Evaluating the Effectiveness of Hot-Poured Crack Surfacing Material

Dr. Khaled Ksaibati

Steven D. Carter

Department of Civil and Architectural Engineering

University of Wyoming

P.O. Box 3295

Laramie, WY 82071-3295

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DISCLAIMER

ABSTRACT

This research project evaluates the effectiveness of hot-poured crack surfacing material and its ability to seal asphaltic cracks. The term “crack surfacing” is used to describe the rigidity of the material and to distinguish it from crack sealants. The University of Wyoming, in cooperation with the Wyoming DOT, conducted field and laboratory evaluations to determine the in-situ performance, temperature and load characteristics, and rutting susceptibility of three selected manufacturer’s products: Deery American Corporation’s Level & Go and Recessed Repair Mastic, and Crafco Incorporated’s PolyPatch.

The field evaluation was accomplished at selected test sections of Wyoming Route 93, US Route 26, and Interstate 25. These evaluations identified the modes of failure, superficial distresses, and percent effectiveness. The laboratory evaluation included performance of the Thermal Stress Restrained Specimen Test (TSRST) and the Georgia Loaded Wheel Tester (GLWT). The TSRST was used to evaluate the cold temperature bonding characteristics, in particular the fracture temperature, and the load capacity of the crack surfacing materials. To represent field conditions, the materials were configured as flush, uniform overband, tapered overband, and mill & fill. The GLWT was utilized to evaluate the rutting susceptibility of the materials in use.

The findings of this research indicate that the Crafco PolyPatch and the tapered overband configuration were the best performers. Based on the results, it is recommended that the PolyPatch material be used with the tapered overband configuration for cold climate applications.

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1. INTRODUCTION

1.1 Background

Throughout the United States, and particularly in the northern Rocky Mountain states (Idaho, Montana and Wyoming), temperature fluctuations can have adverse effects on asphaltic pavements. In Wyoming, ambient air temperatures can range from an average January low of 8°F (-13°C) to an average July high of 80°F (27°C). In addition, this region also experiences extreme record conditions that range from a low temperature of -66°F (-54°C) recorded at Riverside, WY, to a high of 114°F (46°C) recorded at Greybull, WY (NOAA, 2003). Temperature extremes of this nature can cause cracking in asphaltic pavements. Extensive cracking permits water and incompressible materials to infiltrate the pavement structure. These incompressible materials promote further pavement deterioration, such as alligator cracking and potholes, in addition to weakening the pavement structure resulting in reduced service life, ride quality, and the need for costly pavement rehabilitation.

To eliminate the intrusion of water, it is necessary to seal the crack with a material that will bond with the asphalt concrete and resist internally induced stresses. Historically, hot-applied thermoplastic bituminous materials have been used in Wyoming with fair success. The sealant material consists of a blended mixture of bitumen, petroleum, copolymer, and filler. However, sealant materials in current use behave with a glass transition zone that is unable to handle the extreme temperature differences (Bramel, 1999). Depending on the type of material and installation method, the current crack sealants can provide an operational service life ranging from two to nine years (SHRP, 1999).

1.2 Problem Statement and Objectives

The University of Wyoming (UW), in cooperation with the Wyoming Department of Transportation (WYDOT), is researching a new material for sealing cracks in asphaltic pavements. WYDOT has designated the new sealant as crack surfacing material. The material is a pre-packaged, hot-applied, overband mastic repair material that is composed of quality-selected asphalt, select aggregates, synthetic rubber polymers, anti-oxidants, and other naturally occurring and man-made materials. In general, the crack surfacing material is used for sealing extra wide pavement cracks wider than one inch.

The main objective of this research is to evaluate the effectiveness of hot-poured crack surfacing material in sealing asphaltic cracks. The research consists of developing laboratory procedures for evaluating materials previously identified by WYDOT at high and low temperatures, testing these materials in accordance with defined procedures, developing field procedures for evaluating in-situ performance, and recommending materials and configuration methods based on their ability to seal cracked pavements.

1.3 Report Organization

This research project was performed in three separate elements. The first element concentrated on collecting data related to material specifications, and performing a comprehensive literature search for the three materials previously determined by WYDOT. Chapter 2 summarizes the findings of the literature review. The experiment was further divided into field and laboratory evaluations. Chapter 3 presents the design of the experiment, outlining how the research is to be performed and how the data is to be analyzed.

The field evaluation of this research project dealt with evaluating the in-situ performance. Field evaluations were performed on in-situ crack surfacing material at three predetermined locations in Wyoming. Chapter 4 contains the in-situ field evaluation and a summary of the collected data.

The laboratory evaluation of the research project included a laboratory evaluation of the thermal-induced stresses and bonding capabilities of the crack surfacing materials. Chapter 5 summarizes the laboratory evaluation and presents a summary of the resulting data.

Data analyses were performed on the results of the field and laboratory evaluations of this research project, and are presented in Chapter 6. Finally, a summary of the research project in its entirety, conclusions and recommendations for future research are presented in Chapter 7.

2. LITERATURE REVIEW

2.1 Introduction

Sealing cracks in the asphalt binder of bituminous concrete pavements is a common roadway maintenance activity. To prevent the intrusion of water and incompressible material, it is imperative that cracks be sealed by placing specialized material into or above the cracks. Asphalt cracking is unavoidable, and neglecting preventive maintenance of the pavement structure leads to accelerated cracking, which further reduces its ability to sustain traffic.

The phenomenon of cracking in asphalt pavements has been a problem for pavement design and maintenance engineers for many years. This observable fact is one of two major considerations in the pavement design process, fatigue cracking and rutting, and is often the principal manner of deterioration in asphaltic pavements (SHRP, 1999).

Remedial efforts to maintain a serviceable pavement structure range from preventive surface treatments coupled with regular maintenance activities to full-depth rehabilitation. To address the problem of cracking itself, it is common for maintenance departments to employ crack sealing and filling techniques. These techniques have been utilized for many years, with the primary purpose of extending the service life of the pavement structure. Crack sealing and filling operations can extend the pavement life past the point where the benefit of added pavement life exceeds the cost of conducting the operation (SHRP, 1999).

2.2 Assessing the Need for Treatment

If a particular asphalt pavement structure exhibits cracking, the appropriate rehabilitation decision is based on the condition of the pavement structure, and on the condition of the cracks. The potential for moisture-related pavement damage must be evaluated to determine both the need and urgency for treatment. When crack treatment, either sealing or filling, is selected, the proper crack preparation methods, sealant materials, and sealing techniques can also be selected. A number of factors should be considered in this selection. Factors affecting the decision to treat the cracks include (NCHRP, 1982):

1. Functional classification of roadway (arterial, collector, local).
2. Traffic characteristics (volume and type).
3. Climate conditions (precipitation, temperature, etc.).
4. Pavement type.
5. Pavement condition (Pavement Condition Index).
6. Subgrade characteristics (type, permeable or impermeable).
7. Crack type (transverse, longitudinal, etc.).
8. Crack condition (width, depth, secondary cracking, etc.).
9. Crack density (frequency).

The functional classification is primarily used for determining cost-effective procedures and materials. High-traffic-volume arterials are much more difficult to repair than low-volume collectors or locals, and it is cost-effective to use more durable materials to reduce the frequency of repairs and the need for expensive traffic control. For low-volume collectors and locals, the functional classification does not justify the use of more durable materials because the frequency of repair and traffic control is usually not an issue.

Climatic conditions present a critical problem. Contraction and expansion of the pavement structure is a direct result of ambient temperature fluctuations and solar heating by radiation on the pavement surface, which initiates the opening and closing of asphalt cracks. Once asphalt cracks have formed, the crack must be sealed to prevent the intrusion of water and incompressible material. Water entering the pavement structure can have a detrimental affect on the performance of the pavement by causing changes in the subgrade support and causing the binder to strip away from the aggregate (NCHRP, 1982).

Knowledge of the pavement condition is necessary to determine the type and extent of treatment required. The Pavement Condition Index (PCI) is the most widely used measure of the existing condition of the pavement structure. PCI is a measurement of surface condition from an operational standpoint and structural integrity, on a scale of 0 to 100 (ACE, 1982). The main types of distresses in asphaltic pavements are alligator cracking, reflection cracking, maintenance patching, potholes, rutting, weathering, and raveling. The results of the PCI survey are used to identify sections requiring preventive maintenance or rehabilitation. The type of maintenance required depends on the present crack condition, crack width, and type as indicated in the PCI. If a pavement exhibits cracks with widths ranging from 0.2 in. (5 mm) to 1.0 in. (25 mm), then crack sealing and filling strategies are appropriate (SHRP, 1999).

Knowledge of subgrade characteristics and the potential effects of intrusive water are also beneficial in the determination of appropriate maintenance strategies. If the subgrade material is susceptible to water damage when subjected to traffic loading, then timely treatment is essential to maintain the integrity of the pavement structure.

Once the surveys and the collected data have been reviewed, a decision can be made concerning the appropriate type of maintenance to perform and its priority.

2.3 Maintenance Strategies for Cracked Pavements

The appropriate type of maintenance for cracked pavements often depends on the density and present condition of the cracks. In general, a high percentage of cracks or severely deteriorated cracks indicate a pavement in an advanced state of decay. For such a pavement, crack treatment would not be cost-effective because the structure is in need of more extensive rehabilitation.

If cracks are of a low to moderate density and exhibit moderate to low edge deterioration, then crack sealing or filling strategies may be appropriate. Most state highway agencies (SHA) have established policies, taking into account their climates and environmental conditions that specify the type of maintenance strategy to be performed and its frequency. These policies are often based on their assessment of the overall pavement condition, crack density, crack characteristics, and crack type and width. Table 2.1 presents guidelines for determining the type of maintenance strategy to perform (SHRP, 1999).

Table 2.1 Guidelines for Determining Maintenance Type

Crack Density	Average Level of Edge Deterioration (Percentage of Crack Length)		
	Low (0 to 25)	Moderate (26 to 50)	High (51 to 100)
Low	Nothing	Nothing or Crack Treatment	Crack Repair
Moderate	Crack Treatment	Crack Treatment	Crack Repair
High	Surface Treatment	Surface Treatment	Rehabilitation

Cracked asphaltic pavements can exhibit other types of deficiencies, such as vertical displacements, which require alternative repair strategies that are beyond the scope of this research.

As previously mentioned, the maintenance strategies focused on in this research pertain to crack sealing and filling. A distinction between crack sealing and filling is necessary to allow the SHA to select the most cost-effective and durable treatment.

Crack sealing involves the placement of specialized treatment materials above or into working cracks. Working cracks experience a considerable amount of vertical and horizontal movement as a result of temperature change or traffic loading. Sealant must be applied to cracks in a configuration that prevents the intrusion of water and incompressible material, such as sand, stones or dirt, into the pavement structure.

Crack filling involves the placement of ordinary treatment materials into non-working cracks to substantially reduce the infiltration of water and to reinforce the adjacent pavement structure. Non-working cracks experience relatively small amounts of vertical or horizontal movement as a result of temperature change or traffic loading.

As these definitions indicate, crack sealing is a significantly more involved procedure, is more costly, and requires the use of specialized equipment.

The amount of annual horizontal movement should be the principle basis for the decision to seal or fill. Working and non-working cracks can be determined by their type. Working cracks are most often transverse cracks. However, some longitudinal and block cracks may meet the minimum movement criteria. Non-working cracks typically include longitudinal and block cracking. These cracks usually exhibit relatively close crack spacing with little movement. Minimal crack movement is very advantageous to the SHA, because it permits the use of less expensive, specialized materials and equipment.

2.4 Sealing and Filling Strategies

The proper maintenance strategy for treating a particular cracked pavement requires knowledge of the pavement and crack characteristics, and the materials to be utilized. Once the decision has been made to treat the cracks, there are several factors to be considered in the selection of the type of maintenance strategy to employ.

Crack sealing is a preventive maintenance activity, and is ideally conducted shortly after working cracks have widened to the minimum width necessary to perform crack sealing. Typically, crack sealing is performed when temperatures are moderately cool, approximately 45° to 65°F (7° to 18°C). Such temperatures occur in the spring and fall seasons of the year. Sealing asphaltic cracks during this time period minimizes the adverse effects of secondary cracking which is inevitable if cracks are filled during extreme temperatures that occur in summer and winter.

Sealing or filling during the spring and fall is desirable because the moderately cool conditions allow the asphalt cracks to open up sufficiently to permit the material to be placed in the crack without cutting. The width of the crack channel is at the average of its working range and the sealing material will not have to undergo excessive expansion or contraction due to temperature fluctuations.

Crack filling can be either a preventive or routine maintenance strategy, depending on the SHA's maintenance approach. Like crack sealing, preventive crack filling is performed shortly after non-working cracks have widened to the minimum width necessary to perform the procedure, typically during the moderately cool seasons of the year. Table 2.2 contains the Federal Highway Administration's recommended criteria for determining whether to seal or fill (SHRP, 1999).

Table 2.2 Recommended Criteria for Determining Whether to Seal or Fill

Crack Characteristics	Crack Treatment Activity	
	Crack Sealing	Crack Filling
Width	0.2 to 0.75 in. (5 to 19 mm)	0.2 to 1.0 in. (5 to 25 mm)
Edge Deterioration	Minimal to None (25% or Less of Crack Length)	Moderate to None (50% or less of Crack Length)
Annual Horizontal Movement	0.12 in. or Greater (3 mm)	Less than 0.12 in. (3 mm)
Type of Crack	Transverse Thermal Transverse Reflective Longitudinal Thermal Longitudinal Reflective	Longitudinal Thermal Longitudinal Cold-Joint Longitudinal Edge Distantly Spaced Block

2.4.1 Crack Sealant Materials

The range of sealant materials available for sealing and filling use is broad, with each individual product having distinct characteristics pertaining to the type of use. Traditionally, these products are grouped into one of three families: cold-applied thermoplastic bituminous materials, hot-applied thermoplastic bituminous materials, and chemically cured thermosetting materials (SHRP, 1999). Thermoplastic materials have properties that enable the product to become soft when heated and hard when cold. Thermosetting materials harden permanently as a result of heat generated by chemical reactions.

Cold-applied thermoplastic bituminous materials are emulsions of polymer-modified liquid asphalt in water. Liquid asphalt pertains to any asphalt that has been liquefied by blending with petroleum solvents. Polymer-modified liquid asphalts are modified with latex polymer or rubber polymer with resins, oils and additives. The polymers give the asphalt increased temperature range performance, rendering it more flexible in cold climates and not as soft in hot climates.

Hot-applied thermoplastic bituminous materials are comprised of asphalt cement, fiberized asphalt, asphalt rubber, rubberized asphalt and low-modulus rubberized asphalt. Hot-applied materials generally behave the same as their cold-applied counterparts, but vary only in the manner of application. To enable the hot-applied material to enter the crack, it must be heated to temperatures in excess of 380°F (193°C), while cold-applied materials are applied at ambient temperatures (Solaimanian, 2002).

Chemically cured thermosetting materials are generally multi-component materials that cure by chemical reaction from a liquid state to a solid state.

Material selection is based on the properties the material must possess to be effective at sealing the asphalt crack. These properties include the following (SHRP, 1999).

1. Short preparation time
2. Workability
3. Short cure time
4. Adhesiveness
5. Cohesiveness
6. Resistance to softening and flow
7. Flexibility
8. Elasticity
9. Resistance to aging and weathering
10. Abrasion resistance

Actual field performance should be considered when determining the appropriate material. Selection of the sealant material is an involved process, which varies by SHA and their particular experience with the individual products.

2.4.2 Crack Sealant Material Placement Configurations

There are several seal configurations in use by many SHAs. The four most common material configurations are: flush filled, reservoir, overband, and combination.

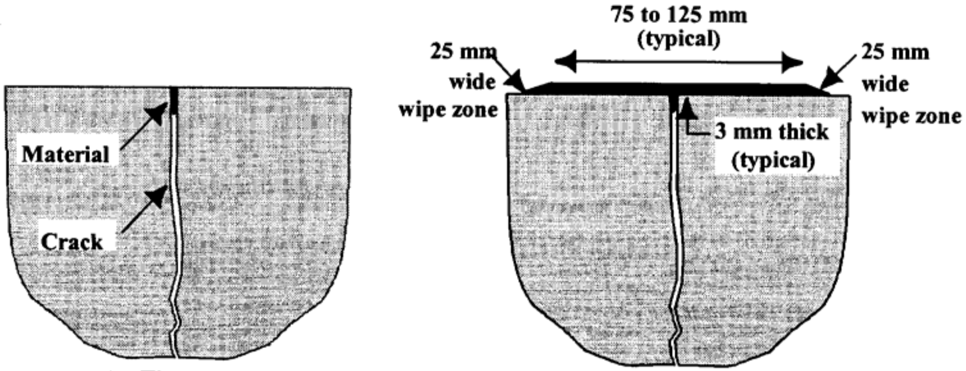
The flush filled configuration is achieved when the material is dispensed into an existing, uncut crack, and the excess is eliminated, so that the material is flush with the pavement surface. This material configuration is the most common placement employed by SHAs.

The reservoir configuration is accomplished by placing the material in the confines of a routed crack. The material can be flush with the pavement surface or recessed.

The overband configuration is executed by placing the material into an uncut crack and above the pavement surface. A band-aid configuration exists if the overband material is shaped into a band using a squeegee, and a capped configuration exists if the material is left unshaped. The band-aid dimensions are typically 3 to 5 inches (75 to 125 mm) wide, and 0.12 to 0.25 inches (3 to 6 mm) deep (SHRP, 1999).

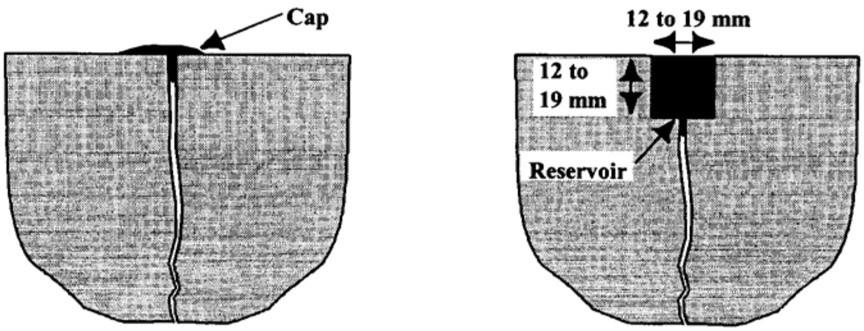
In combination configurations, the material is placed into and over a routed crack. Typically, a squeegee is used to shape the overband into a band configuration centered over the crack reservoir.

Selection of the material configuration is an involved process, and varies by SHA according to their particular experience with the different types of configurations. Figure 2.1 illustrates the four categories and combinations of material configurations (SHRP, 1999).



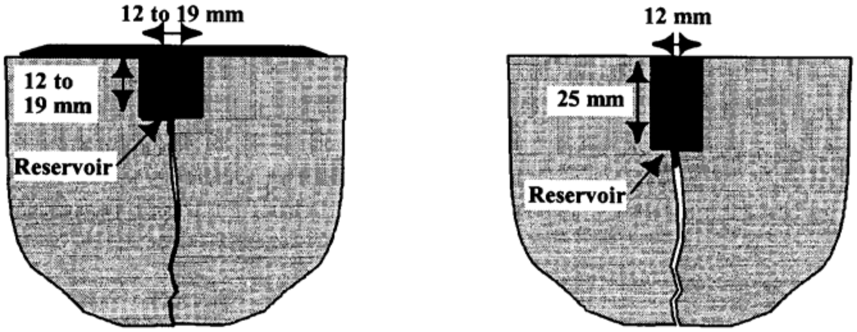
A. Flush-fill

B. Simple Band-Aid



C. Capped

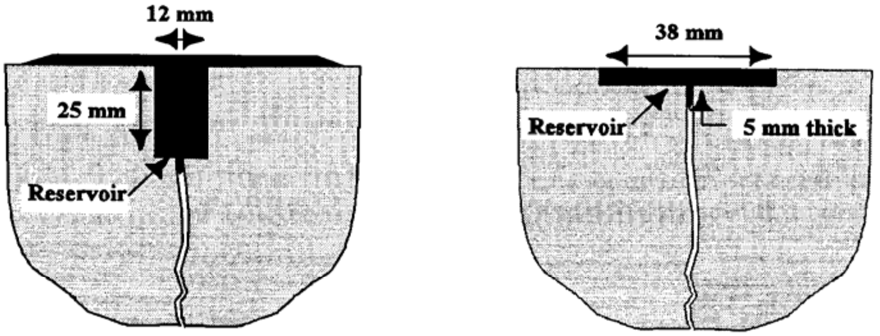
D. Standard Reservoir-and-Flush



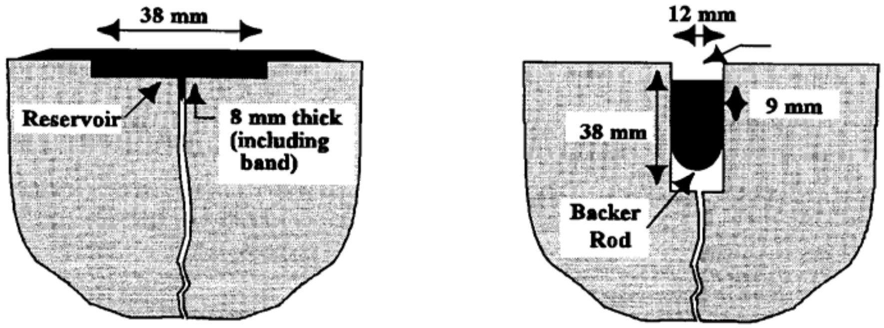
E. Standard Recessed Band-Aid

F. Deep Reservoir-and-Flush

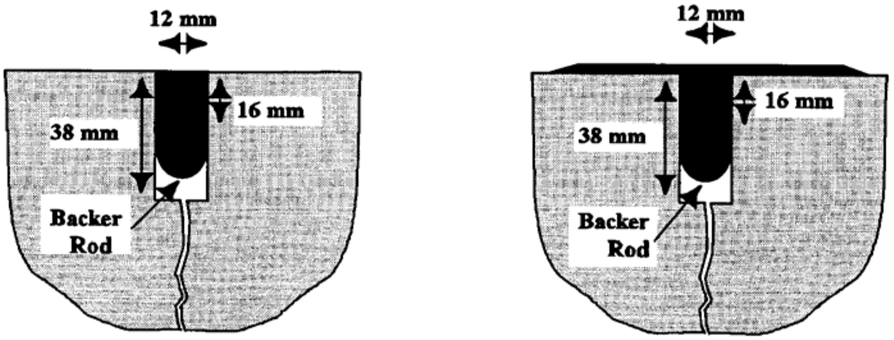
Figure 2.1 Material Placement Configurations



G. Deep Recessed Band-Aid H. Shallow Reservoir-and-Flush



I. Shallow Recessed Band-Aid J. Deep Reservoir-and-Recess (backer rod)



K. Deep Reservoir-and-Flush (backer rod) L. Deep Recessed Band-Aid (backer rod)

Figure 2.1 (Cont.) Material Placement Configurations

2.5 Crack Surfacing

Crack surfacing is a relatively new concept and the terminology applies only to this research. The term crack surfacing was developed by WYDOT to describe the process of sealing extra wide pavement cracks in excess of one inch in width, with a selected manufacturer's pavement preservation product.

In accordance with the main objective of this research, three manufacturer's products were studied: PolyPatch manufactured by Crafco Inc., and Level & Go, and Recessed Repair Mastic manufactured by Deery American Corporation. In general, these products are designated as pavement preservation products by their respective manufacturers.

2.5.1 Crafco Inc. Pavement Preservation Products

Crafco Inc. manufactures PolyPatch pavement preservation products. The PolyPatch products utilized in this research are hot-applied, pourable, self-adhesive materials used for maintenance and repair of both asphalt and concrete pavements, and are produced in two grades: PolyPatch and PolyPatch Fine Mix (Crafco, 2003). PolyPatch Fine Mix contains small aggregate, as opposed to PolyPatch which contains well-graded aggregate, and results in a more uniform texture and improved feathered edges. These products are composed of a highly modified polymer asphalt binder and selected light weight aggregate. They are specifically formulated to repair pavement distresses which are larger than those typically repaired by crack sealing, but smaller than those requiring repair patching procedures. Crafco claims that PolyPatch's unique design features produce materials which are both flexible and resistant to vehicle loadings when properly applied. The PolyPatch products are supplied in four types for use in different climates and applications.

2.5.1.1 Usage Guidelines

The PolyPatch product is available in four formulations: Types 1, 2, 3 and 4. Three types of PolyPatch Fine are available: Type 1, 2 and 3. The manufacturer has recommendations for usage, based on climatic conditions and the desired application, to ensure a well bonded, flexible, load resistant, lasting repair for the applicable pavement distress. Table 2.3 outlines the manufacturer's guidelines for usage (Crafco, 2003).

Table 2.3 Crafco PolyPatch Material Usage Guidelines

	Thermal Crack Repair (Cracks 1-2" (26 mm - 5 cm) Wide)	Leveling and Skin Patch Repair (> 1/2" (13 mm) Deep)	Leveling and Skin Patch Repair (< 1/2" (13 mm) Deep)	Surface Void Repair (Max. 4" (10 cm) Deep by 12" (30 cm) Diameter)	Wheel Rut Repair
Hot Climate: High Temp Range: PG* 70, 64Low Temp Range: PG* -10	1-2" Type 3 (Fine Mix) >2" Type 3	Type 3	Type 3 (Fine Mix)	Type 3	N/A
Moderate Climate: High Temp Range: PG* 58, 64Low Temp Range: PG* -16,-22	1-2" Type 2 (Fine Mix) >2" Type 2	Type 2	Type 2 (Fine Mix)	Type 2	Type 4
Cold Climate: High Temp Range: PG* 52, 58Low Temp Range: PG* -28,34	1-2" Type 1 (Fine Mix) >2" Type 1	Type 2	Type 2 (Fine Mix)	Type 2	Type 4

*Temperature Grades Based on 98% Confidence LTPPBIND

2.5.1.2 Recommended Application Procedures

The following application procedures are applicable to all types of PolyPatch and PolyPatch Fine Mix material.

The product is stripped from the manufacturer's supplied strippable container and placed into the Crafco PolyPatch Applicator to melt, heat and apply the product. The applicator is designed with electric heating element to expedite material heating. During melting and heating, the heat transfer oil should be heated to 450° to 525°F (232° to 274°C). Once the transfer oil is properly heated, the product is then added to the melter. After sufficient melting has occurred, the agitator is engaged for material agitation. The material is then heated to the application temperature range of 375° to 410°F (190° to 210°C) before application.

Prior to application to the pavement, the surface must be properly prepared to ensure an adequate bond. The surface must be clean, sound, dry and free from dust and debris. Caution should be taken to avoid highly distressed areas requiring reconstruction. The application area should be blown with dry, oil-free compressed air to ensure a clean, bondable surface.

In cold, wet climates with a potential for freezing, the manufacturer recommends preheating the pavement surface. This technique is also required on all applications in areas when ambient temperatures fall below 40°F (4°C), or where moisture is present. A heat lance is recommended for high-BTU, quick heating to allow the area to be blown with compressed air.

The material must be applied at least six inches (15 cm) beyond the distressed area to sound pavement surfaces. It is highly recommended that the material be applied at a temperature as close as possible to 400°F (204°C). The thickness should exceed 3/8 inches, to achieve longer heat retention times and proper drainage of the binder. Overworking and down pressure on the product should be avoided to avoid excessive heat loss and segregation which lessens the integrity of the adhesive bond and leads to unnecessary thinning of the product.

After the product has been applied to the pavement the edges should be melted down. A torch or lance is required for this procedure, and it should be accomplished while the product is still warm to reduce the amount of additional heating required. This technique assures that the repair is well-adhered and encapsulated along the edges to prevent the intrusion of moisture under the product.

PolyPatch and PolyPatch Fine Mix both have an application life 12 to 15 hours at the application temperature. The application life may be extended by adding additional kegs of product to the applicator with continual agitation. The material may be reheated to application temperature once following the initial heating. Further heating of the material may result in the degradation of material properties. Once the application life is exceeded, the material will begin to thicken and eventually gel. If this occurs, the material should be immediately removed from the applicator and discarded.

Both the PolyPatch and PolyPatch Fine Mix products may be applied to cracks with a broad range of configurations. For PolyPatch, the manufacturer’s suggested uses include repair of pavement cracks or joints more than 2 inches (5 cm) wide, small potholes up to 4 in. (10 cm) deep and 12 in. (25 cm) in diameter, pavement depressions up to 2 in. (5 cm) deep and 24 in. (60 cm) wide, skin patching in alligator-cracked and other distressed areas (avoiding deteriorated areas in need of reconstruction), leveling recessed transverse thermal cracks, and capping settled utility cuts.

Following proper application, the modified asphalt binder self-adheres and develops a strong bond to the adjoining pavement. The material undergoes shrinkage of approximately 5% as the material cools from the application temperature to the surrounding ambient temperature. No compaction is required. Before opening the area to traffic loading, sufficient time must be allotted for the material to cool. Cooling times will vary, depending on the size of the application and the ambient temperature. Generally, approximately 30 to 60 minutes of cooling should be allowed for each 1 in. (2.5 cm) of material depth.

For areas requiring deep applications, the material should be applied in two separate lifts to reduce the amount of shrinkage as the material cools. The initial lift should fill the work area to within ½ in. (12 mm) to 1 in. (25 mm) of the desired height, and should be allowed to cool prior to placement of the final lift. After cooling, the final lift should be applied level with the surrounding surface.

PolyPatch Fine Mix may be applied in a wide range of configurations as well. However, the recommended configurations are different from those for the PolyPatch product. For PolyPatch Fine Mix, the manufacturer’s suggested uses include repair of pavement cracks or joints more than 1 in. (2.5 cm) to 2 in. (5 cm) wide, small potholes up to 2 in. (5 cm) deep and 12 in. (25 cm) in diameter, pavement depressions up to 2 in. (2.5 cm) deep and 18 in. (45 cm) wide, skin patching of alligator-cracked and other distressed areas (avoiding deteriorated areas in need of reconstruction), leveling recessed transverse thermal cracks, and capping settled utility cuts. It is highly recommended by the manufacturer that PolyPatch Fine Mix not be used to fill long stretches of longitudinal ruts in pavement wheel paths, nor for surfacing skin patches near intersections. For cooling times and deep applications follow the procedures outlined for PolyPatch.

2.5.1.3 Crafco Inc. Testing Procedures

For quality control, Crafco Inc. requires five standard test methods for their PolyPatch products: PolyPatch Viscosity Test, PolyPatch Stability Test, PolyPatch Flexibility Test, PolyPatch Adhesion Test, and PolyPatch Melting Procedure Test (Crafco, 2003). The following paragraphs give a brief summary of the testing procedures. The complete procedures can be found in Appendix A.

The PolyPatch Viscosity Test should be performed on each lot of PolyPatch batch. The test is intended to assure that PolyPatch product flows from the melter easily during field applications without becoming too thin, or being too weak to withstand traffic loading. The procedure requires the PolyPatch sample to be heated to 400°F ± 2° (204°C ± 2°), and the initial weight recorded. The sample is then allowed to flow from its container into a receiver container for five seconds. The weight of the receiver container is recorded and compared with a specified range (Crafco, 2003).

The PolyPatch Stability Test is used to determine the stability of PolyPatch under vehicle loading at elevated ambient temperatures. The test is intended to assure that it has the rut resistance and stability required to perform properly as a repair material. Initially, the PolyPatch is heated to 400°F (204°C), and then poured into a containing ring. The PolyPatch is then allowed to cool for two hours before trimming off the excess material to make it level with the surface of the ring. The material is then allowed to cool to ambient temperature overnight. Once cool, the material is removed and the diameter of the specimen is recorded. The sample is then placed into a Parallel Plate Plastometer and heated in an oven at 158°F (70°C) for 10 minutes. After completion of this conditioning period, the top plate of the plastometer is placed on the specimen for 30 minutes ± 1 minute, and then removed. The diameter of the sample is recorded after a 60-minute conditioning period at ambient temperature. The stability is recorded as the difference between the initial diameter and the final diameter.

The PolyPatch Flexibility Test is used to determine the flexibility of the material at low ambient temperatures. If flexibility is not maintained at low temperatures, the material will become brittle and will break easily when subjected to traffic loading or snowplow abrasion. Initially, the PolyPatch is heated to 400°F (204°C) and placed into a keystock reservoir. Excess material is trimmed to achieve a surface level with the top of the keystock. The specimen is then allowed to cool to ambient temperature for one hour. The specimen is then placed into a freezer maintained at a specified temperature for at least one hour. The specified temperatures for PolyPatch and Fine Mix Type I is -20°F (-29°C); PolyPatch and Fine Mix Type II is 0°F (-18°C); PolyPatch and Fine Mix Type III is 20°F (-7°C). PolyPatch Type IV is not tested. After conditioning, the specimen is removed from the freezer and bent over a mandrel for a period of ten seconds. Any specimen that does not fail or break passes this test.

The PolyPatch Adhesion Test determines the material’s ability to adhere to concrete, a vital property to assure the long-term durability of a crack seal. Initially, the PolyPatch is heated to 400°F (204°C) and allowed to cool for one hour. A 1 in. by 1 in. by 2 in. (25 mm by 25 mm by 51 mm) bond specimen is then produced, and allowed to cool for two hours at ambient temperatures. The specimen’s dimensions are recorded, and it is placed into a device which applies tensile force. The tension test is run at a rate of 0.5 in. (13 mm) per minute until the specimen fails. The adhesion is reported as the tensile force divided by the cross-sectional area (pounds per square inch).

The final standard test is the PolyPatch Melting Procedure, and is intended to confirm production quality control measures. Initially, the Crafco PolyPatch Applicator is preheated from 420° to 500°F (216° to 260°C). Once the appropriate temperature is reached, a gallon can of PolyPatch is placed in the melter. After sufficient melting, the material is then stirred by a spiral stirrer. The material is then poured from the melter at 400°F (204°C), as measured by a thermocouple.

2.5.2 Deery American Corp. Pavement Preservation Products

Deery American Corporation (DAC) manufactures Repair Mastic pavement preservation products. The Repair Mastics utilized in this research are hot-applied, ready-to-melt repair mastics for concrete and asphalt pavements. Two grades are produced: Level & Go Repair Mastic and Recessed Repair Mastic

(Deery, 2003). Both the Level & Go and Recessed Repair Mastics are composed of quality-selected asphalt and/or resins, and include wear-resistant aggregates that are clean, hard, and durable, synthetic rubber polymers, anti-oxidants, and naturally occurring and man made reinforcing materials. The Level & Go Repair Mastic is intended for use in the repair of unconfined, feathered edge, extra wide pavement cracks. Recessed Repair Mastic is intended for high performance, confined repair of extra wide pavement cracks. Deery claims that both products provide a waterproof, flexible and durable repair system that is usually ready for traffic loads in less than 30 minutes.

The manufacturer supplies the repair mastic in cardboard boxes containing 40 pounds of the material. Each individual box contains a quick melt liner, which is dissolved and incorporated into the melted material (Deery, 2003). Both the Level & Go and Recessed Repair Mastics are formulated for applications in all climates. The difference between the products lies in the applications for which they are used.

2.5.2.1 Recommended Application Procedures

These following application procedures are applicable to both the Level & Go and Recessed Repair Mastics for repair of extra wide pavement cracks and distresses, and for non-recessed and recessed installations.

Prior to application, the mastic should be heated to the application temperature of 380° to 400°F (193° to 204°C) in a thermostatically controlled mastic mixer that utilizes oil as a heat transfer medium, and is equipped with a full sweep horizontal shaft agitator capable of gently lifting the material from the bottom of the reservoir and repeatedly turning the material.

Before application to the pavement, the surface requiring repair must be dry and free from dust, dirt, grease, loose particles and any other material that will inhibit bonding of the mastic to the surface (Deery, 2003). Because of unpredictable site and asphalt conditions, it is recommended that the owner determine the required preparation for a particular situation.

For confined repairs in asphalt surfaces, the repair should be centered over the crack within the distress area, and additional material be placed so that the repair area will extend onto adjacent, sound pavement surfaces. The repair cavity should be at least 1 in. (25 mm) deep and have a perimeter bonding face that is approximately perpendicular to the original surface with a minimum depth of ¾ in. (19 mm) (Deery, 2003). The repair cavity may be created by methods such as milling, grinding, saw cutting, and chipping with hammers, or pavement breakers. The loosened material is then removed from the cavity, without causing further damage to the remaining pavement. Once the cavity is cleared, the cavity edges should not be feathered. The removal depth is based on the condition of the underlying pavement. Preparation for unconfined spaces is accomplished in a similar manner.

Prior to placement of repair mastic, the surface must be clean and dry. All loose particles and moisture must be removed from the bonding surface to allow the conditioner and repair mastic to properly bond with the asphalt. To accomplish the cleaning and drying, methods such as high-pressure air blasting, hot air blasting or grit blasting can be employed singly or in combination. When utilizing high-pressure air blasting, the equipment should be capable of providing a continuous, high-velocity air stream of 125 cubic feet per minute that is free of oil and moisture. Hot air blasting equipment should be capable of producing a minimum temperature of 2500°F (1371°C) with a blast velocity of 1900 feet per second. Grit blasting should be accomplished during dry weather followed by air blasting to ensure complete removal of grit from the repair area.

Once the repair area is clean and dry, an even coating of Deery Surface Conditioner should be applied to the prepared surface by brushing or spraying, avoiding puddles or other irregularities. The conditioner should be allowed to dry completely prior to application of the repair mastic. If the conditioner is not completely dried and cured, proper bonding of the repair mastic will be inhibited.

The repair mastic should be heated to the application temperature, placed into the repair area in layers, and allowed to cool. Layering of the material is necessary to minimize the effects of shrinkage. The final layer should be tooled smooth with the surrounding pavement surface. To provide a skid-resistant surface, aggregate chips are broadcast onto the hot mastic surface and lightly tamped to ensure adequate embedment of the chips.

Both the Level & Go and the Recessed Repair Mastic can be installed in the following situations: random crack and joint repair with average crack widths of 2 in. (5 cm); longitudinal and traverse crack repair; paver seam repair, with an average crack width of 2 in. (5 cm); leveling of cupped transverse cracks with depressions less than 2 in. (5 cm) deep and 24 in. (61 cm) wide; leveling depressions at bridge approach slabs and around utility openings with widths of 12 in. to 36 in. (30 cm to 91 cm); repairing small pavement defects, with average depths of 1 in. (2.5 cm) or less, and 20 ft^2 (1.9 m^2) or less in area; repairing pot holes, with average depths of 1 in. (2.5 cm) and 20 ft^2 (1.9 m^2) or less in area (Deery, 2003).

The manufacturer does not recommend the use of repair mastics for leveling wheel path ruts, or filling pot holes in asphaltic bridge plug joints, alligator cracks, highly distressed areas or areas exposed to heavy static point loads.

2.5.2.2 Deery American Corp. Testing Procedures

For quality control, DAC requires their repair mastics to be tested in accordance with American Society for Testing and Materials (ASTM) test methods. The physical properties tested are the wear resistance of the coarse aggregate (ASTM C131), the mastic binder (ASTM D5329, ASTM D36, and ASTM D3111), and the finished mastic product (ASTM D3111 and ASTM D517); these testing procedures can be seen in Appendix A.

Wear resistance of the coarse aggregate to abrasion and impact is governed by ASTM C131. In this test, coarse aggregate smaller than 1½ in. (37.5 mm) is tested for resistance to degradation using the Los Angeles testing machine. In general, this test method is a measure of the degradation of mineral aggregate of standard grading under a combination of actions, including abrasion, impact, and grinding. The Los Angeles testing machine employs a steel drum containing a specified number of steel spheres, the number depending upon the grading of the test sample. As the drum rotates, the steel spheres are picked up by a shelf plate that raises the spheres until they drop free onto the opposite side of the drum, creating an impact-crushing effect. The contents then roll within the drum, with an abrading and grinding action, until the shelf plate picks up the sample and steel spheres again. This process is repeated for a prescribed number of revolutions. Once complete, the contents are removed from the drum and the aggregate is sieved to remove small fragments (ASTM C131, 2003). DAC requires the aggregate to have 20% or less degradation. Aggregate not meeting this standard should be discarded and quality aggregate obtained.

The mastic binder is tested under several ASTM test methods. DAC follows the procedures outlined in ASTM D5329 when testing the mastic for penetration and flow properties; ASTM D36 when testing the softening point of the mastic; and ASTM D3111 when testing the flexibility of the mastic.

The ASTM D5329 penetration test applies to hot-applied types of joint and crack sealants and fillers for Portland cement concrete and asphaltic pavements. DAC prefers the cone penetration, non-immersed penetration test. The total weight of the cone and attachments shall be 150.0 ± 0.1 gram. A sample of the material is poured into a six ounce tin, filled flush with the rim, and allowed to cure at ambient temperatures. Once cured, the specimen is placed in a water bath maintained at 77 ± 0.2°F (25 ± 0.1°C) for two hours immediately before testing, DAC modifies the ASTM test method by placing additional specimens in a water bath at 122 ± 0.2°F (50 ± 0.1°C). After the required time has lapsed, the specimen is removed from the water bath and dried. Three cone penetration determinations are made at locations 120° apart and halfway between the center and outside of the specimen. Results are reported by averaging the three penetrations in 1/10 mm units (D5329, 2003). DAC requires the mastic to have a maximum penetration at 77°F of 1 mm, and 1.5 mm at 122°F.

ASTM D5329 also contains a test to measure the flow of the mastic. A mold measuring 1.57 in. by 2.36 in. by 0.125 in. deep (40 by 60 by 3.2 mm) is placed on a bright tin panel. The mold is filled with an excess amount of mastic and allowed to cool for at least 30 minutes. Then the excess mastic is removed with a heated metal knife. Reference lines are marked on the panel containing the sample before it is placed in a forced-draft oven, where it is maintained at 140°F (60°C) for five hours. The mold is mounted so that the longitudinal axis is at 75 ± 1° with the horizontal, and the traverse axis is horizontal. After the specified test period, the panel is removed from the oven and the movement of the mastic is measured in millimeters (ASTM D5329, 2003). DAC requires the mastic to have a maximum flow of 3 mm.

ASTM D36 covers the determination of the softening point of bitumen in the range from 86°F to 315°F (30°C to 157°C). A ring-and-ball apparatus is immersed in ethylene glycol bath ranging from 86°F to 230°F (30°C to 110°C). Two horizontal disks of bitumen binder are cast in shouldered brass rings and heated at a controlled rate in the liquid bath, while each supports a steel ball. The softening point is reported as the mean of the temperature at which the two disks soften enough to allow each ball, enveloped in bitumen binder, to fall a distance of 1 in. (25 mm). (ASTM D5329, 2003) DAC requires the binder to soften at a minimum temperature of 190°F (88°C).

ASTM D3111 determines the flexibility of hot-melted adhesive in sheet form under specific test conditions. Test strips measuring 0.4 by 3 by 0.05 in. (10 by 75 by 1.25 mm) are conditioned at 73 ± 2°F (23 ± 2°C) and 50 ± 5 % humidity for 24 hours. After conditioning, the test strips are bent 180° over mandrels of decreasing diameters until the test strip fails. The flexibility is reported as the smallest diameter mandrel over which four out of five test strips do not break (ASTM D3111, 2003). DAC has modified this test by changing the temperature to 32°F (0°C) and utilizing a single mandrel of 0.25 in. (6.35 mm) diameter. The test strip is bent only 90° and is held for 10 seconds. The test strip passes if it bends without cracking (Deery, 2003).

DAC utilizes the ASTM D517 procedure for their finished mastic product. The test determines the amount of water absorbed by asphalt planks and their ability to withstand significant water absorption. Resistance to water absorption is a measure of the porosity of the mastic, and therefore of its ability to withstand freezing and thawing conditions. Initially, a 2 by 6 in. (50.8 by 152.4 mm) specimen is cut from an asphalt plank in such a manner so that all edges are freshly cut. The mass of the specimen is determined to the nearest 0.1 gram, and it is then immersed in water for 24 hours. After the required time has elapsed, the specimen is removed and the surface wiped off with a slightly damp cloth. The mass after immersion is determined to the nearest 0.1 gram, and the percent absorption determined (ASTM D517, 2003). DAC modifies the standard ASTM test method by immersing the specimen into a water bath at 122°F (50°C) for 24 hours. DAC requires the finished mastic to have a maximum absorption of 1% (Deery, 2003).

2.6 Chapter Summary

This literature review chapter describes in detail, various factors associated with crack sealing and filling techniques that are currently employed by SHA. The initial steps of assessing the need for treatment are described. Different strategies are detailed which can be employed for crack sealing and filling, to include the types of materials available and the different configurations that are typically utilized for the sealing material. In addition, this chapter introduces the new concept of crack surfacing that is the subject of this research project. Crack surfacing materials are identified, which are available through Crafco Inc. and Deery American Corporation. Material configurations are described and the respective manufacturer's quality control measures are summarized.

3. DESIGN OF EXPERIMENT

3.1 Introduction

The objective of this research is to evaluate the effectiveness of hot-poured crack surfacing material in sealing asphaltic cracks. With the literature review complete, the experiment was further divided into field and laboratory evaluations. Figure 3.1 shows the overall data collection and analysis strategies followed in this research.

Each element of the experiment followed a similar outline. The goal of the experiment was to evaluate and collect data based on the in-situ and laboratory performance of the crack surfacing materials. These collected data were then compiled into a comprehensive database to allow for a statistical analysis to be performed, and conclusions to be made.

3.2 Selection of Test Sections

To evaluate the effectiveness of the in-situ crack surfacing material, test sections needed to be identified. The Wyoming Department of Transportation had previously placed crack surfacing materials on Wyoming Route 93 (WY-93) in 1999 at mileposts 18 – 26; US Route 26 (US-26) in 2002 at mileposts 0 – 13; and Interstate 25 (I-25) in 2002 at mileposts 68 – 76. The crack surfacing material was applied to asphalt cracks for highway sections as long as 13 miles.

It is unrealistic to perform an evaluation on each individual crack within these sections, so a statistical analysis was performed to randomly choose approximate crack locations. If the predetermined location did not contain a crack with crack surfacing material, the nearest cracks were located and an evaluation performed.

Three evaluations were accomplished: the first being a warm weather evaluation performed August 25-26, 2003; the second, a cold weather evaluation performed Jan. 13-14, 2004; and a third performed during the spring, May 21, 2004. The spring evaluation was accomplished for the determination of the materials recoverability, because it was observed during the winter evaluation that very small, hairline cracks had formed and these cracks have the greatest potential to recover. In addition, the spring evaluation was conducted prior to the I-25 rehabilitation of the test section, beginning in late May, 2004. Table 3.1 identifies the road, milepost (MP), and average daily traffic for 2002 (ADT) where the evaluations were accomplished.

3.3 Selection of Material Configurations

To accomplish the laboratory testing, the materials needed to be configured in a manner that is conducive for testing with the laboratory equipment. All four configurations utilized were designed by WYDOT personnel, and consisted of rectangular beams 10 inches (25.4 cm) in total length and 2 in. by 2 in. (5.1 cm by 5.1 cm) square. These configurations were appropriately termed flush, uniform overband, tapered overband, and mill & fill.

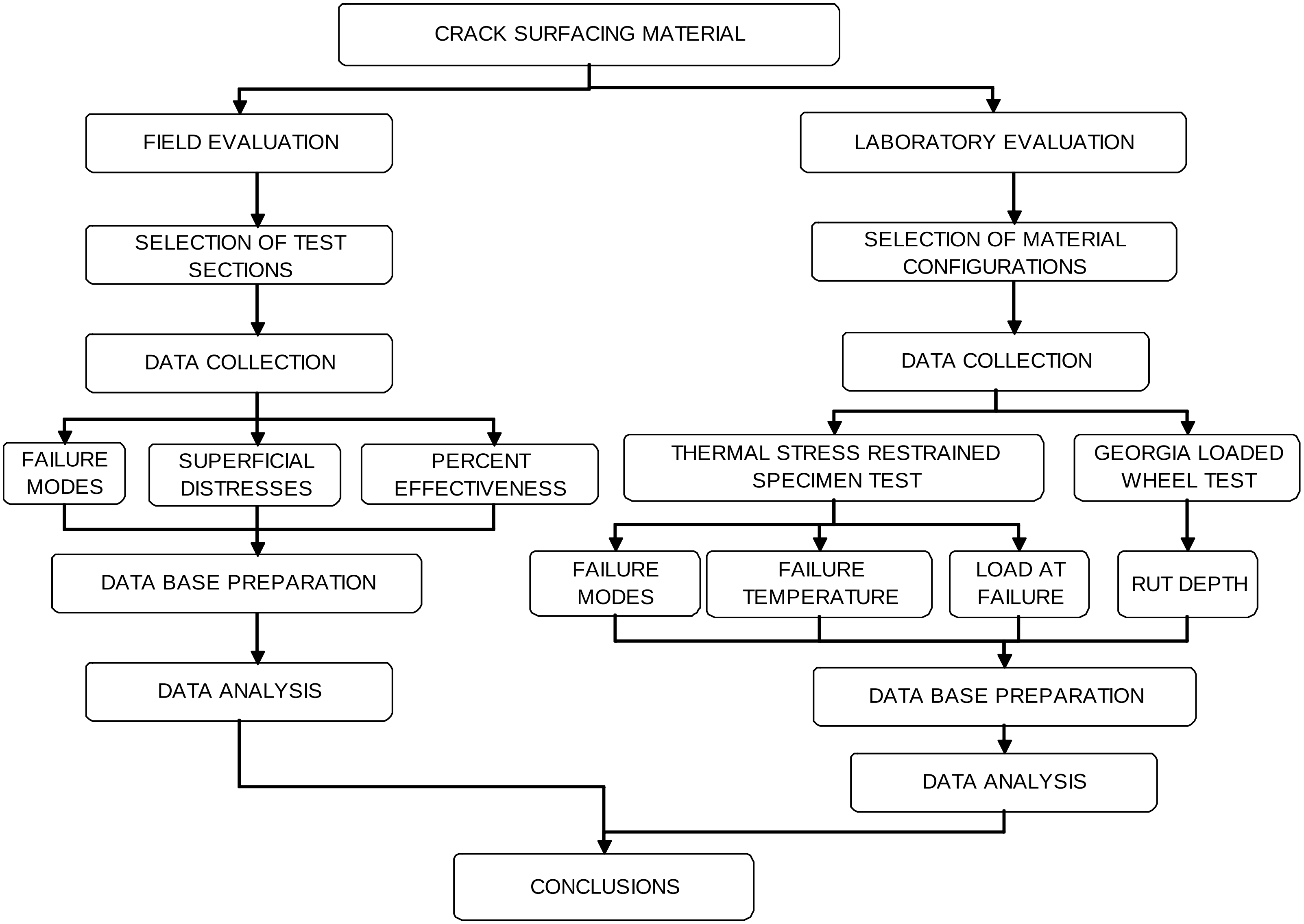


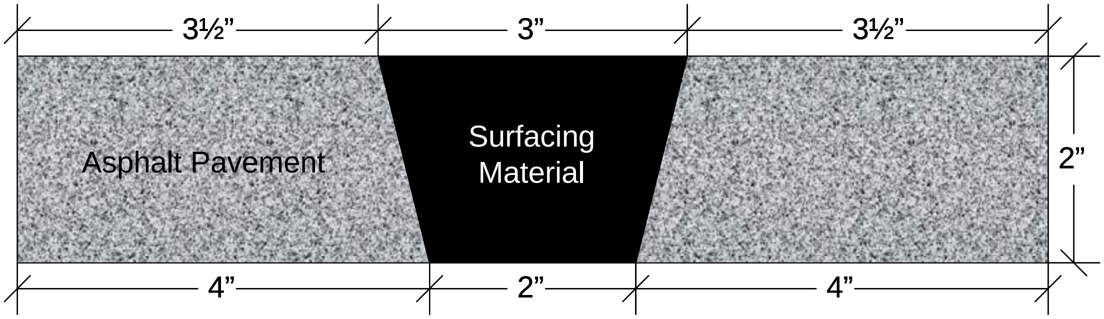
Figure 3.1 Data Collection and Analysis Strategies

Table 3.1 Test Section Milepost and Average Daily Traffic

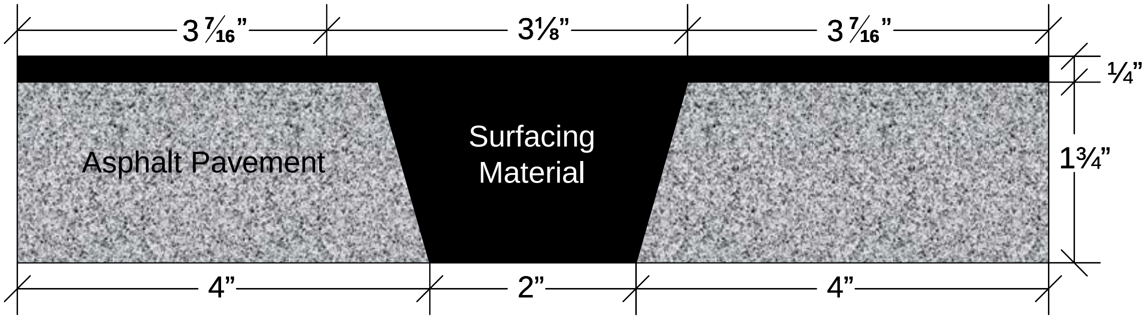
	WY-93 ADT			US-26 ADT			I-25 ADT	
Milepost	All Veh.	Trucks	Milepost	All Veh.	Trucks	Milepost	All Veh.	Trucks
18.895 N	290	40	0.643 E	1380	360	69.669 N	6210	1230
19.611 N	290	40	0.849 E	1380	360	69.669 S	6210	1230
21.683 N	160	20	1.488 E	1380	360	71.484 N	6280	1240
23.152 N	160	20	1.585 E	1380	360	71.485 S	6280	1240
23.152 S	160	20	3.632 E	1920	470	72.862 N	6280	1240
25.264 N	160	20	4.198 E	1920	470	72.869 S	6280	1240
25.554 N	160	20	5.348 E	1920	470	74.743 S	6460	1290
25.839 N	160	20	5.700 E	1920	470	74.832 S	6460	1290
25.839 S	160	20	6.727 E	1920	470	75.248 S	6460	1290
			9.751 E	1920	470			
			10.302 E	1920	470			

The flush configuration was achieved by placing the crack surfacing material into a simulated crack cut into an asphalt beam, so that the surfacing material is flush with the beam surface. The uniform overband configuration consists of a uniform overband of the surfacing material throughout the length of the beam in addition to filling a simulated crack while maintaining the 2 in. by 2 in. square dimensions.

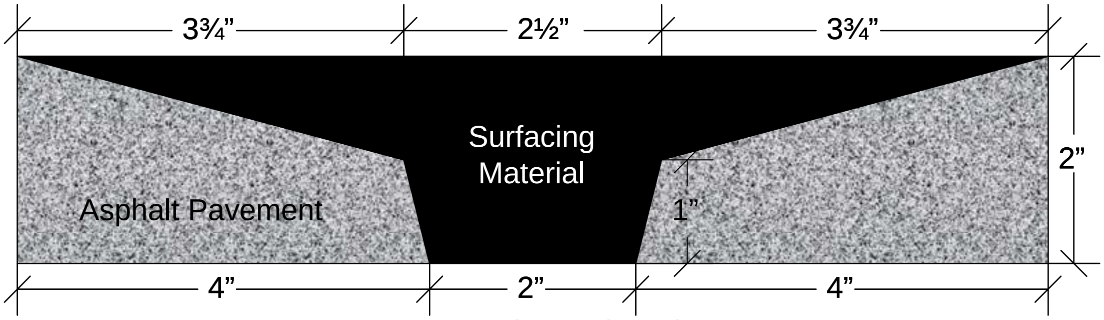
The tapered overband configuration required the beam depth to decrease from the ends toward the simulated crack. The crack surfacing material is thinner at the ends of the beam than at the middle. The mill & fill configuration required a sawed reservoir on either side of the simulated crack, with the surfacing material placed into the reservoirs and crack while being flush with the surface. Figure 3.2 illustrates the crack surfacing material configurations and dimensions.



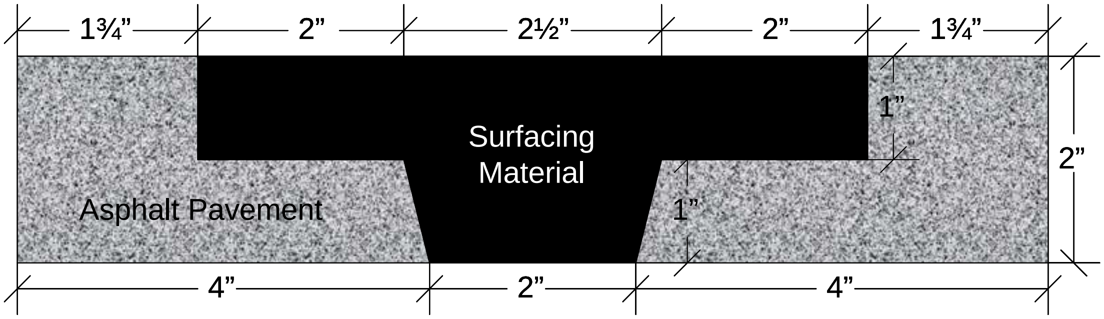
Flush



Uniform Overband



Tapered Overband



Mill & Fill

Figure 3.2 Laboratory Crack Surfacing Material Configurations and Dimensions

3.4 Data Collection and Database Preparation

The data collection for the field evaluation was achieved by identifying the failure modes, superficial distresses, and measuring the percent effectiveness at each test section during the three aforementioned evaluations. An in-depth explanation of the field evaluation is presented in Chapter IV.

The data collection for the laboratory evaluation was done by performing the Thermal Stress Restrained Specimen Test (TSRST) and Georgia Loaded Wheel Tester (GLWT). The TSRST allowed for the identification of the failure modes, temperature at failure, and the total load induced on the specimen for each of the predetermined configurations. The GLWT permitted the measurement of potential rut-depth of the surfacing material. Chapter V further explains the laboratory evaluation.

Once these evaluations were accomplished, the results were compiled into three databases where individual statistical analyses were performed and conclusions drawn.

3.4.1 Laboratory Testing

The TSRST and GLWT procedures previously described were accomplished on all three manufacturer's products, and in all four material configurations. In addition, the TSRST test was accomplished on the surfacing material itself to establish a control set. Table 3.2 outlines the testing program. There are three tests for each combination of material and configuration.

Table 3.2 Laboratory Testing Matrix

	TSRST					GLWT
Material	**Control**	**Flush**	**Overband**	**Tapered Overband**	**Mill & Fill**	
Level & Go	3	3	3	3	3	3
Recessed Repair Mastic	3	3	3	3	3	3
PolyPatch	3	3	3	3	3	3

3.5 Chapter Summary

This chapter described the research project organization for evaluating the effectiveness of crack surfacing material for sealing asphaltic cracks. The selection process was described for the test section of the field evaluation to include evaluation times, milepost locations, and ADT. Material configurations for the laboratory evaluation were also defined with their applicable testing matrix. In addition, a flow chart of the data collection and analysis strategies was presented to provide a further explanation of the organization of this research.

4. FIELD EVALUATION

4.1 Introduction

The purpose of the field evaluation of this research project is to identify the modes of failure, measure the percent failure, and identify existing superficial distresses in existing crack surfacing material. There are four modes of failure for crack surfacing material: adhesion, cohesion, pullouts, and secondary cracking. The crack surfacing material must possess resilient, adhesive and cohesive qualities to resist failure (Van Dam, 1999).

In addition to the failure modes mentioned, the crack surfacing material can undergo further distresses known as superficial distresses. Superficial distresses are not immediate failures, but they can contribute to the future performance of the material and eventually lead to problems. The qualities required to resist failure and superficial distresses of the surfacing material are summarized in the following sections.

4.1.1 Adhesive Qualities of Crack Surfacing Material

The adhesive qualities of a crack surfacing material are its ability to remain bonded to the asphalt surface at the edges of the crack under field conditions. Potential asphalt failures may occur due to the development of high tensile, thermal stresses at the interface between the sealant material and the pavement (Bramel, 1999). Adhesion failure occurs when a weak interface between the pavement material and asphalt is fractured by the continual cycling action of contraction and expansion of the pavement structure. If the initial adhesion of the materials is good and the sealant material is flexible during cold weather, then the sealant joint retains its integrity and the materials remain bonded. In the opposite scenario, the rigidity of the sealant material causes high bond stresses to develop at low temperatures and promotes adhesion failure (Masson, 2002).

4.1.2 Cohesive Qualities of Crack Surfacing Materials

The cohesive qualities of the material are its ability to resist internal failure under deformation and stress. When a sealant material fails in cohesion, it generally fractures or separates while portions of the material remained bonded to the adjoining pavement. Continual contraction and expansion cycling of the pavement structure induces internal tensile stresses that result in cohesion failure. A material with adequate cohesion characteristics is able to resist the internal stresses and not fail; otherwise, cohesion failure is imminent.

4.1.3 Resilient Qualities of Crack Surfacing Materials

The resilient qualities of a material are its ability to recover from any potential type of failure. Once the material has failed due to internal stresses, the integrity of the pavement structure depends on the ability of the sealant material to recover with warmer temperatures. In general, hot-poured materials behave in a plastic state and flow when exposed to high temperatures. In this plastic state, the material can re-bond, to the substrate or itself, and reseal the crack, preventing further infiltration of water and other incompressible material.

4.1.4 Superficial Distresses of Crack Surfacing Materials

Superficial distresses generally promote the deterioration of the material, but do not necessarily contribute to overall failure. There are many ways of categorizing superficial distresses. This research follows procedures outlined by the Federal Highway Administration (SHRP, 1999). Superficial distresses to crack surfacing material include weathering, overband wear, tracking, stone intrusion, and edge deterioration.

Weathering is the action of the weather over a long period of time on the appearance and integrity of the exposed material. Effects on the material include discoloration from solar radiation, breakdown of the material into fine-sized particles, and brittleness. Major contributors to weathering are temperature, radiation, and moisture.

Overband wear occurs over time and is the gradual diminishment or disintegration of the material on the surface of the overband, with no relation to the crack itself, and is a result of physical wear. Snow plows and vehicles are the major contributors to overband wear.

Tracking occurs when the material has a less viscous behavior and is deformed by the tires of passing vehicles. The applied load causes perpendicular displacement of the material, and is of concern in warmer weather.

Stone intrusion is the penetration of rocks into the sealant material where they remain in-place. Stone intrusion is commonly a resultant of tire loads. Stone intrusion can cause superficial cohesive damage to rigid or brittle materials.

Edge deterioration is the disintegration or diminishment of the material at its edges. It is most commonly seen at the edge of the overband, and can cause an adhesion failure between the sealant and the underlying pavement. Also, edge deterioration may have the appearance of raveling at the edges. Numerous applications of wheel loads and the shearing force of snow plows are the main contributors to edge deterioration.

4.2 Modes of Failure of Crack Surfacing Materials

Crack surfacing material can fail in separate modes or in a combination of modes. Individual failure modes are adhesion failure, cohesion failure, pullouts, and secondary cracking. Adhesion failure of the material involves the loss of bond between the crack surfacing material and the adjoining edge of the pavement (Johnson, 2000). This failure can be caused by the material composition and its inability to bond, or by improper installation; i.e., placing the material in a crack that is not dry, intact or free from dirt and debris.

Cohesive failure involves fractures within the crack surfacing material itself and is typically seen as transverse cracks parallel with the crack in the pavement (Johnson, 2000). Cohesion failure is usually a result of internal stresses that occur as the pavement structure expands and contracts.

Pullouts are a combination of adhesive and cohesive loss, and are complete removals of sections of the crack surfacing material from the pavement structure (Johnson, 2000). Typically, this occurs in warm weather climates where the material can reach temperatures in excess of 150°F (66°C). At such high temperatures, the material has a low viscosity and can attach itself to passing tires, pulling out of the crack. In cold climates, pullouts can be caused by external forces acting to extract the material from the crack. Snow plows are one major source of pullouts in cold climates. The edge of the plow penetrates the material, exerting sufficient force for the material to fail adhesively and pull out of the crack.

Secondary cracking is the continuation of cracking in asphalt concrete. A particular failure mode is not readily visible, but new cracks form from the original location of the crack. Secondary cracking is analogous to edge cracking, alligator cracking and spalling.

4.3 Field Evaluation of Crack Surfacing Materials

The field evaluation was designed to identify any existing modes of failure, types of superficial distresses, and to determine the percent effectiveness of the crack surfacing material. Two field evaluations were performed to identify any failure or deterioration of the surfacing material.

Initially, a mid-summer evaluation was performed during Wyoming's hottest month, August. This warm weather evaluation resulted in a near maximum expansion of the pavement structure and a near minimum crack opening. In addition to the mid-summer evaluation, a mid-winter evaluation was performed during Wyoming's coldest month, January. This cold weather evaluation resulted in a near maximum contraction of the pavement structure and a near maximum crack opening. An evaluation was performed at each of these times to identify the modes of failure, superficial distresses and percent effectiveness. To complete the field evaluation, a third evaluation was completed during the spring on limited sections because of road construction and time constraints.

The following section explains the evaluation process that was carried out at individual locations within a predetermined test section of highway containing crack surfacing material.

4.3.1 Test Section Evaluation

The crack surfacing material was applied to the traveled way, which consists of a 12-foot lane. The interior of the lane is broken down into identifiable sections. The far right of the roadway is the outer edge and the far left is the inner edge when facing the travel direction. According to this basic definition, starting from the left side of the traveled way and progressing to the right, the different sections are the inside edge (ISE), inner wheel path (IWP), junction between wheel paths (JCN), outer wheel path (OWP), and pavement outer edge (POE). The ISE, IWP, OWP, and POE are two feet wide (0.61 m), while the JCN has a width of four feet (1.22 m). This convention was used throughout the evaluation process for the summer, winter, and spring evaluations.

At each location, the traveled way sections were marked on the pavement structure. This allowed the modes of failure and superficial distresses to be assigned to an area if applicable. In addition, the length of failure was measured and recorded.

To determine the percent effectiveness, the percent of treatment failure was calculated. The measured failure lengths of segments were summed and divided by the total length of treated crack (SHRP, 1999).

$$\%Fail = \frac{L_f}{L_t}(100)$$

where: $\%Fail$ = Percentage of treatment length failed.

L_f = Length of treatment failure, ft.

L_t = Total treatment length, ft.

The effectiveness of the treatment area is then determined by subtracting the percentage of treatment failure from 100 percent.

$$\%Eff = 100 - \%Fail$$

where: $\%Eff$ = Percentage of treatment length that is effective.

$\%Fail$ = Percentage of treatment length failed.

At each test section a series of photos were taken to provide a further explanation of the failure modes, superficial distresses, and percent effectiveness of the treated area. Appendix B presents an outline of the evaluation sheet that was utilized.

4.4 Field Evaluation Summary of Results

A summary of the August, January, and May field evaluation results for the test section locations is presented in Figures 4.1 through 4.3. The complete evaluation results can be found in Appendix C. In addition, each location demonstrated unique situations. The following sections summarize and present photos of the field evaluations and identify some of these unique situations.

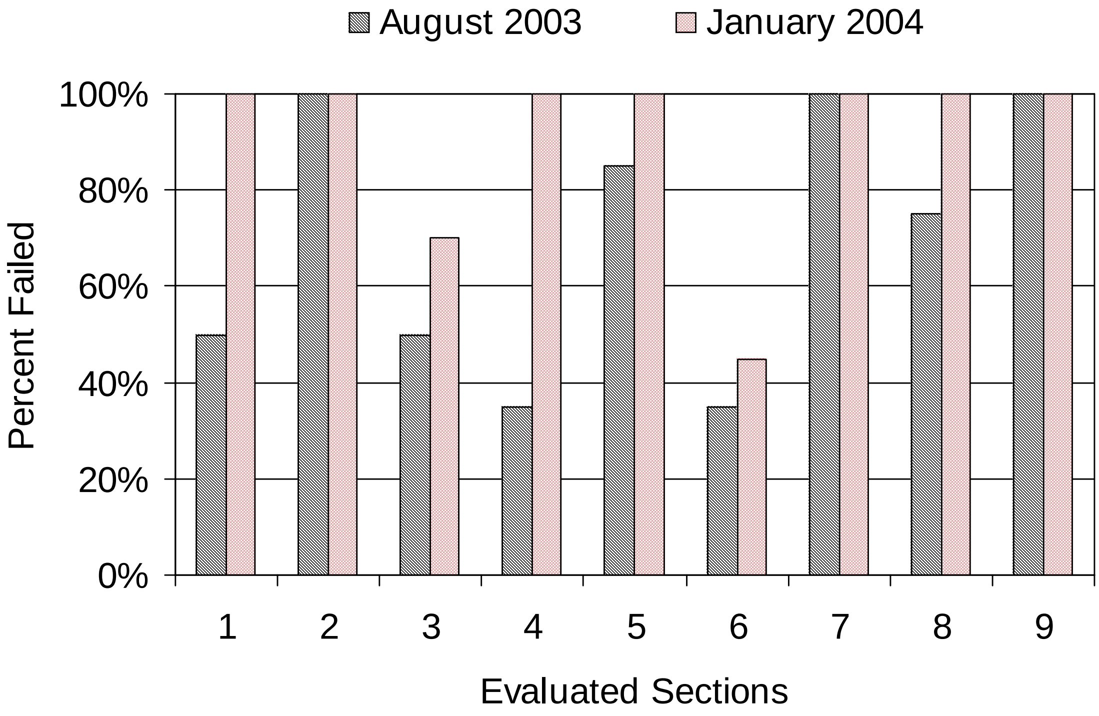


Figure 4.1 Crack Surfacing Failure Rates on WY-93 for PolyPatch (1999)

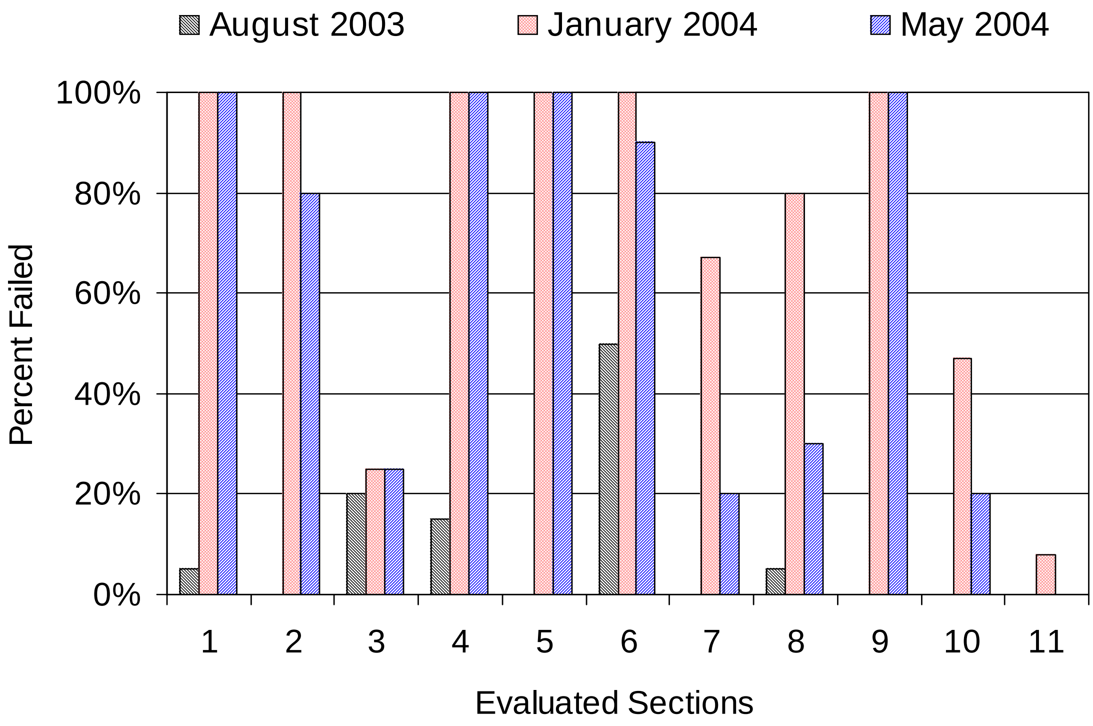


Figure 4.2 Crack Surfacing Failure Rates on US-26 for Level & Go (2002)

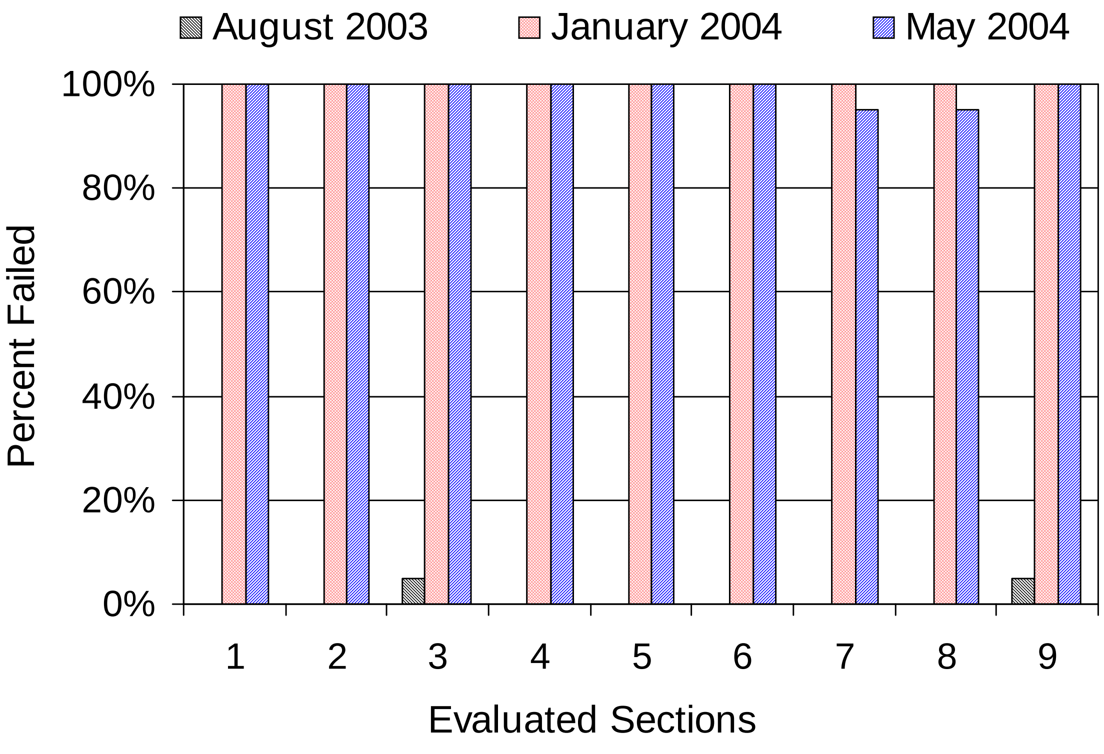


Figure 4.3 Crack Surfacing Failure Rates on I-25 for Level & Go (2002)

4.4.1 Wyoming Route 93 Summary of Results

Wyoming Route 93 is located to the northwest of Douglas, WY in a highly rural, ranching area. The roadway has a functional classification as a rural local, with the ADT ranging from 160 to 290 vehicles per day. Crafco PolyPatch Fine Mix Type I was installed at this location in 1999.

The test section had failure modes consisting of adhesion and cohesion failure in the 2003 and 2004 evaluations. The superficial distresses that were observed included bubbling and weathering. Bubbling is a warm weather phenomenon; therefore, it was not expected to occur in the crack surfacing material that contains small aggregate, which enhances the performance of the material by providing adequate rigidity, yet remaining flexible as well. Bubbling was not included in the main evaluation sheet, but it was taken into account and documented. Figure 4.4 illustrates the adhesion and cohesion failure observed throughout the section, while Figure 4.5 illustrates the bubbling phenomenon that was encountered.

Figure 4.4 WY-93 (MP 19.611) Adhesion and Cohesion Failure

Figure 4.5 WY-93 (MP 25.554) Bubbling and Weathering Effects

4.4.2 US Route 26 Summary of Results

US Route 26 is located to the northeast of Wheatland, WY, and serves as a major freight route for the ranching and small town communities of eastern Wyoming. The roadway has a functional classification as a rural collector, with the ADT ranging from 1380 to 1930 vehicles per day. Deery Level & Go was installed at this location in 2002.

The test section had failure modes consisting of mostly pullout failure in the 2003 evaluation, while adhesion failure was very prominent in the 2004 evaluation. This adhesion failure, caused by the decrease in ambient temperature as the seasons changed from summer to winter, was the determinant for the high failure rate. The superficial distresses that were observed included excessive overband wear and edge deterioration. Primarily, these distresses were caused by snow plows shearing the mastic material at high spots, typically at the JCN, and by applying enough force at the edges to rapidly deteriorate them. Figure 4.6 illustrates pullouts that were typically encountered at the JCN. Figure 4.7 presents a section with excessive edge deterioration throughout the traveled way, and Figure 4.8 illustrates the occurrence of adhesion failure during the 2004 winter evaluation.

Figure 4.6   US-26 (MP 4.198) Pullouts at JCN

Figure 4.7   US-26 (MP 5.700) Edge Deterioration Throughout Traveled Way

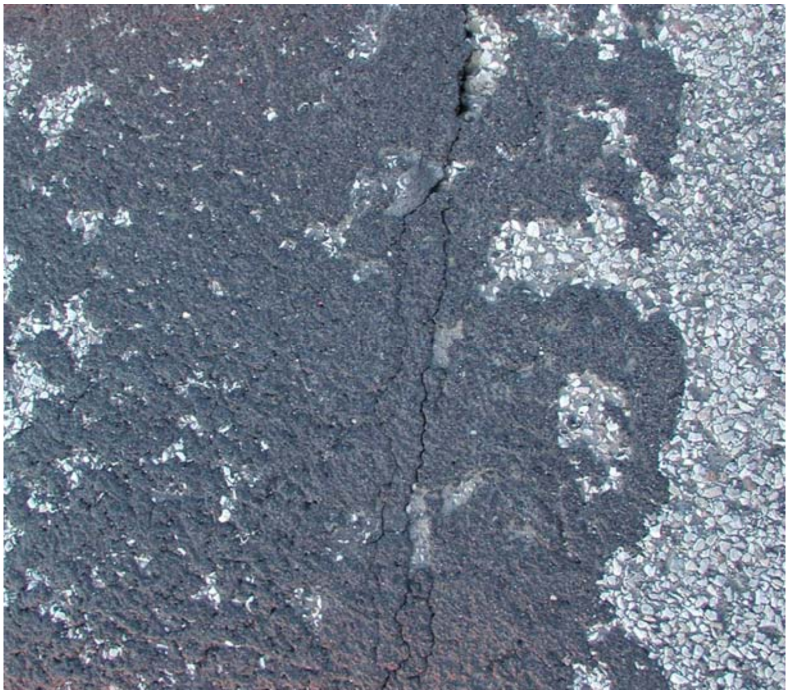


Figure 4.8 US-26 (MP 1.585) Adhesion Failure with Pullouts

4.4.3 Interstate 25 Summary of Results

The test section location for I-25 is located to the south of Wheatland, WY, and serves as a major arterial for north and south travel throughout Wyoming. The roadway has a functional classification as a rural arterial, with the ADT ranging from 6210 to 6460 vehicles per day. Deery Level & Go was installed at this location in 2002.

The test section demonstrated excellent performance during the 2003 evaluation, having a minor failure rate, but the section was unable to withstand the cold winter temperatures. The 2004 evaluation revealed adhesion failure at all locations, and the failure rate climbed to 100%, while minor recovery was noted in the May 2004 evaluation. The only superficial distresses observed were minor overband wear and edge deterioration at some of the locations. Figure 4.9 demonstrates the excellent performance encountered during the 2003 evaluation, and Figure 4.10 illustrates the adhesion failure that occurred at all locations.

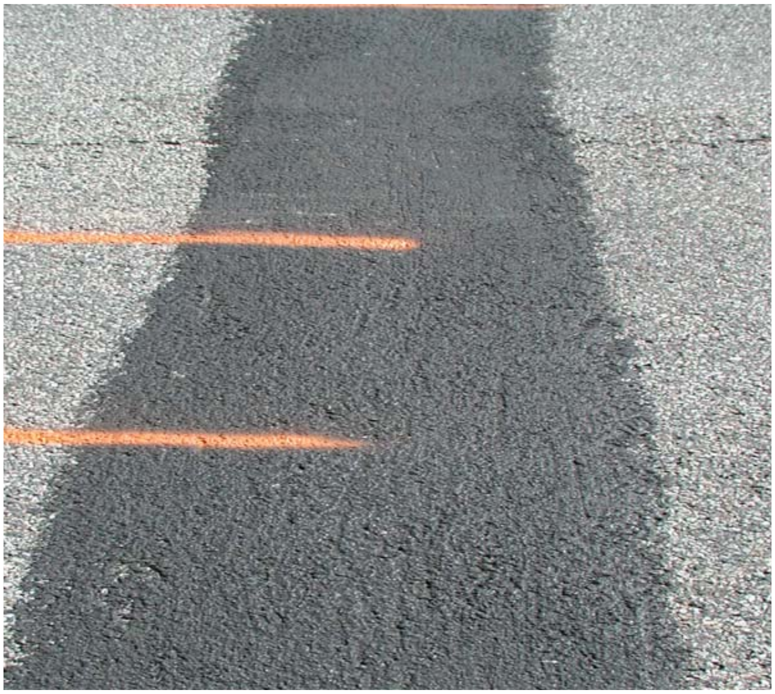


Figure 4.9 I-25 (MP 74.832) No Failure, Excellent Performance Throughout Traveled Way

Figure 4.10 I-25 (MP 72.862) Adhesion Failure Throughout Traveled Way

4.5 Chapter Summary

This chapter describes in detail the factors affecting the field evaluation of existing crack surfacing installations. Special attention is given to describing the importance of adhesive, cohesive, and resilient qualities that the material must have to resist failure. In addition, it is important to identify any existing superficial distresses that may eventually contribute to failure of the material. The field evaluation consisted of test sections that identified existing modes of failure, superficial distresses, and percentages of effectiveness for each individual crack location.

Summary results for WY-93, US-26, and I-25 were presented with their respective failure rates. For complete results see Appendix C. Representative photos are included which show common types of failures and distresses that were encountered.

5. LABORATORY EVALUATION

5.1 Introduction

The purpose of the laboratory evaluation is to analyze the hot-poured crack surfacing material's ability to seal pavement cracks at extremely low temperatures and to evaluate its ability to resist rutting. Thermally induced stresses incurred at very low temperatures can affect the surfacing material's bonding capabilities and cause the surfacing material bond to fail in adhesion or cohesion, which promotes a decrease in the effectiveness of sealing cracks by allowing the intrusion of water and deleterious materials. Once the material has cracked, warm weather, with the addition of traffic loading, can promote the recovery of the material, which is the ability of the material properties to re-bond at the locations of adhesive and cohesive failures.

Traffic loading can have a negative effect on the material as well. Rutting in asphaltic pavements is a normal occurrence that takes place throughout the life of the pavement structure, and typically takes place in warm weather climates. Rutting is defined as the accumulation of small amounts of unrecoverable strain resulting from applied loads to the pavement (Kandhal, 2003). The crack surfacing material properties should render it flexible and resilient enough to resist rutting to circumvent a reduction in service life of the pavement, and eliminate the potential of standing water that can initiate hydroplaning—a safety concern.

Two laboratory procedures were utilized for these analyses: Thermal Stress Restrained Specimen Test (TSRST), and Georgia Loaded Wheel Tester (GLWT). The TSRST is designed to evaluate the low temperature cracking characteristics of asphalt concrete mixtures and was utilized for the evaluation of the crack surfacing material. The GLWT is a loaded wheel tester that simulates traffic loading.

5.2 Thermal Stress Restrained Specimen Test

The TSRST was applied to evaluate the low temperature cracking characteristics of the crack surfacing material. The testing equipment simulates field conditions by cooling the specimen while restraining it from contracting. Thermally induced stresses build up in the specimen as temperature decreases, and when the tensile stress equals the tensile strength of the specimen, the specimen fractures. The equipment is comprised of three subsystems: cooling system, load/displacement system, and test control/data acquisition system.

The cooling system includes an environmental cabinet, cooled by liquid nitrogen (LN_2), and a programmable temperature controller. The specimen is enclosed in the insulated environmental cabinet to minimize the effects of ambient temperature. When the temperature controller is programmed at a user-specified cooling rate, typically 18°F per hour (10°C/hr), LN_2 is periodically injected through a solenoid valve and passed through an interior copper coil to allow the nitrogen to change from the liquid into the vapor. An internal fan circulates the LN_2 vapor throughout the cabinet to promote an even temperature distribution. Figure 5.1 illustrates the TSRST equipment components (OEM, 1995).

The load/displacement system includes a load frame, a screw jack and associated step motor, and a load cell. The specimen is connected to the load frame, which is housed inside the environmental cabinet, with swivel and clevis connectors at the screw jack and load cell. Utilizing swivel and clevis connectors promotes concentric loading of the specimen. As the specimen cools the step motor operates the screw jack to restrain the specimen from contracting, and the load cell measures the load induced on the specimen. Figure 5.2 illustrates the TSRST load system components (OEM, 1995).

The test control/data acquisition system consists of measurement instrumentation, signal conditioning electronic components, a computer, and user-interface software. Five resistance temperature devices (RTD) structure the measurement instrumentation. Four RTDs measure the surface temperature on the specimen during testing and one, the temperature control RTD, measures the ambient temperature of the cabinet.

Measurements are sent through the signal conditioning electronic components where they are modified for interpretation by the computer. The computer stores all measurements and uses them to compute parameters such as tensile stress and average temperature. In addition, the computer controls specimen contraction via displacement readings received from the linear variable differential transformers (LVDT). Two LVDTs are placed at opposite ends of the specimen and send a displacement signal when the specimen contracts. When the average of the two LVDT readings indicate the specimen has contracted more than 0.0001 inch, the computer instructs the step motor to stretch the specimen back to its original length. The user-interface software provides an interface between the user and the test equipment. The software performs the execution of the TSRST as well as the reduction of the test data.

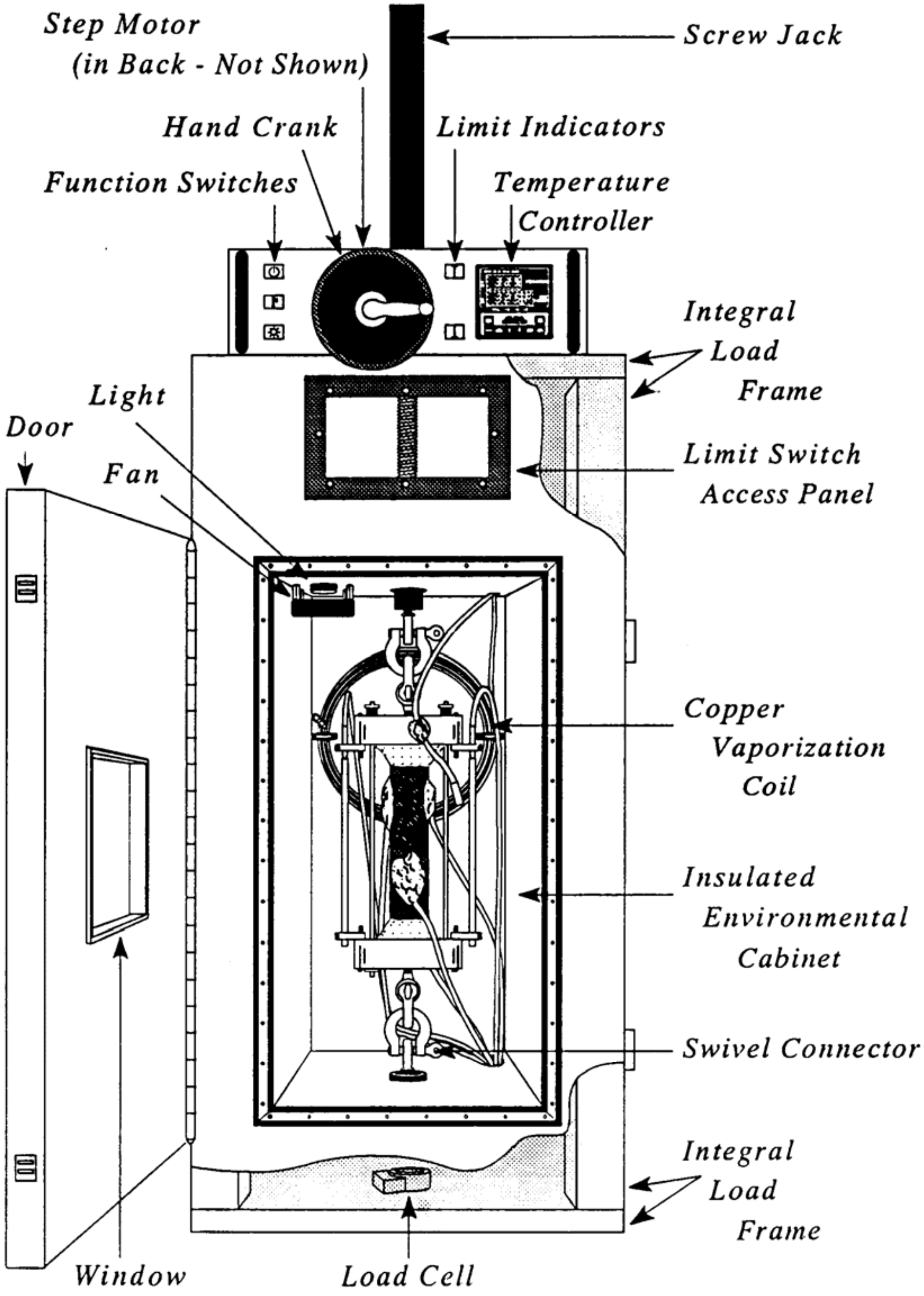


Figure 5.11 TSRST Equipment Components (OEM, 1995)

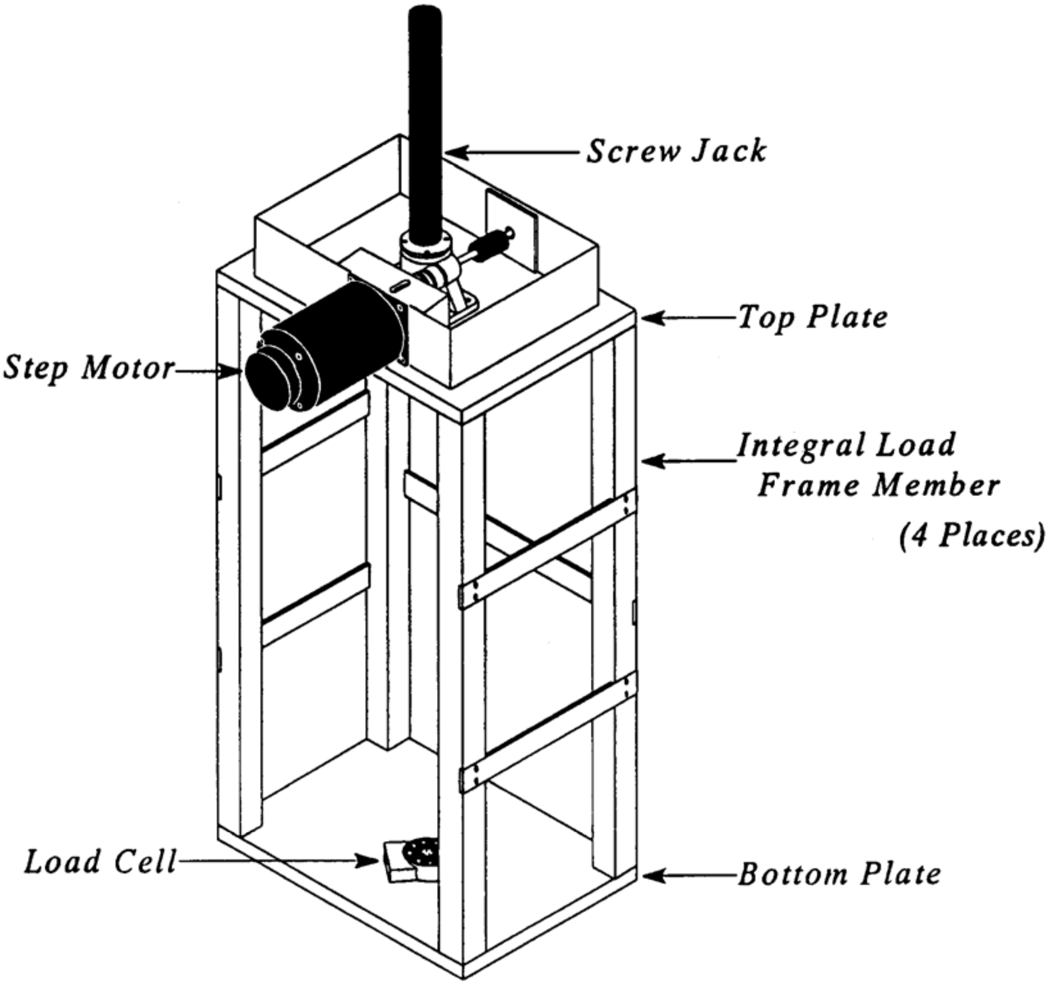


Figure 5.12   TSRST Load System Components (OEM, 1995)

5.2.1 TSRST Test Preparation

Prior to execution of the TSRST, the specimen must be properly prepared to ensure quality data collection. Initially, specimen platens are cleaned and sanded with 240-grit sandpaper to completely remove any epoxy or specimen-end residue remaining from prior tests and to provide a rough surface for epoxy adhesion (AASHTO, 1993). The two platens are then screwed into the alignment stand where a thin film of epoxy is placed on the center of the bottom platen. The specimen is placed on the epoxy and centered on the platen. The epoxy is then built up around the specimen in a sloping manner (thicker at the bottom) to provide adequate adhesion between the specimen and the platen. The alignment is rechecked and the procedure repeated for the top platen. The epoxy is 100% cured in 24 hours.

After the epoxy has cured, the specimen is ready for assembly in the environmental cabinet. The specimen is removed from the alignment stand and attached to the swivel and clevis connectors located on the load frame via the clevis eyelets. The specimen is hung vertically in the environmental cabinet, and the RTDs attached to the specimen in a spiral, downward progression. The fifth RTD is attached to the top platen and allowed to hang freely in the environmental cabinet. Next, the LVDTs are attached to the top platen and are aligned with the invar rods to measure displacement. The LVDTs are then adjusted to read 0 ± 0.005 inch on the instrument readout. Finally, the screw jack is manually adjusted so that the bottom clevises are within a tenth of an inch (.254 cm) of each other. Figure 5.3 illustrates an instrumented TSRST specimen connected to the load system (OEM, 1995).

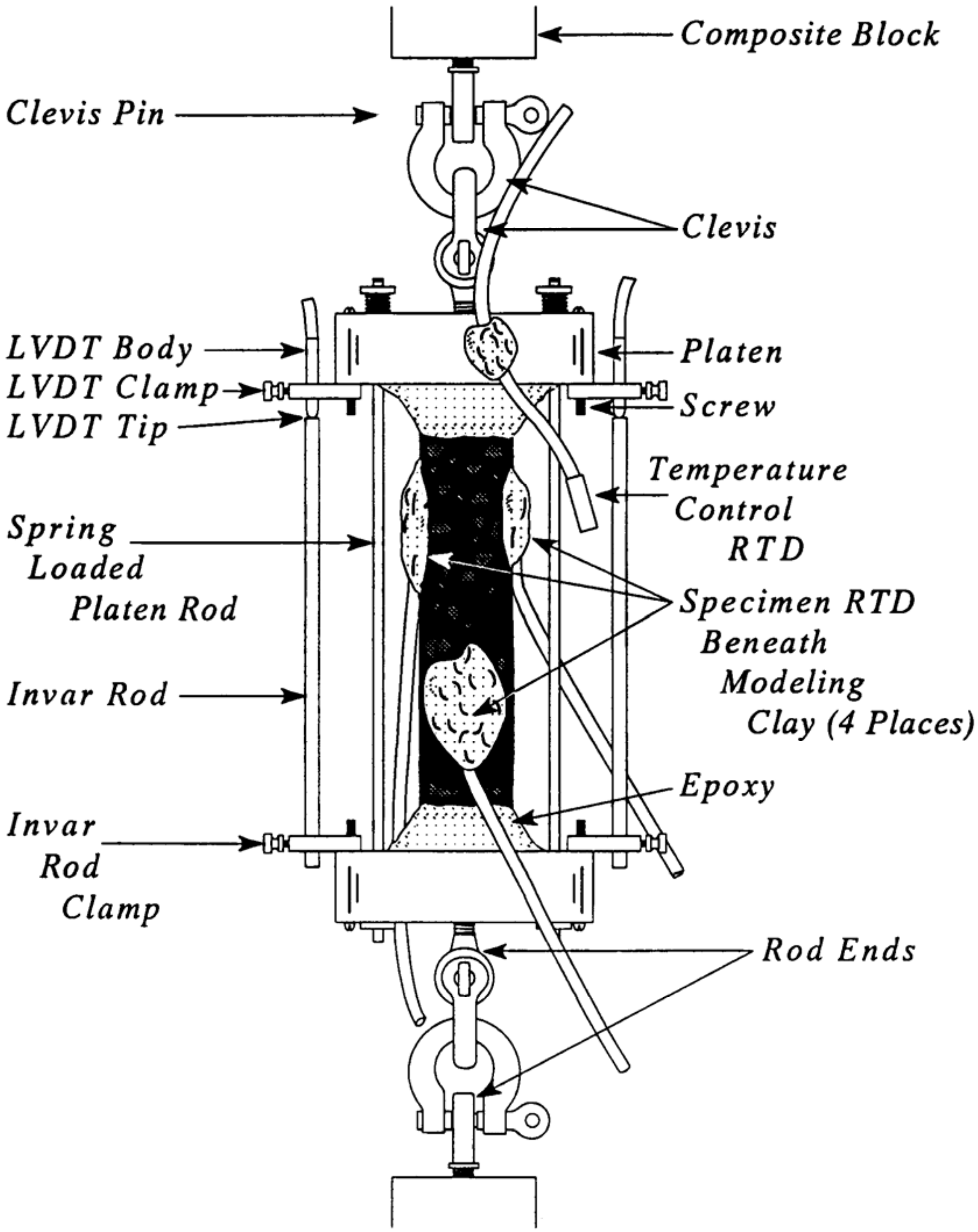


Figure 5.3 Instrumented TSRST Specimen Connections (OEM, 1995)

The test specimen must be pre-cooled to the desired test start temperature prior to testing, and this can be accomplished either inside the TSRST environmental cabinet, or in a separate cabinet. When using the TSRST environmental cabinet for pre-cooling it is essential to disengage the servo motor drive switch, which activates the step motor, to prevent loading of the specimen. Initially, the specimen is placed in the environmental cabinet and the cabinet door securely closed. The test is placed in a run/hold status so that the computer will cool the cabinet, but hold at the specified temperature. The LN_2 valve is opened on the tank and the solenoid activated. The temperature is observed until the specimen has cooled to within +4°F (+ 2°C) of the specified hold temperature. The specimen is now ready for testing.

5.2.2 TSRST Test Execution

With the specimen holding at the specified hold temperature, test execution is conducted in accordance with AASHTO TP 10-93. The test is activated by inputting the file name, time interval for data collection, and sample cross-sectional area (in^2) into the TSRST software. The software requires verification that the LVDT tolerance is within 0 ± 0.005 inch, and requests the operator to re-zero if necessary. When all initial inputs have been provided, the test commences. The operator activates the servo drive motor switch, disables the hold/standby status, and within one minute, the TSRST begins its cooling ramp at 10°C/hr. The software takes data recordings at the specified time intervals, which will continue until the specimen fractures or the test reaches -50°C. At this point the test holds briefly at -50°C. The test then ends, and the environmental cabinet is allowed to warm.

5.3 Georgia Loaded Wheel Tester

The GLWT was used to evaluate the rutting susceptibility of the crack surfacing material. The testing equipment is an accelerated simulation of field traffic loading conditions and is used to determine if permanent rutting deformation is likely to result. Subjecting the crack surfacing material to repetitive wheel loading provides a fast and accurate means of predicting rutting at both the design and production stages.

The GLWT utilizes cylindrical specimens 6 inches (150 mm) in diameter and 3 inches (75 mm) high that are molded in a gyratory compactor mold (Cooley, 2000). The GLWT applies a 100 pound (445 N) load onto a pneumatic linear hose that is pressurized to 100 psi (690 kPa). The linear hose is centered on the sample and the load is applied to the hose via an aluminum wheel to simulate a tire. Cyclic, back and forth loading is applied to the specimen for 8000 cycles, where one cycle is defined as the backward and forward movement of the wheel over the sample.

The GLWT is enclosed in an environmental cabinet and test temperatures range from 95 to 140°F (35 to 60°C). Upon completion of the 8000 cycle loadings the permanent deformation is measured. Rut depths are obtained by determining the average difference in specimen surface profile before and after testing. In general, specimens are considered to “pass” the GLWT if the average of the rut depths is less than 0.30 inches (0.762 cm) after 8000 cycles. Figure 5.4 illustrates the GLWT.

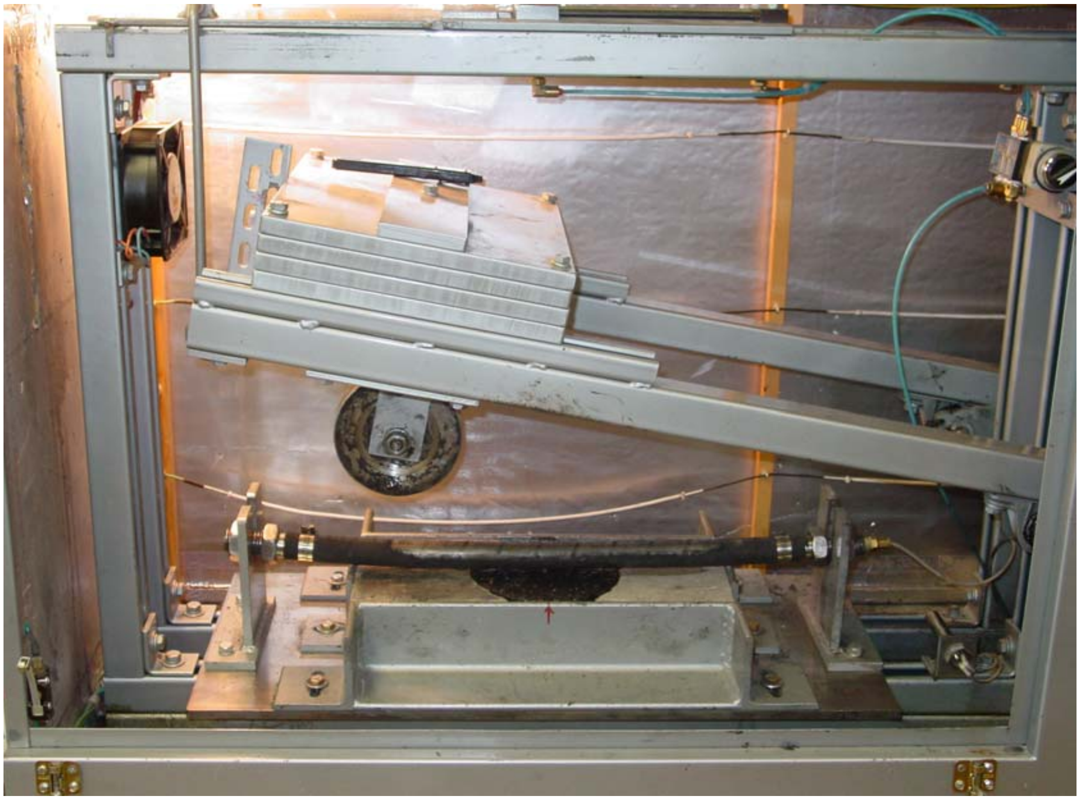


Figure 5.4 Georgia Loaded Wheel Tester

5.3.1 GLWT Test Execution

The GLWT procedure used was the University of Wyoming modified GLWT. The procedure is accomplished at 115°F (46°C), and requires the specimen to be preconditioned for a minimum of six hours at the specified temperature. The specimens consisted of 2 in. concrete cylinders with 1 in. of surfacing material on top. This was done do give a more accurate representation of field conditions.

Initially, the preheated specimen is placed in the GLWT, and the temperature is allowed to stabilize before recording any measurements. Initial measurements of rut depth are made before any cycles by placing the measurement apparatus in the hose mounting brackets. The measurement apparatus incorporates three dial gages that are pre-positioned at equal distances across the width of the specimen surface. Once the measurement is accomplished, the load is reapplied and the environmental cabinet closed. Rut depths are recorded at 1000, 4000, and 8000 cycles. Testing is halted if it is determined that the average rut depth exceeds 0.30 inches (0.762 cm). When the GLWT has completed the 8000 cycles it will shut itself off. The final step is to remove the load and pneumatic hose to take the final measurement. The differences of the three measurements are average and recorded.

5.4 Laboratory Evaluation Summary of Results

A summary of the TSRST and GLWT test results, as previously described are presented in Figures 5.5 and 5.6, and Table 5.1. The complete laboratory evaluations results can be found in Appendix D. Figure 5.5 presents the average failure temperature for the three crack surfacing materials in their respective configurations, while Figure 5.6 illustrates the maximum load incurred in the specimens at fracture.

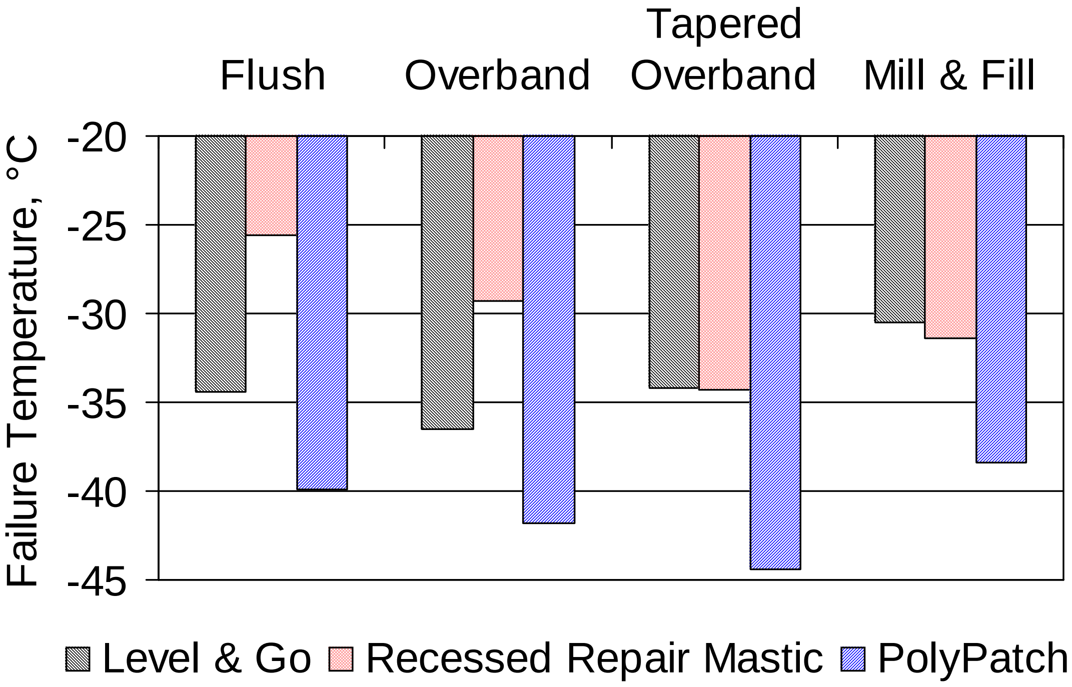


Figure 5.5 TSRST Average Failure Temperatures for Materials and Configurations

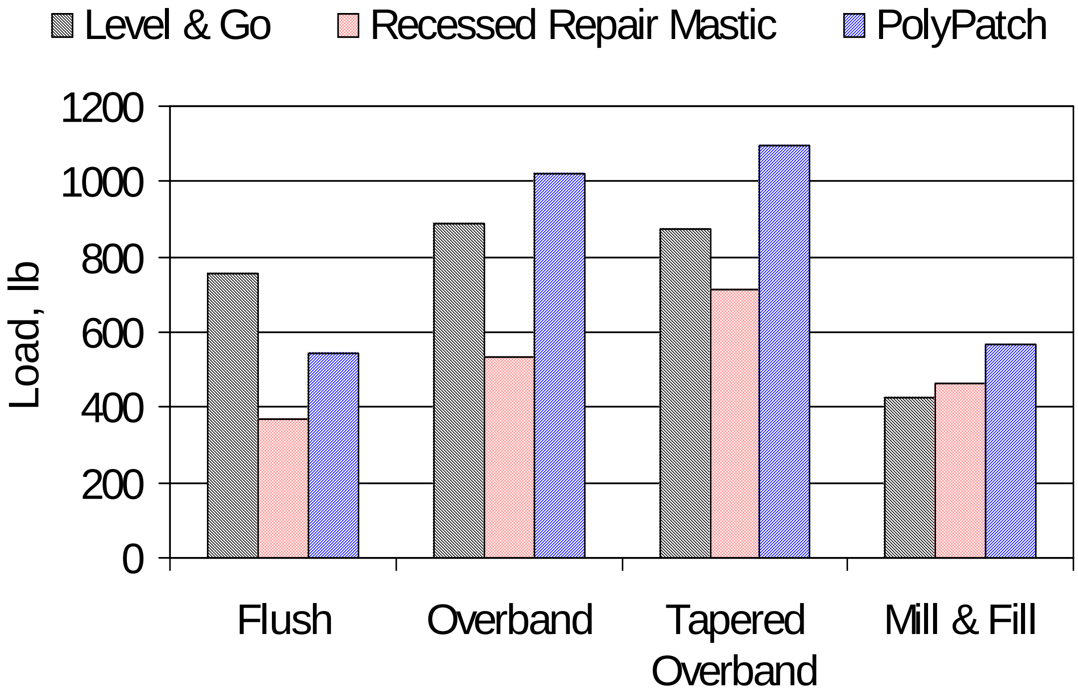


Figure 5.6 TSRST Average Incurred Loads for Materials and Configurations

5.4.1 TSRST Summary of Results

The TSRST failure modes generally began with adhesion failure at the asphalt and surfacing material interface, and subsequent cohesive failure occurred along these newly developed planes of weaknesses.

The behavior of the flush configuration was very uniform for all crack surfacing materials. The specimens failed adhesively at the asphalt and surfacing material interface. Figure 5.7 illustrates the adhesion failure for the flush configuration.

The performance of the uniform overband was extremely consistent in failure as was its flush counterpart. The specimens failed adhesively at the vertical asphalt and surfacing material interface, then cohesively along the newly developed failure plane. Figure 5.8 illustrates the adhesive and cohesive failure for the uniform overband configuration.

The tapered overband configuration demonstrated adhesive failure at the vertical asphalt and surfacing material interface, and then failed cohesively along the failure plane. Figure 5.9 illustrates the failures encountered for the tapered overband configuration.

The mill & fill configuration exhibited two failure modes. The primary mode of failure that occurred was adhesion failure at the asphalt and surfacing material interface of the reservoir, and then having an asphalt fracture below this failure plane. This primary failure mode may not be realistic because typical field applications have pavement structures that are thicker and less prone to failure in this manner. The secondary failure mode, adhesive failure, at the vertical asphalt and surfacing material interface in the crack below the reservoir, and then cohesively parallel to this failure plane. Figure 5.10 and 5.11 illustrate these two types of failures encountered for the mill & fill configuration.

Figure 5.7 TSRST Flush Configuration Failure Mode for All Surfacing Materials

Figure 5.8 TSRST Overband Configuration Failure Mode for All Materials

Figure 5.9 TSRST Tapered Overband Configuration Failure Mode for All Materials

Figure 5.10 TSRST Mill & Fill Configuration Primary Failure Mode for All Materials

Figure 5.11 TSRST Mill & Fill Configuration Secondary Failure Mode for All Materials

5.4.2 GLWT Summary of Results

All specimens failed the GLWT, and a summary of the results is presented in Table 5.1. Complete results can be viewed in Appendix D. As can be seen, rutting is evident in all materials, as no single specimen completed 8000 cycles. The Recessed Repair Mastic material performed the best out of all materials, completing 4000 cycles per test, while Level & Go generally completed 3000 cycles. The PolyPatch material completed 1000 to 2030 cycles per test, but the tests were stopped prematurely because the material was disintegrating and adhering to the machine and eminent damage to the machine would occur. Figures 5.12 through 5.14 illustrate the rutting failure for Level & Go, Recessed Repair Mastic, and PolyPatch respectively.

Table 5.1 Georgia Loaded Wheel Tester Summary of Rutting Results

Average Rut Depth (in.)													
Level & Go				**Recessed Repair Mastic**				**PolyPatch**					
Cycle	**Test 1**	**Test 2**	**Test 3**	**Cycle**	**Test 1**	**Test 2**	**Test 3**	**Test 1**		**Test 2**		**Test 3**	
0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0	0.000	0	0.000
1000	0.208	0.155	0.195	1000	0.172	0.193	.121	1000	0.195	1000	0.126	1000	0.104
3000	0.305	0.318	0.293	4000	0.325	0.353	.298	2030	0.268	-	-	1300	0.179

Figure 5.12 Rutting in Level & Go Crack Surfacing Material

Figure 5.13 Rutting in Recessed Repair Mastic Crack Surfacing Material

Figure 5.14 Rutting in PolyPatch Crack Surfacing Material

5.5 Chapter Summary

This chapter describes the laboratory research testing procedures for the Thermal Stress Restrained Specimen Test and the Georgia Loaded Wheel Test. The laboratory evaluation consisted of performing the TSRST; documenting the fracture temperature, load and nature of the fracture; and measuring the average rut depth for the GLWT. A summary of results was presented for each material configuration and each type of crack surfacing material.

6. DATA ANALYSIS

6.1 Introduction

After completion of the field and laboratory evaluation procedures, descriptive statistics were obtained for the collected field data and statistical analysis was performed on the collected TSRST data. The analysis was initiated by utilizing basic two-way Analysis of Variance (ANOVA) with interactions, and Analysis of Covariance (ANCOVA); the analysis was performed using MINITAB release 14.

6.2 Field Data Analysis

The mean percent effectiveness and the corresponding 95% confidence intervals were calculated for the three field evaluations, and for each individual location. Figure 6.1 summarizes the August, January and May evaluations, and presents the overall mean percent effectiveness for their respective road sections. The full summaries of all evaluations for the test sections can be viewed in Appendix C.

As Figure 6.1 illustrates, the mean effectiveness for all sections decreased from the August to the January evaluation, due to low ambient temperatures, with I-25 experiencing the worst failure rate out of all test sections. The confidence interval provides the range in which the estimated mean response for the test section is expected to fall. These upper and lower limits are calculated from the confidence level and the standard error of the fitted values.

For instance, it is estimated with 95% confidence that the mean effectiveness for WY-93 during the August evaluation is between approximately 51% and 8%, a rather large amount of uncertainty. Vice versa, the mean effectiveness for I-25 during this same period is between approximately 100% and 97%, a tight interval with little uncertainty to where the mean is located. The May evaluation indicated some recovery on US-26 as ambient temperatures evolved into typical springtime temperatures, but this improvement is insignificant because the mean remained in the range of the 95% confidence interval. Minor recovery was noted on I-25, but again, it is insignificant.

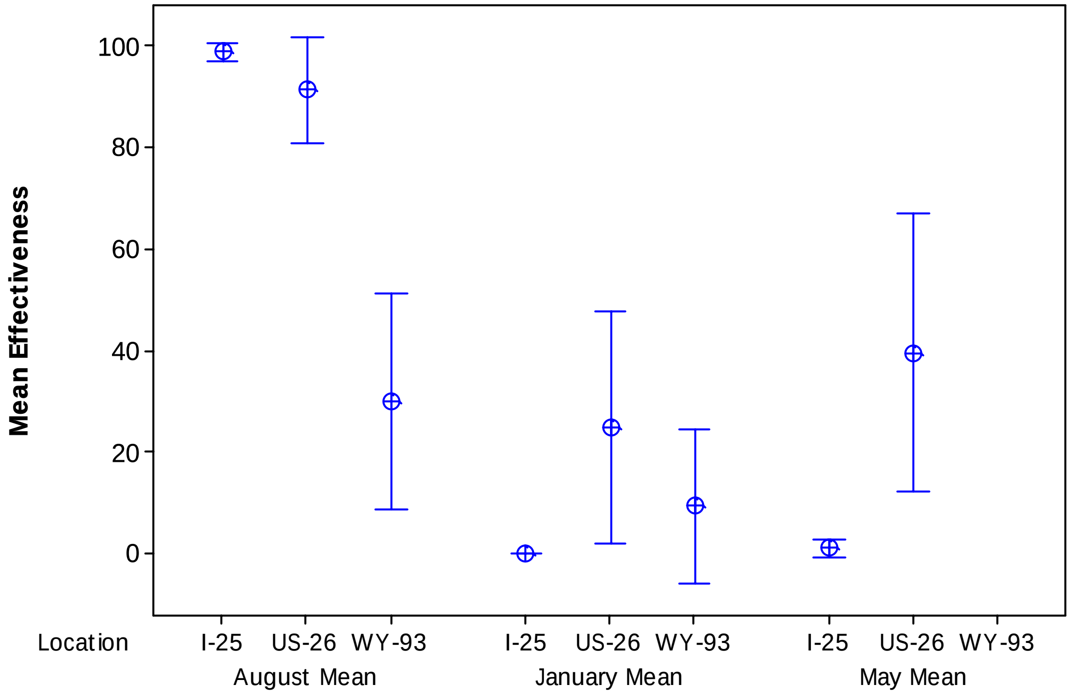


Figure 6.1 95% Confidence Interval for the Mean Effectiveness for WY-93, US-26, I-25 and their Respective Evaluations

6.3 Laboratory Data Analysis

Statistical analysis was performed on the TSRST laboratory collected data. Because all specimens failed the GLWT, there was no statistical analysis performed on these data. The TSRST data were analyzed using the aforementioned ANOVA with the fracture temperature and fracture load as the response variables and materials and configurations as the predictor variables. Results of the temperature analysis are shown using an interaction plot, main effects plot, and Tukey 95% confidence intervals. The load analysis utilized an Analysis of Covariance with main effects and scatter plots. In addition, a third regression was performed to obtain prediction intervals at the 90% and 50% reliability levels.

6.4 Analysis of Variance for Temperature

The relationship of the materials and configurations to fracture temperature was analyzed using two-way ANOVA with interactions on the collected TSRST data. A summary of the results is displayed in Table 6.1. The full ANOVA analyses for temperature, load, and tukey comparisons can be found in Appendix E. The ANOVA examines whether the variance of the factor is zero, and whether all level means are the same. The ANOVA includes an F-test, which is a hypothesis test that produces a p-value. The p-value is the probability that a random variable having an F distribution is greater than the observed F-test at the predetermined 0.05 level of significance. The results of the ANOVA indicate that material contributed significantly to the temperature characteristics of the crack surfacing materials, its p-value was less than the level of significance. The configuration and interaction variables did not significantly contribute.

Table 6.1 ANOVA Results for Temperature

Source	Degree of Freedom	F	P
Material (M)	2	7.86	0.003
Configuration (C)	3	1.63	0.210
M*C	6	0.66	0.680
Error	23	-	-

6.4.1 Plots for TSRST Temperature Data

Two types of plots were produced by the analyses, interaction, and main effects plots. The Interaction plot shown in Figure 6.2 illustrates the least squares (LS) means for fracture temperature versus material and configuration. As indicated, the materials and configurations performed with variable results. For temperature versus material, the PolyPatch performed exceptionally well with its LS means occurring below the average fracture temperature of -34.95°C (-30.90°F), while Level & Go and Recessed Repair Mastic had performances above the average fracture temperature. In particular, the LS means for PolyPatch are significantly different from Level & Go and Recessed Repair Mastic. These findings illustrate that the bonding capabilities of the PolyPatch crack surfacing material are statistically significant. For temperature versus configuration, the LS means suggests that the tapered overband and mill & fill configurations are below the average fracture temperature, especially when utilized with PolyPatch material. In addition, the LS means suggests that the overband configuration is below the average fracture temperature when utilized with Level & Go and PolyPatch materials.

The main effects plot in Figure 6.3 illustrates the LS means for fracture temperature versus materials and configurations, and further reinforces the interaction plot. The LS means for PolyPatch is below the average, while Level & Go and Recessed Repair Mastic were both above the average. As can be seen, PolyPatch is significantly different from the other two materials. In addition, the LS means suggests that the overband and tapered overband configurations are below the average fracture temperature.

Evidence from these two plots suggests that the tapered overband configuration may perform best and the flush configuration may be least reliable. The interaction plot (Figure 6.2) shows that performance of configurations with different materials may not be completely uniform across materials, but data are inadequate to state this conclusively.

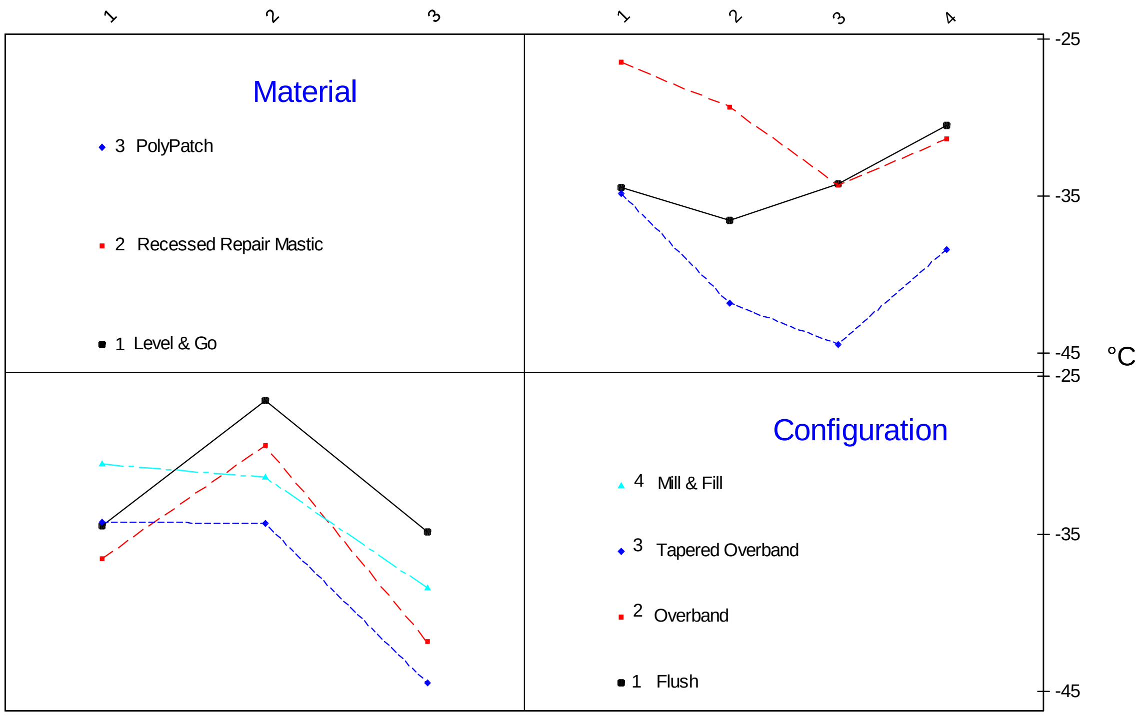


Figure 6.2 Interaction Plot of LS Means for Temperature versus Material and Configuration

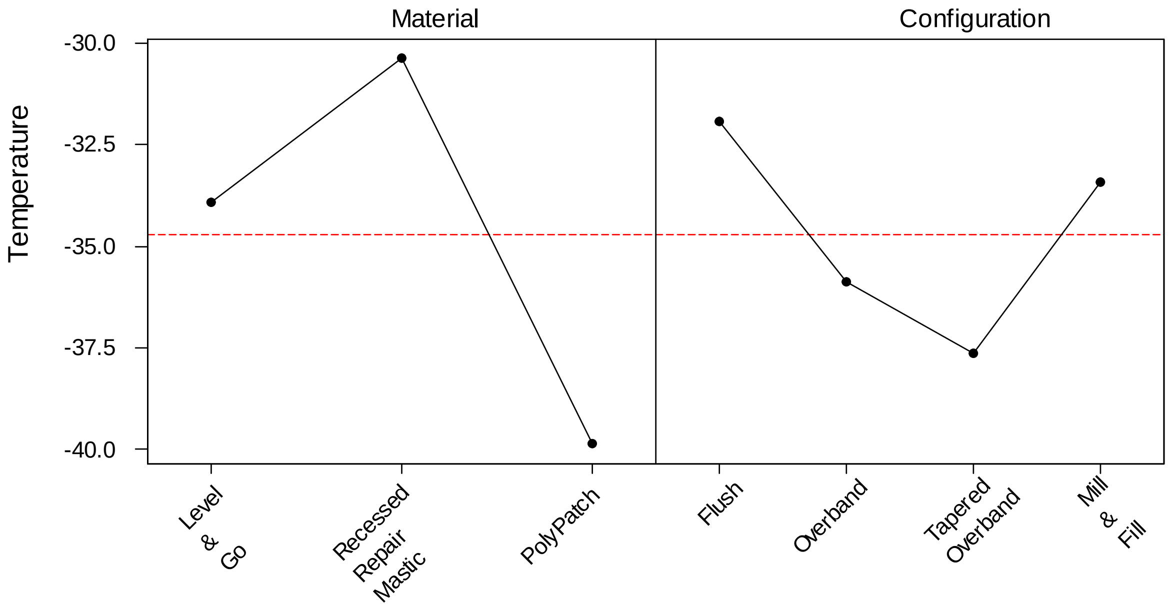


Figure 6.3 Main Effects Plot of LS Means for Temperature versus Material and Configuration

6.4.2 Tukey Simultaneous Pairwise Comparisons

In addition to the ANOVA analysis, Tukey 95% confidence intervals were obtained for all pairwise comparisons among levels of materials and configurations. Figure 6.4 illustrates the comparisons among levels of materials. The comparisons for levels of materials indicate that the differences when Level & Go is subtracted from Recessed Repair Mastic and PolyPatch, and Recessed Repair Mastic from PolyPatch, are not significantly different from zero. From the confidence intervals it can be concluded that differences between Level & Go and Recessed Repair Mastic are insignificant because their confidence intervals include zero, and PolyPatch significantly differs from Recessed Repair Mastic because its confidence interval does not contain zero. Figure 6.5 illustrates the comparisons among levels of configurations, which is inconclusive. The confidence intervals for all pairwise comparisons indicate that all configurations are insignificant because all confidence intervals contain zero.

```
Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Temperature
All Pairwise Comparisons among Levels of Material

Material = 1(L&G) subtracted from:

Material     Lower    Center     Upper  ---+---------+---------+---------+---
2 (RRM)     -2.55     3.542   9.63073                     (--------*--------)
3 (PP)      -11.85    -5.942  -0.03441        (--------*-------)
                                        ---+---------+---------+---------+---
                                        -14.0      -7.0       0.0       7.0


Material = 2 subtracted from:

Material     Lower    Center     Upper  ---+---------+---------+---------+---
3 (PP)      -15.57    -9.483    -3.394   (-------*--------)
                                        ---+---------+---------+---------+---
                                        -14.0      -7.0       0.0       7.0
```

Figure 6.4 Tukey 95% Confidence Intervals for Comparisons among Levels of Materials

```
Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Temperature
All Pairwise Comparisons among Levels of Configuration

Configur = 1(Flush) subtracted from:

Configur     Lower    Center     Upper  ----------+---------+---------+------
2 (OB)      -11.80    -3.956     3.886     (----------*-----------)
3 (TOB)     -13.55    -5.711     2.131   (----------*----------)
4 (M&F)      -9.35    -1.511     6.331         (----------*----------)
                                        ----------+---------+---------+------
                                                -7.0       0.0       7.0


Configur = 2(OB-Overband) subtracted from:

Configur     Lower    Center     Upper  ----------+---------+---------+------
3 (TOB)     -9.290    -1.756     5.778         (---------*----------)
4 (M&F)     -5.090     2.444     9.978               (---------*----------)
                                        ----------+---------+---------+------
                                                -7.0       0.0       7.0


Configur = 3(TOB-Tapered Overband) subtracted from:

Configur     Lower    Center     Upper  ----------+---------+---------+------
4(M&F)      -3.334     4.200     11.73                 (----------*----------)
                                        ----------+---------+---------+------
                                                -7.0       0.0       7.0
```

Figure 6.5 Tukey 95% Confidence Intervals for Comparisons among Levels of Configurations

6.5 Analysis of Covariance for Load

The relationship of load versus materials and configuration was analyzed utilizing an additional factor, a covariate named Tstar, where this variable is defined as the fracture temperature minus the average temperature. This factor allowed for temperature to be rescaled so that zero corresponds to the average observed temperature in the experiment. In addition, an interaction variable is included between material and Tstar. The statistical model is thus an Analysis of Covariance (ANCOVA), which allows for different load-temperature relationships for different materials and configurations. Initial results of the ANCOVA are presented in Table 6.2.

The analysis indicated that configuration and Tstar notably contributed to the load capacity characteristics of the surfacing materials, with Tstar being highly significant in this analysis. Material was included in the analysis because of its significance with the interaction variable. The interaction shows that the relationship between Tstar and load differed for different materials. The rate of change between temperature and load depended mostly on material, while the overall level of load (at an average temperature) depended mostly on configuration.

Table 6.2 ANCOVA Results for Load

Source	Degree of Freedom	F	P
Material (M)	2	1.87	0.174
Configuration (C)	3	4.45	0.012
Tstar	1	16.28	0.000
M*Tstar	2	3.97	0.031
Error	26	-	-

6.5.1 Plots for TSRST Load Data

Two types of plots were produced by the analyses, main effects, and scatter plots. The main effects plot in Figure 6.6 illustrates the fitted means for load versus material and configuration. For load versus material, the fitted means for Level & Go was above the average load of 650.03 pounds, while PolyPatch was below the average load and Recessed Repair Mastic was approximately equivalent to the average. These findings indicate that there is little difference between materials; therefore, all materials are insignificant. For load versus configuration, the fitted means of Figure 6.6 indicate that the overband and tapered overband configurations exceed the average load. These findings show that the difference between the overband and tapered overband are highly significant from the mill & fill configuration, illustrating that these configurations are statistically significant. Simply put, the overband and tapered overband configurations have higher load capacities than the flush and mill & fill configurations.

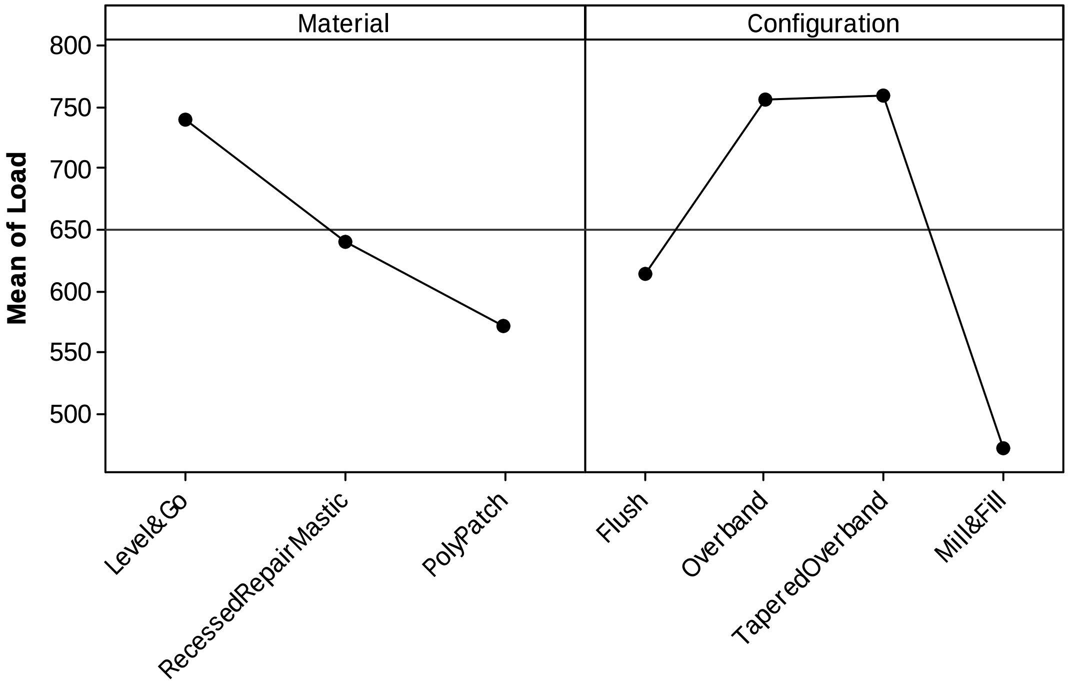


Figure 6.6 Main Effects Plot of Fitted Means for Load versus Material and Configuration

In addition, the ANCOVA analysis allows for the storage of the fitted load values that correspond to each material and configuration. Using the fitted values in scatter plots allows for further explanation of the materials and configurations performance. Figure 6.7 demonstrates a scatter plot of the fitted load values versus temperature for all 12 combinations of materials and configurations.

By utilizing a scatter plot, the performance of the materials and configurations can be visualized and used as a reinforcement of the main effects plot. As Figure 6.7 illustrates, material and configuration combinations with higher loads and lower temperatures have better performance over combinations with high temperatures and low loads. In addition, it can be seen that there are four parallel lines for each material and their four configurations. These lines illustrate the rate of change for the material, or slope.

Further, Figure 6.8 demonstrates the fitted load values for Level & Go against temperature. Note the flatter slope of the parallel lines, which indicates that Level & Go does not undergo much change, and the material is highly flexible. The plot suggests that Level & Go is stronger when coupled with the overband and tapered overband configuration, and can be seen having higher load capacities at lower temperatures. Given the slope, range of loads, and temperatures, it performs well in comparison to the other materials.

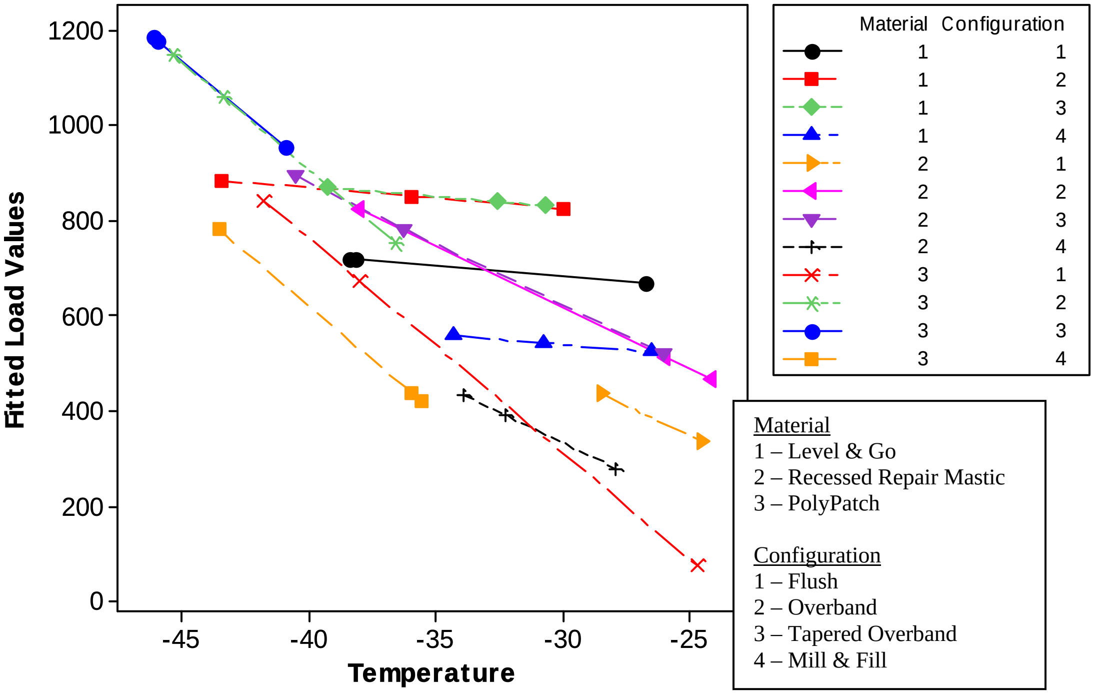


Figure 6.7 Scatter Plot of Fitted Load Values versus Temperature

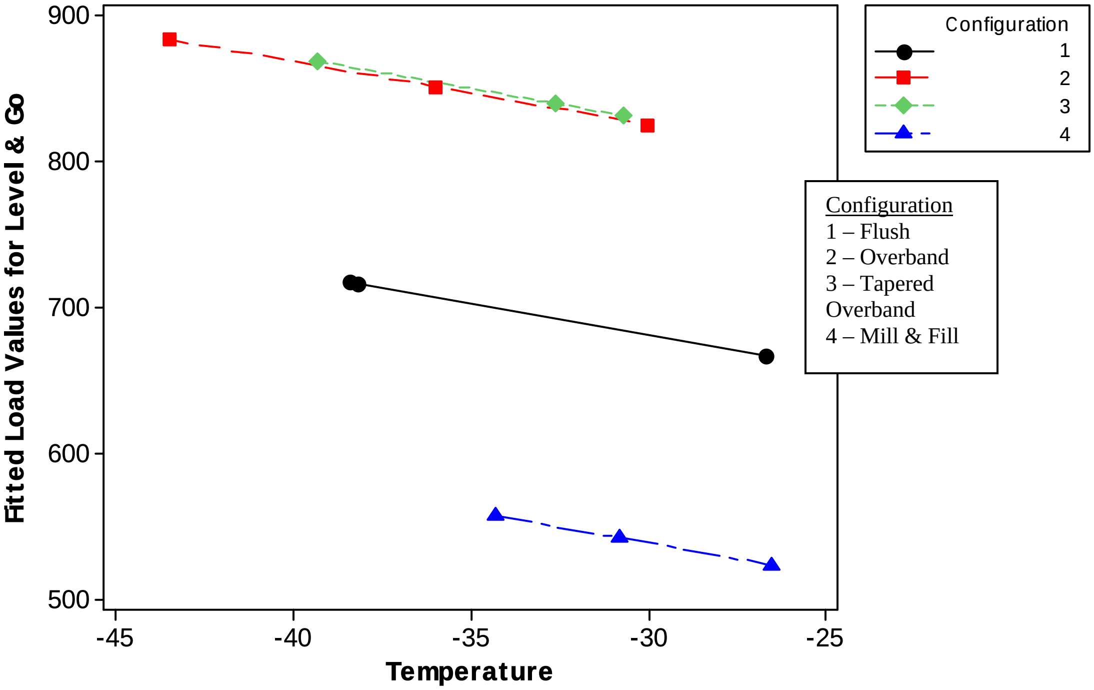
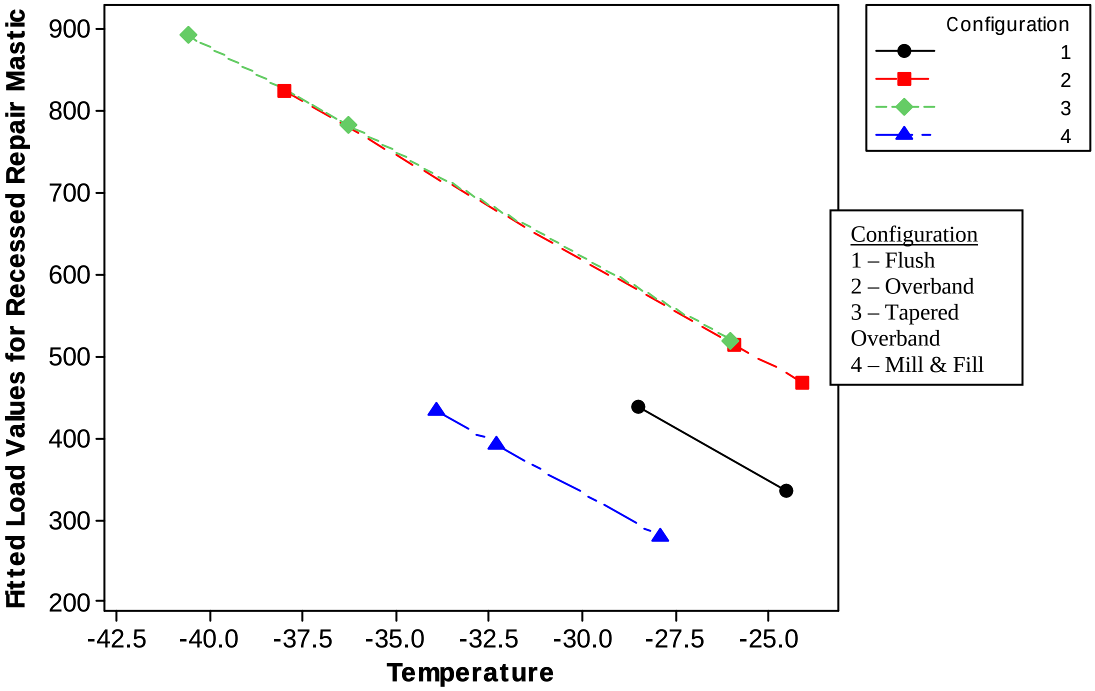


Figure 6.8 Scatter Plot of Fitted Load Values for Level & Go versus Temperature

Figure 6.9 demonstrates the fitted load values for Recessed Repair Mastic against temperature. As can be seen, the slope of the parallel lines is steeper, indicating that Recessed Repair Mastic undergoes moderate change, and the material is moderately flexible. Again, the plot suggests that Recessed Repair Mastic is stronger when coupled with the overband and tapered overband configuration, which have higher load capacities at lower temperatures. The slope and range of loads suggests that it performs fair in comparison to the other materials.



Configuration
1 – Flush
2 – Overband
3 – Tapered Overband
4 – Mill & Fill

Figure 6.9 Scatter Plot of Fitted Load Values for Recessed Repair Mastic versus Temperature

Figure 6.10 demonstrates the fitted load values for PolyPatch against temperature. As indicated, the slope of the parallel lines is very steep, which is indicative of an inflexible material that undergoes large amounts of change at low temperatures. The plot suggests that PolyPatch is very strong when coupled with the overband and tapered overband configuration, which have very high load capacities at lower temperatures. The slope and range of loads suggests that it performs best in comparison to the other materials. However, the main effects plot indicates that the PolyPatch is insignificant, but, as can be seen in the scatter plot, this material has high load capabilities. The analysis suggests that this large change may occur over the range for temperature beyond the linear elastic range of the material, and at the average the material is flexible and not undertaking much load.

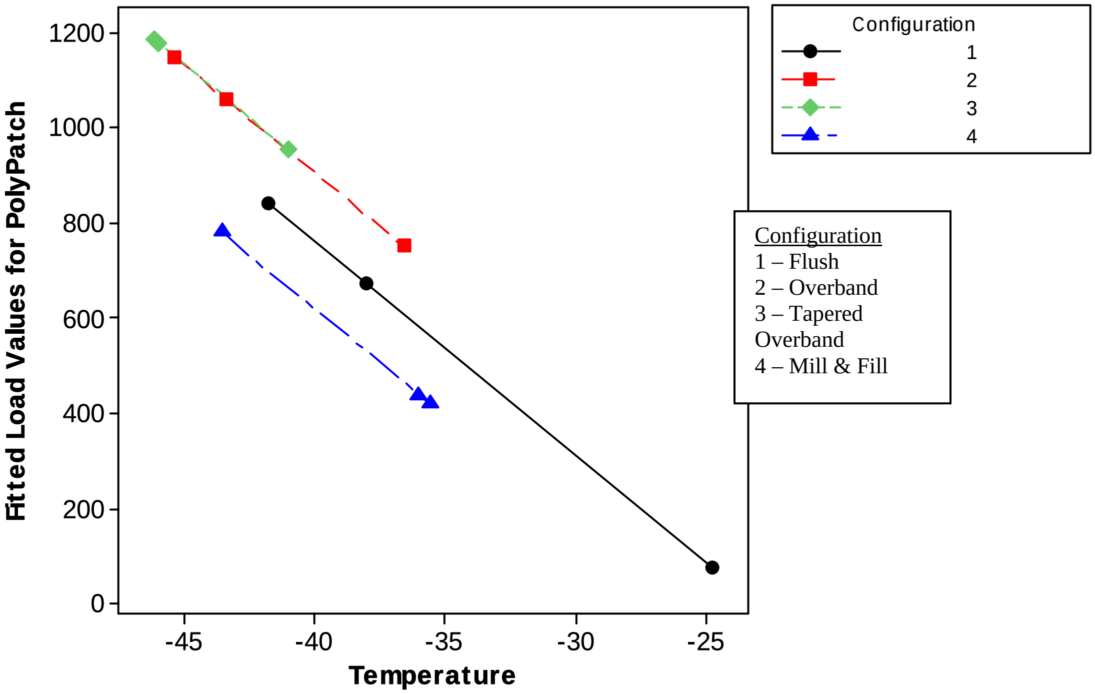


Figure 6.10 Scatter Plot of Fitted Load Values for PolyPatch Versus Temperature

6.6 Prediction Intervals for Material Fraction Temperatures

Performing this basic linear regression analysis allows for the comparison of mean fracture temperatures for the crack surfacing materials to asphalt binders at the selected 98% and 50% reliability levels. These reliability levels correspond to the reliability levels used by the Asphalt Institute's classifications of asphalt binder grades for selected cities (AI, 1996). In the regression analysis, the response variable was the fracture temperatures of the materials, and the predictor variables were materials and configurations in the form of indicator variables. The complete analysis is summarized in Appendix E. Table 6.3 presents the obtained prediction intervals at the 98% and 50% reliability levels for each material and configuration.

Table 6.3 Temperature Prediction Intervals at the 98% and 50% Reliability Level

Configuration	Material	Temperature Prediction Interval			
		98%		50%	
		High	Low	High	Low
Flush	Level & Go	-46.1	-16.4	-35.4	-27.1
	Recessed Repair Mastic	-42.8	-12.8	-32.0	-23.6
	PolyPatch	-52.1	-22.3	-41.3	-33.0
Uniform Overband	Level & Go	-49.9	-20.2	-39.2	-30.9
	Recessed Repair Mastic	-46.5	-16.8	-35.7	-27.5
	PolyPatch	-55.8	-26.2	-45.1	-36.9
Tapered Overband	Level & Go	-51.6	-22.0	-40.9	-32.7
	Recessed Repair Mastic	-48.2	-18.5	-37.5	-29.2
	PolyPatch	-57.6	-27.9	-46.9	-38.6
Mill & Fill	Level & Go	-47.4	-17.8	-36.7	-28.5
	Recessed Repair Mastic	-44.0	-14.3	-33.3	-25.0
	PolyPatch	-53.4	-23.7	-42.7	-34.4

For example, the asphalt binder grade for Cheyenne, Wyoming at the 50% reliability level is PG 52-22 (Performance Grade 52°C and -22°C) (AI, 1996). The lower temperature limit of the asphalt binder is the major concern of this research project, and is hence the main focus. When comparing the asphalt binder grade to the 50% prediction intervals, they reveal that all materials and configurations are applicable for use because their respective intervals are below the -22°C fracture temperature. At the 98% reliability level, the asphalt binder grade is PG 58-28. The only material able to meet the asphalt binder grade requirement is the PolyPatch material configured as a tapered overband. The 98% prediction interval includes the -28°C low temperature limit at the extreme high temperature point of the interval; therefore, the PolyPatch material configured in this manner is adequate for applications in the Cheyenne area. The Level & Go and Recessed Repair Mastic materials are not usable in this case.

6.7 Chapter Summary

This chapter describes the analyses utilized on the field and laboratory collected data. Methods employed were descriptive statistics on the field data, a statistical analysis of variance on the TSRST temperature data, analysis of covariance on the TSRST load data, and regression analysis on the TSRST fracture temperatures. No analysis was performed on the GLWT data because all specimens failed the test. The purpose of the analyses was to statistically verify the in-situ performance, bonding, and load capacity characteristics of the crack surfacing materials.

The descriptive statistics performed on the field data revealed that all sections experienced a decrease in the mean effectiveness during the winter months, and the observed recovery was determined to be insignificant.

The ANOVA performed on the TSRST temperature data found that the PolyPatch material was highly significant, while Level & Go and Recessed Repair Mastic were not. This was further reinforced by the Tukey simultaneous comparisons that indicate that the PolyPatch is significant. The analysis suggested that the tapered overband configuration performed best and the flush configuration was the least reliable.

The ANCOVA analysis performed on the TSRST load data indicated that materials were insignificant, but evidence from the scatter plots suggests that PolyPatch has a higher load capacity than indicated in the main effects plot. In addition, the tapered overband and overband configurations have the highest observed load capacities, and are statistically significant.

The prediction intervals obtained from the regression analysis on the TSRST fracture temperatures allow for the comparison of crack surfacing materials in their respective configurations to asphalt binder grades at the 98% and 50% reliability levels.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The main objective of this research project was to examine the effectiveness of crack surfacing material and its ability to seal asphaltic cracks. The project was divided into three elements: literature review, field evaluation, and laboratory evaluation. The field evaluation consisted of identifying the in-situ modes of failure, measuring the percent failure, and identifying existing superficial distresses in existing crack surfacing material. The laboratory evaluation included the performance of the Thermal Stress Restrained Specimen Test and the Georgia Loaded Wheel Tester. The TSRST was employed to identify the modes of failure of the specimens and identify the fracture temperature and induced load of the specimen at failure. The GLWT was utilized to evaluate the susceptibility to rutting of the crack surfacing materials.

7.2 Conclusions from the Field Evaluation

The following conclusions were drawn from the field evaluation of this research project:

1. After four years of service, the PolyPatch crack surfacing material installed on WY-93 displayed better performance than the Level & Go displayed on I-25 after one year of service. This is due, at least in part, to the lower traffic volumes on WY-93. In addition, WYDOT plows US-26 and I-25 much more frequently because these routes are major freight corridors.

2. The PolyPatch material on WY-93 exhibited bubbling, which is usually a warm weather phenomenon.

3. The Level & Go, Recessed Repair Mastic, and PolyPatch materials have insignificant abilities to recovery and reseal the crack, as outlined in the descriptive statistics and prediction intervals.

4. The uniform overband configuration was utilized at all test sections with poor-to-marginal performance. This particular configuration could not handle the destructive forces that were placed upon it, especially snow plows.

5. Quality control was noted as a major concern during this research project. Materials were not applied properly to the pavement structure. All materials and test sections had crack surfacing materials applied directly over existing crack sealant. It was observed that the two products have very different expansion rates, which promoted failure of the material. In addition, the products had very thin coverage over the cracks. Exposed pavement was visible along cracks, and the material was sparsely applied throughout the traveled way. Shoulders were neglected in their entirety.

6. There was no documented rutting at any of the test sections due to the thin application of the materials.

7. Surfacing materials were applied to cracks less than 1 in. in width. These slender cracks prevented the surfacing material from penetrating the crack for proper bonding. In addition, the manufacturer’s recommendations for application were not followed.

7.3 Conclusions from the Laboratory Evaluation

There were 36 test specimens subjected to the TSRST evaluation, three of each material with all four configurations. Statistical analyses were performed and the following conclusions were drawn:

1. All crack surfacing materials performed differently, as demonstrated by the TSRST laboratory evaluation.

2. PolyPatch crack surfacing material was the best-performing material as indicated by its low fracture temperature and high load capacity. Level & Go and Recessed Repair Mastic had good-to-fair performances, respectively.

3. Based on TSRST results, the tapered overband was the best performing configuration, followed by the uniform overband configuration. The least reliable configuration was the flush fill. The tapered overband configuration may be very difficult to construct.

4. The mill & fill configuration failed in the laboratory in a mode that probably would not occur in the field. A typical pavement structure has adequate depth in the structure underneath the outer edges of the milled reservoir that would potentially be uncracked and have its integrity intact. From this, it can be concluded that failure probably would not occur, the primary failure mode that occurred in the laboratory. Therefore, the laboratory performance of the mill & fill configuration may not accurately reflect the true field performance, and further research is needed.

There were nine specimens subjected to the GLWT, three of each material. The following conclusions can be drawn from the GLWT evaluation of this research:

1. Based on GLWT results, all materials configured with a significant amount of width and depth will endure some level of rutting, as no material was able to complete the required 8000 cycles.

2. Recessed Repair Mastic was the best performer, being capable of handling up to 4000 cycles, while Level & Go managed 3000 cycles and PolyPatch managed anywhere from 1000 to 2030 cycles.

3. The materials presented themselves as soft and pliable at the 115°F test temperature. Recessed Repair Mastic was the most rigid, while Level & Go had marginal rigidity and PolyPatch had poor rigidity, essentially being very soft and pliable. The PolyPatch disintegrated during testing and stuck to the machine.

7.4 Recommendations

Based on the results of this research project, the following recommendations are suggested:

1. For cold climate applications, the PolyPatch material should be utilized. The ANOVA indicated that the PolyPatch material is highly significant due to its low fracture temperature and high load capacity in comparison to the other materials. In particular, the Tukey simultaneous pairwise comparisons defined the PolyPatch as the only significant material.

2. The tapered overband configuration followed by the uniform overband, are the strongest of all configurations, as seen in the ANCOVA analysis, and should be used for all working and nonworking cracks, and where construction doesn't pose a problem.

    a) If constructing the tapered overband is difficult, the uniform overband configuration can be utilized. It is highly suggested that the uniform overband be used on working and nonworking pavement cracks that will permit the surfacing material into the crack and provide a minimum of 3/8 in. depth of material over the crack. Use of this method should be avoided, is possible, in areas of high frequency snowplowing.

    b) In addition, it is intuitive that the mill & fill configuration will be a strong configuration, as it is common practice to route pavement cracks. It is highly suggested that further research be performed prior to using this configuration. The flush configuration should be avoided.

3. The obtained 98% and 50% prediction intervals (Table 6.3) can be utilized by SHA to determine if the crack surfacing materials presented in this research project are compatible with their respective asphalt binder grades. Appendix F presents the Asphalt Institute's recommended asphalt binder grades for selected cities in all 50 states, the District of Columbia, and Puerto Rico.

4. When rutting is of concern or using in areas of high traffic volumes, it is recommended that Level & Go or Recessed Repair Mastic be utilized instead of the PolyPatch material. As indicated by the GLWT, these materials have improved rutting qualities over the PolyPatch, in addition to having adequate bonding characteristics that are conducive for use.

5. Increase quality control measures to ensure the proper use and application of the surfacing material. It is paramount that adequate coverage of surfacing material be given to the pavement structure, including the shoulders.

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APPENDICES

APPENDIX A. Deery American Corp. and Crafco Inc. Testing Procedures

WORLDWIDE DEERY AMERICAN CORPORATION
Pavement Preservation Products

DATA SHEET
REVISION 1

IS DEERY RECESSED REPAIR MASTIC

DESCRIPTION Deery Recessed Repair Mastic is a hot applied pre-packaged, ready to melt recessed mastic repair material for concrete and asphalt pavements. Deery Recessed Repair Mastic is composed of quality-selected asphalt and/or resins, clean, hard, durable particles of wear resistant aggregates, synthetic rubber polymers, anti-oxidants, naturally occurring and man made reinforcing materials. Available in black asphalt or neutral concrete color.

USE A high performance confined repair for extra wide pavement cracks, pavement joint separations, bridge approaches, spalled concrete joints, utility cuts, and other pavement distresses. Deery Recessed Repair Mastic provides a waterproof, flexible, yet tough and durable repair system. Quick, simple, safe installation is usually ready for trafficking in less than 30 minutes.

HEATING Deery Recessed Repair Mastic shall be heated in a thermostatically controlled mastic mixer that utilizes oil as a heat transfer medium and has a full sweep horizontal agitator capable of gently lifting the material from the bottom of the reservoir and turning the material over and over. The agitation shall be capable of mixing and suspending materials, filled with aggregates having a specific gravity as high as 3.0.

APPLICATION A recess cavity shall exist or be constructed, by milling or grinding to a minimum depth of 1 inch (25mm). All surfaces must be dry and free from dust, dirt, grease, loose materials and any other matter that will inhibit the bonding of the repair mastic compound. Deery Surface Conditioner (DSC) shall be applied to the prepared surfaces with a light spray or brushed application, avoiding puddles. The applied (DSC) shall be dry prior to the installation of the hot mastic material. The heated repair mastic shall be dispensed into the properly prepared pavement recess, in layers if needed, leveled and smoothed with the surrounding pavement surface to form a durable repair. For enhanced surface texture and optimum skid resistance, broadcast approved aggregate chips into the hot mastic repair material and tamp lightly to assist embedment of the chips. Do not apply on wet, frosted surfaces or over coal tar coatings. The user should confirm suitability of use and compatibility with surface treatments through field-testing prior to application.

PROPERTIES of DEERY RECESSED REPAIR MASTIC

When sampled and heated to maximum heating temperature in accordance with ASTM D-5167:

WEAR RESISTANT COARSE AGGREGATE		
Resistance to Abrasion and Impact (grading C)	ASTM C131	20% degradation Maximum
MASTIC BINDER		
Penetration @ 77°F (25°C), 150 g, 5 sec	ASTM D5329	100 dmm Maximum
Penetration @ 122°F (50°C), 150 g, 5 sec	ASTM D5329	150 dmm Maximum
Flow @ 140°F, 75° angle, 5 hours	ASTM D5329	3 mm Maximum
Softening Point (R&B)	ASTM D36	190°F (88°C) Minimum
Flexibility@ 32°F, .25" mandrel, 90° bend, 10 sec	ASTM D3111 Modified per DAC	Bend without cracking
FINISHED MASTIC PRODUCT		
Low Temperature Flexibility	ASTM D3111 Modified per DAC	Pass @32°F
Water Absorption after 24 hours @ 122°F	ASTM D517 Section 9.2 Modified per DAC	1% Maximum absorption
Recommended Application Temperature	ASTM D5167	380-400°F (193-204°C)*
Maximum Heating Temperature	ASTM D6690	400°F (204°C)

*Temperature of product measured at pavement surface. Use highest Recommended Application Temperature in cool weather.
*Prolonged heating at or above Recommended Application Temperature may severely damage product.
TEST, TEST METHODS AND CONDITIONS, PROCEDURES, AND SPECIFICATIONS PER DEERY AMERICAN CORPORATION GUIDELINES.

PACKAGING Mastic is packaged in cardboard boxes containing a maximum of 40 lb (18.00 kg). Each box contains a quick melt liner, which is dissolved and incorporated into the melted Mastic product. All ingredients shall be accurately pre-proportioned in one container. The container shall be designed to insure that the binder portion shall be kept separate from and not pre-mixed with any other ingredient.

FOR ADDITIONAL INFORMATION

Call: 1-800-227-4059 toll free
Email: info@deeryamerican.com
Web: www.deeryamerican.com

PERFORMANCE Temperature fluxuations, site conditions, surface preparation, traffic, installation technique, material selection, shape factor and surface treatment compatibility influence the effectiveness and useful life of Pavement Preservation treatments. Consider and monitor each element for optimum results. Purchaser and end user should determine applicability for use in their specific conditions.

WARRANTY COMPLETE DETAILS ON REVERSE SIDE OF THIS DATA SHEET

WORLDWIDE DEERY
AMERICAN CORPORATION
Pavement Preservation Products

DATA SHEET
REVISION 3

DEERY LEVEL & GO REPAIR MASTIC

DESCRIPTION Deery Level & Go Repair Mastic is a hot applied, pre-packaged, ready to melt overband mastic repair material for concrete and asphalt pavements. Deery Level & Go Repair Mastic is composed of quality-selected asphalt and/or resins, clean, hard, durable particles of wear resistant aggregates, synthetic rubber polymers, anti-oxidants, naturally occurring and man made reinforcing materials. Available in black asphalt or neutral concrete color.

USE An unconfined, feathered edge repair for extra wide pavement cracks, pavement joint separations, bridge approaches, spalled concrete joints, utility cuts, and other pavement distresses when installation is not recessed into existing pavement. Deery Level & Go Repair Mastic provides a waterproof, flexible, yet tough and durable repair system. Quick, simple, safe installation is usually ready for trafficking in less than 30 minutes.

PHYSICAL PROPERTIES	TEST METHOD	SPECIFICATION
WEAR RESISTANT COARSE AGGREGATE		
Resistance to Abrasion and Impact (grading C)	ASTM C131	20% degradation Maximum
MASTIC BINDER		
Penetration @ 77°F (25°C), 150 g, 5 sec	ASTM D5329	100 dmm Maximum
Penetration @ 122°F (50°C), 150 g, 5 sec	ASTM D5329	150 dmm Maximum
Flow @ 140°F, 75° angle, 5 hours	ASTM D5329	3 mm Maximum
Softening Point (R&B)	ASTM D36	190°F (88°C) Minimum
Flexibility@ 32°F, .25" mandrel, 90° bend, 10 sec	ASTM D3111 Modified per DAC	Bend without cracking
FINISHED MASTIC PRODUCT		
Low Temperature Flexibility	ASTM D3111 Modified per DAC	Pass @32°F
Water Absorption after 24 hours @ 122°F	ASTM D517 Section 9.2 Modified per DAC	1% Maximum absorption
Recommended Application Temperature		380-410°F.(193-204°C)**
Maximum Safe Heating Temperature		410°F (204°C)***

***Temperature of product measured at pavement surface. Use Maximum Application Temperature in cool weather*

****Prolonged heating at or above Maximum Safe Heating Temperature may severely damage product.*

TEST, TEST METHODS AND CONDITIONS, PROCEDURES, AND SPECIFICATIONS PER DEERY AMERICAN CORPORATION GUIDELINES.

SURFACE PREPARATION All surfaces must be dry and free from dust, dirt, grease, loose materials and any other matter that will inhibit the bonding of the repair mastic compound. Deery Surface Conditioner (DSC) shall be applied to the prepared surfaces with a light spray or brushed application, avoiding puddles. The applied (DSC) shall be dry prior to the installation of the hot mastic material.

INSTALLATION Deery Level & Go Repair Mastic shall be heated in a thermostatically controlled mastic mixer that utilizes oil as a heat transfer medium and has a full sweep horizontal agitator capable of gently lifting the material from the bottom of the reservoir and turning the material over and over. The agitation shall be capable of mixing and suspending materials, filled with aggregates having a specific gravity as high as 3.0. The heated repair mastic shall be dispensed onto the properly prepared repair area, in layers if needed, leveled and smoothed with the surrounding pavement surface to form a durable repair. For enhanced surface texture and optimum skid resistance, broadcast approved aggregate chips into the hot mastic repair material and tamp lightly to assist embedment of the chips.

LIMITATION Do not apply on wet, frosted surfaces or over coal tar coatings. The user should confirm suitability of use and compatibility with surface treatments through field-testing prior to application

PACKAGING Mastic is packaged in cardboard boxes containing a maximum of 40 lb (18.00 kg). Each box contains a quick melt liner, which is dissolved and incorporated into the melted Mastic product. All ingredients shall be accurately pre-proportioned in one container. The container shall be designed to insure that the binder portion shall be kept substantially separated from and not pre-mixed with any other ingredient.

FOR ADDITIONAL INFORMATION

Call: 1-800-227-4059 toll free
Email: info@deeryamerican.com
Web: www.deeryamerican.com

PERFORMANCE Temperature fluxuations, site conditions, surface preparation, traffic, installation technique, material selection, shape factor and surface treatment compatibility influence the effectiveness and useful life of Pavement Preservation treatments. Consider and monitor each element for optimum results. Purchaser and end user should determine applicability for use in their specific conditions.

WARRANTY COMPLETE DETAILS ON REVERSE SIDE OF THIS DATA SHEET

CRAFCO INC
AN ERGON COMPANY

Original Date: November 30, 1999

PTM 1

Revision Date: January 10, 2001

Written By: _____________

Reviewed By:____________

Test Procedure

Polypatch Viscosity Test

Purpose

This is Crafco's standard method of test for determining that the flow of Polypatch is within the specified range. This method shall be used for approval of each lot of Polypatch Batch. Polypatch must flow from the melter as well as be easy to apply in the field without being so thin as to flow out of certain installations or be too weak to withstand traffic.

Apparatus

Crafco viscosity test stand
5 7/8" diameter stainless steel can, 7" tall
2000 gams of material at 398°F – 402°F
Receiver can 6 1/8" diameter, 7" tall
Balance capable of weighing 2000g
Watch with a second hand

Calibrated Probe thermometer

Procedure

1. Determine that Polypatch is 400°F ±2 with probe thermometer while stirring in the melter.
2. Place viscosity stand on a flat surface next to the balance and place the receiver can on the balance and tare.
3. Remove the stainless steel can from the melter and wipe clean.
4. Within 50 seconds of removal from the melter move the can up to the high end of the angle iron ramp
5. Tilt the can over and start the stopwatch.
6. At the end of 5 seconds stand the can back up.
7. Record the weight of material in the receiver can in grams
8. The remainder of the material in the stainless steel can be restirred and used to pour remaining samples for QC testing.

Report

Report the weight in grams in the receiver can on the testing instruction sheet.

PTM2

Original Date: November 8, 1999

Revision Date: October 9, 2002

Written By:_____________

Reviewed By:____________

Test Procedure

PolyPatch Stability Test

Purpose

This is Crafco's standard method of test for determining the dimensional Stability under vehicle loading of Poly Patch at elevated ambient temperatures. PolyPatch must have a significant amount of rutting resistance and stability in order to function as a repair material.

Apparatus

Parallel Plate Plastometer as shown in Figure 1.
Brass ring with a 2.0 ±0.05" inner diameter and 1.0 ±0.05" in height.
158 °F oven
PolyPatch at 400°F from can after viscosity pour.
Burner and spatula
Melter capable of maintaining material at 400°F
Release coating, and release paper
Calipers

Procedure

9. Heat Polypatch to 400°F while stirring in the melter.
10. Coat the inside of the brass ring with release coating and Place on release paper.
11. Pour material into the brass ring to just overfill the ring.
12. Allow the material to cool at least 2 hours and cut off the surface with the hot spatula to be even with the top of the brass ring.
13. Allow the material to condition at lab conditions overnight.
14. Remove the PolyPatch specimen from the ring and place a 4.5” x 4.5” square of release paper on the top and the bottom of the specimen.
15. Measure the diameter of the specimen with calipers to hundredths of an inch and write this number down as initial diameter.
16. Place the PolyPatch specimen with release paper on top and bottom on the bottom plate of the Parallel Plate Plastometer. The top plate should be secured in position above the specimen.
17. Place the entire set up in the 158°F oven for 10 minutes.
18. After the 10 minute conditioning period, rotate the top plate so that it is removed from its support and gently rest it on the specimen.
19. After 30 ± 1 minutes of compression lift the top plate off the specimen and remove the apparatus from the oven to the bench top.
20. After 60 ± 1 minutes of conditioning at room temperature, measure the diameter of the specimen in two different directions with calipers to hundredths of an inch. Write the average of these down as final diameter

Report

Subtract the initial diameter from the final diameter and record this as Stability.

Original Date: November 30, 1999

PTM3

Revision Date: January 10, 2001

Written By:_____________

Reviewed By:_____________

Test Procedure

PolyPatch Flexibility Test

Purpose

This is Crafco’s standard method of test for determining the Flexibility at low ambient temperatures. Flexibility is important so that PolyPatch does not become brittle at low temperatures and break off the road surface when contacted by traffic or snowplows.

Apparatus

2 ½” keystock pieces at least 12” long
2 1” wide by ½” high spacers.
Freezer
PolyPatch material at 400°F, remainder from viscosity pour is ok.
Burner and spatula
Melter capable of maintaining material at 400°F
Release coating, and release paper
½” mandrel

Procedure

21. Heat Polypatch to 400°F while stirring in the melter.
22. Coat the inside of the keystock and the spacers with release coating and Place on release paper.
23. Arrange the Keystock and spacers to create a reservoir ½” x 1” x 10” with the release coating to the inside. Hold spacers together with clamps or other suitable device.
24. Pour material into the reservoir to just overfill it.
25. While the material is still hot, strike off the surface with the hot spatula to be even with the top of the keystock.
26. Allow the material to condition at lab conditions at least 1 hour.
27. Remove the Keystock, spacers and release paper and place the specimen in a freezer maintained at the temperature specified in the testing instructions for at least 1-hour. Condition the ½” mandrel at the same time.
28. Remove the mandrel from the freezer and place on the bench top.
29. Within 10 seconds remove specimen from the freezer, center the flat side over the mandrel and at a rate of ten seconds, and slowly bend the specimen ends to the tabletop.

Report

Report, as passing any specimen that does not fail 100%.

PTM4

Original Date: November 30, 1999

Revision Date: January 10, 2001

Written By:_____________

Reviewed By:____________

Test Procedure

Poly Patch Adhesion Test

Purpose

This is Crafco's standard method of test for determining the Adhesion to concrete. Adhesion is vital to the long term durability of PolyPatch.

Apparatus

2 Concrete blocks 7/8" x 7/8" x 2 7/8".
2 1" wide spacers.
2 ½" x ½" x 3" Spacers
Universal Testing machine with Tensile Adhesion grips
PolyPatch material at 400°F, remainder in can after PTM-1viscosity is OK
Burner and spatula
Melter capable of maintaining material at 400°F
Release coating, and release paper
Rubber Bands
Calipers

Procedure

30. Heat Polypatch to 400°F while stirring in the melter.
31. Allow blocks to SSD 1 hour.
32. Assemble 1” x 1” x 2” bond specimen with Blocks, spacers, release coating, and rubber bands.
33. Pour material into the reservoir to just overfill it.
34. Allow the material to condition at lab conditions at least 2 hours.
35. Remove the spacers and Cut specimen flush with the top of the blocks with a hot spatula.
36. Allow the specimen to condition at lab conditions at least 1 hour.
37. Set UTM to run Tensile adhesion with the grips and to measure force.
38. Measure the height, width and length of the specimen with the calipers.
39. Place the specimen in the grips and jog the crosshead until the specimen first feels snug in the grips.
40. Run the test at 0.5” per minute until complete failure.
41. Record the maximum force reached.

Report

Multiply the length by the width to get the cross sectional area. Divide the force in pounds by the cross sectional area in inches to get the Psi. Report this as the adhesion.

CRAFCO™ INC
AN ERGON COMPANY

Original Date: October 1, 1998

PTM5

Revision Date: January 10, 2001

Written By:_____________

Reviewed By:___________

Poly Patch Melting Procedure

Purpose

This is Crafco's standard method for the melting of Poly Patch to be tested.

This procedure shall be followed when testing quality control of Poly Patch.

Apparatus

Melter capable of maintaining material at 400°F
At least 2000 grams of material in a gallon can.
Spiral Mixing paddle

Procedure

42. Preheat melter to 420°F to 500°F.
43. Place gallon can with Polypatch in the melter.
44. When the material is liquid enough to stir attach the spiral stirrer and begin to mix.
45. Pour the test specimens from the material when it reaches 400°F. as determined by a thermocouple.

APPENDIX B. Field Evaluation Form

Field Evaluation: | Section: | Date Performed:

Material Type:

Deery Level & Go | Deery Recessed Repair Mastic | Crafco PolyPatch

Material Failure:

Adhesion:

Cohesion:

Pullouts:

Secondary Cracking:

Superficial Distresses:

Weathering:

Overband Wear:

Tracking:

Stone Intrusion:

Edge Deterioration:

Percentage of Crack Failure:

$\%Fail = L_{fail}/L_{total}$

$\%Eff = 100 - \%Fail$

Rating - %	
Very Good	90-100
Good	80-89
Fair	65-79
Poor	50-64
Very Poor	<50

-

L_{fail} = ______

L_{total} = ______

%EFF = ______

Comments:

APPENDIX C. Field Evaluation Results Matrix

August 2003 Evaluation Results Matrix

WY-93	Modes of Failure					Superficial Distresses								
Section	% Adhesion	% Cohesion	% Pullouts	% Secondary Cracking	% Total Failure	% Weathering	% Overband Wear	% Tracking	% Stone Intrusion	% Edge Deterioration	% Rutting	% Effective	Mean Effectiveness	Standard Deviation
18.985 N	0	50	0	0	50	0	10	0	5	0	0	50	30	28
19.611 N	100	30	0	0	100	0	15	0	5	0	0	0		
21.683 N	50	15	0	5	50	0	0	0	0	0	0	50		
23.152 N	20	5	0	0	35	65	0	0	0	0	0	65		
23.152 S	65	20	0	0	85	0	0	0	0	0	0	15		
25.264 N	10	35	0	35	35	0	0	0	0	0	0	65		
25.554 N	80	0	0	0	100	10	0	0	0	0	0	0		
25.839 N	75	0	0	0	75	5	5	0	0	10	0	25		
25.839 S	85	15	0	0	100	0	0	0	0	0	0	0		

US-26	Modes of Failure					Superficial Distresses								
0.643 E	0	0	75	0	5	0	10	0	0	75	0	95	91	15
0.849 E	0	0	10	0	0	0	10	0	0	15	0	100		
1.488 E	15	0	0	0	20	0	0	0	0	0	0	80		
1.585 E	0	0	15	0	15	0	15	0	0	15	0	85		
3.632 E	0	0	5	0	0	0	10	0	0	5	0	100		
4.198 E	0	0	50	0	50	10	50	0	0	85	0	50		
5.348 E	0	0	0	0	0	0	5	0	0	5	0	100		
5.700 E	0	0	5	0	5	0	20	0	0	30	0	95		
6.727 E	0	0	5	0	0	0	10	0	0	15	0	100		
9.751 E	0	0	0	0	0	0	5	0	0	30	0	100		
10.302 E	0	0	65	0	0	0	40	0	0	45	0	100		

August 2003 Evaluation Results Matrix

I-25	Modes of Failure						Superficial Distresses								
Section	% Adhesion	% Cohesion	% Pullouts	% Secondary Cracking	% Total Failure		% Weathering	% Overband Wear	% Tracking	% Stone Intrusion	% Edge Deterioration	% Rutting	% Effective	Mean Effectiveness	Standard Deviation
					ISL	OSL									
69.669 N	0	0	0	0	0	0	0	0	0	0	0	0	100	99	2
69.669 S	0	0	0	0	0	0	0	0	0	0	0	0	100		
71.484 N	10	0	0	0	10	0	0	0	0	0	0	0	95		
71.485 S	0	0	5	0	0	0	0	0	0	0	0	0	100		
72.862 N	0	0	0	0	0	-	0	0	0	0	0	0	100		
72.869 S	0	0	5	0	0	0	0	0	0	0	0	0	100		
74.743 S	0	0	0	0	0	0	0	0	0	0	0	0	100		
74.832 S	0	0	0	0	0	0	0	0	0	0	0	0	100		
75.248 S	10	0	0	0	10	0	0	0	0	0	0	0	95		

January 2004 Evaluation Results Matrix

WY-93	Modes of Failure					Superficial Distresses								
Section	% Adhesion	% Cohesion	% Pullouts	% Secondary Cracking	% Total Failure	% Weathering	% Overband Wear	% Tracking	% Stone Intrusion	% Edge Deterioration	% Rutting	% Effective	Mean Effectiveness	Standard Deviation
18.985 N	100	50	0	0	100	0	10	0	5	0	0	0	9	20
19.611 N	100	38	0	0	100	0	0	0	5	5	0	0		
21.683 N	70	15	0	20	70	0	0	0	0	0	0	30		
23.152 N	100	5	0	0	100	65	10	0	0	0	0	0		
23.152 S	100	100	0	0	100	0	0	0	0	0	0	0		
25.264 N	38	45	0	0	45	0	0	0	0	0	0	55		
25.554 N	100	8	0	0	100	10	0	0	0	5	0	0		
25.839 N	100	0	0	0	100	45	15	0	0	20	0	0		
25.839 S	100	35	0	0	100	0	0	0	0	0	0	0		

US-26	Modes of Failure					Superficial Distresses								
0.643 E	100	0	85	0	100	0	20	0	0	75	0	0	25	34
0.849 E	100	0	15	0	100	0	20	0	0	20	0	0		
1.488 E	25	0	0	0	25	0	0	0	0	40	0	75		
1.585 E	100	0	60	0	100	0	20	0	0	30	0	0		
3.632 E	100	0	15	0	100	0	10	0	0	15	0	0		
4.198 E	100	0	80	0	100	10	65	0	0	90	0	0		
5.348 E	67	0	5	0	67	0	10	0	0	10	0	33		
5.700 E	80	0	35	0	80	0	20	0	0	40	0	20		
6.727 E	100	0	10	0	100	0	30	0	0	20	0	0		
9.751 E	47	0	0	0	47	0	5	0	0	30	0	53		
10.302 E	8	0	80	0	8	0	45	0	0	70	0	92		

January 2004 Evaluation Results Matrix

I-25	Modes of Failure						Superficial Distresses								
Section	% Adhesion	% Cohesion	% Pullouts	% Secondary Cracking	% Total Failure		% Weathering	% Overband Wear	% Tracking	% Stone Intrusion	% Edge Deterioration	% Rutting	% Effective	Mean Effectiveness	Standard Deviation
					ISL	OSL									
69.669 N	100	0	0	0	100	100	0	10	0	0	0	0	0	0	0
69.669 S	100	0	10	0	100	100	0	5	0	0	15	0	0		
71.484 N	100	0	10	0	100	100	0	0	0	0	0	0	0		
71.485 S	100	0	10	0	100	100	0	5	0	0	5	0	0		
72.862 N	100	0	0	0	100	-	0	0	0	0	0	0	0		
72.869 S	100	0	5	0	100	100	0	5	0	0	0	0	0		
74.743 S	100	0	0	0	100	100	0	0	0	0	0	0	0		
74.832 S	100	0	0	0	100	100	0	0	0	0	0	0	0		
75.248 S	100	0	5	0	100	100	0	0	0	0	0	0	0		

May 2004 Evaluation Results Matrix

US-26	Modes of Failure					Superficial Distresses								
Section	% Adhesion	% Cohesion	% Pullouts	% Secondary Cracking	% Total Failure	% Weathering	% Overband Wear	% Tracking	% Stone Intrusion	% Edge Deterioration	% Rutting	% Effective	Mean Effectiveness	Standard Deviation
0.643 E	100	0	85	0	100	0	85	0	0	80	0	0	40	41
0.849 E	80	0	15	0	80	0	20	0	0	30	0	20		
1.488 E	25	0	0	0	25	0	0	0	0	80	0	75		
1.585 E	100	0	60	0	100	0	20	0	0	90	0	0		
3.632 E	100	0	15	0	100	0	10	0	0	15	0	0		
4.198 E	90	0	80	0	90	10	65	0	0	100	0	10		
5.348 E	20	0	5	0	20	0	10	0	0	100	0	80		
5.700 E	30	0	35	0	30	0	20	0	0	100	0	70		
6.727 E	100	0	10	0	100	0	30	0	0	20	0	0		
9.751 E	20	0	10	0	20	0	5	0	0	60	0	80		
10.302 E	0	0	80	0	0	0	45	0	0	80	0	100		

I-25	Modes of Failure						Superficial Distresses								
					ISL	OSL									
69.669 N	100	0	10	0	100	100	0	0	0	0	5	0	0	1	2
69.669 S	100	0	5	0	100	100	0	0	0	0	15	0	0		
71.484 N	100	0	80	0	100	100	0	0	0	0	15	0	0		
71.485 S	100	0	75	0	100	100	0	0	0	0	5	0	0		
72.862 N	100	0	75	0	100	-	0	0	0	0	10	0	0		
72.869 S	100	0	30	0	100	100	0	0	0	0	15	0	0		
74.743 S	100	0	5	0	100	90	0	0	0	0	65	0	5		
74.832 S	100	0	0	0	100	90	0	0	0	0	30	0	5		
75.248 S	100	0	5	0	100	100	0	0	0	0	10	0	0		

APPENDIX D. Laboratory Evaluation Results Matrix

Laboratory Test Log Sheet

Date	File Name	Start Time	Ending Time	Configuration	Product	Ave. Failure Temp. (°C)	Failure Type (Adh./Coh.)	Load at Failure (lb)
3/22/2004	CF1A01	12:45 PM	4:54 PM	1	A	-38.2	Adh./Partial Asphalt Fracture at Vertical Asphalt Face	643
3/23/2004	CF1A02	12:52 PM	3:33 PM	1	A	-26.7	Adhesion at Vertical Asphalt Face	674
3/24/2004	CF1A03	10:20 AM	2:30 PM	1	A	-38.4	Adhesion at Vertical Asphalt Face	948
3/17/2004	CF1B01	10:15 AM	1:20 PM	1	B	-28.5	Adhesion at Vertical Asphalt Face	478
3/18/2004	-	-	-	1	B	-4.0	Adh./During Setup (Freezer Temp = -4.0°C)	-
3/19/2004	CF1B03	10:28 AM	12:58 PM	1	B	-24.5	Adhesion at Vertical Asphalt Face	263
3/11/2004	CF1C01a	4:00 PM	6:15 PM	1	C	-24.7	Adhesion at Vertical Asphalt Face	370
3/12/2004	CF1C02	11:40 AM	3:55 PM	1	C	-38.0	No Failure/Limit Switches Activated	256
3/15/2004	CF1C03	11:45 AM	4:30 PM	1	C	-41.8	Adhesion at Vertical Asphalt Face	827

Configurations:

1 = Flush
2 = Uniform Overband
3 = Tapered Overband
4 = Mill & Fill

Products:

A = Deery Level & Go
B = Deery Recessed Repair Mastic
C = Crafco PolyPatch Fine Mix

Laboratory Test Log Sheet

Date	File Name	Start Time	Ending Time	Configuration	Product	Failure Temp. (°C)	Failure Type (Adh./Coh.)	Load at Failure (lb)
3/25/2004	CF2A01	1:10 PM	4:27 PM	2	A	-30.0	Adhesively at vert. asphalt face, then cohesively parallel to vert. asphalt face	918
4/8/2004	CF2A02	10:45 AM	2:43 PM	2	A	-36.0	Adhesively at vert. asphalt face, then cohesively parallel to vert. asphalt face, w/ slight asphalt fracture	1021
4/21/2004	CF2A03	9:37 AM	2:39 PM	2	A	-43.5	Putty Failure at Platen	724
3/30/2004	CF2B01	10:49 AM	1:21 PM	2	B	-25.9	Adhesively at vert. asphalt face, then cohesively parallel to vert. asphalt face	468
4/9/2004	CF2B02	10:55 AM	3:11 PM	2	B	-38.0	Adhesively at vert. asphalt face, then cohesively parallel to vert. asphalt face	861
5/5/2004	CF2B03	10:32 AM	12:50 PM	2	B	-24.1	Adhesively at vert. asphalt face, then cohesively parallel to vert. asphalt face	271
4/5/2004	CF2C01	10:15 AM	3:26 PM	2	C	-45.4	Adhesively at vert. asphalt face, then cohesively parallel to vert. asphalt face, w/ slight asphalt fracture	1336
4/13/2004	CF2C02	10:48 AM	3:47 PM	2	C	-43.4	Putty Failure at Platen	1332
4/30/2004	CF2C03	7:37 AM	11:37 PM	2	C	-36.6	Putty Failure at Platen	394

Laboratory Test Log Sheet

Date	File Name	Start Time	Ending Time	Configuration	Product	Failure Temp. (°C)	Failure Type (Adh./Coh.)	Load at Failure (lb)
3/26/2004	CF3A01	11:07 AM	3:30 PM	3	A	-39.3	Putty Failure at Platen	892
4/12/2004	CF3A02	10:22 AM	2:54 PM	3	A	-32.6	Adhesively at vert. asphalt face, then cohesively perpendicular to sample	891
4/22/2004	CF3A03	11:12 AM	2:30 PM	3	A	-30.7	Adhesively at vert. asphalt face, then cohesively perpendicular to sample	839
3/31/2004	CF3B01	10:14 AM	2:50 PM	3	B	-40.6	Putty Failure at Platen	832
4/15/2004	CF3B02	10:50 AM	2:48 PM	3	B	-36.3	Adhesively at vert. asphalt face, then partial cohesion (1/2" crack) perpendicular to sample--machine stopped test	691
4/21/2004	CF3B03	10:40 AM	1:24 PM	3	B	-26.0	Adhesively at vert. asphalt face, then cohesively perpendicular to sample	622
3/7/2004	CF3C01	10:37 AM	3:43 PM	3	C	-46.2	Putty Failure at Platen	1040
4/19/2004	CF3C02	10:37 AM	3:17 PM	3	C	-41.0	Adhesively at vert. asphalt face, then cohesively perpendicular to sample	1011
5/3/2004	CF3C03	10:46 AM	3:58 PM	3	C	-46.0	Asphalt fracture near platen, surfacing material pulled away	1237

Laboratory Test Log Sheet

Date	File Name	Start Time	Ending Time	Configuration	Product	Failure Temp. (°C)	Failure Type (Adh./Coh.)	Load at Failure (lb)
3/29/2004	CF4A01	1:01 PM	4:23 PM	4	A	-30.8	Asphalt fracture at milled reservoir to bottom of sample, then adhesively at vert. face of reservoir	460
4/14/2004	CF4A02	10:25 AM	1:09PM	4	A	-26.5	Adhesive failure at the vert. asphalt face of crack boundry below the reservoir--machine stopped test	435
5/4/2004	CF4A03	10:20 AM	2:00 PM	4	A	-34.3	Asphalt fracture at milled reservoir to bottom of sample, then adhesively at vert. face of reservoir	381
4/1/2004	CF4B01	12:54 PM	3:42 PM	4	B	-27.9	Asphalt fracture at milled reservoir to bottom of sample, then adhesively at vert. face of reservoir	488
4/20/2004	CF4B02	10:41 AM	3:27 PM	4	B	-33.9	Asphalt fracture at milled reservoir to bottom of sample, then adhesively at vert. face of reservoir	387
4/26/2004	CF4B03	10:20 AM	1:54 PM	4	B	-32.3	Asphalt fracture at milled reservoir to bottom of sample, then adhesively at vert. face of reservoir	515
4/6/2004	CF4C01	2:28 PM	6:22 PM	4	C	-36.0	Putty Failure at Platen	513
4/16/2004	CF4C02	10:25 AM	2:17 PM	4	C	-35.6	Putty Failure at Platen	242
4/29/2004	CF4C03	10:46 AM	3:40 PM	4	C	-43.6	Asphalt fracture at milled reservoir to bottom of sample, then adhesively at vert. face of reservoir	943

APPENDIX E. MINITAB Analysis

General Linear Model: Temperature versus Material, Configuration

```
Factor     Type Levels Values
Material  fixed      3 1 2 3
Configur  fixed      4 1 2 3 4

Analysis of Variance for Temperat, using Adjusted SS for Tests

Source              DF     Seq SS     Adj SS     Adj MS       F      P
Material             2     498.06     525.02     262.51    7.86  0.003
Configur             3     158.82     163.39      54.46    1.63  0.210
Material*Configur    6     132.99     132.99      22.17    0.66  0.680
Error               23     768.55     768.55      33.42
Total               34    1558.43

Unusual Observations for Temperat

Obs  Temperat       Fit      SE Fit  Residual   St Resid
  6  -24.7000  -34.8333      3.3374   10.1333      2.15R

R denotes an observation with a large standardized residual.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Temperature
All Pairwise Comparisons among Levels of Material

Material = 1(L&G) subtracted from:

Material     Lower    Center     Upper  ---+---------+---------+---------+---
2 (RRM)     -2.55     3.542   9.63073                      (--------*--------)
3 (PP)      -11.85    -5.942  -0.03441        (--------*-------)
                                        ---+---------+---------+---------+---
                                        -14.0      -7.0       0.0       7.0


Material = 2 subtracted from:

Material     Lower    Center     Upper  ---+---------+---------+---------+---
3 (PP)      -15.57    -9.483    -3.394   (-------*--------)
                                        ---+---------+---------+---------+---
                                        -14.0      -7.0       0.0       7.0


Tukey Simultaneous Tests
Response Variable Temperature
All Pairwise Comparisons among Levels of Material

Material = 1 subtracted from:

Level        Difference       SE of             Adjusted
Material       of Means  Difference   T-Value    P-Value
2                 3.542       2.433     1.456     0.3301
3                -5.942       2.360    -2.518     0.0486

Material = 2 subtracted from:

Level        Difference       SE of             Adjusted
Material       of Means  Difference   T-Value    P-Value
3                -9.483       2.433    -3.899     0.0020

Tukey 95.0% Simultaneous Confidence Intervals
```

```
Response Variable Temperature
All Pairwise Comparisons among Levels of Configuration

Configur = 1(Flush) subtracted from:

Configur     Lower    Center     Upper  ----------+---------+---------+------
2 (OB)      -11.80    -3.956     3.886     (----------*-----------)
3 (TOB)     -13.55    -5.711     2.131   (----------*----------)
4 (M&F)      -9.35    -1.511     6.331         (----------*----------)
                                        ----------+---------+---------+------
                                                -7.0       0.0       7.0


Configur = 2(OB-Overband) subtracted from:

Configur     Lower    Center     Upper  ----------+---------+---------+------
3 (TOB)     -9.290    -1.756     5.778         (---------*----------)
4 (M&F)     -5.090     2.444     9.978               (---------*----------)
                                        ----------+---------+---------+------
                                                -7.0       0.0       7.0


Configur = 3(TOB-Tapered Overband) subtracted from:

Configur     Lower    Center     Upper  ----------+---------+---------+------
4(M&F)      -3.334     4.200     11.73                 (----------*----------)
                                        ----------+---------+---------+------
                                                -7.0       0.0       7.0


Tukey Simultaneous Tests
Response Variable Temperat
All Pairwise Comparisons among Levels of Configur

Configur = 1 subtracted from:

Level        Difference       SE of             Adjusted
Configur       of Means  Difference   T-Value    P-Value
2                -3.956       2.836    -1.395     0.5152
3                -5.711       2.836    -2.014     0.2122
4                -1.511       2.836    -0.533     0.9502

Configur = 2 subtracted from:

Level        Difference       SE of             Adjusted
Configur       of Means  Difference   T-Value    P-Value
3                -1.756       2.725   -0.6442     0.9165
4                 2.444       2.725    0.8970     0.8064

Configur = 3 subtracted from:

Level        Difference       SE of             Adjusted
Configur       of Means  Difference   T-Value    P-Value
4                 4.200       2.725     1.541     0.4304
```

Material:
1 – Level & G0
2 – Recessed Repair Mastic
3 – PolyPatch

Configuration:
1 – Flush
2 – Overband
3 – Tapered Overband
4 – Mill & Fill

General Linear Model: L versus M, C

```
Factor     Type Levels Values
M         fixed      3 1 2 3
C         fixed      4 2 3 4 5

Analysis of Variance for L, using Adjusted SS for Tests

Source     DF     Seq SS     Adj SS     Adj MS       F      P
M           2     416072     128924      64462    1.87  0.174
C           3    1080237     459966     153322    4.45  0.012
tstar       1     600304     560672     560672   16.28  0.000
M*tstar     2     273391     273391     136696    3.97  0.031
Error      26     895256     895256      34433
Total      34    3265261

Term          Coef   SE Coef        T      P
Constant    650.03     37.78    17.20  0.000
M
1            89.96     49.43     1.82  0.080
2           -11.03     57.98    -0.19  0.851
C
1           -37.09     60.31    -0.61  0.544
2           106.93     55.28     1.93  0.064
3           110.00     57.78     1.90  0.068
tstar      -24.972     6.189    -4.04  0.000
tstar*M
      1     20.633     8.818     2.34  0.027
      2     -0.639     8.432    -0.08  0.940
```

Material:
1 – Level & G0
2 – Recessed Repair Mastic
3 – PolyPatch

Configuration:
1 – Flush
2 – Overband
3 – Tapered Overband
4 – Mill & Fill

Regression Analysis: Temperature versus m1, m2, c1, c2, c3

```
The regression equation is
Temperature = - 38.5 + 5.94 m1 + 9.38 m2 + 1.37 c1 - 2.44 c2 - 4.20 c3


Predictor     Coef  SE Coef       T      P
Constant   -38.539    2.283  -16.88  0.000
m1           5.942    2.276    2.61  0.014
m2           9.375    2.332    4.02  0.000
c1           1.367    2.715    0.50  0.618
c2          -2.444    2.628   -0.93  0.360
c3          -4.200    2.628   -1.60  0.121


S = 5.57565   R-Sq = 42.2%   R-Sq(adj) = 32.2%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       5   656.88  131.38  4.23  0.005
Residual Error  29   901.55   31.09
```

```
Total           34  1558.43


Source  DF  Seq SS
m1       1   19.55
m2       1  478.51
c1       1   78.73
c2       1    0.71
c3       1   79.38


Unusual Observations

Obs    m1  Temperature      Fit  SE Fit  Residual  St Resid
  6  0.00      -24.700  -37.172   2.332    12.472      2.46R

R denotes an observation with a large standardized residual.


Predicted Values for New Observations

New
Obs      Fit  SE Fit        98% CI              98% PI
  1  -31.230   2.332  (-36.973, -25.488)  (-46.110, -16.350)
  2  -31.230   2.332  (-36.973, -25.488)  (-46.110, -16.350)
  3  -31.230   2.332  (-36.973, -25.488)  (-46.110, -16.350)
  4  -27.797   2.494  (-33.936, -21.658)  (-42.834, -12.759)
  5  -27.797   2.494  (-33.936, -21.658)  (-42.834, -12.759)
  6  -37.172   2.332  (-42.915, -31.429)  (-52.052, -22.292)
  7  -37.172   2.332  (-42.915, -31.429)  (-52.052, -22.292)
  8  -37.172   2.332  (-42.915, -31.429)  (-52.052, -22.292)
  9  -35.042   2.283  (-40.661, -29.422)  (-49.875, -20.209)
 10  -35.042   2.283  (-40.661, -29.422)  (-49.875, -20.209)
 11  -35.042   2.283  (-40.661, -29.422)  (-49.875, -20.209)
 12  -31.608   2.301  (-37.274, -25.942)  (-46.459, -16.757)
 13  -31.608   2.301  (-37.274, -25.942)  (-46.459, -16.757)
 14  -31.608   2.301  (-37.274, -25.942)  (-46.459, -16.757)
 15  -40.983   2.283  (-46.603, -35.364)  (-55.817, -26.150)
 16  -40.983   2.283  (-46.603, -35.364)  (-55.817, -26.150)
 17  -40.983   2.283  (-46.603, -35.364)  (-55.817, -26.150)
 18  -36.797   2.283  (-42.417, -31.178)  (-51.630, -21.964)
 19  -36.797   2.283  (-42.417, -31.178)  (-51.630, -21.964)
 20  -36.797   2.283  (-42.417, -31.178)  (-51.630, -21.964)
 21  -33.364   2.301  (-39.030, -27.698)  (-48.214, -18.513)
 22  -33.364   2.301  (-39.030, -27.698)  (-48.214, -18.513)
 23  -33.364   2.301  (-39.030, -27.698)  (-48.214, -18.513)
 24  -42.739   2.283  (-48.359, -37.119)  (-57.572, -27.906)
 25  -42.739   2.283  (-48.359, -37.119)  (-57.572, -27.906)
 26  -42.739   2.283  (-48.359, -37.119)  (-57.572, -27.906)
 27  -32.597   2.283  (-38.217, -26.978)  (-47.430, -17.764)
 28  -32.597   2.283  (-38.217, -26.978)  (-47.430, -17.764)
 29  -32.597   2.283  (-38.217, -26.978)  (-47.430, -17.764)
 30  -29.164   2.301  (-34.830, -23.498)  (-44.014, -14.313)
 31  -29.164   2.301  (-34.830, -23.498)  (-44.014, -14.313)
 32  -29.164   2.301  (-34.830, -23.498)  (-44.014, -14.313)
 33  -38.539   2.283  (-44.159, -32.919)  (-53.372, -23.706)
 34  -38.539   2.283  (-44.159, -32.919)  (-53.372, -23.706)
 35  -38.539   2.283  (-44.159, -32.919)  (-53.372, -23.706)
```

Regression Analysis: Temperature versus m1, m2, c1, c2, c3

```
The regression equation is
Temperature = - 38.5 + 5.94 m1 + 9.38 m2 + 1.37 c1 - 2.44 c2 - 4.20 c3


Predictor     Coef  SE Coef       T      P
Constant   -38.539    2.283  -16.88  0.000
m1           5.942    2.276    2.61  0.014
m2           9.375    2.332    4.02  0.000
c1           1.367    2.715    0.50  0.618
c2          -2.444    2.628   -0.93  0.360
c3          -4.200    2.628   -1.60  0.121


S = 5.57565   R-Sq = 42.2%   R-Sq(adj) = 32.2%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       5   656.88  131.38  4.23  0.005
Residual Error  29   901.55   31.09
Total           34  1558.43


Source  DF  Seq SS
m1       1   19.55
m2       1  478.51
c1       1   78.73
c2       1    0.71
c3       1   79.38


Unusual Observations

Obs    m1  Temperature      Fit  SE Fit  Residual  St Resid
  6  0.00      -24.700  -37.172   2.332    12.472      2.46R

R denotes an observation with a large standardized residual.


Predicted Values for New Observations

New
Obs      Fit  SE Fit         50% CI             50% PI
  1  -31.230   2.332  (-32.823, -29.637)  (-35.358, -27.102)
  2  -31.230   2.332  (-32.823, -29.637)  (-35.358, -27.102)
  3  -31.230   2.332  (-32.823, -29.637)  (-35.358, -27.102)
  4  -27.797   2.494  (-29.500, -26.093)  (-31.969, -23.625)
  5  -27.797   2.494  (-29.500, -26.093)  (-31.969, -23.625)
  6  -37.172   2.332  (-38.765, -35.579)  (-41.300, -33.044)
  7  -37.172   2.332  (-38.765, -35.579)  (-41.300, -33.044)
  8  -37.172   2.332  (-38.765, -35.579)  (-41.300, -33.044)
  9  -35.042   2.283  (-36.601, -33.483)  (-39.157, -30.927)
 10  -35.042   2.283  (-36.601, -33.483)  (-39.157, -30.927)
 11  -35.042   2.283  (-36.601, -33.483)  (-39.157, -30.927)
 12  -31.608   2.301  (-33.180, -30.036)  (-35.728, -27.488)
 13  -31.608   2.301  (-33.180, -30.036)  (-35.728, -27.488)
 14  -31.608   2.301  (-33.180, -30.036)  (-35.728, -27.488)
 15  -40.983   2.283  (-42.543, -39.424)  (-45.099, -36.868)
 16  -40.983   2.283  (-42.543, -39.424)  (-45.099, -36.868)
 17  -40.983   2.283  (-42.543, -39.424)  (-45.099, -36.868)
```

```
18  -36.797   2.283  (-38.356, -35.238)  (-40.913, -32.682)
19  -36.797   2.283  (-38.356, -35.238)  (-40.913, -32.682)
20  -36.797   2.283  (-38.356, -35.238)  (-40.913, -32.682)
21  -33.364   2.301  (-34.936, -31.792)  (-37.484, -29.244)
22  -33.364   2.301  (-34.936, -31.792)  (-37.484, -29.244)
23  -33.364   2.301  (-34.936, -31.792)  (-37.484, -29.244)
24  -42.739   2.283  (-44.298, -41.180)  (-46.854, -38.624)
25  -42.739   2.283  (-44.298, -41.180)  (-46.854, -38.624)
26  -42.739   2.283  (-44.298, -41.180)  (-46.854, -38.624)
27  -32.597   2.283  (-34.156, -31.038)  (-36.713, -28.482)
28  -32.597   2.283  (-34.156, -31.038)  (-36.713, -28.482)
29  -32.597   2.283  (-34.156, -31.038)  (-36.713, -28.482)
30  -29.164   2.301  (-30.736, -27.592)  (-33.284, -25.044)
31  -29.164   2.301  (-30.736, -27.592)  (-33.284, -25.044)
32  -29.164   2.301  (-30.736, -27.592)  (-33.284, -25.044)
33  -38.539   2.283  (-40.098, -36.980)  (-42.654, -34.424)
34  -38.539   2.283  (-40.098, -36.980)  (-42.654, -34.424)
35  -38.539   2.283  (-40.098, -36.980)  (-42.654, -34.424)
```

APPENDIX F. Asphalt Institute's Asphalt Binder Grades and Reliability for Selected Cities

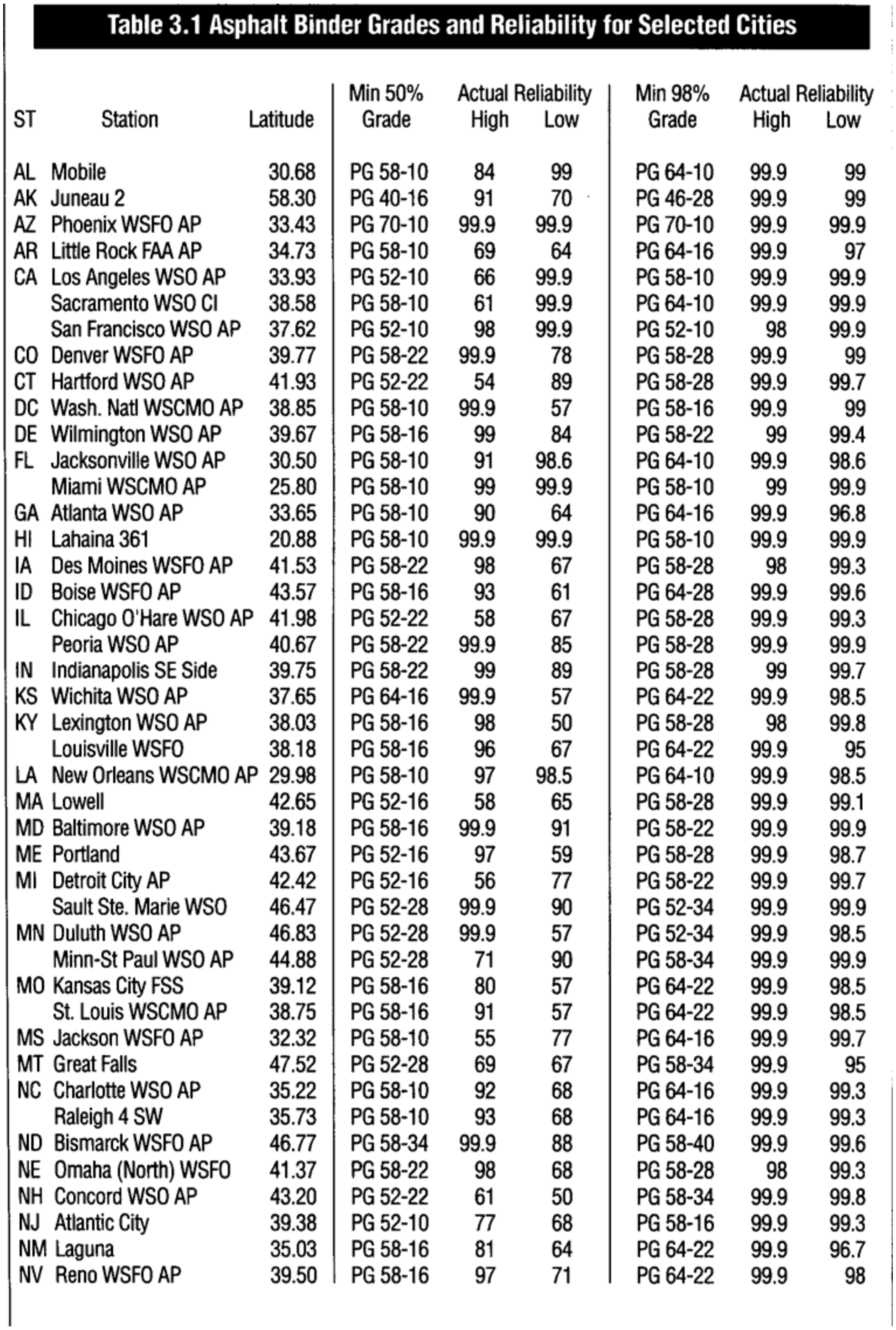

Table 3.1 Asphalt Binder Grades and Reliability for Selected Cities

ST	Station	Latitude	Min 50% Grade	Actual Reliability High	Actual Reliability Low	Min 98% Grade	Actual Reliability High	Actual Reliability Low
AL	Mobile	30.68	PG 58-10	84	99	PG 64-10	99.9	99
AK	Juneau 2	58.30	PG 40-16	91	70	PG 46-28	99.9	99
AZ	Phoenix WSFO AP	33.43	PG 70-10	99.9	99.9	PG 70-10	99.9	99.9
AR	Little Rock FAA AP	34.73	PG 58-10	69	64	PG 64-16	99.9	97
CA	Los Angeles WSO AP	33.93	PG 52-10	66	99.9	PG 58-10	99.9	99.9
	Sacramento WSO CI	38.58	PG 58-10	61	99.9	PG 64-10	99.9	99.9
	San Francisco WSO AP	37.62	PG 52-10	98	99.9	PG 52-10	98	99.9
CO	Denver WSFO AP	39.77	PG 58-22	99.9	78	PG 58-28	99.9	99
CT	Hartford WSO AP	41.93	PG 52-22	54	89	PG 58-28	99.9	99.7
DC	Wash. Natl WSCMO AP	38.85	PG 58-10	99.9	57	PG 58-16	99.9	99
DE	Wilmington WSO AP	39.67	PG 58-16	99	84	PG 58-22	99	99.4
FL	Jacksonville WSO AP	30.50	PG 58-10	91	98.6	PG 64-10	99.9	98.6
	Miami WSCMO AP	25.80	PG 58-10	99	99.9	PG 58-10	99	99.9
GA	Atlanta WSO AP	33.65	PG 58-10	90	64	PG 64-16	99.9	96.8
HI	Lahaina 361	20.88	PG 58-10	99.9	99.9	PG 58-10	99.9	99.9
IA	Des Moines WSFO AP	41.53	PG 58-22	98	67	PG 58-28	98	99.3
ID	Boise WSFO AP	43.57	PG 58-16	93	61	PG 64-28	99.9	99.6
IL	Chicago O'Hare WSO AP	41.98	PG 52-22	58	67	PG 58-28	99.9	99.3
	Peoria WSO AP	40.67	PG 58-22	99.9	85	PG 58-28	99.9	99.9
IN	Indianapolis SE Side	39.75	PG 58-22	99	89	PG 58-28	99	99.7
KS	Wichita WSO AP	37.65	PG 64-16	99.9	57	PG 64-22	99.9	98.5
KY	Lexington WSO AP	38.03	PG 58-16	98	50	PG 58-28	98	99.8
	Louisville WSFO	38.18	PG 58-16	96	67	PG 64-22	99.9	95
LA	New Orleans WSCMO AP	29.98	PG 58-10	97	98.5	PG 64-10	99.9	98.5
MA	Lowell	42.65	PG 52-16	58	65	PG 58-28	99.9	99.1
MD	Baltimore WSO AP	39.18	PG 58-16	99.9	91	PG 58-22	99.9	99.9
ME	Portland	43.67	PG 52-16	97	59	PG 58-28	99.9	98.7
MI	Detroit City AP	42.42	PG 52-16	56	77	PG 58-22	99.9	99.7
	Sault Ste. Marie WSO	46.47	PG 52-28	99.9	90	PG 52-34	99.9	99.9
MN	Duluth WSO AP	46.83	PG 52-28	99.9	57	PG 52-34	99.9	98.5
	Minn-St Paul WSO AP	44.88	PG 52-28	71	90	PG 58-34	99.9	99.9
MO	Kansas City FSS	39.12	PG 58-16	80	57	PG 64-22	99.9	98.5
	St. Louis WSCMO AP	38.75	PG 58-16	91	57	PG 64-22	99.9	98.5
MS	Jackson WSFO AP	32.32	PG 58-10	55	77	PG 64-16	99.9	99.7
MT	Great Falls	47.52	PG 52-28	69	67	PG 58-34	99.9	95
NC	Charlotte WSO AP	35.22	PG 58-10	92	68	PG 64-16	99.9	99.3
	Raleigh 4 SW	35.73	PG 58-10	93	68	PG 64-16	99.9	99.3
ND	Bismarck WSFO AP	46.77	PG 58-34	99.9	88	PG 58-40	99.9	99.6
NE	Omaha (North) WSFO	41.37	PG 58-22	98	68	PG 58-28	98	99.3
NH	Concord WSO AP	43.20	PG 52-22	61	50	PG 58-34	99.9	99.8
NJ	Atlantic City	39.38	PG 52-10	77	68	PG 58-16	99.9	99.3
NM	Laguna	35.03	PG 58-16	81	64	PG 64-22	99.9	96.7
NV	Reno WSFO AP	39.50	PG 58-16	97	71	PG 64-22	99.9	98

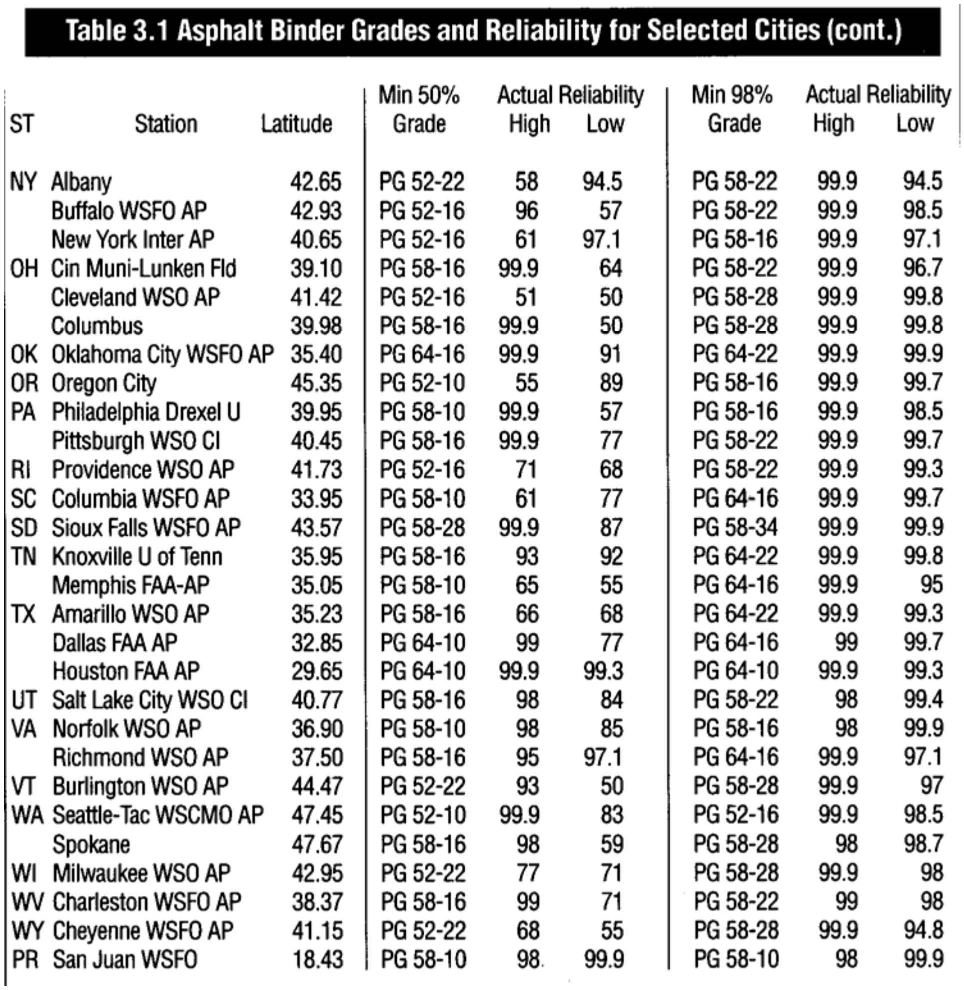

Table 3.1 Asphalt Binder Grades and Reliability for Selected Cities (cont.)

ST	Station	Latitude	Min 50% Grade	Actual Reliability High	Actual Reliability Low	Min 98% Grade	Actual Reliability High	Actual Reliability Low
NY	Albany	42.65	PG 52-22	58	94.5	PG 58-22	99.9	94.5
	Buffalo WSFO AP	42.93	PG 52-16	96	57	PG 58-22	99.9	98.5
	New York Inter AP	40.65	PG 52-16	61	97.1	PG 58-16	99.9	97.1
OH	Cin Muni-Lunken Fld	39.10	PG 58-16	99.9	64	PG 58-22	99.9	96.7
	Cleveland WSO AP	41.42	PG 52-16	51	50	PG 58-28	99.9	99.8
	Columbus	39.98	PG 58-16	99.9	50	PG 58-28	99.9	99.8
OK	Oklahoma City WSFO AP	35.40	PG 64-16	99.9	91	PG 64-22	99.9	99.9
OR	Oregon City	45.35	PG 52-10	55	89	PG 58-16	99.9	99.7
PA	Philadelphia Drexel U	39.95	PG 58-10	99.9	57	PG 58-16	99.9	98.5
	Pittsburgh WSO CI	40.45	PG 58-16	99.9	77	PG 58-22	99.9	99.7
RI	Providence WSO AP	41.73	PG 52-16	71	68	PG 58-22	99.9	99.3
SC	Columbia WSFO AP	33.95	PG 58-10	61	77	PG 64-16	99.9	99.7
SD	Sioux Falls WSFO AP	43.57	PG 58-28	99.9	87	PG 58-34	99.9	99.9
TN	Knoxville U of Tenn	35.95	PG 58-16	93	92	PG 64-22	99.9	99.8
	Memphis FAA-AP	35.05	PG 58-10	65	55	PG 64-16	99.9	95
TX	Amarillo WSO AP	35.23	PG 58-16	66	68	PG 64-22	99.9	99.3
	Dallas FAA AP	32.85	PG 64-10	99	77	PG 64-16	99	99.7
	Houston FAA AP	29.65	PG 64-10	99.9	99.3	PG 64-10	99.9	99.3
UT	Salt Lake City WSO CI	40.77	PG 58-16	98	84	PG 58-22	98	99.4
VA	Norfolk WSO AP	36.90	PG 58-10	98	85	PG 58-16	98	99.9
	Richmond WSO AP	37.50	PG 58-16	95	97.1	PG 64-16	99.9	97.1
VT	Burlington WSO AP	44.47	PG 52-22	93	50	PG 58-28	99.9	97
WA	Seattle-Tac WSCMO AP	47.45	PG 52-10	99.9	83	PG 52-16	99.9	98.5
	Spokane	47.67	PG 58-16	98	59	PG 58-28	98	98.7
WI	Milwaukee WSO AP	42.95	PG 52-22	77	71	PG 58-28	99.9	98
WV	Charleston WSFO AP	38.37	PG 58-16	99	71	PG 58-22	99	98
WY	Cheyenne WSFO AP	41.15	PG 52-22	68	55	PG 58-28	99.9	94.8
PR	San Juan WSFO	18.43	PG 58-10	98	99.9	PG 58-10	98	99.9