# 0-4872-P2

# MIXTURE DESIGN MANUAL AND PERFORMANCE-BASED SPECIFICATIONS FOR COLD PATCHING MIXTURES

Authors:
Vanessa I. Rosales-Herrera
Jorge A. Prozzi

*TxDOT Project 0-4872: Material Design and Testing Methods for Home Made and Containerized Cold Mix*

**MAY 2007, REVISED JANUARY 2008**

| **Performing Organization:** | **Sponsoring Organization:** |
|---|---|
| Center for Transportation Research<br>The University of Texas at Austin<br>3208 Red River, Suite 200<br>Austin, Texas 78705-2650 | Texas Department of Transportation<br>Research and Technology Implementation Office<br>P.O. Box 5080<br>Austin, Texas 78763-5080 |
| Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration. | |

# Disclaimer

# Table of Contents

# List of Tables

# List of Figures

# Introduction

The purpose of these cold mixture design guidelines is to provide recommendations to the Texas Department of Transportation (TxDOT) for a homemade design procedure for cold patching mixtures under cold weather conditions. This manual identifies and discusses the special considerations that must be given to critical mixture properties. Ensuring specific mixture characteristics translates into an increase in patch performance and cost effectiveness with the corresponding associated savings to the Department.

In addition, these guidelines suggest preliminary performance-based specifications based on testing results from TxDOT Project 0-4872, "Material Design and Testing Methods for Home Made and Containerized Cold Mix." These specifications help to identify those homemade and containerized cold patching mixtures that are expected to perform satisfactorily in the field. Furthermore, these guidelines can evolve into standard specifications for approving or rejecting the use of a specific mixture in the field. To this effect more testing of a wider range of mixtures is necessary.

It is important to note that these recommendations were developed primarily for cold and wet weather conditions. Most of the field experiments and validation were carried out in the TxDOT Lubbock District. However, this procedure may serve as a framework for use in other districts. In all cases, modifications to the proposed procedure must be made based on local experience, available material and testing, and specific environmental and project demands.

# Mixture Design Procedure

## *Aggregate Selection*

The type of aggregate used in the design of homemade cold patching mixtures should be chosen based on material availability in the area of the project. Materials may include crushed rock or crushed gravel. The use of rounded, uncrushed aggregate should be discouraged due to potential stripping, durability and stability considerations. Good quality materials should be used at all times, when price permits, to support the integrity of the mixtures. Use of leftover materials from construction projects may also be cost-effective, such as pre-coated Grade 4 that has been used successfully in the Bovina maintenance area.

Angular aggregates (crushed rock or crushed gravel) shapes may be used in the design. Aggregate angularity generally provides higher stability, while rounded aggregates tend to increase mixture workability but at a significant loss of stability.

## *Gradation*

Different gradations may be used in the design of cold patching mixtures. Field and laboratory observations showed that relatively open gradations demonstrated desirable strength and tend to be very workable. Table 1.1 presents the recommended range of aggregate proportions based on observations and testing conducted under TxDOT Project 0-4872. Actual target aggregate proportions may vary slightly from district to district. These proportions should be based on material availability, transportation and cost considerations, and desired mixture properties. Local experience with locally available materials may, in some cases, override the recommendations in Table 1.1.

**Table 1.1: Cold Patching Aggregate Proportions**

| Sieve Size | Percent Passing |
|---|---|
| 3/8 in (9.5 mm) | 95-100 |
| No. 4 (4.75 mm) | 40-85 |
| No. 8 (2.36 mm) | 15-40 |
| No. 16 (1.18 mm) | 6-25 |
| No. 200 (0.075 mm) | 1-6 |

## *Binder Selection*

Binder selection is one of the most important decisions in the homemade mixture design procedure. Both cutback and emulsified asphalts of different grades can be used in the design of cold patching mixtures. Asphalt type and grade should be carefully selected based on desired mixture properties. However, these guidelines focus on the use of cutback asphalts. MC-250 was identified as encompassing desired characteristics, particularly when the homemade mixture is to be stockpiled for longer than two weeks.

As a general rule, the most viscous grade that can be adequately worked during mixing and installation should be used. Open-graded mixtures often require a more viscous binder than dense-graded mixtures. Those mixtures with a high percentage of fines, on the other hand, require less viscous binder in order to mix.

Special consideration must be given to the ambient temperature, or season, in the selection of the binder viscosity. This is particularly important for stockpile patching mixtures. At lower temperatures the binder becomes more viscous and may result in an unworkable mass. To ensure mixture workability, the viscosity of the binder chosen should be relatively low at lower temperatures. The lower viscosity grades also provide a longer stockpile life. In the particular case of homemade mixtures, MC-250 is preferred if the mixture is to be used two or more weeks after mixing. On the other hand, if mixtures are to be used immediately, or within two weeks, RC-250 is preferred. This recommendation depends on local environmental conditions and may differ from district to district.

Factors that affect the curing rate include asphalt type, quantity, grade, rain, and ambient temperature. For example, material at lower temperatures and higher humidity will experience a low curing rate. The rate at which volatiles evaporate from the mixture must be controlled. Otherwise, the stockpile will cure prematurely and become unworkable.

## *Binder Content*

The MC-250 residual binder content for use with the recommended target gradation range is typically between 3.0 and 4.0 percent. Lower binder contents are preferred if the mixture is to be used quickly. However, if the mixture is to be used at a slow rate, higher binder contents are preferred. Cold Patch Slump Test (CPST) and Texas Stability Test (TST) (as described in Appendices A and B, respectively) should be performed to identify the optimal binder content for varying aggregate types, shapes, and gradations. Figure 1.1 displays the process for the selection of the optimal binder content.

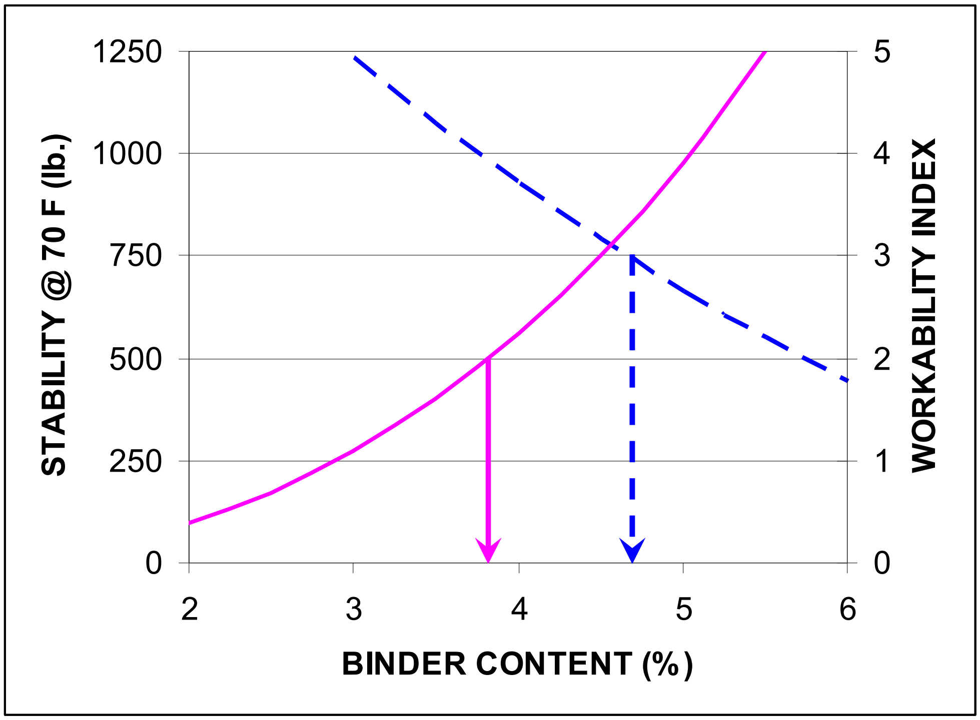


*Figure 1.1: Selection of Binder Content*

Given a minimum stability value (for illustration purposes 750 lb. in Figure 1.1, dashed line) and a minimum workability requirement (e.g. 2.0, full line), the maximum and minimum acceptable binder contents could be determined. The optimum should be selected within this range depending on local project conditions. In addition, Model Mobile Load Simulator (MMLS3) testing, as described in Appendix C, may be performed to validate the optimal binder content and to estimate the relative expected performance of the mixtures. The MMLS3 offers a better estimate of expected field performance because testing conditions are more realistic. Environmental conditions (such as temperature and moisture) should be tightly controlled.

### *Admixtures*

Although the use of additional diesel is common in several districts, no significant added benefit was observed as a result of its use. In fact, mixtures prepared with diesel tended to display excessive workability, which limited its use in the field. Therefore, the use of additional diesel should be avoided, and considered only when the stockpiled mixtures become “too dry” due to long stockpile life and exposure to the environment.

The use of hydrated lime, however, is strongly recommended to improve aggregate-asphalt bonding and to reduce stripping potential. A percentage of lime, by weight, of 1 to 3 percent should be considered. Optimal lime content can be identified through TST. Yet, the percentage of lime added to the mixture will also be somewhat dictated by cost considerations. For the conditions and materials evaluated in this research, 2 percent lime seems to be satisfactory and results in a significant increase in expected field performance. This percentage is also dependent on the filler content of the aggregates.

## Performance-Based Specifications

Performance-based specifications are intended to identify those homemade and containerized cold patching mixtures that are expected to perform adequately in the field. These specifications were developed with a focus on mixture stability and workability. All recommendations are based on testing results from CPST, TST, and MMLS3 conducted at the University of Texas under TxDOT Project 0-4872. Procedures for all three tests are included in Appendices A, B, and C, respectively.

### *Cold Patch Slump Test (CPST)*

The CPST should be performed on homemade and containerized cold patching mixtures as a measure of mixture workability. The procedure for the CPST is outlined in detail in Appendix A. All specimens should be prepared with a compaction effort of 10 blows of the Marshall hammer per lift, and prepared and tested at room temperature (77° F). The time to fill the containment unit should be plotted versus the logarithmic time to slump under own weight (as discussed in Appendix A) to obtain a graphic representation of the relative workability of all mixtures tested. Mixtures with long time to fill and long time to slump values are representative of unworkable mixtures. On the other hand, mixtures with short time to fill and short time to slump values are representative of mixtures with excessive workability and should also be avoided. Based on testing results, those mixtures with short time to fill values and long time to slump values displayed the best performance in the field. As an interim guideline, any mixture with a time to fill less than 50 seconds or greater than 150 seconds should be deemed unacceptable. These interim values should be validated by testing a wider range of mixtures than the ones tested under TxDOT Project 0-4872.

### *Texas Stability Test (TST)*

The TST should be performed on cold patching mixtures as an indicator of the mixture's early stability. The TST procedure developed as part of this project is included in Appendix B. Specimens should be cured and tested at various times and temperatures to adequately capture the effects of stockpiling and temperature susceptibility of the various binders. This is particularly important if the mixture will be stockpiled for several weeks or if the expected ambient temperature at time of installation is highly variable. Corrected stability (based on a standard thickness of two inches) values should be plotted as a function of temperature to indicate the susceptibility of the material stability to temperature, as discussed in Appendix B. As in the case of hot asphalt mixes, high temperature susceptibility is undesirable. In addition, too high or too low stability may adversely affect other material characteristics, resulting in poor patch workability or performance. As a general guideline, mixtures with corrected stability values above 3,500 pounds and below 500 pounds at lower temperatures should be rejected.

### *Model Mobile Load Simulator (MMLS3)*

Proposed mixtures meeting the minimum requirements for CPST and TST should be further validated in the field under the MMLS3. This test measures the mixture's resistance to deformation under a moving wheel load and serves as a general indicator of relative expected patch performance. Procedures for MMLS3 testing are outlined in detail in Appendix C. All patch installations should be protected from rain and tested within 24 hours after installation, which is the critical period in the life of the patch in terms of early stability. The material temperature during testing should be kept constant. For the purposes of this research, material temperatures in the range of 60˚ F to 70˚ F were considered acceptable for comparative purposes. Because TxDOT currently approves Instant Road Repair (IRR), all materials displaying good performance relative to IRR should be deemed acceptable for use in the field. The average number of wheel passes to failure, which was defined as a rut depth under the MMLS3 of 3/8 inch, for IRR was 76. Therefore, any material failing before the application of 75 wheel passes under the MMLS3 will be deemed unacceptable for use in the field.

## Other Considerations: Drop Test

Another important consideration for cold patching mixtures is material storageability. Storageability is vital in safeguarding essential material properties. For example, a storage life of at least six months is desired to ensure workability during installation. An advantage of bagged containerized mixtures over stockpiles is the increased storage life. However, these bags are often handled manually and tossed from location to location once in the maintenance yards. This results in potential problems as some of the bags are less resistant to impact and tear easily. This is particularly a problem if there is a significant loss in material or bag punctures, which will lead to loss of volatiles.

The drop test, described in Appendix D, may be used to evaluate the impact resistance of cold patch containers to free falls. The objective of the test was to submit the bags to free falls from a predetermined height and observe the progressive container deterioration and ultimate failure. This test can be used as a measure of container effectiveness and indicator of handling resistance and storage life. Those bags more resistant to impact will not lose the material and will minimize the loss of volatiles as a result of tears or slits on the bags. As a general rule, those bags that endure less than one cycle of drops should be considered unacceptable, while those bags that endure between one and two cycles should be considered marginal.

# Interim Recommendations

Based on the materials and conditions investigated in this research study, Table 1.2 lists interim recommendations. These recommendations should be further evaluated in light of new testing results as they are generated.

**Table 1.2: Interim Acceptance Recommendations**

| Test | Parameter | Acceptance Criterion |
|---|---|---|
| CPST | Minimum time to fill | 50 s |
| CPST | Maximum time to fill | 150 s |
| CPST | Workability Index | > 2.0 |
| TST | Maximum stability | 3,500 lb. |
| TST | Minimum stability | 500 lb. |
| MMLS3 | < 3/8 rut depth | 75 wheel passes |
| Drop Test | Drop cycles | 2 cycles |

## Conclusions and Recommendations

Many of the protocols developed as part of this project provide the framework for future work in the area of cold patching mixtures. Standardized testing methods will facilitate data comparison and validation. The homemade mixture design developed herein provides useful guidelines for those maintenance areas mixing and utilizing homemade mixtures. Modifications might have to be made for areas with hot and dry weather since the homemade mixture design procedure was developed for areas with cold and wet weather. When such modifications must be made, material performance must be ascertained through CPST, TST, and MMLS3.

The recommendations for performance-based specifications provide guidelines for rejection or approval of homemade and containerized mixtures. Those mixtures designed locally in the maintenance yards can be easily tested prior to a full-scale installation throughout the district to ensure that the material will perform adequately in the field. In addition, any containerized mixture previously not approved for use by TxDOT can also be evaluated. Until now, only one containerized material, IRR, has been approved for use by the state due largely to the lack of such specifications. An increase in the number of approved containerized materials will provide, among other things, a more competitive price. In conjunction, the homemade mixture design procedure and performance-based specifications should ensure the material characteristics necessary for adequate patch performance in the field. This, in turn, will reduce the failure rates of cold patching mixtures and make it a more cost effective maintenance operation.

# Appendix A: Cold Patch Slump Test (CPST) Procedure

## *Overview*

This method outlines the specimen preparation and testing procedure used to assess the workability of cold patching mixtures. Objective and subjective measures of workability are attained through measurement of time to fill containment unit and time to slump under own weight.

## *Apparatus*

The following apparatus is required to perform the Cold Patch Slump Test (see Figure A1).

- Scale—accurate to 0.5 gram
- Non-stick coating spray
- Steel chute
- Metallic disk—4 in. diameter
- Measuring tape
- Temperature gun—accurate to 0.5° F
- Timer—accurate to 1 sec.
- Standard Marshall hammer
- Standard spatula with 8 in. blade
- 24 in. x 24 in. wooden containment unit with a cylindrical cavity 16 in. diameter by ¾ in.
- Polyvinyl chloride (PVC) tube—4 in. diameter by 10 in. height
- Two PVC end caps per tube—4 in. diameter
- Conditioning chamber, capable of maintaining 35° F ± 5° F
- Conditioning chamber, capable of maintaining 55° F ± 5° F
- Superpave gyratory compactor extractor

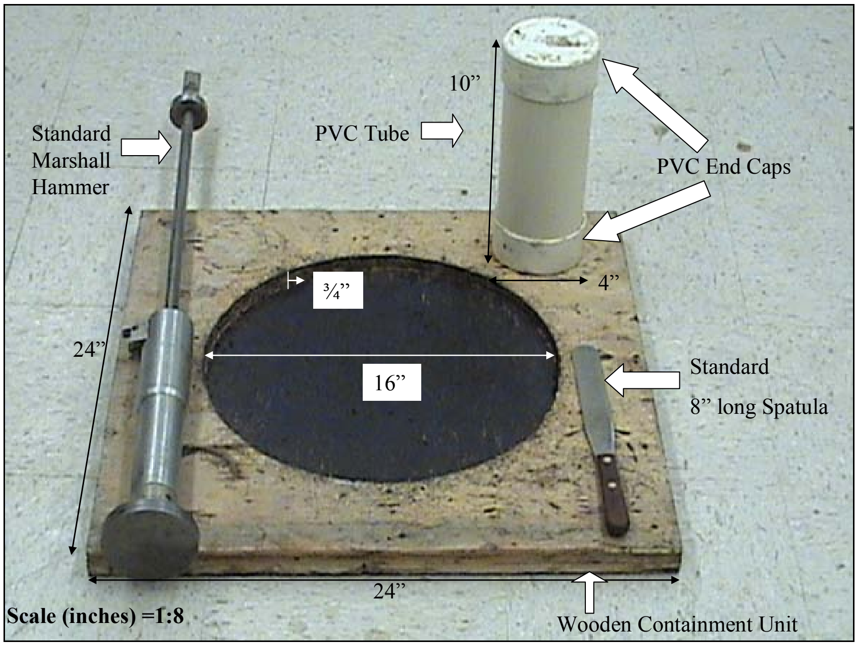


*Figure A1: CPST Apparatus (Chatterjee et al., 2006)*

## *Procedure*

Use the procedures in Tables A1 and A2 to prepare and test the CPST specimens.

**Table A1: Procedure for Preparation of CPST Specimens**

| Step | Action |
|---|---|
| 1 | Fit a PVC cap to the bottom end of the PVC tube. |
| 2 | Spray the inside of the mold with non-stick coating spray. |
| 3 | Weigh 1400 g of material to be used for the first lift of the specimen. |
| 4 | Use the steel chute to place the material into the mold. |
| 5 | Level material with spatula. |
| 6 | Pre-compact lift for 10 sec. by resting the Marshall hammer over the material. |
| 7 | Compact the first lift with 10 blows of the Marshall hammer. Keep the Marshall hammer level to ensure a level specimen surface. |
| 8 | Weigh 1400 g of material to be used for the second lift of the specimen. |
| 9 | Use the steel chute to place the material in the mold. Measure height to ensure this is enough material to form a specimen with a height of 8 in. (± 0.5 in.) |
| 10 | Level material with spatula and place 4 in. metallic disk on top. |
| 11 | Pre-compact material for 10 sec. by resting the Marshall hammer over the material. |
| 12 | Compact the second lift with 10 blows of the Marshall hammer. Keep the Marshall hammer level to ensure a level specimen surface. |
| 13 | Remove the metallic disc from the top of the specimen. |
| 14 | Place the second PVC cap on the top of the mold. |
| 15 | Repeat Steps 1 thru 14 to prepare three specimens of each material to be tested. |

**Table A2: Procedure for Conditioning and Testing of CPST Specimens**

| Step | Action |
|---|---|
| 1 | Place one specimen of each material in the temperature control chambers at 35˚ F and 55˚ F for 24 hours. Store the third specimen at room temperature. |
| 2 | After conditioning, remove the specimen from the temperature control chamber. Measure and record the specimen temperature. |
| 3 | Use the extractor on a Superpave gyratory compactor to extrude the specimen from the mold. |
| 4 | Place the specimen in the cylindrical cavity of the wooden containment unit. |
| 5 | Measure and record the time to slump in sec. |
| 6 | Place the slumped material back into the mold following the specimen preparation procedures outlined in Table A1. |
| 7 | Recondition the specimen to the temperature in Step 1 by placing in the adequate control chamber for 24 hours. |
| 8 | Repeat Steps 2 through 4. |
| 9 | Have a rater work the material into the cavity of the wooden containment unit using the 8 in. spatula. |
| 10 | Measure and record the time to fill in sec. |
| 11 | Ask the rater to provide a subjective rating of the material workability based on a scale of 1 to 5.<br>• 1=Very workable<br>• 5=Not workable |
| 12 | Repeat steps 2 thru 8 for all other prepared specimens. |

## *Analysis*

Time-to-fill values should be validated through comparison with subjective ratings. These values should exhibit a linear correlation. Time to fill and logarithmic time to slump should be graphed as a function of conditioning temperature to determine their susceptibility to conditioning temperature. Time to fill should also be graphed as a function of logarithmic time to slump to determine if the materials are workable, workable and cohesive, or unworkable.

# Appendix B: Texas Stability Test (TST) Procedure

## *Overview*

This method outlines the testing procedure used to determine the stability of cold patching mixtures.

## *Apparatus*

The following apparatus is required to perform the Texas Stability Test.

- Texas Gyratory Compactor
- Scale—accurate to 0.5 gram
- Non-stick coating spray
- Paper gaskets
- Steel chute
- Large bent spoon
- Plastic wrap
- Calipers
- Temperature gun—accurate to 0.5˚ F
- Conditioning chamber, capable of maintaining 35˚ F ± 5˚ F
- Conditioning chamber, capable of maintaining 50˚ F ± 5˚ F
- Marshall stability apparatus

## *Procedure*

Use the procedure outlined in Table B1 to prepare and test specimens with the TST.

**Table B1: Procedure for Preparation and Testing of TST Specimens**

| Step | Action |
|---|---|
| 1 | Weigh 950 g of material to be used for specimen preparation. |
| 2 | Prepare specimens with the Texas Gyratory Compactor (TGC) as described in part I of Tex-206-f. |
| 3 | Prepare 18 specimens of each material to be tested. |
| 4 | Cure the 18 specimens for 0, 168, and 336 hours as follows:<br>• Immediately wrap six 0-hr specimens in plastic wrap.<br>• Store six 168-hr specimens at room temperature for 168 hours (7 days).<br>• Store six 336-hr specimens at room temperature for 336 hours (14 days). |
| 5 | Immediately after specimen preparation, condition the six 0-hr specimens as follows:<br>• Place two specimens in a conditioning chamber at 35˚ F for 48 hours (2 days).<br>• Place two specimens in a conditioning chamber at 50˚ F for 48 hours (2 days).<br>• Store two specimens at room temperature for 48 hours (2 days). |
| 6 | After the 2 day conditioning, test the six 0-hr specimens with the Marshall Stability apparatus as follows:<br>• Measure and record the specimen temperature (˚F), weight (g), height (mm), and initial height and diameter (mm) prior to testing.<br>• Place specimen on Marshall Stability breaking head.<br>• Subject specimen to a compressive load under the Marshall frame of 2 in. /min. until failure.<br>• Measure and record the final height and diameter (mm) and maximum load applied (lbs). |
| 7 | After curing for 168 hrs, condition and test the six 168-hr specimens by following Steps 5 and 6. |
| 8 | After curing for 336 hrs, condition and test the six 336-hr specimens by following Steps 5 and 6. |

## *Calculations*

The total load value applied had to be corrected to account for variations in specimen thickness. The corrected load value should be calculated with Equation A1.

$$CS = \left( \frac{50.8}{H_t} \right)^{1.64} \times L \qquad \text{(A1)}$$

Where the variables are defined as follows:

CS = Corrected stability value (lbs)
$H_t$ = Specimen height (mm)
L = Load applied (lbs)

## *Analysis*

The corrected load values should be graphed as a function of temperature to illustrate the effects of temperature on material stability. This graph will indicate which materials have too little or too much stability.

# Appendix C: MMLS3 Testing Procedure and Data Collection Form

## *Overview*

This method outlines the Model Mobile Load Simulator (MMLS3) testing procedure used to evaluate the resistance to deformation of cold patching materials. This method can also be used as a measure of expected relative field performance.

## *Apparatus*

The following apparatus is required to perform MMLS3 testing.

- Model Mobile Load Simulator (MMLS3)
- Pothole installation site
- Concrete saw
- Shovel and pick
- Broom
- Hydraulic cement concrete
- Insulated shed construction
- 6 in. square compaction hammer
- Vibratory plate compactor
- Level
- Temperature gun—accurate to 0.5° F
- Ruler, or other straight edge
- Measuring tape

## *Procedure*

The procedure outlined in Table C1 describes site preparation and material installation. The MMLS3 testing procedure is presented in Table C2.

### Table C1: MMLS3 Procedure for Site Preparation and Material Installation

| Step | Action |
|---|---|
| 1 | Identify or construct a pavement structure for material installation and testing of the mixtures under the MMLS3. |
| 2 | Use a pavement saw to cut four potholes into the pavement structure.<br>• Length = 12 in.<br>• Width = 12 in.<br>• Depth = 6 in.<br>• Transverse spacing = not less than 3 ft.<br>• Longitudinal spacing = not less than 8 ft. |
| 3 | Remove the cut pavement material and sweep away any debris. |
| 4 | Use hydraulic cement concrete to fill the bottom 2 in. of all potholes. |
| 5 | Place insulated shed over fabricated potholes. |
| 6 | For material installation, ensure the pothole is clean of debris. |
| 7 | Place about 2 in. of material into the pothole for the first lift. |
| 8 | Compact the first lift with the 6 in. square compaction hammer by applying 5 blows to each corner and the middle of the pothole area. |
| 9 | Place about 5 in. of material into the pothole for the second lift so that 3 in. of material form a mound over the pothole area. |
| 10 | Compact the second lift with one pass of the vibratory plate compactor by holding it in place over the material installation for 5 sec. |
| 11 | Remove any excess material on the sides of the pothole with the edge of the shovel. |
| 12 | Compact the second lift a second time with the vibratory plate compactor by holding it in place over the material installation for 5 sec. |
| 13 | If necessary, remove any excess material on the sides of the pothole with the edge of the shovel. |
| 14 | Compact the second lift a third time with the vibratory plate compactor by holding it in place over the material installation for 5 sec. |
| 15 | The initial mound height relative to the adjacent pavement area should be greater than 0, but less than 1/2 in. Otherwise, remove material and follow Steps 6 through 14. |
| 16 | Repeat Steps 6 through 15 for the three other patch installations. |
| 17 | Sweep the area around the four patches in preparations for MMLS3 testing. |

**Table C2: MMLS3 Testing Procedure**

| Step | Action |
|---|---|
| 1 | Carefully position the MMLS3 over the patch installation to be tested. |
| 2 | Lower the MMLS3 machine over the patch so that the wheel path will run directly over the center of the material installation during testing. Do not lower the MMLS3 with a wheel directly over the patch. |
| 3 | Use the level to make sure the machine is level relative to the pavement slope. |
| 4 | Check the spring gap size in the loading frame. This spring gap should be between 1/4 and 1/2 in. If necessary, lower or raise the MMLS3 to attain an adequate spring gap. |
| 5 | Measure and record the pertinent information in the MMLS3 Data Collection Form in Figure C1.<br>• Material type<br>• Initial mound height (in.)<br>• Ambient temperature (˚F)<br>• Pavement temperature (˚F)<br>• Patch temperature (˚F) |
| 6 | Connect the MMLS to a power source. |
| 7 | Set the MMLS frequency to 10. |
| 8 | Begin testing by applying 4 wheel passes to the patch installation. |
| 9 | Place the straight edge over the material mound and use the measuring tape to measure the rut depth ($R_t$) and shove height ($R_s$) illustrated in Figure C1. Record these on the MMLS3 Data Collection Form. |
| 10 | Calculate the rut depth due to densification ($R_d$) according to Equations C1 and C2. Record this value on the MMLS3 Data Collection Form. |
| 11 | Repeat Steps 8 through 10 following the total number of wheel passes prescribed in the MMLS3 Data Collection Form (Figure C2). |
| 12 | Terminate testing when rut depth due to densification ($R_d$) is greater than 3/8 in. |
| 13 | Unplug the MMLS3 from the power source. |
| 14 | Raise the MMLS3 over the patch installation. |
| 15 | Repeat Steps 1 through 10 for the three remaining patch installations. |

## Calculations

The following equations and definitions should be used in conjunction with the MMLS3 testing procedure.

$$R_s = S_h - S_0 \qquad \text{(C1)}$$

$$R_d = R_t - R_s \qquad \text{(C2)}$$

Where the variables are defined as follows:

$R_s$ = Rut due to Shoving
$S_h$ = Shove Height
$S_0$ = Initial Mound Height
$R_d$ = Rut due to Densification
$R_t$ = Total Rut Depth

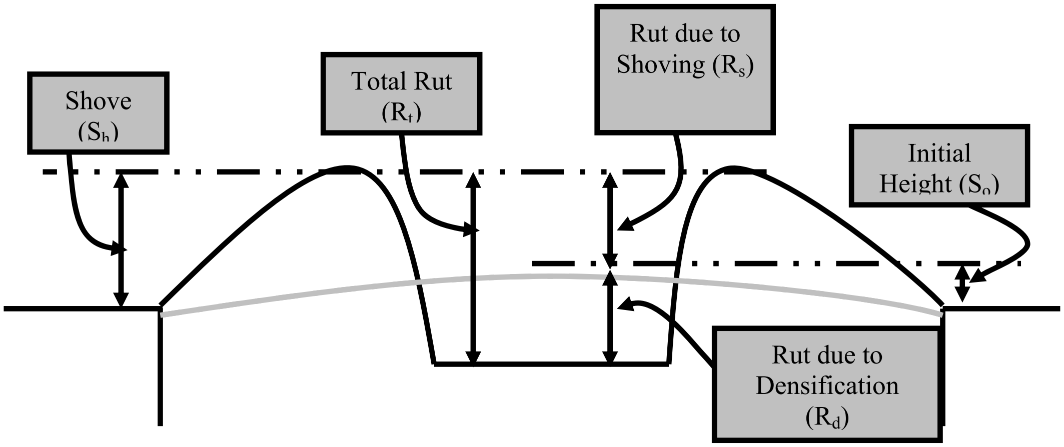
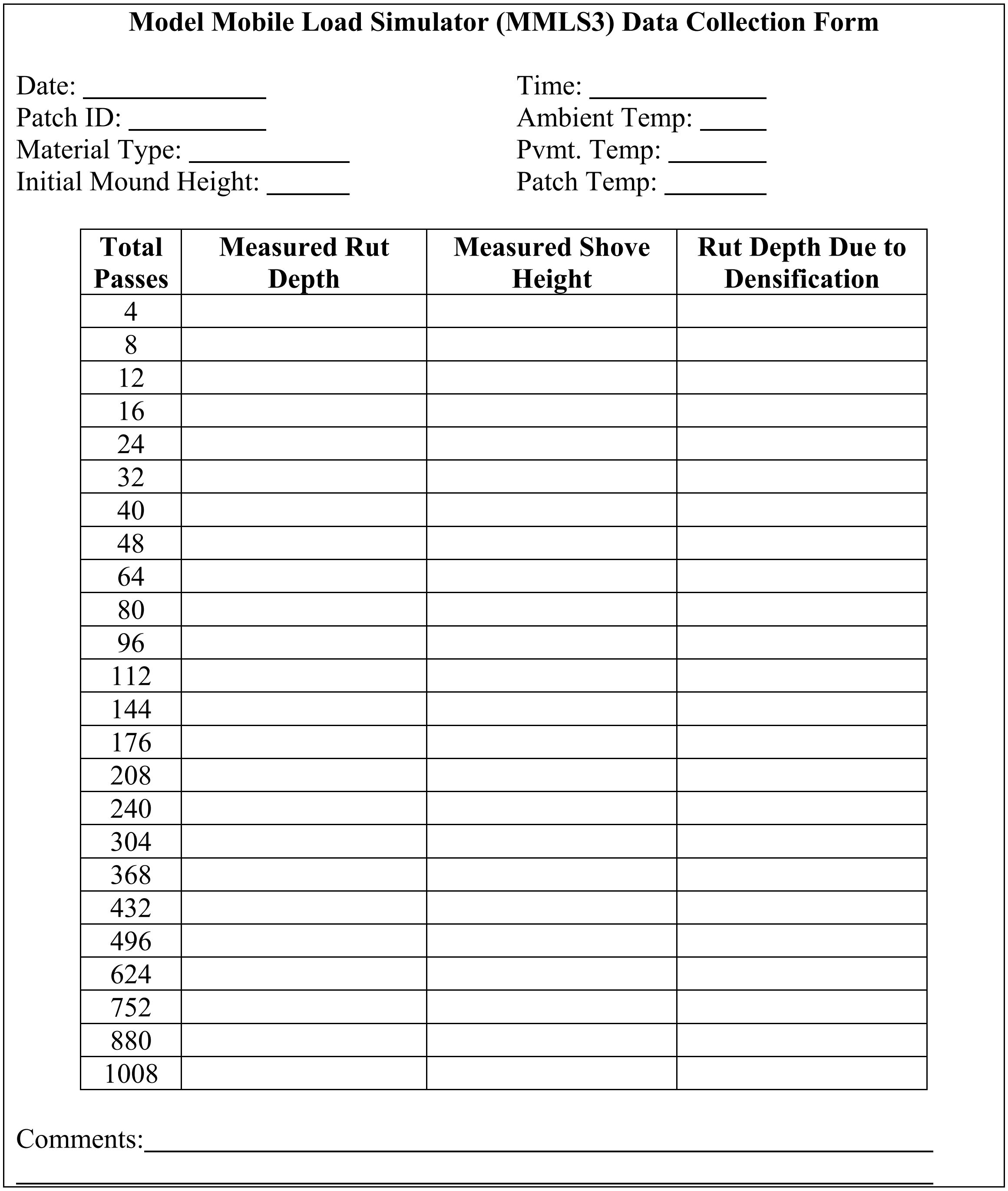


*Figure C1: MMLS3 Measured and Calculated Values*

## Analysis

The rut depth due to densification should be graphed as a function of the logarithmic total number of wheel passes applied to the patch to determine whether the material is acceptable for use in the field.



**Model Mobile Load Simulator (MMLS3) Data Collection Form**

Date: ______________ Time: ______________
Patch ID: __________ Ambient Temp: _____
Material Type: ____________ Pvmt. Temp: _______
Initial Mound Height: ______ Patch Temp: ________

| Total Passes | Measured Rut Depth | Measured Shove Height | Rut Depth Due to Densification |
|---|---|---|---|
| 4 | | | |
| 8 | | | |
| 12 | | | |
| 16 | | | |
| 24 | | | |
| 32 | | | |
| 40 | | | |
| 48 | | | |
| 64 | | | |
| 80 | | | |
| 96 | | | |
| 112 | | | |
| 144 | | | |
| 176 | | | |
| 208 | | | |
| 240 | | | |
| 304 | | | |
| 368 | | | |
| 432 | | | |
| 496 | | | |
| 624 | | | |
| 752 | | | |
| 880 | | | |
| 1008 | | | |

Comments:____________________________________________________________
_____________________________________________________________________

*Figure C2: MMLS3 Testing Data Collection Form*

# Appendix D: Drop Testing Procedure and Data Collection Forms

## *Overview*

This method outlines the testing procedure used to evaluate the impact resistance of cold patch containers (bags) to free falls.

## *Apparatus*

The following apparatus is required to perform the Drop Test.

- Drop Test apparatus—as illustrated in Figure D1
- Forklift
- Large mallet
- Temperature gun—accurate to 0.5˚ F
- Measuring Tape

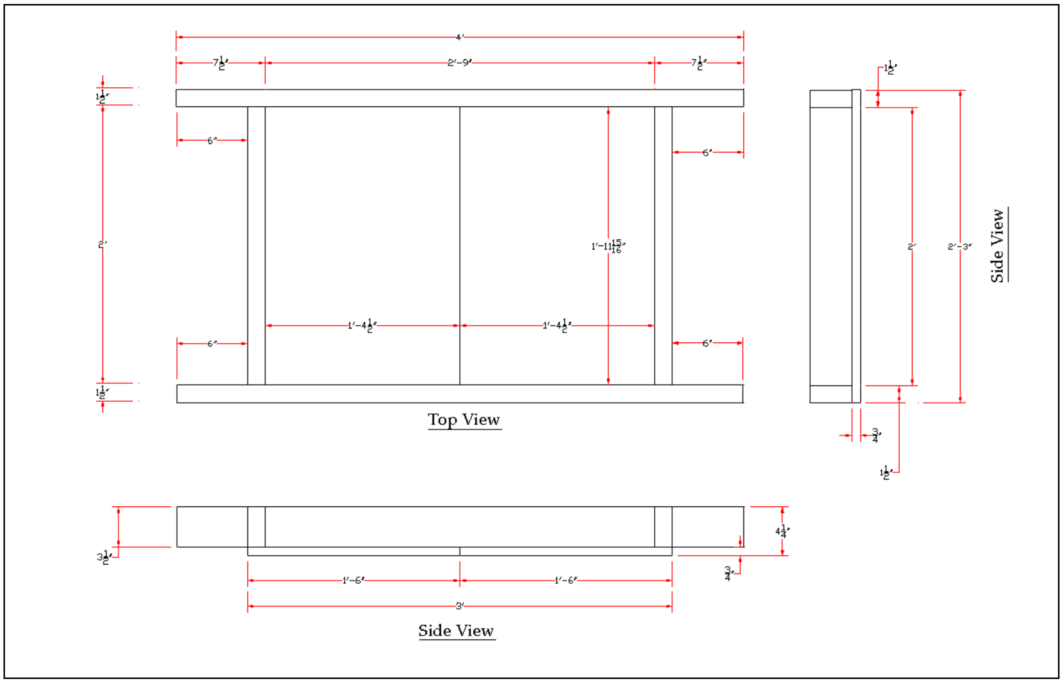


*Figure D1: Drop Test Apparatus Design*

## *Procedure*

Use the procedure outlined in Table D1 to evaluate the impact resistance of cold patch bag with the drop test.

**Table D1: Drop Testing Procedure**

| Step | Action |
|---|---|
| 1 | Identify a horizontal impact surface of concrete, stone, or steel. |
| 2 | Place forklift over the impact surface. |
| 3 | Place drop test apparatus over the forklift so that the trap doors are able to open and move freely. |
| 4 | Record all the pertinent bag information requested in the Drop Test Specimen Information Sheet in Figure D2.<br>• Material type<br>• Temperature (˚F)<br>• Bagged material weight (lbs)<br>• Bag description<br>• Bag condition |
| 5 | Identify and label all faces of the container according to ASTM standards. |
| 6 | Place bag in the cavity of the drop test apparatus so that Face 1 faces the impact surface. Ensure the load is distributed evenly on the apparatus. |
| 7 | Raise the drop test apparatus to a height of 5 ft. |
| 8 | Use the large mallet to tap the trap door release mechanism and drop the bag. The face tested should be parallel to the impact surface throughout the drop. |
| 9 | Inspect the bag for any damage and record any observations in the Drop Test Results Sheet in Figure D3. |
| 10 | Repeat Steps 6 through 9 for Faces 2 through 6. |
| 11 | If necessary, repeat Steps 6 through 10. |
| 12 | Terminate testing when the bag has an opening larger than 3 inches. |
| 13 | Repeat this procedure with at least two bags of each material being tested. |

## *Analysis*

The total number of drops to failure should be reported to determine whether the bag is adequate for impact resistance purposes.

## DROP TEST SPECIMEN INFORMATION SHEET

Date:________________ Time:________________

Bag Number:_________

Material Type: Asphalt Patch

Perma Patch

Proline

QPR

Stayput

UPM

Approx. Material Age:___________

Material Temperature:___________

Material Weight:________________

**Bag Description**

Bag Material:__________________________________________________________

Bag Construction:______________________________________________________

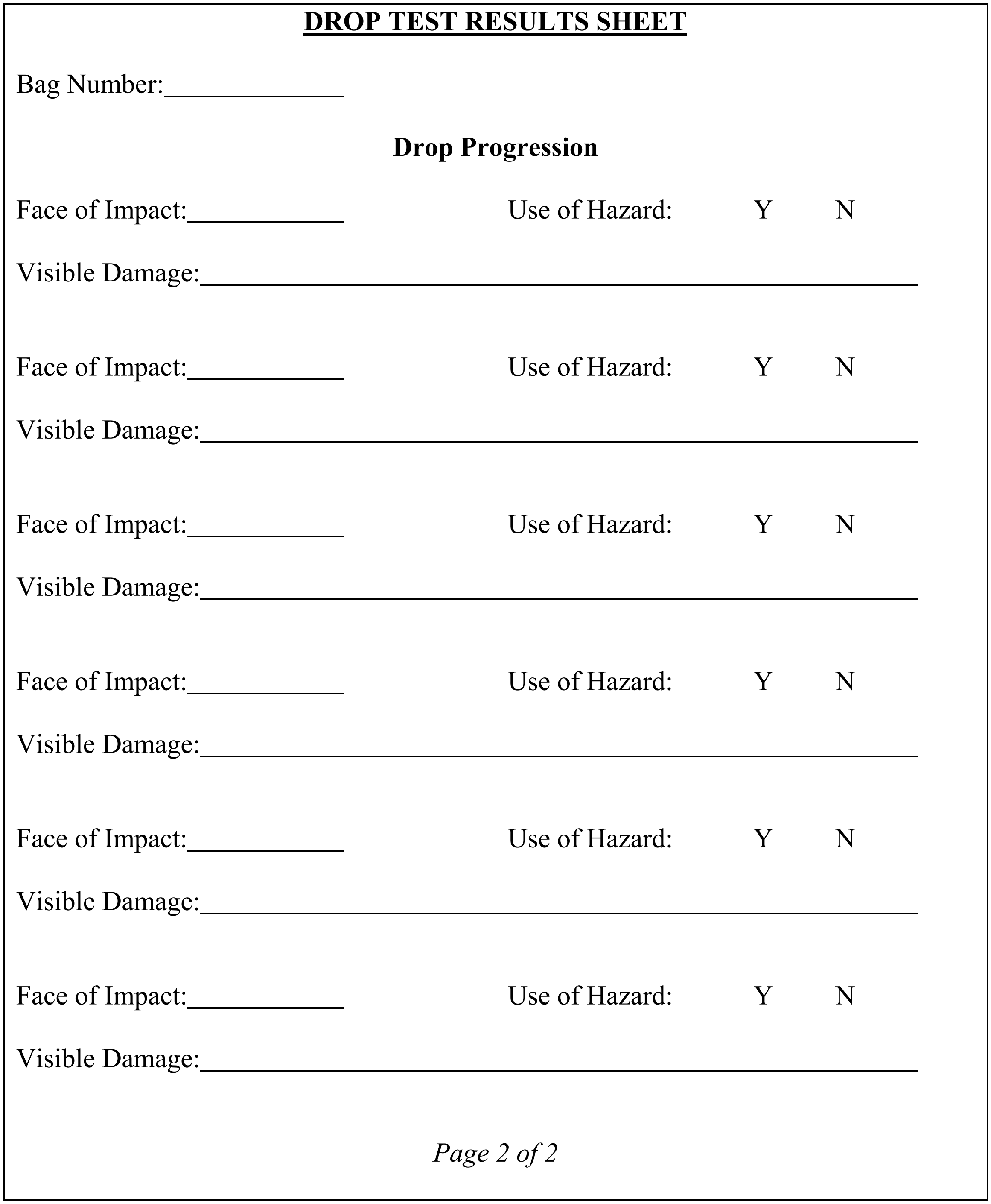
**Bag Condition**

Visible Damage:________________________________________________________

_______________________________________________________________________

*Page 1 of 2*

*Figure D2: Drop Testing Data Collection Form (Page 1 of 2)*



**DROP TEST RESULTS SHEET**

Bag Number:____________

**Drop Progression**

Face of Impact:__________ Use of Hazard: Y N

Visible Damage:______________________________________________

Face of Impact:__________ Use of Hazard: Y N

Visible Damage:______________________________________________

Face of Impact:__________ Use of Hazard: Y N

Visible Damage:______________________________________________

Face of Impact:__________ Use of Hazard: Y N

Visible Damage:______________________________________________

Face of Impact:__________ Use of Hazard: Y N

Visible Damage:______________________________________________

Face of Impact:__________ Use of Hazard: Y N

Visible Damage:______________________________________________

*Page 2 of 2*

*Figure D3: Drop Testing Data Collection Form (Page 2 of 2)*