and to provide room for old sealant to pump up from below during rehabilitation work in the summer months.

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Product Information
Silicone
Sealants

DOW CORNING

Dow Corning® 888 Silicone Joint Sealant

FEATURES

- Can be extruded from -20 to 120°F
- Unprimed adhesion to Portland cement concrete
- May be used in joints that are not uniform in width
- Movement capability 100% extension and 50% compression
- Low modulus
- Weather and UV resistant
- Meets or exceeds the requirements of ASTM D5893

BENEFITS

- One component, cold applied, ready-to-use as supplied; dispensed directly from the bulk container into the joint by hand or with an air-powered pump.
- Unprimed adhesion – primer is not required for bonding to Portland cement concrete. For optimum adhesion, the surface must be clean, dry and frost-free.
- High movement capability; 100% extension and 50% compression.
- Low modulus.
- Weather and UV resistant.
- Cure time – typically, the sealant will have a skin-over time of one hour or less at standard conditions.

COMPOSITION

- One-part, cold applied, non-sag silicone sealant.

Non-sag silicone joint sealant for Portland cement concrete pavement joints.

DESCRIPTION

Dow Corning® 888 Silicone Joint Sealant is a one-part, non-sag silicone material that cures to a low-modulus silicone rubber upon exposure to atmospheric moisture. Can be applied over a wide temperature range.

APPLICATIONS

- *Dow Corning* 888 Silicone Joint Sealant can be used for concrete to concrete pavement joints.
- For use in new construction, repair or remedial applications. *Dow Corning* 888 Silicone Joint Sealant may be used to seal joints that are not uniform in width provided the movement capability of the sealant is not exceeded. May also be used in joints with minor spalling.

TYPICAL PROPERTIES

Specification Writers: These values are not intended for use in preparing specifications. Please contact your local Dow Corning sales office or your Global Dow Corning Connection before writing specifications on this product.

Test	Property	Result	D5893 Requirement
	As Supplied		
	Color	Gray	
ASTM D2202	Slump	Pass	<0.30 inches
ASTM C 1183	Extrusion Rate, minimum	72 mL/min	20 mL/min
ASTM C 679	Tack Free Time	Pass	5 hours max
ASTM C 792	Heat Aging	3.05%	10% loss max
ASTM C 661	Durometer Shore A-2	15	25 maximum
ASTM D 792	Specific Gravity	1.48	
	Cure Time, 1/2" x1/2"x2" (73°F, 50% R.H.)	Pass	21 day Cure
	As Cured – 21 days at 25°C (77°F) and 50% RH		
	Bond, Non-Immersed	Pass	No cracks or separation
	Bond, Water Immersed	Pass	No cracks or separation
	Bond, Oven Aged	Pass	No cracks or separation
ASTM D 412 (Die C)	Ultimate Elongation	≥1000%	600% min
ASTM D 412 (Die C)	Tensile Stress @ 150%	28 psi	45 psi max

HOW TO USE

Please refer to the Dow Corning Silicone Pavement Sealants Installation Guide 61-507N-01

HANDLING PRECAUTIONS

Caution: Before handling sealant, read product and material safety data sheets for detailed use and health information.

This product contains a proprietary acetamidosilane that liberates N-ethyl acetamide (N-EA) during cure. N-EA may cause birth defects based on animal data. Toxicology studies indicate that repeated, pro-longed overexposure to N-EA causes an adverse reproductive effect in lab-oratory animals. Avoid breathing vapors. Do not use in poorly ventilated spaces. Avoid prolonged skin contact. KEEP OUT OF REACH OF CHILDREN.

Fully cured sealant is nonhazardous.

PRODUCT SAFETY INFORMATION REQUIRED FOR SAFE USE IS NOT INCLUDED IN THIS DOCUMENT. BEFORE HANDLING, READ PRODUCT AND MATERIAL SAFETY DATA SHEETS AND CONTAINER LABELS FOR SAFE USE, PHYSICAL AND HEALTH HAZARD INFORMATION.
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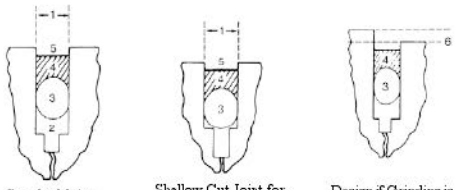
Keep stored in original, unopened containers at or below 32°C (90°F). Refer to product packaging for "Use By" date. Keep containers tightly closed.

TYPICAL PROPERTIES (con't)

Test	Property	Result	D5893 Requirement
ASTM C 793	Effects of Accelerate Weathering	Pass	5,000 hours
	Resilience	77%	75% min
ASTM C719	Joint Movement Capability, +100/-50 percent, 10 cycles	No failure	

ASTM: American Society for Testing and Materials.

Figure 1: Good Joint Design



Standard Joint | Shallow Cut Joint for New Construction | Design if Grinding is Anticipated

1. Joint width wide enough to accommodate movement. (For additional information on joint width, see papers by Spells and Klosowski, "Silicone Sealants for Use in Concrete Construction," Vol. 1, No. 1, American Concrete Institute, SP-70, 1981; J.B. Cock, "Construction Sealants and Adhesives," Wiley-Interscience, 1970; and J.M. Klosowski, "Sealants in Construction," Marcel Dekker, 1989.)
2. Joint sawed deep enough to allow backer rod/sealant placement and space for pumping of old sealant compounds. NOTE: This applies to standard joints only; void space beneath backer rod in new construction is not needed.
3. Proper backer rod placement to prevent three-sided adhesion.
4. Sealant installed to proper depth and width.
5. Sealant recessed a minimum of 3/8 inch to 1 /2 inch (9.53 mm to 12.7 mm) below pavement surface.
6. Depth of lowest slab determines the amount of recess required if grinding is anticipated; once grinding is complete, the sealant will have proper recess below the pavement surface.

PACKAGING INFORMATION

Dow Corning 888 Silicone Joint Sealant is supplied in 29-fl oz (857-mL) dispos-able plastic cartridges, 4.5-gal (17-L) bulk pails, and 50-gal (189-L) bulk drums.

LIMITATIONS

Dow Corning 888 Silicone Joint Sealant is not recommended for continuous water immersion. It should not be applied in totally confined spaces where the sealant is not exposed to atmospheric moisture.

Not intended for use with asphalt.

The sealant should never be applied to wet or damp concrete pavements or installed during inclement weather.

Dow Corning does not promote or warrant the use of *Dow Corning*® brand sealants in applications

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associated with spill containment areas of any kind.

This product is neither tested nor represented as suitable for medical or pharmaceutical uses.

SHIPPING LIMITATIONS

None.

HEALTH AND ENVIRONMENTAL INFORMATION

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Table 1: Recommended Backer Rod Installation (Shallow Cut)[1]

Measured in Inches						
Joint Width	1/4	3/8	1/2	3/4	1	>1
Recessed Below Surface	3/8	3/8	3/8 to 1/2	3/8 to 1/2	1/2+	Contact
Sealant Thickness	1/4	1/4	1/4	3/8	1/2	Dow
Backer Rod Diameter	3/8	1/2	5/8	7/8	$1^{1}/_{4}$	Corning
Total Joint Depth	$1 - 1^{1}/_{8}$	$1^{1}/_{8} - 1^{1}/_{4}$	$1^{1}/_{4} - 1^{3}/_{8}$	$1^{5}/_{8} - 1^{3}/_{4}$	$2^{1}/_{4} - 2^{3}/_{8}$	
Measured in Millimeters						
Joint Width	6	9	13	19	25	
Recessed Below Surface	9	9	9 to 13	9 to 13	13+	
Sealant Thickness	6	6	6	9	13	
Backer Rod Diameter	9	13	16	22	32	
Total Joint Depth	25 - 29	29 - 32	32 - 35	41 - 45	57 - 60	

[1]On road surfaces where grinding is planned at a later date, the sealant and backer rod should be installed so that sealant is approximately 3/8 inch (9.35 mm) below the road surface after grinding is complete. An additional small amount should be added to allow for surface imperfections on the bottom and to provide room for old sealant to pump up from below during rehabilitation work in the summer months.

2012, April 4
Ref No. 61-408M-01

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Dow Corning®

832

Multi-Surface Adhesive Sealant

• 100% Silicone •

Engineered for Assembly and Maintenance Applications

Dow Corning® 832 Multi-Surface Adhesive Sealant is a one-component, ready-to-use, noncorrosive silicone material that seals, bonds and protects. Engineered for use as an all-purpose assembly and maintenance sealant, *Dow Corning* 832 Multi-Surface Adhesive Sealant bonds to many surfaces and offers superior adhesion to glass, metal, masonry, concrete, rubbers and plastics.

Features

- 100 percent silicone RTV rubber
- Superior unprimed adhesion to a wide variety of surfaces, including glass, metal, masonry, concrete, most rubber and plastics, including ABS, PVC and polycarbonate
- Low odor
- Neutral (alcohol) cure
- Will not corrode metal or other corrosion-sensitive materials
- Use temperatures: -67 to 300°F (-55 to 149°C); intermittent to 350°F (177°C)
- Forms flexible, long-lasting seal
- Available in off-white, black and gray

Applications

Dow Corning 832 Multi-Surface Adhesive Sealant is used for bonding, sealing and assembly where superior unprimed adhesion or noncorrosive sealant is required. Typical applications include sealing and repairing roof penetrations, gutters, concrete floor seams, marine equipment and windows, pipes, threaded connections, and assembling original equipment components.

To Learn More ...

For more information about *Dow Corning* 832 Multi-Surface Adhesive Sealant, contact your Dow Corning representative or call (517) 496-6000.

DOW CORNING

How To Use

Apply to clean, dry, frost-free surfaces. Typically, no primer is necessary; however, for best adhesion to concrete, use a primer such as *Dow Corning*® 1205 Primer. *Dow Corning* 832 Multi-Surface Adhesive Sealant will dry to the touch in 20 minutes.

Limitations

- Not intended for food-contact applications
- Requires atmospheric moisture to cure
- Not for use in submerged structural or adhesive applications
- Not designed for high-movement joints
- Not for application to oily or dirty surfaces
- Most paints will not adhere to sealant

This product is neither tested nor represented as suitable for medical or pharmaceutical uses.

Storage/Useable Life

When stored at or below 90°F (32°C), *Dow Corning* 832 Multi-Surface Adhesive Sealant has a useable life of 18 months from date of manufacture by Dow Corning. For best results, use completely within 6 months of opening.

Since this material cures by reaction with moisture in the air, keep the container sealed when not in use. A plug of cured material may form in the tip of the tube during storage, but is easily removed and does not affect the remaining contents.

Available Packaging

Dow Corning 832 Multi-Surface Adhesive Sealant is available in 10.1-fl oz (299-mL) cartridges, 4.5-gal (17-L) pails, and 45-gal (170-L) drums in selected colors.

Typical Properties

These values are not intended for use in preparing specifications.

As Supplied[1]		
	Consistency	Nonslumping paste
	Corrosion Properties	Noncorrosive
CTM[2] 0364	Extrusion Rate, 1/8-inch nozzle at 90 psi, grams/minute	133
CTM 0098	Skin-Over Time, minutes	20
CTM 0095	Tack-Free Time, minutes	50-90
CTM 0022	Specific Gravity at 77°F (25°C)	1.33
As Cured[3]		
	Color	Off-white, black, gray
CTM 0293	Peel Strength, ppi	
	ABS	>35
	Acrylic, primed	>30
	Polycarbonate, primed	>35
	Polycarbonate, unprimed	>35
	Phenolic G-10	>30
	Polystyrene	>20
	PVC	>30
	Aluminum, anodized	>30
	Aluminum, milled	>35
	Brass	>30
	Steel, carbon	>35
	Steel, galvanized	>30
	Steel, millled	>25
	Steel, stainless	>30
	Wrought Iron	>30
	Copper	>35
	Glass	>30
	Neoprene	>25
	Silicone Rubber	>30
CTM 0099	Durometer Hardness, Shore A	35
CTM 0137A	Tensile Strength, psi	350
CTM 0137A	Elongation, percent	420

[1]All cure conditions are 77°F (25°C) and 50 percent RH.
[2]CTMs (Corporate Test Methods) correspond to standard ASTM tests in most instances. Copies of CTMs are available upon request.
[3]After 7 day cure at 77°F (25°C) and 50 percent RH.

Specification Writers: Please obtain a copy of the Dow Corning Sales Specification for this product and use it as a basis for your specifications. It may be obtained from any Dow Corning Sales Office, or from Dow Corning Customer Service in Midland, MI. Call (517) 496-6000.

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DOW CORNING

Dow Corning Corporation
Midland, Michigan 48686-0994

PRODUCT DATA

NO. 773-A

MasterFormat:
07 92 13
32 13 73

W. R. MEADOWS, SEALTIGHT

NOVEMBER 2013
(Supersedes July 2013)

POURTHANE® SL

Self-Leveling Joint Sealant

DESCRIPTION

POURTHANE SL is an elastic, one-component, self-leveling, premium-grade polyurethane sealant specifically developed to be used as a multi-purpose horizontal joint sealant in applications where a high chemical resistance to fuels, oils, and hydrocarbons is required. The product is a moisture cure sealant with excellent adhesive properties and resistance to aging and weathering.

USES

POURTHANE SL is used to seal horizontal expansion joints in concrete and cementitious slabs, such as sidewalks, balconies, pavement, terraces, warehouses, factories, civil structures, plazas, runways, and pitch pans.

FEATURES/BENEFITS

- One-component, no mixing.
- Self-leveling.
- Movement capacity of +/-25%.
- Accelerated curing.
- Jet fuel resistant.
- Permanently elastic.
- High durability.
- Resists aging and weathering.
- Excellent adhesion.
- Convenient, easy-to-use packaging.
- Low VOC content.

PACKAGING

20 Oz. (592 mL) Sausages
29 Oz. (825 mL) Cartridges
5 Gal. (18.93 L) Pails
55 Gal. (208.20 L) Drums

AVAILABLE COLORS

Limestone, Stone Gray, Tan

COVERAGE

This chart shows the approximate number of lineal feet that can be sealed per gallon. One gallon is approximately four cartridges.

Joint Depth	Joint Width						
	1/4" (6.4 mm)	3/8" (9.5 mm)	1/2" (12.7 mm)	5/8" (15.9 mm)	3/4" (19.1 mm)	7/8" (22.2 mm)	1" (25.4 mm)
1/4" (6.4 mm)	308	205	154	122			
3/8" (9.5 mm)				82	68	58	51
1/2" (12.7 mm)					51	44	38

When estimating, figure 5 cartridges/gal. (2 cartridges/1.5 L).
Cubic inches/gal. – 231 (1000 cm^3)
Cubic inches/cartridge – 21 (344.13 cm^3)

For triangular cross-section joints:
1/4" (6.35 mm) each side – 616 linear ft./gal. (49.6 m/L)
1/2" (12.7 mm) each side – 154 linear ft./gal. (12.4 m/L)
3/4" (19.1 mm) each side – 68 linear ft./gal. (5.5 m/L)

SHELF LIFE

When stored indoors and in original, unopened containers at temperatures between 41 - 77° F (5 – 25° C), shelf life is a minimum of one year from date of manufacture, except for pails and drums, which have a shelf life of six months.

SPECIFICATIONS

- ASTM C 920-11, Type S, Grade P, Class 25, Use T_1, T_2, NT, M, O, G.
- Conforms to BS 5212 for determination of resistance to heat, aging, and fuel immersion.
- Can/CGSB 19.13-M87, Classification C-1-40-B-N and C-1-25-B-N, No. 81028
- Canadian approval for use in areas that handle food
- Federal Specification TTS-00230C, Type 1, Class A
- Approval/Standards Conform to ISO 11600 F 25 HM
- USDA compliant for use in areas that handle meat and poultry

CONTINUED ON REVERSE SIDE…

W. R. MEADOWS, INC.
P.O. Box 338 • HAMPSHIRE, IL 60140-0338
Phone: 847/214-2100 • Fax: 847/683-4544
1-800-342-5976
www.wrmeadows.com

HAMPSHIRE, IL /CARTERSVILLE, GA /YORK, PA
FORT WORTH, TX /BENICIA, CA /POMONA, CA
GOODYEAR, AZ / MILTON, ON /ST. ALBERT, AB

TECHNICAL DATA (Typical Results)

Appearance	Pasty
Specific Gravity	1.509
Viscosity @ 74° F (23° C)	Brookfield RVT / spindle 6 / 5 rpm : ca. 15,000 mPa.s
Density @ 68° F (20° C)	1.52 ± 0.05
Application Temperature	40 - 100° F (4.4 – 37.8° C)
Skin Formation Time @ 74° F (23° C) and 50% RH	60/120 Min.
Shore A Hardness (ASTM D 2240) 21 Day	35 +/- 5
Temperature Resistance	-40 - 176° F (-40 - 80° C)
Resistance to Dilute Acids and Bases	Average
UV Resistance	Good
Water and Salt Spray Résistance	Excellent
Compatibility w/Paints	Water-Based: Yes Solvent-Based: Test beforehand
Modulus @ Break ASTM D412	>0.6 MPA
Elongation @ Break ASTM D412	>800%
VOC Content	24 g/L

APPLICATION

Surface Preparation … Clean all surfaces. Joint walls must be sound, clean, dry, frost-free, and free of all oil and grease. Curing compound residues and any other foreign matter must be thoroughly removed. Install bond breaker tape or KOOL-ROD™ from W. R. MEADOWS to prevent bond at base of joint.

Priming … Priming is not usually necessary. Substrates only require priming if testing indicates a need or where sealant will be subjected to water immersion after cure. If priming is required, use P/G PRIMER from W. R. MEADOWS.

Application Method … Condition material to 65° - 75° F (18.3° - 23.9° C) before using. Sealant should be installed when joint is at mid-range of anticipated movement. Gun sealant into joint opening in one direction and allow sealant to flow and level out as necessary. Tool as required; minimum tooling is necessary. Joint dimensions should allow for ¼" (6.35 mm) minimum and ½" (12.7 mm) maximum thickness for sealant. Proper design is 2:1 width-to-depth ratio. Always use bond breaker tape or KOOL-ROD™ from W. R. MEADOWS for support on horizontal joints.

Cleanup … Application tools can be cleaned with toluene or xylene before curing. Afterwards, mechanical cleaning will be required.

PRECAUTIONS

Allow one-week cure at standard conditions when used in total water immersion applications. Maximum exposure level of chlorine is 5 ppm. Do not cure in presence of curing silicone sealants. Avoid contact with alcohol and other solvent cleaners during cure. Do not apply when moisture vapor transmission condition exists from the substrate. High temperatures or humidity may cause uncured material to bubble. Product may bubble if substrates are not absolutely dry or if material is applied too deep. Maximum depth of POURTHANE SL should be 3/8" (10 mm). Do not use caulks, sand, or incompressibles as a bottom in a joint. Do not install when rain is expected before the product develops a substantial skin. Storing at elevated temperatures will reduce shelf life.

LEED INFORMATION

May help contribute to LEED credits:

- IEQ Credit 4.1: Low Emitting Materials: Adhesives & Sealants
- MR Credit 2: Construction Waste Management
- MR Credit 5: Regional Materials

For most recent data sheet, further LEED information, and MSDS, visit www.wrmeadows.com.



LIMITED WARRANTY

W. R. MEADOWS, INC. warrants at the time and place we make shipment, our material will be of good quality and will conform with our published specifications in force on the date of acceptance of the order. Read complete warranty. Copy furnished upon request.

Disclaimer

The information contained herein is included for illustrative purposes only, and to the best of our knowledge, is accurate and reliable. W. R. MEADOWS, INC. cannot however under any circumstances make any guarantee of results or assume any obligation or liability in connection with the use of this information. As W. R. MEADOWS, INC. has no control over the use to which others may put its product, it is recommended that the products be tested to determine if suitable for specific application and/or our information is valid in a particular circumstance. Responsibility remains with the architect or engineer, contractor and owner for the design, application and proper installation of each product. Specifier and user shall determine the suitability of products for specific application and assume all responsibilities in connection therewith.

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CRAFCO INC
AN ERGON & COMPANY
420 N. Roosevelt Ave. • Chandler AZ 85226
1-800-528-8242 • (602) 276-0406 • FAX (480) 961-0513
www.crafco.com

PRODUCT DATA SHEET

ROADSAVER 231

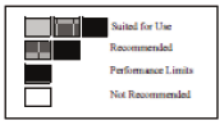
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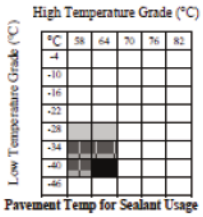
MARCH 2010

READ BEFORE USING THIS PRODUCT

GENERAL Crafco RoadSaver 231 is a hot-applied, asphalt based product used to seal cracks and joints in asphalt or portland cement concrete pavements in cold to very cold climates. RoadSaver 231 is supplied in solid form which when melted and properly applied forms a resilient, adhesive and flexible compound with high elongation capability at low temperatures, and resistance to flow during the summer. RoadSaver 231 is used in highway, street, and airfield pavements and is applied to pavement cracks and joints using either pressure feed melter applicators or pour pots. At application temperature it is free flowing and self-leveling. Due to it's softness, RoadSaver 231 is not recommended for use as a crack sealant in parking lots or other areas with high levels of foot traffic. RoadSaver 231 has been a quality Crafco product for 25 years. RoadSaver 231 has proven to be an exceptional performing sealant in cold climates and has achieved the Crafco **CERTIFIED PERFORMANCE** designation. VOC = 0 g/l.

USAGE GUIDELINES RoadSaver 231 pavement temperature performance limits are 64-40 for crack sealing. Usage recommendations are shown in Crafco pavement temperature grade charts shown at the right. Refer to Crafco Product Selection Procedures to determine sealant or filler use and pavement temperature grades.





SPECIFICATION CONFORMANCE RoadSaver 231 meets all requirements of ASTM D6690 (AASHTO M324), Type IV, "Joint and Crack Sealants, Hot-Applied for Concrete and Asphalt Pavements", and several state low modulus modified versions of ASTM D3405.

Test	ASTM D6690 (AASHTO M324), Type IV Limits
Cone Penetration 77°F (25°C)	90-150
Softening Point	176°F (80°C) min
Resilience, 77°F (25°C)	60% min
Bond, -20°F, (-29°C) 200% ext	Pass 3 cycles
Asphalt Compatibility	Pass
Minimum Application Temperature	380°F (193°C)
Maximum Heating Temperature	400°F (204°C)

INSTALLATION The unit weight of Crafco RoadSaver 231 is 9.8 lbs. per gallon (1.18 kg/L) at 60°F (15.5°C). Prior to use, the user must read and follow Installation Instructions for Hot-Applied RoadSaver, PolyFlex, Parking Lot and Asphalt Rubber Products to verify proper product selection, heating methods, pavement preparation procedures, application geometry, usage precautions and safety procedures. These instructions are provided with each pallet of product.

PACKAGING Packaging consists of individual boxes of product which are palletized into shipping units. Boxes contain a non-adherent film which permits easy removal of the product. Each pallet contains 72 boxes which are stacked in six layers of 12 boxes per layer. The weight of product in each box does not exceed 40 lbs. (18kg) and pallet weights do no exceed 2,880 lbs. (1310 kg). Pallets of product are weighed and product is sold by the net weight of product. Product boxes are manufactured from double wall kraft board producing a minimum bursting test certification of 350 psi (241 N/cm^2) and using water resistant adhesives. Boxes use tape closure and do not contain any staples. Boxes are labeled with the product name, part number, lot number, specification conformance, application temperatures and safety instructions. Palletized units are protected from the weather using a three mil thick plastic bag, a weather and moisture resistant cap sheet and a minimum of two layers of six month u.v. protected stretch wrap. Pallets are labeled with the product part number, lot number and net weight. Installation Instructions are provided with each pallet in a weather resistant enclosure.

WARRANTY CRAFCO, Inc. warrants that CRAFCO products meet applicable ASTM, AASHTO, Federal or State specifications at time of shipment. Techniques used for the preparation of the cracks and joints prior to sealing or filling are beyond our control as are the use and application of the products; therefore, Crafco shall not be responsible for improperly applied or misused products. Remedies against Crafco, Inc., as agreed to by Crafco, are limited to replacing nonconforming product or refund (full or partial) of purchase price from Crafco, Inc. All claims for breach of this warranty must be made within three (3) months of the date of use or twelve (12) months from the date of delivery by Crafco, Inc. whichever is earlier. There shall be no other warranties expressed or implied. **For optimum performance, follow Crafco recommendations for product installation**

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acetone or IPA may also be helpful. Different cleaning techniques may give better results than others. Users should determine the best technique for their applications. For especially difficult-to-bond-to surfaces, it may be necessary to increase the surface reactivity by chemical etchants or oxidizers, or by exposing the surface to UV, corona, plasma or flame sources. Allow solvents to completely evaporate before applying the primer.

Processing/Curing

These products require moisture in the air to cure, and are generally cured at room temperature and in a range of 20 to 90 percent relative humidity for 1 to 2 hours. Low humidity and/or low temperature conditions require longer cure times. Mild heat acceleration of the cure rate may be possible but temperatures above 60°C (140°F) are not recommended. During application, the carrier solvent typically evaporates off quickly, allowing the active ingredients to begin to react with atmospheric moisture and bonding surfaces. For optimal bonding, different cure times may be required for different temperature and humidity conditions. Users should determine the best cure schedule and conditions for their applications. The desired silicone elastomer should be applied after the primer, prime coat or adhesion promoter has fully cured.

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USABLE LIFE AND STORAGE

Shelf life is indicated by the "Use Before" date found on the product label. For best results, Dow Corning primers, prime coats and adhesion promoters should be stored below 32°C (90°F). Special precautions must be taken to prevent moisture from contacting these materials before use. Containers should be kept tightly closed and head or air space minimized. Partially filled containers should be purged with dry air or other gases such as nitrogen to maximize shelf life. Small amounts for immediate use should be poured into clean, dry containers and discarded when finished. Material should not be used once it takes on a milky appearance or a large amount of white precipitate is observed, indicating moisture contamination. Repeated opening of the container can cause a small amount of white precipitate to form inside the container cap area, which does not affect the bulk material.

HANDLING PRECAUTIONS

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HEALTH AND ENVIRONMENTAL INFORMATION

To support customers in their product safety needs, Dow Corning has an extensive Product Stewardship organization and a team of Product Safety and Regulatory Compliance (PS&RC) specialists available in each area.

For further information, please see our website, dowcorning.com, or consult your local Dow Corning representative.

LIMITATIONS

This product is neither tested nor represented as suitable for medical or pharmaceutical uses.

LIMITED WARRANTY INFORMATION – PLEASE READ CAREFULLY

The information contained herein is offered in good faith and is believed to be accurate. However, because conditions and methods of use of our products are beyond our control, this information should not be used in substitution for customer's tests to ensure that our products are safe, effective, and fully satisfactory for the intended end use. Suggestions of use shall not be taken as inducements to infringe any patent.

Dow Corning's sole warranty is that our products will meet the sales specifications in effect at the time of shipment.

Your exclusive remedy for breach of such warranty is limited to refund of purchase price or replacement of any product shown to be other than as warranted.

DOW CORNING SPECIFICALLY DISCLAIMS ANY OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY.

DOW CORNING DISCLAIMS LIABILITY FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES.

For More Information

To learn more about these and other products available from Dow Corning, please visit the Dow Corning Electronics website at dowcorning.com/electronics.

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dowcorning.com

AMPM030-10
2010, January 20
Ref. No. 11-1768-01

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Product Information
Primers

DOW CORNING

Dow Corning® PR-1204 RTV Prime Coat

BENEFITS

- Enhances adhesion of many moisture cure RTV silicones

Enhances bonding/adhesion of RTV and heat cure silicones to many metals, ceramics, glass and masonry.

APPLICATION METHODS

- Apply in a very light, even coat by wiping, dipping or spraying.
- Excess material should be wiped off to avoid overapplication.
- Diluting by a factor of 2 to 4 with additional solvent may avoid excessive build-up.

TYPICAL PROPERTIES

Specification Writers: These values are not intended for use in preparing specifications. Please contact your local Dow Corning sales office or your Global Dow Corning Connection before writing specifications on this product.

Property	Unit	Value
NVC (Non Volatile Content)	%	7.9
Adhesion - 180 Degree Peel Strength (aluminum)	ppi N/cm^2	66 45.5
Shelf Life @ 25°C	months	18

DESCRIPTION

Dow Corning® brand primers, prime coats and adhesion promoters are dilute solutions of silane coupling agents and other active ingredients. The surface reactive components typically must be applied in a very thin layer for best bonding. The solvents used in these products serve to deliver the active ingredients in a thin, uniform coating, enhance surface cleaning, and in some cases, aid in the penetration of the active ingredients into the bonding surface. Primers can be used to increase design flexibility, reduce total costs or increase performance reliability of electronic systems. They do this by enabling adhesion to lower-cost substrates or lower temperature processes which reduce energy budgets, among other possibilities.

HOW TO USE

These products should be applied in a very light, even coat by wiping, dipping or spraying. Excess material should be wiped off to avoid overapplication, which generally appears as a white, chalky surface. When dip or spray coating, diluting by a factor of 2 to 4 with additional solvent may avoid excessive build-up. Apply additional cleaner/primer to the cloth every 3 to 5 minutes to ensure fresh material can react with the substrate.

Preparing Surfaces

The active ingredients must thoroughly wet out and coat the bonding surfaces. Mild abrasion, solvent cleaning, plasma, corona discharge and other pre-treatments have been used to clean and enhance surface reactivity to bonding. In general, light surface abrasion is recommended whenever possible, because it promotes good cleaning and increases the surface area for bonding. Surfaces should be cleaned and/or degreased with naphtha, mineral spirits, methyl ethyl ketone (MEK) or other suitable solvents that will remove oils and other contaminants that may be present. A final surface wipe with

Product Information
Primers

DOW CORNING

Dow Corning® PR-1205 Prime Coat

BENEFITS

- Enhances adhesion of many RTV and heat cure silicones

Enhances bonding/adhesion of RTV and heat cure silicones to many metals, ceramics and plastics.

APPLICATION METHODS

- Apply in a very light, even coat by wiping, dipping or spraying.
- Excess material should be wiped off to avoid overapplication.
- Diluting by a factor of 2 to 4 with additional solvent may avoid excessive build-up.

TYPICAL PROPERTIES

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Property	Unit	Value
Color	–	Light Straw
Primed Adhesion - 180 Degree Peel Strength	ppi N/cm^2 kg/cm^2	34 23.4 2.3
Shelf Life @ 25°C	months	12

DESCRIPTION

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contaminants that may be present. A final surface wipe with acetone or IPA may also be helpful. Different cleaning techniques may give better results than others. Users should determine the best technique for their applications. For especially difficult-to-bond-to surfaces, it may be necessary to increase the surface reactivity by chemical etchants or oxidizers, or by exposing the surface to UV, corona, plasma or flame sources. Allow solvents to completely evaporate before applying the primer.

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LIMITATIONS

This product is neither tested nor represented as suitable for medical or pharmaceutical uses.

LIMITED WARRANTY INFORMATION – PLEASE READ CAREFULLY

The information contained herein is offered in good faith and is believed to be accurate. However, because conditions and methods of use of our products are beyond our control, this information should not be used in substitution for customer's tests to ensure that our products are safe, effective, and fully satisfactory for the intended end use. Suggestions of use shall not be taken as inducements to infringe any patent.

Dow Corning's sole warranty is that our products will meet the sales specifications in effect at the time of shipment.

Your exclusive remedy for breach of such warranty is limited to refund of purchase price or replacement of any product shown to be other than as warranted.

DOW CORNING SPECIFICALLY DISCLAIMS ANY OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY.

DOW CORNING DISCLAIMS LIABILITY FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES.

For More Information

To learn more about these and other products available from Dow Corning, please visit the Dow Corning Electronics website at dowcorning.com/electronics.

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2010, January 20
Ref. No. 11-1773-01

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RELTEK LLC
adhesives, sealants & coatings for harsh environments

BONDiT™ A-43

Bonding Agent, Primer and Adhesive

Bonding agent	Promotes adhesion with previously considered non-reactive polymers, and bonding between many dissimilar polymers with, and without adhesives. Good adhesion to polyethylene, polypropylene, epoxy, esters, urethanes, fluoropolymers, silicone, rubbers, glass, ceramic and metals.
Primer for molding	A one part, one coat, thin film, ambient or thermal cure primer on metals, glass, ceramics and plastics for adhesion of thermoplastics, thermoset, rubbers and urethane molding.
Versatile production application	Excellent high and low temperature performance, Unlimited selflife on cured coating. Dip, spray, brush, and roll application
Harsh environments	Marine, Industrial, Downhole oil, Mining, Automotive, Medical.



BONDiT™ A-43

Description

BONDiT™ A-43 is a high performance, high and low temperature one-part primer, adhesive, adhesion promoter for metals, glass & ceramics, elastomers and polymers. ***BONDiT™*** A-43 offers a wide range of capabilities for promoting single coat chemical bonding between minerals and polymers, as well as dissimilar polymers. it is used as a primer coat for other ***BONDiT™*** coatings and encapsulants.

Curing Guide

A wide range of curing regimes may be employed. Typical cure is ambient 30 to 60 minutes or 75°C for 15 minutes, or 150°C (302°F) for 5 minutes. May be brushed, sprayed, or poured. Wetting qualities are superior, even on non-polar surfaces.

Storage

The usable shelf life of unopened containers of ***BONDiT™*** A-43 resin is one year, and should be stored in cool, dry place. When not in use, containers should be kept tightly closed after purging with dry nitrogen. ***BONDiT™*** A-43 is available in syringes cans, bulk container, and custom packaging.

Typical Properties

Property	***Value***
Viscosity @ 25°C, ASTM D445	4.5-8.5
Specific gravity, ASTM D1298	1.018-1.038
Refractive index, ASTM D1218	1.4420-1.4480
Color	Clear with stray color

Application Notes

BONDiT™ A-43 is very effective in promoting reactions with materials such as polyolefins including non-polar and cross linked polyethylenes, urethanes, floropolymers, epoxies, silicone rubber. Diverse adhesive combinations of dissimilar materials with significant environmental resistance are obtained when used with other ***BONDiT™*** products.

Information

For further information, engineering support and sales service, contact the ***RELTEK*** sales office.

Phone • 707-284-8808 *e-mail • reltek@reltekllc.com*
2345 Circadian Way, Santa Rosa, CA 95407 *Fax • 707-284-8812*

LOCTITE®

Laboratory Data Sheet

Product 3035

July 2012

PRODUCT DESCRIPTION

LOCTITE® 3035 is a high strength, faster fixturing two-component acrylic adhesive system designed for bonding low energy plastics without surface pre-treatment. This easy to use, 1:1 mix ratio product cures very rapidly forming tough, durable bonds. LOCTITE® 3035 is low odor, non-flammable, halogen and solvent free and will also bond metals and a host of other plastics. This product requires no refrigeration.

UNCURED PROPERTIES

Mix Ratio	1:1
Viscosity	7,500 cP (Part A), 60,000 cP (Part B)
Sustainability	halogen-free, non-flammable, low outgassing
Odor	mild

CURING PROPERTIES

Color	pale yellow
Working Time, min	4
Fixture Time, min.	>10<15 (HDPE), >10<15 (HDPE/Steel)
Surface Cure	pass (24 hr. closed container)
Shrinkage (read-thru)	not tested

MECHANICAL PROPERTIES, PSI

- Block Shear Strength, ISO 13445, cured 72 hr. at 22ºC

Polyolefins	
HDPE	1658 psi (14.3 MPa)
HDPE/Steel	657 psi (13.5 MPa)
LDPE	532 psi (9.9 MPa)
Metals	
Steel	879 psi (14.5 MPa)
Aluminum	423 psi (6.7 MPa)
Other Plastics	
ABS	642 psi (10.1 MPa)
Acrylic	886 psi (12.3 MPa)
Delrin	120 psi (2.6 MPa)
G-10 Epoxy	1045 psi (19.4 MPa)
Nylon	226 psi (1.9 MPa)
PC	726 psi (10.3 MPa)
Phenolic	416 psi (9.2 MPa)
PVC	1237 psi (8.8 MPa)
Valox 420	1081 (8.8 MPa)

- Impact Strength cured 72 hr. at 22ºC

Metals	
Steel	3 Joules

- T-Peel Strength, ISO 11339

Metals	
Steel	2 lbf/in

For safe handling information on this product, consult the Material Safety Data Sheet (MSDS).

Storage

Store product in cool, dry location, in unopened containers at a temperature between 8°C and 28°C (26°F to 82°F) unless otherwise labeled. Optimal storage is at the lower half of this temperature range. To prevent contamination of unused product, do not return any material to its original container. For further specific shelf life information, contact Application Engineering at (860) 571-5100.

Data Ranges

The data contained herein may be reported as a typical value and/or range. Values are based on actual test data and are verified on a periodic basis.

Note

The developmental product for which the data provided herein is furnished for informational purposes only and is believed to be accurate and reliable. Nevertheless, Henkel Corporation cannot and will not assume responsibility for the results obtained by others over whose production methods we have no control. Thus, it is the user's responsibility to determine the suitability of this developmental product for the user's purpose of any production methods mentioned herein and to adopt such precautions as may be advisable for the protection of property and of persons against any hazards that may be involved in the handling, storage, disposal and use thereof. In light of the foregoing, **HENKEL CORPORATION SPECIFICALLY DISCLAIMS ANY AND ALL WARRANTIES EXPRESSED OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND FREE FROM CLAIMS OF THIRD PARTY PATENT INFRINGEMENT, ARISING FROM THE SALE, POSSESSION, HANDLING, STORAGE, DISPOSAL, TRANSPORTATION OR USE OF THIS DEVELOPMENTAL PRODUCT. HENKEL CORPORATION SPECIFICALLY DISCLAIMS ANY LIABILITY FOR CONSEQUENTIAL OR INCIDENTAL DAMAGES OF ANY KIND, INCLUDING LOST PROFITS.** Neither the developmental product, nor the data or discussion herein of various processes for which, are to be interpreted as an express or implied license under any Henkel Corporation patents. Henkel Corporation recommends that any and all proposed commercial application(s) using this developmental product be evaluated for reproducibility in the exact manner and on the production equipment with which it is intended to be used before repetitive commercial production use, using this data as a guide. One or more United States or foreign patents or patent applications of Henkel Corporation may cover this developmental product, or under which Henkel Corporation is licensed.

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Henkel Technologies

RELTEK LLC
adhesives, sealants & coatings for harsh environments

BONDiT™ B-45TH

Adhesive & Sealant System

Bonds dissimilar materials

An adhesives for bonding dissimilar materials such as plastics including UHMW, HDPE, PP, PET, PEEK, PPS, PBT, Acetal, ETFE, PVC, PVCF, PVDF, ABS, ECTFE, polyamide, polyimide rubber and urethane compounds on metal, glass, composites, cement, wood and cellulose.

High chemical resistance

Superior chemical resistance for moisture and oil, acids and bases in continuous full submersion. High thermal stability in a rugged flexible system.

Easy use

Two part, primerless, flexible epoxy, ambient and thermal cure. Low HAZMAT impact. Available in handheld and pneumatic gun actuated cartridges, quarts, gallons and drums.

Harsh environments

Marine,
Civil Engineering,
Downhole oil,
Underwater,
Electronic,
Mining,
Industrial,
Automotive.



BONDiT™ B-45TH

Description

BONDiT™ B-45TH is a two-part, state-of-the-art 100% solids, room-temperature curing flexible epoxy resin system. Especially designed for adhesive and sealant applications in bonding to engineering plastics and elastomers to various substrates. Bondable plastics include the polyolefins--UHMW, HDPE, and PP, PET (Ertylite & Mylar), PEEK, PPS, PBT (Valox) Acetal (Delrin), ETFE, PVC, PVCF, PVDF (Kynar), ABS, ECTFE (Halar), polyamide and polyimide (Ultem & Torlon), fiberglass and composites. Elastomers include EPDM, butyl, neoprene, urethanes, and some thermoplastic elastomers (Hytrel). The B-45TH will bond these materials to metals, glass, ceramic, cement, wood and cellulose substrates, as well as to each other.

B-45TH handles harsh environments easily and particularly effective against moisture, salt water, acids, alkalies, oils, and detergents. B-45TH has high thermal stability--in exposure of rubber/metal bonds to 500°F for 8 minutes bulk-rubber-tear/cohesive adhesion was retained. B-45TH offers good corrosion resistance. The flexible properties of B-45TH permits assembly of materials with dissimilar thermal expansion and survive thermal cycling. Likewise mechanical vibration, shock and impact are easily absorbed by B-45TH and protect surfaces, bonded assemblies and encapsulated sensitive electronics. These systems are often superior in performance to urethane adhesives and sealants.

B-45TH is silicate filled and thixotropic, meaning a thick coating on vertical surfaces will not sag, but is easily poured from a can. Apply B-45TH by roller or brush. B-45TH is very easy to use with low HAZMAT impact as a 100% solids epoxy system--no plasticizers that bloom to the surface and no solvents causing VOC problems. The product is also available in the unfilled version B-45, most useful for potting and clear coating applications to replace urethanes.

Mixing, Curing, and Storage

A wide range of curing regime may be employed: ambient set in 4 hours, tack free in 12 hours, and 95% cure in 24 hours. Post curing at 150°F, after 2 hours at ambient to allow bubble escape, will cure 98% in 4 hours, or 2 hours at 200°F.

Mix part A with part B, 2: 1 ratio by volume or weight. Degassing is optional. Pot life is typically 30 - 40 minutes, at ambient temperature. Surface prep by abrading or grit blasting substrates with # 100 AlOx followed by degrease and/or alcohol wipe.

The usable shelf life of unopened containers of ***BONDiT™*** B-45TH resin is one year, and should be stored in cool, dry place. When not in use, containers should be kept tightly closed.

BONDiT™ B-45TH is available in side-by-side handheld and pneumatic actuated gun cartridges, quarts, gallons, pails and drums. Custom packaging, such as premixed and degassed frozen cartriges, is also available.

BONDiT™ B-45TH

Test Data

Lapshear test: ASTM D3163; all values mean; all failures adhesive/cohesive at plastic-adhesive interface.

Adhesive	Substrate #1	Substrate #2	Cure Temp °F	Peak Stress PSI	Sample Range Hi/Lo Peak Stress PSI	Strain Peak Load %	Energy Peak Load In-Lb	Break Stress PSI	Elongation at Break %	Yield Stress PSI	Elongation at Yield %	Tangent Modulus PSI
B-42	HDPE	HDPE	150	295	299/290	1.65	2.96	290	1.7	295	1.7	22882
B-42	UHMW	UHMW	150	312	—	3.16	5.81	307	3.3	308	2.7	14184
B-45TH	UHMW	UHMW	150	279	325/256	2.22	3.69	279	2.4	274	2.3	14478
B-45TH	UHMW	UHMW	Ambient*	288	308/246	2.20	3.69	282	2.2	279	2.1	15760
B-45TH	UHMW	Steel	150	424	484/364	1.74	4.69	424	1.6	424	1.6	33556
B-45TH	UHMW	Steel	Ambient*	361	401/326	1.68	3.7	361	1.7	361	1.7	27291
B-45TH	PPS	SS	150	812	—	1.05	4.61	813	1.0	813	1.0	82478
B-45TH	PPS	SS	Ambient**	492	—	0.77	2.25	490	0.8	492	0.8	77347
B-45TH	ABS	PVC	150	677	677/677	2.68	10.39	676	2.8	677	2.8	27247
B-45TH	ACETAL	ACETAL	150	339	362/323	1.50	3.20	339	1.5	333	1.5	24759

*Ambient cure 31 days **Ambient cure 7 days

Peel tests

Adhesive	Substrate #1	Substrate #2	Failure mode
B-42	PBT	PET	cohesive/adhesive failure of PET film
B-42	PBT	Polyurethane foam	cohesive failure of PU foam
B-42	PEEK	PET	cohesive/adhesive failure of PET film
B-42	PEEK	Polyurethane foam	cohesive failure of PU foam
B-42	G10 fiberglass	PET	cohesive/adhesive failure of PET film
B-42	G10 fiberglass	Polyurethane foam	cohesive failure of PU foam
B-45TH	Neoprene	Steel	cohesive failure of rubber
B-45TH	Neoprene	Neoprene	cohesive failure of rubber
B-45TH	EPDM	Steel	cohesive failure of rubber
B-45TH	Butyl	Aluminum	cohesive failure of rubber after 500°F, 8 minute exposure

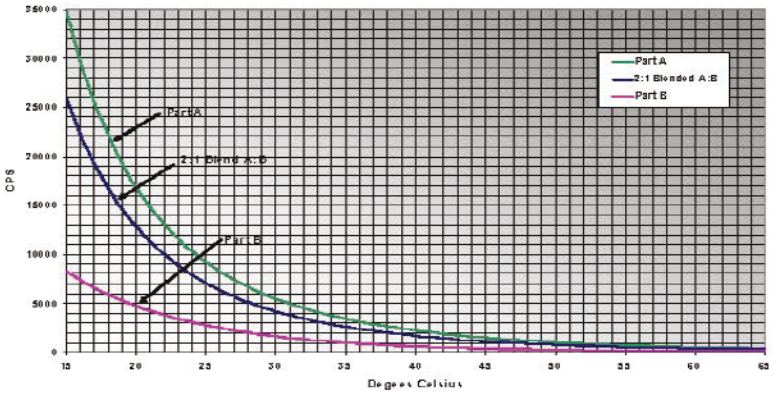
BONDIT™ B-45TH

Typical Properties

Property	B-45TH
Color	Clear with haze/slight amber
Viscosity	~9000 cps @ 25°C, Thixotropic****
Moisture absorption*	< 1%*
Oil absorption**	< 1%***
Gasoline	No effect to slight increase in durometer, ambient
Acids	Little or no effect, > pH 4, <85%, ambient
Bases	Little or no effect, < 13 pH, < 85%, ambient
Tensile strength	
Peak stress	1438 PSI
Break stress	1422 PSI
Elongation at break	130%
Yield stress	1438 PSI
Elongation at yield	130%
Durometer, ultimate	80 A-Shore
Insulation Resistance	>500 VDC / .001"
Temperature range	-50°F to 350°F

*90 days ambient DI water ** Isopar M by Shell Oil *** 60 days ambient

Viscosity BONDIT B-45



Information

For further information, engineering support and sales service, contact the **RELTEK** sales office.

Phone • 707-284-8808 • Fax • 707-284-8812
2345 Circadian Way, Santa Rosa, CA 95407
e-mail • reltek@reltekllc.com
Website • www.reltekllc.com

rev031008

3M

Adhesive Transfer Tapes with Adhesive 300LSE

8132LE • 8153LE • 9453LE • 9471LE • 9472LE 9653LE • 9671LE • 9672LE

Technical Data **April, 2013**

Product Description

3M™ Adhesive Transfer Tapes with 3M™ Low Surface Energy Acrylic Adhesive 300LSE provides high bond strength to most surfaces, including many low surface energy plastics such as polypropylene and powder coated paints. The acrylic adhesive also provides excellent adhesion to surfaces contaminated lightly with oil typically used with machine parts.

Product Construction

Product Number	Adhesive: (Solvent Free)	Liner:
3M™ Adhesive Transfer Tape 8132LE	2.3 mils (58 microns) 3M High Strength Acrylic Adhesive 300LSE	4.0 mils (100 microns) 58# Polycoated kraft 6.2 mils (157 microns) 83# Polycoated kraft
3M™ Adhesive Transfer Tape 8153LE	3.5 mils (88 microns) 3M High Strength Acrylic Adhesive 300LSE	4.0 mils (100 microns) 58# Polycoated kraft 6.2 mils (157 microns) 83# Polycoated kraft
3M™ Adhesive Transfer Tape 9453LE	3.6 mils (91 microns) 3M High Strength Acrylic Adhesive 300LSE	4.2 mils (107 microns) 58# Polycoated kraft
3M™ Adhesive Transfer Tape 9471LE	2.3 mils (58 microns) 3M High Strength Acrylic Adhesive 300LSE	4.2 mils (107 microns) 58# Polycoated kraft
3M™ Adhesive Transfer Tape 9472LE	5.2 mils (132 microns) 3M High Strength Acrylic Adhesive 300LSE	4.2 mils (107 microns) 58# Polycoated kraft
3M™ Adhesive Transfer Tape 9653LE	3.5 mils (88 microns) 3M High Strength Acrylic Adhesive 300LSE	6.2 mils (157 microns) 83# Polycoated kraft
3M™ Adhesive Transfer Tape 9671LE	2.3 mils (58 microns) 3M High Strength Acrylic Adhesive 300LSE	6.2 mils (157 microns) 83# Polycoated kraft
3M™ Adhesive Transfer Tape 9672LE	5.0 mils (127 microns) 3M High Strength Acrylic Adhesive 300LSE	6.2 mils (157 microns) 83# Polycoated kraft

3M™ Adhesive Transfer Tapes with Adhesive 300LSE

8132LE • 8153LE • 9453LE • 9471LE • 9472LE • 9653LE • 9671LE • 9672LE • 9698LE

Typical Physical Properties and Performance Characteristics

Typical Adhesion Properties

Note: The following technical information and data should be considered representative or typical only and should not be used for specification purposes.

Peel Adhesion - ounces/inch (Newtons/100 mm) ASTM D3330, modified: 90° peel, 2 mil aluminum backing.

Typical Adhesion Chart

	3M™ Adhesive Transfer Tape	15 Minute Room Temperature Oz./In.	15 Minute Room Temperature N/100 mm	72 Hour Room Temperature Oz./In.	72 Hour Room Temperature N/100 mm
Stainless Steel	8132LE	71	78	75	82
	8153LE	90	98	100	109
ABS	8132LE	70	77	79	86
	8153LE	80	88	113	124
Polypropylene	8132LE	69	75	74	81
	8153LE	89	97	103	113
Stainless Steel	9453LE	90	98	100	109
	9471LE	71	78	75	82
	9472LE	109	119	140	153
ABS	9453LE	80	88	113	124
	9471LE	70	77	79	86
	9472LE	102	112	128	140
Polypropylene	9453LE	89	97	103	113
	9471LE	69	75	74	81
	9472LE	115	126	136	149
Stainless Steel	9653LE	90	98	100	109
	9671LE	71	78	75	82
	9672LE	109	119	140	153
ABS	9653LE	80	88	113	124
	9671LE	70	77	79	86
	9672LE	102	112	128	140
Polypropylene	9653LE	89	97	103	113
	9671LE	69	75	74	81
	9672LE	115	126	136	149

3M™ Adhesive Transfer Tapes with Adhesive 300LSE

8132LE • 8153LE • 9453LE • 9471LE • 9472LE • 9653LE • 9671LE • 9672LE

Typical Physical Properties and Performance Characteristics *(continued)*

Typical Adhesion Properties

Note: The following technical information and data should be considered representative or typical only and should not be used for specification purposes.

The properties defined are based on the attachment of impervious faceplate materials (such as aluminum) to a stainless steel test surface.

Bond Build-up: The bond strength of 3M™ Adhesive 300LSE increased as a function of time and temperature, and has very high initial adhesion.

Humidity Resistance: High humidity has a minimal effect on adhesive performance. No significant reduction in bond strength is observed after exposure for 7 days at 90°F (32°C) and 90% relative humidity.

U.V. sistance: When properly applied, nameplates and decorative trim parts are not adversely affected by exposure.

Water Resistance: Immersion in water has no appreciable effect on the bond strength. After 100 hours at room temperature, the high bond strength is maintained.

Temperature Cycling Resistance: High bond strength is maintained after cycling four times through:

4 hours at 158°F (70°C)
4 hours at -20°F (-29°C)
4 hours at 73°F (22°C)

Chemical Resistance: When properly applied, nameplates and decorative trim parts will hold securely after exposure to numerous chemicals including oil, mild acids and alkalis.

Temperature Resistance: 3M™ Adhesive 300LSE is usable for short periods (minutes, hours) at temperatures up to 300°F (148°C) and for intermittent longer periods of time (days, weeks) up to 200°F (93°C).

Lower Service Temperature: -40°F (-40°C).

Available Sizes

Width and Length (subject to minimum order requirements):

	3M™ Adhesive Transfer Tapes 8132LE, 8153LE*	3M™ Adhesive Transfer Tapes 9453LE, 9471LE, 9472LE, 9653LE, 9671LE, 9672LE
Standard Sheet Size:	24 in. x 36 in.	–
Limitations:	Maximum 360 yards	1/2 in. to 63/64 in.: Maximum 180 yards 1 in. to 54 in.: Maximum 360 yards
Minimum Slit Width:	12 in.	1/2 in.
Maximum Slit Width:	48 in.	54 in.
Normal Slitting Tolerance:	± 1/32 in.	± 1/32 in.
Core	6.0 in.	3.0 in.

*Custom sheets are available.

3M™ Adhesive Transfer Tapes with Adhesive 300LSE

8132LE • 8153LE • 9453LE • 9471LE • 9472LE • 9653LE • 9671LE • 9672LE • 9698LE

Features

- 3M™ Adhesive 300LSE is a hi-strength acrylic adhesive that provides a very high bond strength to most surfaces.
- Excellent bond to low surface energy plastics such as, polypropylene and powder coatings.
- Excellent adhesion to lightly oiled surfaces typical of machine parts.
- Thickness range of 2.0 mils, 3.5 mils, 5.0 mils and 8.5 mils for use on smooth, or rough surfaces.
- Extremely smooth adhesive for excellent graphics appearance.
- Double linered for selective die-cutting.
- Polycoated kraft liner for die-cutting end tabs and waste removed nameplates on a common carrier.
- 3M™ Adhesive Transfer Tapes 8132LE and 8153LE are double linered for selective die-cutting.

Application Techniques

For maximum bond strength, the surface should be thoroughly cleaned and dried. Typical cleaning solvents are heptane or isopropyl alcohol. Carefully read and follow manufacturer's precautions and directions for use when using cleaning solvents.

Bond strength can also be improved with firm application pressure and moderate heat, from 100°F (38°C) to 130°F (54°C), causing the adhesive to develop intimate contact with the bonding surface.

Ideal tape application temperature range is 70°F to 100°F (21°C to 38°C). Initial tape application to surfaces at temperatures below 50°F (10°C) is not recommended for most pressure-sensitive adhesives because the adhesive becomes too firm to adhere readily. However, once properly applied, low temperature holding is generally satisfactory.

General Information

- Plastic nameplates or graphic overlays for use on low surface energy plastics.
- Waste removed nameplates on a common sheet for ease of application.
- Attaching membrane switch assemblies to powder coated surfaces and low surface energy plastics.
- Graphic overlays with end tabs for easy liner removal.
- Graphic application to surfaces such as wood, fabric, plastic, where very high bond strength is required.
- Attaching identification material to lightly oily surfaces typical of machine parts.

Application Ideas

Processing:

Slitting and die-cutting: This adhesive is very aggressive and may be difficult to convert depending on your application requirements. Chilling the adhesive between 35°F and 50°F will improve the processability. In addition, dies can be lubricated with Laminoleum evaporative stamping oil, which is available from Metal Lubricants Company (708-333-8900), or with Lubri-Blade 907 from Ceramic Technologies Inc. (800-258-8495). You may also refer to our Technical Bulletin on 3M™ Adhesive 300LSE converting. (70-0707-6205-2)

Roll Laminating: A combination of metal and rubber rollers with moderate pressure is recommended.

Note: Please refer to the Technical Bulletin on slitting. (70-0709-3905-6)

3M™ Adhesive Transfer Tapes with Adhesive 300LSE

8132LE • 8153LE • 9453LE • 9471LE • 9472LE • 9653LE • 9671LE • 9672LE

Storage	Store at room temperature conditions of 70°F (21°C) and 50% relative humidity.
Shelf Life	If stored properly, product retains its performance and properties for 18 months from date of shipment.
Recognition/ Certification	**TSCA:** These products are defined as articles under the Toxic Substances Control Act and therefore, are exempt from inventory listing requirements. **MSDS:** These products are not subject to the MSDS requirements of the Occupational Safety and Health Administration's Hazard Communication Standard, 29 C.F.R. 1910.1200(b)(6)(v). When used under reasonable conditions or in accordance with the 3M directions for use, the products should not present a health and safety hazard. However, use or processing of the products in a manner not in accordance with the directions for use may affect their performance and present potential health and safety hazards. **Note:** One of 3M's core values is to respect our social and physical environment. 3M is committed to comply with ever-changing, global, regulatory and consumer environmental, health, and safety (EHS) requirements. As a service to our customers, 3M is providing information on the regulatory status of many 3M products. Further regulation information including that for OSHA, USCPSI, FDA, California Proposition 65, READY and RoHS, can be found at 3M.com/regs.
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ISO 9001

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3M

Industrial Adhesives and Tapes Division
Converter Markets
3M Center, Building 225-3S-06
St. Paul, MN 55144-1000
800-223-7427 • 651-778-4244 (fax)
www.3M.com/converter

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Acronyms

Term	Definition
AAS	Aircraft Arresting System
AFB	Air Force Base
AFI	Air Force Instruction
AFCEC	Air Force Civil Engineer Center
ANOVA	Analysis of Variance
ASTM	American Society of Testing and Materials
EMAS	Engineered Material Arresting Systems
FAA	Federal Aviation Administration
LSD	Least Significant Difference
PCC	Portland Cement Concrete
S.F.	Safety Factor
UHMW	Ultra-High Molecular Weight
UHMWPE	Ultra-High Molecular Weight Polyethylene

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
inches	0.0254	meters
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
mils	0.0254	millimeters

REPORT DOCUMENTATION PAGE

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5e. TASK NUMBER

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Geotechnical and Structures Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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"Aircraft Arrestor System UHMW Panel Joint Sealant," MIPR F4ATA44136J001

14. ABSTRACT

Aircraft Arresting Systems (AAS) for military applications utilize sacrificial panels made of Ultra-High Molecular Weight polyethylene (UHMWPE) that are embedded into the pavement beneath the AAS cable to protect the pavement from cable damage. Problems have been observed with the materials and practices used to seal the UHMWPE panel joints from water and debris. Data obtained from laboratory and field studies were used make improvements to current practice for sealing UHMWPE panel joints. The study evaluated four joint-sealant materials, eight alternative surface treatment and preparation techniques to promote adhesion to UHMWPE, and seven joint-edge geometries. Bond-strength testing of joint-sealant specimens was conducted in the laboratory, followed by field evaluation of construction techniques. Field performance of the joint systems was monitored for 24 months after installation. Additionally, a thermal response model was developed to refine the joint design dimensions. Results confirmed that the best material to use was self-leveling silicone joint sealant. It was recommended that a dovetail groove be cut into the edge of UHMW panels to provide positive mechanical interlock and to reduce adhesive failures of the sealant. It was also recommended that the panel-to-panel joint-sealant reservoir be widened to prevent sealant compression damage.

15. SUBJECT TERMS

Aircraft arresting system
Ultra high molecular weight polyethylene
Cables
Joint sealant
Portland cement concrete
Pavement
Sealing compounds
Airfield
Runways (Aeronautics)
Landing aids (Aeronautics)
Runways (Aeronautics)--Joints

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