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**Comparing Various Characteristics of Oven-Cured and Field-Cured
Prime Coat Materials Applied to Granular Bases**

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**Comparing Various Characteristics of Oven-Cured and Field-Cured
Prime Coat Materials Applied to Granular Bases**

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Dedication

I would like to dedicate my thesis to my parents

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Abstract

Comparing Various Characteristics of Oven-Cured and Field-Cured Prime Coat Materials Applied to Granular Bases

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The University of Texas at Austin, 2014

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A prime coat is defined as a low-viscosity bituminous material such as cutback, asphalt emulsions, or polymer-based chemicals applied onto the surface of road bases in order to protect the base from the penetration of moisture into the base layer. Other functions of prime coat include (1) providing good adhesion between a granular base and the bituminous surface, (2) strengthening the surface of the base by binding the fine particles, and (3) sealing against any voids along the base surface in order to reduce water absorption. To achieve these functions, a prime coat should successfully penetrate the granular base and should cure fully.

In this study, field-curing data on selected prime coats was collected during March 12th-18th, 2014 and April 12th-18th, 2014. Oven-curing data was also collected in

a laboratory using an adjustable oven. Identical prime coats including the four most commonly used prime coats by TxDOT ((1) Cutback MC-30, (2) asphalt emulsions and cutback mixture AEP, (3) polymer emulsions EC-30 and (4) asphalt emulsions SS-1H and CSS-1H) and base materials were divided into the two types of testing environments, one field-cured, and one in an accelerated and controlled indoor, oven-curing environment. Once the specimens were fully cured, evaluation of the engineering properties of the specimens were carried out in order to determine if oven-cured specimens can be expected to exhibit the same engineering characteristics as the field-cured specimens. Evaluation of water absorption tests, indirect indicator of relative strength, and penetration tests were performed on all specimens for both field-cured and oven-cured specimens. Importantly, a comparison of these results shows the viability of using accelerated, laboratory curing procedures. Prime coat field-testing procedures will be suggested using oven-curing rather than field-curing, reducing the amount of time required for sample preparation. Prime coat testing could conceivably be completed in a single day due to the accelerated curing rates. This advantage would reduce cost and man-hours of new prime coat material testing.

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CHAPTER 1 Introduction

1.1 BACKGROUND INFORMATION ON PRIME COAT

A prime coat is defined as a low-viscosity bituminous material such as cutback, asphalt emulsions, or polymer-based chemicals. Prime coats are applied onto the surface of non-bituminous bases before the application of the bituminous surface.

The primary purpose of a prime coat is to prevent the penetration of moisture into the base layer (Mohan 2011). Other functions of prime include: (1) promoting adhesion between a granular base and the bituminous surface, (2) strengthening the surface of the base by binding the fine particles, (3) sealing against any voids along the base surface in order to reduce water absorption, and (4) providing temporary protection against detrimental weather conditions. (Mohan 2011)

A prime coat is only able to achieve these functions if it successfully penetrates the granular base. A successful amount of prime coat penetration requires a depth of 5mm-10mm into the granular base. Penetration depth relies very heavily upon the application method, prime coat materials, base materials, and curing time. (Kim and Little 2000)

In order for a prime coat to penetrate into the base layer fully, it has to sit for an extended amount of time after it is applied to the base. This waiting time is referred to as curing (Mohan 2011). The rate of curing is dependent on the same factors as penetration (application method, prime coat materials and base materials) but also include the weather conditions at the location of the construction project. Prime coat materials can differ between petroleum-based (cutback, asphalt emulsion and cutback mixture) and

water-based polymers. These categories of prime coat vary dramatically in terms of both penetration and curing due to their different solvent properties. A cutback is made by blending asphalt cement with petroleum solvent. Cutbacks are able to penetrate efficiently due to the properties of its solvent and are the most widely used prime coat material. However, curing of cutbacks take longer than other prime coat materials, and because curing is a process of evaporating a prime coat's solvent once it is applied to the base surface, the solvent of the cutback releases volatile organic compounds (VOCs) into the atmosphere as it cures. The release of VOCs into the atmosphere is considered to be an environmental hazard. Currently, engineers are looking for alternatives to cutback asphalt in less harmful materials such as emulsions and water-based polymers.

According to TxDOT personnel the most widely used prime coat is Cutback MC-30. After that, the lesser used prime coat materials are: AEP which is an asphalt emulsion and cutback mixture, EC-30 a polymer emulsion prime coat which does not present an immediate threat to the environment and CSS-1H and SS-1H which are asphalt emulsions.

1.2 PROBLEM STATEMENT AND RESEARCH OBJECTIVE

To learn more about prime-coat properties, data are needed to compare oven-cured prime coat material with outside-cured prime coat material. With these data developers, builders, and state transportation agencies will be better able to understand prime coat performance. By comparing the engineering properties of outside-cured materials and oven-cured materials, this study will make recommendations about how to

simulate field conditions in laboratory settings in order to more quickly prepare prime coat specimens for testing.

First, an understanding of the outside curing process is essential to proceed properly with oven curing. Curing time for a prime coat in the field is affected by a number of factors, including: (1) the type of material (emulsion or cut-back), (2) the application method and rate, (3) the weather conditions, (4) the dilution of the material, and (5) the type of base material to which the prime coat is applied (Freeman, Button and Estakhri, 2010). Existing data for prime coat curing processes were collected outside under varying conditions. In laboratory conditions in which prime coats are cured in an oven, weather is eliminated as a variable and curing temperatures can be much higher than they are in the field. The higher temperature substantially accelerates curing times.

As newer and more advanced prime coats are being developed, it is necessary to have baseline performance data that can be used easily and efficiently in laboratories. To this aim, this research has the following objectives:

- Collect data from field-cured prime coat specimens regarding an indirect indicator of relative strength, water absorption and penetration depth.
- Collect data from oven-cured prime coat specimens regarding an indirect indicator of relative strength, water absorption and penetration depth.
- Compare the data collected from outside-cured prime coat and oven-cured prime coat specimens
- Provide a range of oven temperatures and curing times which simulate outside-curing and reasonably reduce the amount of time needed for laboratory testing.

1.3 ORGANIZATION OF THESIS

This thesis is broken into five chapters. Chapter 1 the problem statement, research objectives and organization of the thesis is outlined. A Literature Review on the subject of prime coats is presented in Chapter 2. The research done in the last several years includes studies focusing on the engineering properties of prime coat. This research includes different prime coat materials used in this study, different base finishing procedures, methods for application design, permeability, curing time, and penetration. A summary of specific research done at the University of Texas at Austin, from which this study derives much of its methodology, is included as well as research dealing with environmental concerns that result from prime coat application.

Following the Literature Review, a detailed account of the testing materials, equipment, and testing procedure carried out in this study are presented in Chapter 3. The materials include the different prime coats (Cutback, Polymer Emulsions, Asphalt Emulsions and Cutback Mixture, Asphalt Emulsions and Water-Based Polymers) and different base materials (Silt-Size Crushed Limestone and Natural Reference Fine Sand). The testing procedure includes variables involving curing time, water absorption, an indirect indicator of relative strength and penetration.

In Chapter 4, the results of the curing testing procedure done in Chapter 3 are presented. A comparison of the data obtained outdoors and data from oven dried testing in the laboratory are compared. It will compare the outside and oven data achieved followed by an explanation of what the data mean and how the data were collected. Included in this chapter are graphs and tables showing percentages and values for curing.

In Chapter 5, the results of water absorption tests are presented. A discussion about what exactly the data suggest about field-cured versus oven-cured is also presented.

In Chapter 6, the indirect indicator of relative strength results are presented. Two types of indirect indicator of relative strength are performed: (1) immediately after water absorption tests and (2) 5 days of field-drying after water absorption tests. A discussion on the overall data trends based on the results observed from field-curing versus oven-curing are presented.

In Chapter 7, the results of penetration tests are presented. A discussion about what exactly the data suggest about field-cured versus oven-cured is also presented.

In the last chapter, Chapter 8, a discussion is presented on how prime coat can be more cost effectively used via different materials and curing methods. Recommendations are also presented on how prime coat can be more effectively prepared in the laboratory and to evaluate future field performance.

CHAPTER 2 Literature Review

2.1 BACKGROUND AND GENERAL INFORMATION

As of today, the amount of literature on the subject of prime coats is minimal. Therefore, the research done in this study serves to examine: (1) the effectiveness of different methodologies available for prime coat research and (2) add to the growing body of data that are currently being collected in the transportation industry.

The primary purpose of a prime coat is to reinforce and protect the roadway asphalt base. A prime coat can do this in three different ways: (1) it coats and binds together the loose particles on the surface of the asphalt base, (2) it hardens the base surface and (3) it fills cracks, holes and other inconsistencies in the base surface.

This study includes different curing methods (oven-curing and field-curing), different base materials (silt-size crushed limestone and reference fine sand), and the engineering properties of prime coat performance (water absorption, indirect indicator of relative strength, and penetration). The tests performed in this study and their results are covered in greater detail in the following chapters.

The environmental impact of prime coats is an issue addressed by many engineers and studies in the literature. The majority of prime coats used in the past and present are primarily petroleum-based which has led to an increasing awareness of and demand for more eco-friendly materials. This study seeks to prove that not only are these new prime coat options more efficient, but the materials used are better for the environment.

The research done on prime coat materials, base materials, application design, curing time, penetration, strength, structural and functional properties of a prime coat and environmental concerns of using a prime coat are presented in this chapter.

2.2 PRIME COAT MATERIALS

There are four common prime coats used by TxDOT: (1) Cutback MC-30, (2) asphalt emulsions and cutback mixture AEP, (3) polymer emulsions EC-30 and (4) asphalt emulsions SS-1H and CSS-1H.

A cutback asphalt is a petroleum-based asphalt blended with water containing an emulsifying agent. A cutback is the most frequently used prime coat by TxDOT but is also known to contain VOCs (volatile organic compounds).

Polymer emulsions are made without petroleum solvents or other oil bases. This allows them to cure more quickly, perform better in terms of penetration and reduce the amount of pollutants they emit.

An asphalt emulsion is an asphalt blended with water and an emulsifying agent. The levels of penetration for asphalt emulsions are substantially less than that of a cutback which is why they are mixed with water (Mohan 2011). Most emulsions are differentiated by different setting rates: Rapid Setting (RS) or Slow Setting (SS). The levels of penetration for asphalt emulsions are substantially less than that of cutbacks (Mohan 2011). Since an emulsified asphalt consists of discrete particles, they have difficulty penetrating well compacted bases when compared to other asphalts. The soil can act as a filter if the spaces between the soil particles are small, screening the emulsified particles. These particles collect along the surface creating a residue of black

sealant. However, there are emulsified products that have better penetration success (Mantilla and Button 1994).

According to Mantilla and Button (1994) the nature and quantity of emulsifying stabilizing agents determines the type, stability and setting rate of an emulsion. There are two classifications of a bitumen emulsion, anionic and cationic. Anionic emulsions are classified by their setting times: rapid set (RS), medium set (MS) and slow set (SS). A RS emulsion may be diluted by water at a concentration that does not exceed a 1 to 1 ratio. On the other hand, a MS emulsion may be diluted with a concentration that does not exceed a 2 to 1 ratio. A SS emulsion can be used for soil stabilization, where high dilution rates with water is required (1:1 or more by volume). Cationic emulsions are broken into the same classification of setting time as anionic: rapid setting (CRS) medium setting (CRM) and slow setting (CSS). However, cationic emulsions may have the potential to bond better with asphalt and base layers when compared to anionic (Mohan 2011).

Because a cutback asphalt causes air pollution and other environmental hazards, more environmentally friendly, water-based polymers, such as Terra Prime (TP) and polymer emulsions such as EC-30, are becoming more popular.

2.3 BASE FINISHING

The surface of the base must be fully compacted, presumably smooth, porous and free from dust before prime coat application. According to Mantilla and Button (1994), small amounts of dust on the surface may decrease the strength of the primed surface considerably. Therefore, how the base finishes is very important when bonding the base

to the surface material. A list of the most commonly used base material, from most to least, are limestone, caliche, iron ore gravel, fly ash stabilized base, cement treated base, and an asphalt stabilized base (Sendaheera and Vignarajah 2007).

The most widely used base material in Texas is limestone. In order to finish the base, TxDOT districts use three different methods:

- Slush Rolling
- Blade and roll
- Trimming

Slush rolling is the most commonly used method. But, this method, depending on the amount of water used, can vary among different districts. An excessive amount of water can weaken the base by decreasing its density (Senadheera and Vignarajah 2007). From this process we are able to get a very smooth surface which may cause penetration problems during prime coat application.

Trimming is used by certain districts during the base finishing process. The surface of the base is compacted 1-2 inches above, then a subgrade trimmer is used in order to achieve the finished level. The trimmed surface is then rolled. This process allows for the elimination of slush rolling (Senadheera and Vignarajah 2007).

The base should have certain qualities which maximizes its efficiency before a prime coat can be applied. Those qualities are that the surface should be reasonably smooth, reasonably porous, free from dust, and structurally strong. However, these conditions may not work well together. The two most important aspects that should be achieved are that the surface should be reasonably smooth and free from dust. The

surface must be reasonably smooth in order to get the maximum efficiency. However, if the surface is too smooth, then the prime coat may have problems penetrating into the base.

The TxDOT Standard Specification Item 247.4E advises to “cure the finished section until the moisture content [of the base] is at least 2 percentage points below optimum or as directed before applying the next successive course or prime coat.” After finishing the base process, the base should be allowed to sit and dry before the prime coat can be applied. But, a base that is too dry can result in a fine dust layer on top of the surface. The fine dust can constrain the bonding of the prime coat to the base.

2.4 PRIME COAT APPLICATION DESIGN

There are three aspects involved in the process of prime coat application design: the priming method, the prime coat material used and the application rate (Senadeera, Vignarajah 2007). The location, weather conditions, and traffic exposure are also contributing factors that should be considered in the design. (Freeman, Button and Estakhri 2010)

Senadheera and Vignarajah (2007) have described four different methods for prime coat application to base material. Those methods include: (1) Spray-Prime (with or without blotting material), (2) Worked-in (sometimes referred to as Cut-In), (3) Inverted-Prime (Covered), and (4) Mixed-In Prime.

Generally, emulsions are mixed into the top part of the base layer in order to control the level of penetration (Freeman, Button and Estakhri, 2010). The most commonly used application method is the Spray-Prime. This involves mostly cutback

asphalts such as MC-30, asphalt emulsions and a cutback mixture such as AEP. However, low penetration rates of asphalt emulsions cause this method of application to not be very effective. Worked-In or Cut-In prime coat application involves taking a diluted emulsified asphalt and spraying it onto the base material. Common emulsions used for this method are SS-1H, CSS-1H and MS-2. In order to observe the desired level of penetration, the emulsified asphalt is sprayed onto the base and then covered by a layer of finer base material. This process is typically repeated 2 or 3 times to get a total emulsion application rate of 0.2 gal/yd² (Mohan, 2011).

Inverted-Prime or Covered-Prime can allow 2-3 months of satisfactory service when there is no heavy traffic. This method is most useful as a temporary method when roadways are finished in stages and when construction traffic is allowed on one side of the roadway while the other is being primed. As Mohan states, “In this method, prime coat is applied onto the prepared base and then covered by spreading Grade 5 rock” (Mohan 2011).

With the mixed-in method, after the compaction, the top 2-3 inches of the base is re-mixed with the diluted emulsion and then re-compacted in order to get the desired level of penetration. There is some ambiguity in the terms “Cut-In,” “Worked-In,” and “Mixed-In.” Cut-In and Worked-In prime are similar in that their prime coat binder is sprayed onto the completed base and creates a thin sand-asphalt base layer that resembles a prime coat.

The selection of the prime coat material used also relies on the type of base material. Other factors that determine the prime coat material used are the strength of the

specimen after curing, the low permeability of the specimen after curing, and finally, the availability of particular prime coat materials. Selecting the application ratio of a prime coat to base material is very important to how well the prime coat behaves and performs. For example, because TP is a water-based polymer, water must be added at a specific ratio in order to create a sufficient dilution. Cracks appear in specimens that are not mixed with the same ratio of dilution. These cracks lower the strength and negatively affect the permeability properties of the specimen.

The application rate for typical spray-prime binder is 0.2-.5 gal/yd² which can be calibrated depending on the impermeability of the base layer and if the project is constructed under traffic. The application rate is an important factor when testing for adequate penetration. (Senadheera and Vignarajah, 2007).

The main purpose of the design of the prime coat is to ensure that the required penetration is achieved uniformly in all areas (Mohan 2011).

2.5 CURING TIME

Curing is another important aspect of the prime coat application process. If the prime coat is not properly or completely cured, the base and the asphalt layers do not properly bond, rutting may occur and other distress as well. A prime coat is considered cured once a certain amount of its solvent has evaporated. The amount of time that is required for a prime coat to have adequately evaporated its solvent is known as the curing time. The curing time depends on numerous factors including: the types of prime coat used, base material, weather conditions, application method (spray-on or mixed-in), the priming method and other factors. A prime coat should be fully cured in order to perform

properly. A fully cured surface should not be tacky or have any excess film and can accommodate light traffic without damages or allowing excess pick-up of the prime coat.

The curing periods of an emulsified asphalt and a cutback asphalt vary. The curing of a cutback may take several days. On the other hand, an emulsified product, within a certain deviation, may take only a single day. This is because an emulsified product does not require the evaporation of excess amounts of solvent and is able to cure faster (Mantilla and Button 1994). As of today, it is not exactly clear what the exact or minimum amount of time required for a product to be completely cured is. It is not clear because the weather conditions and the types of prime coat materials are subject to change. The United States Army Corp of Engineers (USACE) has suggested that priming should not take place during the winter season because it cures improperly. An improperly cured prime coat that is paved over may become hazardous.

According to Ishai and Livneh (1984), a cutback asphalt, such as MC-30, after one day of curing released 15 percent of its kerosene-based solvent. After two days, it released 24 percent. After 7 days, it released 40 percent. These rates depend upon the weather conditions the prime coat is exposed to (temperature, relative humidity, sunlight, and wind speed).

2.6 PENETRATION OF PRIME COAT

The application of a prime coat ensures a good bond between the asphalt layer and the base. A good bond is primarily reliant on the levels of penetration achieved. The amount of penetration is reliant upon numerous factors including: the types of prime coat used, the base material, weather conditions, the application rate and the priming method.

The rate of which a prime coat is able to penetrate depends on the density of the base. A higher density, presumably, allows for less penetration (Freeman, Button and Estakhri 2010). According to Senadheera and Vignarajah (2007) a cutback observes a penetration depth around 1/8 to 3/8 in. On the other hand, a penetration depth of at least 0.2 inch is required for desirable performance (Mantilla and Button 1994).

Ordinarily, when asphalt emulsions are applied to a compacted base, it has difficulty penetrating. An asphalt typically leaves a sticky residue after a waiting period of 4 hours. This residue can be picked up by car tires (Ubben and Floersch 1981). Because of this, it is recommended to not use ordinary asphalt in the place of a prime coat.

According to Gray (1982), CSS-1H, an emulsified asphalt, did not properly penetrate the road surface. CSS-1H stayed on the top of the roadway and was covered with crushed aggregate to carry ongoing, local traffic. The lifespan of CSS-1H may not be very long because it remains on the top layer of the surface rather than penetrating into the base. In figure 2.1, the effects of an improperly penetrating emulsified asphalt is presented.



Figure 2.1 Emulsified asphalt with insufficient penetration (Cross, Voth, Shrestha 2005)

2.7 PREVIOUS STUDIES OF PRIME COAT MATERIALS AT UT AUSTIN

In 2011, Gouri Mohan, Yetkin Yilidirim and Kenneth H. Stokoe collaborated on an article identifying the engineering characteristics of prime coats on granular bases. In the article Mohan, Yildirim and Stokoe identified that the curing time of prime coats have not been adequately studied. Tests were performed on the most commonly used prime coats in Texas in order to observe the effects that different variables have on curing time. Spray-on and mixed-in application were used on each prime coat specimen. The experiments conducted at the University of Texas at Austin included strength tests,

permeability tests, and penetration tests in order to conclude which of the prime coat would performance best (Mohan, Yildirim and Stokoe 2011).

The study revealed, in terms of permeability, TP and MC-30 showed the best result. In terms of penetration, EC-30 showed the best results. In terms of strength, TP showed the best result (Mohan, Yildirim, Stokoe 2011).

2.7.1 Investigation of Curing Time and Prime Coat Characteristics

One of the most recent studies made at the University of Texas at Austin by Gouri Mohan involved observing the curing times and engineering properties of various prime coat materials (Mohan 2011). The following is a summary of the materials, testing procedure and conclusions.

2.7.1.1 Materials

The properties of a prime coat are very important to the overall stability of the pavement structure. After curing, Gouri performed permeability, strength and penetration tests on six different types of prime coats.

Crushed limestone was used as the base material for all specimens. After sieve analysis testing, Crushed limestone passed through the #10 sieve (2mm) and retained #40 sieve (.42mm), passing though #40 sieve (.42mm) in equal weight.

The six different types of prime coat used in Mohan's thesis were MC-30, EC-30, AEP, SS-1H, CSS-1H, and TP. MC-30 is a cutback asphalt. EC-30 is a non-bituminous emulsion. AEP is an asphalt emulsion and a cutback mixture. SS-1H and CSS-1H are both emulsions. In addition to these, TP is a water-based polymer (Mohan 2011).

2.7.1.2 Specimen Preparation

16 oz containers with a diameter of 4 inches and a height of 2.4 inches were used to prepare the specimens. All of the specimens were tested in terms of curing, permeability, strength and penetration. These containers required that 7.3 ml of a prime coat to be applied in order to properly cover the top layer. The 7.3 ml TP sample required that it be diluted in 50ml water as it would be in the field (Mohan et al 2013).

There are two application methods used in this study: Spray-on and Mixed-In prime. For the spray-prime method, one container holds 300 g of the soil in total. The soil is added at 100g intervals. Each interval was added then compacted 25 times with a wooden hammer. After this, it is well compacted and ready to have 7.3 ml of a prime coat added on top (Mohan 2011).

The specimen preparation for the mixed-in prime is similar to the spray-prime. The difference between the two methods entailed that the mixed-in specimen's final 100g added to the base material had the 7.3 ml prime coat already mixed in. This mixture was placed on the top layer and compacted another 25 times (Mohan 2011).

After these steps were completed, the specimens were ready for testing. The tests performed on these specimens involved identifying, curing time, permeability, strength and penetration of each of the prime coat specimens.

2.7.1.3 Curing Time

The curing time testing procedure involved three different testing seasons. Season 1 testing period in October had a maximum temperature of 87.6°F, minimum of 47.5°F and average of 69.6°F. Season 2 testing period in November-December had a maximum

temperature of 81.4°F, minimum of 30.2°F and average of 58.1°F. Season 3 in February and March had a maximum temperature of 88°F, minimum of 20.5°F and average of 55.4°F. The most important aspect of this test is that when temperature is increased, the time taken for curing is decreased. The results of the curing tests showed that MC-30 required the longest time to cure while TP took the shortest in all testing seasons (Mohan 2011).

The prime coat materials were ranked in terms of curing as follows from shortest time to longest: TP, EC-30, SS-1H, AEP, CSS-1H and MC-30 (Mohan 2011).

2.7.1.4 Strength

The strength tests performed on these samples were to observe how well prime coats can maintain the surface structure of the base. When the pavement is exposed to traffic, the weight of the vehicles is transferred from the wheels onto the aggregate. The aggregate transfers that weight to the top of the base where the prime coat is applied (Mohan 2011).

For this study, cured specimens were subjected to strength tests. A pocket penetrometer was used to determine the prime coat strength. To accommodate the size of the specimen, which is comparatively small, the diameter of the penetrometer had to be adjusted from 6.4 mm to 1mm. The study determined that the mixed-in specimen has a greater strength than the sprayed. The maximum strength determined in this study for both mixed-in and sprayed-prime is TP. The minimum for both is AEP (Mohan 2011).

2.7.1.5 Permeability

The aim of the permeability test in this study was to determine how prime coat materials can prevent water from penetrating into the base course. This gives an idea to engineers which type of prime coat is more effective in terms of permeability. After curing, the samples were weighed, then 100 ml of water was poured on top of the sample. After 10 minutes, the water was removed and weighed, along with the sample, to determine how much water had penetrated the base. From this change in water volume, it is possible to calculate permeability. Results from these tests concluded that the mixed in method resulted in a lower permeability rate than the spray-on method. The maximum permeability for mixed-in was EC-30, and for spray specimens, CSS-1H. MC-30 produced the minimum permeability rate for both spray-on and mixed-in samples (Mohan 2011).

2.7.1.6 Penetration Tests

Sand penetration tests were carried out to determine the extent with which a prime coat is able to penetrate the base. Five grams of a prime coat is applied to the sand base surface at a stable speed with a height of approximately 11cm. The specimen was then allowed to sit for 24 hrs. After this, the specimen was cut vertically in order to determine the penetration depth of the prime into the sand. The penetration depth ranged from 12000-1000 microns in the following order: EC-30>MC-30=TP>AEP>SS-1H=CCS-1H. EC-30 showed the highest or maximum penetration depth. MC-30 and TP showed the

next highest penetration depth. And CSS-1H and SS-1H showed the minimum amount of penetration (Mohan 2011).

2.7.1.7 Mohan's Findings

Strength, permeability, curing times and sand penetration tests were performed on prepared specimens using six different types of prime coat. For curing, strength and permeability tests, two different types of application methods were used: spraying onto the surface or mixing into the top layer of the base course. The following points were concluded from this study:

- In terms of curing time, TP showed the shortest curing time while MC-30 showed the longest.
- In terms of strength values TP was five times greater than all of the other prime coats. The differences between wet TP strength and dry TP strength were imperceptible. On the other hand, the other prime coats were comparably lower when considering the wet strength.
- The spraying method increased the permeability rather than the mixing method. MC-30 and TP were determined to yield the lowest permeability in this study.

Mohan's thesis primarily dealt with the curing of a prime coat in a field setting. The present study seeks to study the curing of prime coats field as well as inside an oven. This study compares the two in order to, first, better understand the relationship between curing time and prime coat material, and second, to develop a more cost efficient research methodology for prime coat curing.

2.7.2 Relationship Between Curing Time and Strength

Juan Du performed a study in 2011 at the University of Texas at Austin to determine the relationship between the curing time and strength. By performing this experiment, Du sought to determine how long of a curing process is required for a prime coat to achieve its maximum strength. Du claims that there is a correlation between weight loss of a prime coat and strength improvement (Du 2011).

In this study, six different prime coats were used: MC-30, CSS-1H, SS-1H, AEP EC30 and TP. Crushed limestone was used as the base material. Two prime coat application methods were used: spray-on and mixed-in (Du 2011).

This test was conducted in the summer season with a temperature range of 73.6°F-101.5°F. Relative humidity was determined as 55.5 percent. The weight of each sample was measured in 24 hr intervals. A pocket penetrometer was used in order to determine the unconfined compressive strength of the primed samples. The measurement is determined by embedding the penetrometer with a depth of 0.25 in. into the soil sample with a constant force. From the reading on the penetrometer, the strength value is able to be determined from the top of the indicator ring (Du 2011).

One interval on the scale means 1 kg per sq. cm which is 14.2 psi. Three samples were prepared for each application method and each type of prime coat in order to reduce the amount of influential variables that would affect the results. A prime coat is considered to be cured when the solvent's reduction in weight drops below 0.1 gram, or when the maximum strength value is obtained. The following conclusions are revealed from this study:

- In terms of curing, TP is the fastest among the observed prime coats. MC-30 is the slowest.
- In terms of strength, TP has the highest strength. AEP has the lowest strength

Application method does not alter the outcome of the curing time. Application method does, however, alter the strength values of a prime coat for unconfined compressive strength. Mixed in samples showed higher strength values, while spray-on showed lower strength values (Du 2011).

2.8 FUNCTIONAL AND STRUCTURAL PROPERTIES OF PRIME COAT

Many engineers and researchers claim that prime coats may not add any significant amount of structural benefit. However, Mantilla and Button (1994) have defined some functional roles of a prime coat. Those roles are to improve the adhesive properties between the base and the asphalt layer, filling any inconsistencies along the top layer, preventing water from penetrating that base, improve the strength of the base near the surface and protect against rain, snow, temperature variation and traffic.

Mantella and Button (1994) have conducted laboratory and field tests identifying some of the important functional and structural necessity of a prime coat. The specific goals of their study were to determine the importance of bonds between the base and various types of surface courses to discover the different techniques of construction and materials in order to improve a prime coat's performance and to develop a distinct testing process for assessment of prime coat materials.

In order to achieve the goals that Mantilla and Button define, they performed some field and laboratory tests as follows:

- Torsional shear tests
- Direct shear tests

These tests helped them discover the functional and structural properties of prime coats and also show how meaningful the bond between the primed base and asphalt layer is.

Torsional shear tests performed by Mantilla and Button (1994) reported that, when high normal static stress is applied, there is a minute difference between different prime coat materials. Unprimed samples resulted in a lower torsional shear strength. On the other hand, primed sample such as MC-30 and AEP resulted in higher values.

In the direct shear tests, according to Mantilla and Button (1994), MC-30 and AEP performed better than unprimed samples under two different normal stress conditions: 50 kPa and 100 kPa.

Chellgren (2005) has stated that the primary purpose of a prime coat is to protect against rain and light traffic. Freeman, Button and Estakhri (2010) claim that most engineers and researchers have challenged the above statement with field and laboratory testing that suggests that prime coats add additional significant benefits. It is necessary, according to Tschegg et al. (1995) that there should be a good bond between the base layer and asphalt layer in order to achieve the desired loading capacity and longer service life. The failure of many highway projects has been the result of a deficient bond between these layers.

Jha (2005) defines distress as cracking or settlement and loss of aggregate, and he states that distress takes place, relatively speaking, whenever new pavement is laid on

poorly primed surfaces. Isahi and Livneh (1984) have concluded that to avoid distresses, a properly formed prime coat must be applied to the base.

There are many factors that can contribute to the formation of distresses on the prime coat layer. West et al (2005) determined that beneath the Hot Mix Asphalt layer, an insufficient bond, may cause distresses on the prime coat layer. Insufficient bonds occur because of complications during compaction and cracking on the surface. Senadeera, Leaverton and Vignarajah (2007) concluded that a prime coat can be stripped from the pavement if not properly cured. Because of this, heavy traffic and rain can easily erode a prime coat from the surface. Rain can also damage an improperly cured prime coat and base. Proper curing of a prime coat is very important in order to get a sufficient bond between each individual layer.

2.9 ENVIRONMENTAL PROBLEMS OF USING PRIME COAT

This section is intended to address the environmental issues related to prime coat usage. When considering the application of prime coats, it is important to consider any subsequent effects it can have on the environment. There are damaging environmental concerns identified, broken up primarily into air and water quality concerns. It is also important to consider contractor health since the products and materials being used can be hazardous to the people who handle them.

A Cutback asphalt is a major carrier of volatile organic compounds (VOCs). These materials are the primary concern for air pollution that results from asphalt projects. It is scientifically proven that the releasing of VOCs into the atmosphere has been damaging the ozone. The releasing of VOCs can take place at mixing plants and

road sites. However, road sites are where a substantial amount of VOCs are released into the atmosphere.

Because the effects of VOCs have become better documented over the last several years, emulsified asphalts are becoming popular alternatives to cutback asphalts in order to reduce VOCs emissions. However, emulsified asphalts contain a certain amount of similar solvent to cutbacks and do not completely solve the problem of VOC releasing into the air (Freeman, Button, Estakhri) (2010). Legislation such as the Clean Air Act has done much to regulate and minimize the emission of VOCs during certain times of the year, or to do away with them permanently. The Texas Natural Resource Conservation Commission has suggested a ban on the use of cutback asphalts from the dates of April 16 to September 15 of any year. It may be assumed that during this period of the year, temperature and sun exposure in Texas is at its highest and VOCs are easily released due to the high solvent evaporation rates (Erten and Azimov 2012). The article “MC-30: Exploring its Risks and Continued Use” by Adbullah Suzek and Yetkin Yildirim explains that MC-30 is the most popular and widely used a prime coat in the transportation industry. Despite its popularity, it does pose a threat to the public, the environment and pavement workers. MC-30 contains VOCs, causing ground-level ozone damage and poses short term as well as long term dangers to humans and the ozone layer (Suzek and Yildirim 2013).

Water contamination can be the result of heavy rainfall that causes a freshly applied prime coat to make its way into drains, sewers, and other drainage systems. Because of this, prime coats are generally not applied if there is a strong probability of

rain runoff. According to the Environmental Protection Agency (EPA), emulsions and cutback asphalts are defined as oil. Therefore, any spill of oil that could access a waterway would violate water quality standards or cause an identifiable pollution to groundwater in the form of a film or sheen. Any occurrence of contact between either an emulsified or a cutback asphalt with a waterway should be reported to the National Response Center and local authorities.

The Resource Conservation and Recovery Act (RCRA) has stated that any hazardous chemicals in cutbacks and emulsion asphalts should be less than the reportable quantity (RQ). RQ may be defined as a single spill greater than 1,000 gal, or a spill of more than 42 gal of oil both taking place within a 12 month period. When a spill reaches or exceeds the RQ as set by these standards it should be reported to the National Response Center. However, the RQ is generally never reached.

When considering the possibility of accidental spills, liability, regulation and accountability arise in the public dialogue. Many city and county jurisdictions routinely ban some of the substances that are involved in producing hazardous waste (oil and VOCs). Prohibiting certain kinds of prime coats, however, does not completely solve the liability issue because there are other products that contractors use, including oils and fuels, which are just as detrimental to the environment as prime coats.

Cutback asphalts may also cause a potential fire hazard during road construction, especially during the summer. According to the Material Safety Data Sheet (MSDS), the flash point of MC-30 is in the range of 120F-140F. Because of this range, fire can be a factor when using MC-30 for a prime coat or a rapid cure cutback. What's more, MC-30

releases vapors and other by-products that may affect the health of construction personnel as well. Workers can inhale fumes, vapors and mist resulting in “headaches nausea, dizziness and intoxication” (Erten and Azimov 2012).

2.10 LITERATURE REVIEW OVERVIEW

In this chapter, the research performed on a prime coat in the last several years and the properties that research revealed are presented. The literature obtained from previous research studies helped create the testing procedure used in this study. The information gathered from the research presented in this chapter and the subsequent testing performed for this study seek to make a workable and available oven-curing method that would reduce the cost of future testing.

CHAPTER 3 Experimental Design, Equipment, and Testing Procedures

3.1 INTRODUCTION

In order for a prime coat to be effective it must be cured properly. The structure of pavement is reliant upon proper curing. A prime coat is considered to be properly or totally cured once a certain amount of its solvent or water has evaporated. Evaporation rates depend on environmental conditions, the type of prime coat, the application method and the type of base material. The primary purpose of this study is to measure the effects of weather on prime coat curing and also to evaluate the feasibility of a laboratory curing procedure. After investigating the curing times of these two scenarios, this study goes on to employ non-conventional as well as conventional experiments such as water absorption tests, indirect indicator of relative strength and penetration tests in order to compare the engineering characteristics of both field-cured and oven-cured prime coat specimens.

For field-curing tests, the different prime coats and the different base materials are exposed to all of the weather conditions that affect curing (fluctuating temperatures, humidity, wind, and atmospheric pressure) in the months of March 12th-18th, 2014 and April 12th-18th, 2014. Oven-curing tests are also conducted with the same prime coats and base materials. The oven removes the specimens from the sporadic weather conditions of the field and exposes the specimens to higher temperatures. Two different temperature ranges are used in order to cure specimens: 50°C-100°C using reference fine sand and 50°C-90°C using silt-size crushed limestone. By comparing the curing data of field-cured and oven-cured specimens, this study seeks to determine an appropriate oven temperature

for curing that is able to recreate the same levels of evaporation and engineering properties that occur in the field. In order to develop a methodology that is able to recreate the same amount of evaporation in an oven that occurs in the field, the curing rates for both field and oven specimens are recorded and compared.

Specific testing materials and equipment, testing method and design, and a detailed description of the testing procedure are included in this chapter.

3.2 MATERIALS

3.2.1 Prime Coat Materials

Prime coats have been widely used in the transportation industry for many years. A prime coat is the application of penetrating liquid asphalt on a compacted aggregate base course (OCAPE, 02).

The most commonly used prime coat by TxDOT is a cutback asphalt. However, the use of cutback asphalts is being reconsidered as a popular material due to the environmental issues resulting from its petroleum solvent. Currently, emulsified prime coat materials are becoming the more widely used prime coat material.

This study examines the following type of prime coat: cutback, polymer emulsions, asphalt emulsion and cutback mixture, asphalt emulsion and water-based polymer. MC-30, a cutback asphalt, is the most commonly used prime coat by TxDOT. Asphalt Emulsion Prime (AEP) is an asphalt emulsion and cutback mixture. Cationic Slow Setting (CSS-1H) and Slow Setting (SS-1H) are asphalt emulsions. EC-30 is a polymer emulsion prime coat which does not present an immediate threat to the environment. TP (Terra Prime) is a water-based polymer which is environmentally

friendly as well. The table shown below includes the various prime coat materials used in this study.

Table 3.1 Prime coat materials used in this study

Prime Coat	Type	Suppliers
MC-30(Medium Cure)	Cutback	Valero, TX
EC-30(Eco Cure)	Polymer Emulsion	PrimeEco, TX
AEP(Asphalt Emulsion Prime)	Asphalt Emulsion and Cutback Mixture	Ergon, Waco, TX
CSS-1H (Cationic Slow-Setting Hard Base)	Asphalt Emulsion	Ergon, Waco, TX
SS-1H(Slow-Setting Hard Base)	Asphalt Emulsion	Ergon,Mt.Pleasant, TX
TP(Terra Prime)	Water-Based Polymer	Terra Pave International, TX

Details for these prime coat materials are provided in Appendix A.

3.2.2 Base Materials

For this study two different types of base materials are used: silt-size crushed limestone and reference fine sand. These two base materials are used in order to observe any difference between the behaviors of a prime coat with the base. Both silt-size crushed limestone and reference fine sand are provided by TxDOT.

3.2.2.1 Silt-Size Crushed Limestone

In Texas, silt-size crushed limestone is the most commonly used base material for transportation projects. It is used by 90 percent of the districts in the state (TxDOT Item 247). As a method of fine-grain analysis, hydrometer testing and sieve analysis help to estimate the grain size of the silt-size crushed limestone. The gradation curve of silt-size crushed limestone obtained from hydrometer testing and sieve analysis is presented in

Figure 3.1. In the same figure, the median particle size, D_{50} , is found at approximately 0.010 mm for the silt-size crushed limestone used during testing. The maximum density of the silt-size crushed limestone soil is 136.7 pcf. The optimum moisture content is 6.9%.

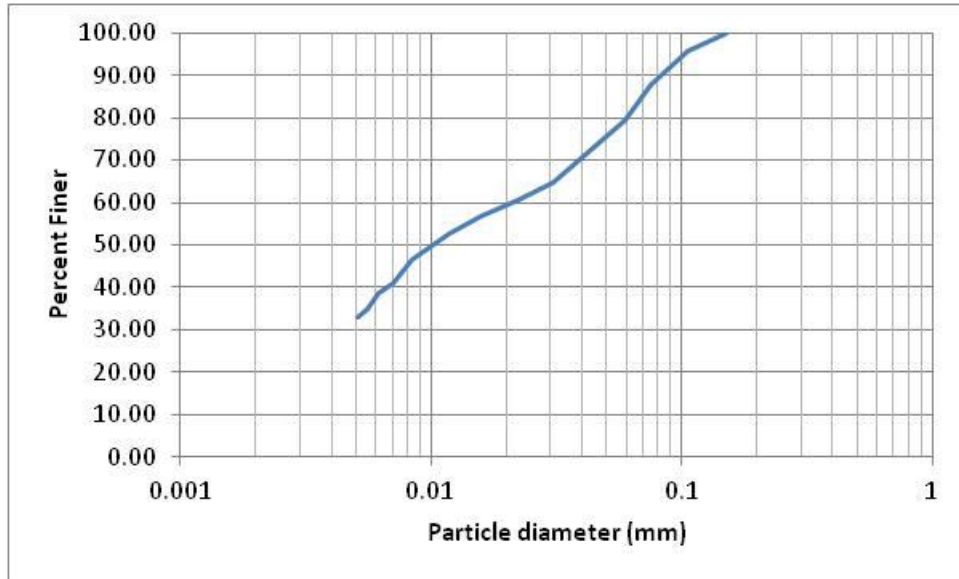


Figure 3.1 Gradation curves of silt-size crushed limestone used as a base material

3.2.2.2 Reference Fine Sand

The reference fine sand used in this study is provided by TxDOT as a second base material. Reference fine sand is generally used only for penetration tests. However, for this study, both silt-size crushed limestone and the reference fine sand are used in all tests.

Table 3.2 Gradation requirements for reference fine sand

Sieve	Percentage Passing for Reference fine sand (%)
#80	100
#100	97
#140	50
#200	2

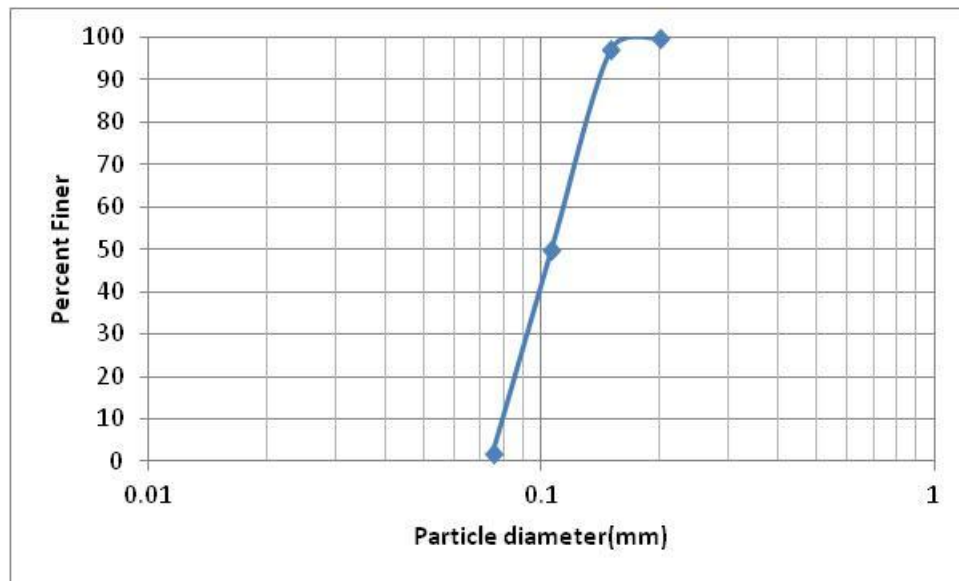


Figure 3.2 Gradation curve of reference fine sand used as a base material

The gradation requirements for the reference fine sand used in this study are presented in Table 3.2. In Figure 3.2, the median particle size, D_{50} , is found at approximately 0.11 mm.

3.3 SAMPLE DESIGN

In the field there are generally four methods used for prime coat application: namely, (1) spray-on prime, (2) worked in prime, (3) inverted prime and (4) mixed-in

prime. Other studies have shown little variation in the results of spray-on and mixed-in methods. Because of this, this study only uses the spray-on prime method.

The application rate used in this study is 0.395 gallon per square yard. After making the necessary calculations, a measurement of 4 ml of a prime coat per specimen is used. Based on the size of the containers used, 4ml (0.395 gal/ square yard) of a prime coat is required to cover the surface of the specimen. Only the water-based polymer prime coat (TP) must first be diluted with water at a ratio of 1:5 (prime coat: water). After dilution, the water-based polymer prime is measured to 4 ml and applied to the base material. This testing procedure is based on the Mohan (2011) testing procedure which required 10 ml of TP diluted with 50 ml of water and two session. First, 45ml of the prime coat was applied. Then, after two days, the remaining 15 ml was applied. The other prime coats used in Mohan's (2011) and this study do not require dilution in water. This study only applied one application.

3.3.1 Spray-Prime Specimens

In order to prepare specimens for testing, 2.1 inch diameter and 1.4 inch height cylindrical cans were used (Figure 3.3). The can is filled with 80g of soil and compacted 25 times using a tool to make the surface even. After the surface is compacted, the prime coat material (4ml) is sprayed on to the surface. The initial weight of soil and weight of the following application of prime coat is measured by a precision digital analytical balance (Figure 3.4). Once all of these steps are completed, the specimens are ready for field-curing and oven-curing tests.



Figure 3.3 2.1 inch diameter by 1.4 inch high circular cans used for preparing specimens



Figure 3.4 Precision digital analytical balance used in this study

3.4 TEST METHOD AND DESIGN

Six different types of prime (MC-30, EC-30 AEP, TP, CSS-1H, SS-1H) and two types of base materials (reference fine sand and silt-size crushed limestone) are used and tested. For field-curing, 48 specimens were prepared. Reference fine sand and silt-size crushed limestone bases were used with the different types of prime coat materials during March and April. For oven-curing, 66 specimens were prepared (Table 3.3). Oven-cured specimens were exposed to six different temperatures (50°C, 60°C, 70°C, 80°C, 90°C, 100°C). For 100°C, only the reference fine sand was tested. Table 3.4 shows the maximum, minimum and average temperatures of the field-testing periods. A total of 114 specimens were created and tested.

Table 3.3 Oven-curing experimental design table for prime coat

	AEP	MC-30	CSS-1H	SS-1H	TP	EC-30
Silt-Size Crushed Limestone	5	5	5	5	5	5
Reference Fine Sand	6	6	6	6	6	6

Table 3.4 Max., min. and average field temperature during the field studies

Testing Period	Max. Temp. °F	Min. Temp. °F	Average Temp. °F
March 12-18, 2014	68°	52°	59.7°
April 12-18, 2014	75°	52°	63.7°



Figure 3.5 Adjustable temperature oven used for laboratory curing

3.4.1 Curing Time

Investigating the proper curing time of different prime coat materials is an important question for engineers. Evaporation of the prime coat solvent is an important measuring component for determining whether or not a specimen has completely cured. Once the sample is completely cured, the weight begins to tend toward a constant and ceases to change dramatically. Observing this rate of weight loss is a fundamental factor of evaluating curing time.

By collecting both field and oven data, field conditions can be simulated in the laboratory, effectively reducing testing cost. Field-curing tests were conducted in the parking lot of the Cockrell School of Engineering at the University of Texas at Austin. Testing was performed in two different weather conditions: March 12th-18th, 2014 and

April 12th-18th, 2014. During rain, all samples were moved inside the engineering building and returned to the field once the rain subsided. The samples were weighed in the first hour to account for high evaporation rates. After that, the samples are only measured for weight every 12 hours.

Oven specimen tests were carried out in oven at the University of Texas at Austin. These tests exposed samples to six different temperature settings ranging from 50°C to 100°C. The weight of the samples were measured every 30 minutes in the first hour.

3.4.2 Water Absorption Tests

Water absorption tests were performed in order to gain more information regarding the different prime coats and different curing methods. There are permeability testing procedures that exist in the literature of prime coat research. Permeability tests primarily allow water to pass completely through the specimen. However, in this study, water absorption tests were conducted. Water absorption tests do not allow water to completely pass through the specimen. There are many factors that can contribute to a prime coat's water absorption. The type of prime coat material, which base material is used, and the application method are all contributing factors.

Two different base materials were used on each specimen as well, silt-size crushed limestone and reference fine sand. After the curing of each specimen, they were weighed. 20 ml of standing water was then added to the specimen and left to sit for 10 minutes. After 10 minutes, the water is poured out and weighted again in order to determine how much of the water had been absorbed.

After these calculations, it is possible to determine how well a prime coat is able to resist water penetration. The data on the water absorption tests are provided in Appendix B.

3.4.3 Indirect Indicator of Relative Strength

After testing for water absorption, indirect indicator of relative strength is performed. Just as for water absorption, the indirect indicator of relative strength is dependent upon the type of prime coat, application method and base material.

For the purpose of this study, two indirect indicator of relative strength were performed, one immediately after water absorption tests and the second after the specimens are allowed to dry in the field for 5 days after the water absorption tests. The indirect indicator of relative strength was performed on two different groups of cured specimens: oven-cured and field-cured. A pocket penetrometer with additional modified diameter tip (Figure 3.6) is used to measure an indirect indicator of relative strength. The original pocket penetrometer is able to measure compression strength via a spring loaded calibrating tool. An unmodified pocket penetrometer is able to measure strength up to 4.5 kg/cm^2 . One interval on the scale is equivalent to 1 kg/cm^2 (14.2 psi) (Du 2011). In the field, the pocket penetrometer can be used directly and accurately without being modified. However, because this study used a finer base material the pocket penetrometer had to be modified. A finer base material required a smaller testing diameter in order to accurately measure an indirect indicator of relative strength. The original 6.4 mm diameter of the penetrometer is fitted over with an attachment allowing for adjustable

diameters: a 1 mm diameter tip and a 2 mm diameter tip. The data for the indirect indicator of relative strength data are presented in Appendix B.



Figure 3.6 Pocket penetrometer with additional modified diameter tip

The pocket penetrometer with additional modified tip is pushed onto the sample surface at a 90 degree angle. The force is measured by the position of slip ring along the shaft once force is no longer applied in order to determine an indirect indicator of relative strength for each sample. Force is constantly and evenly applied until the base of the modified pocket penetrometer tip reaches the surface. The tip of the penetrometer is modified by attaching an adjustable tip head in order to test different diameter heads. Each sample is tested eight times, four times for each modified diameter. The average of the four tests per diameter is recorded.

3.4.4 Penetration

As stated by Sandheera and Vignarajah, “The penetration of the prime coat into the base is very important to obtain maximum benefit from the prime coat” (2007). Penetration of a prime coat is also necessary to achieve a good bond between the asphalt layer and the base layer.

Sand penetration tests are typically performed to determine the penetrative values of a prime coat. These tests consist of using reference fine sand in 3 oz containers at a depth of 45 millimeters. Sand is compacted at 100 psi using a load frame. 5 grams of a prime coat is applied at a height of 40-50 inches at a constant rate. After the prime coat is applied, the specimen is allowed to stand for 24 hours. The specimen is then cut vertically in order to measure the depth of penetration (Mohan 2011).

For this study, both silt-size crushed limestone and reference fine sand are used for the penetration testing procedure. The penetration tests are performed following the indirect indicator of relative strength. The prime coat layer of the sample is removed from its container rather than being cut vertically. The thickness of this layer is measured with a digital ruler (Figure 3.8) in order to determine the average penetration depth. This procedure is done for each of the different prime coat materials as well as on the different base materials. Each specimen is measured three times and the average depth of penetration is recorded. With this procedure, it is possible to see how well each of the prime coat materials are able to penetrate into the two different types of base material.



Figure 3.7 Water-Based Polymer Penetration on Reference fine sand

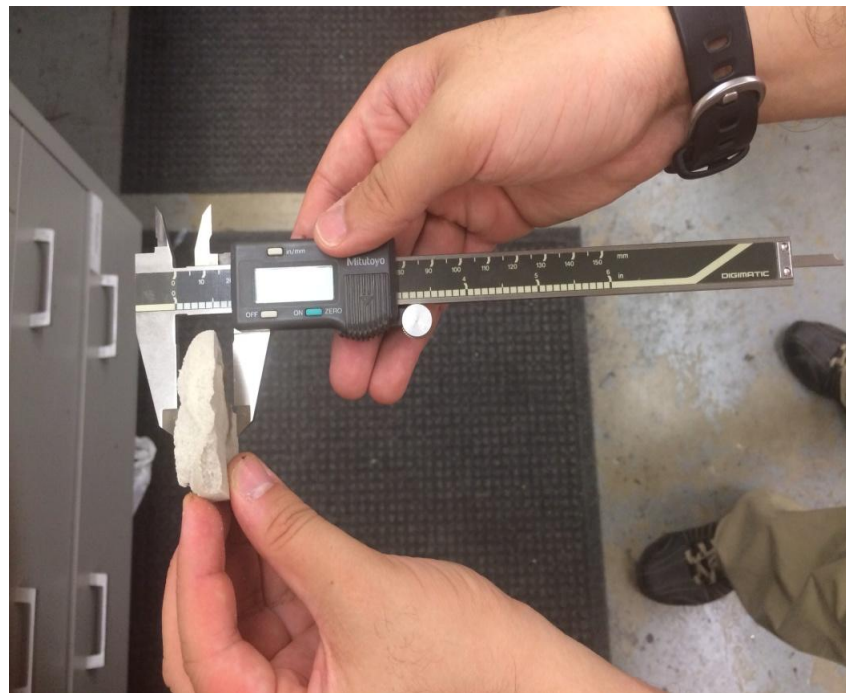


Figure 3.8 Digital Ruler Measuring Penetration Thickness

3.5 CONCLUSION

In this chapter, detailed descriptions of the materials and procedures for the testing done in this study are presented. The prime coat materials and two different base materials used are described at the beginning of this chapter. The sample and experimental design is described through size and application method followed by the curing, water absorption, indirect indicator of relative strength and penetration testing procedures. Equipment used (primarily the modified pocket penetrometer) are also included. The results of these tests are described in Chapter 4. The collected data from all experiments are included in the Appendix B.

CHAPTER 4 Curing Time Tests Results

4.1 INTRODUCTION

This study focuses on the time required for prime coat materials to be considered cured. A prime coat is considered to be cured once a specimen exhibits weight loss of less than 1% over consecutive 12-hour intervals. Weight loss is the result of solvent or water evaporation depending on the type of prime coat material used. During the curing process, there may be time intervals when the material does not evaporate consistently due to sporadic weather conditions (average temperature (°F), relative humidity percentage (%), and wind speed), this is why the “consecutive” criterion is set.

Because of the physical and chemical characteristics of prime coat materials, field-curing may take longer than 1 week. However, samples cured in an oven may take no more than 10 hours, due to higher and controlled temperatures. In order to determine the curing time for oven-cured specimens, field-curing must first take place in order set benchmarks for the oven-curing procedure. Target evaporation percentages are based on the average evaporation percentages of field-cured specimens. This target percentage is applied to the design of the oven-curing procedure specimens of the same type. When the same target evaporation percentages are observed in the laboratory, it can be assumed that curing has occurred.

4.2 TESTED PRIME COAT MATERIALS

4.2.1 MC-30

MC-30 is a kerosene-based prime coat. It is the most commonly used prime coat in the state of Texas. However, there are environmental problems associated with MC-30 due to its kerosene-base. The aim of this research is to understand how many days are required to fully

cure a specimen and to understand all of the weather parameters that can affect the curing process.

The amount of time required for curing to take place along with the relationship between time and solvent evaporation for MC-30 in the months of March 12th-17th, 2014 and April 12th-17th, 2014 including the average daily temperature (°F), average relative humidity, average daily wind speed, average daily atmospheric pressure, and lists the evaporation percentage and the type of base material used are presented in Table 4.1, Figure 4.1 and Figure 4.2.

Table 4.1 Curing time, average weather parameters and evaporation percentage for MC-30 during field-curing

Testing Month	Curing Time (Days) Silt-Size Crushed Limestone/Reference Fine Sand	Average Daily Temp.	Average Relative Humidity	Average Daily Wind Speed	Average Daily Atmospheric Pressure	Evaporation Percentage (%) Silt-Size Crushed Limestone/Reference Fine Sand
March 12 th -17 th , 2014	5/5	58.8°F	53.6%	7mph	30 Hg	25.61/22.83
April 12 th -17 th , 2014	5/5	62.8°F	65%	7mph	30 Hg	21.05/21.36

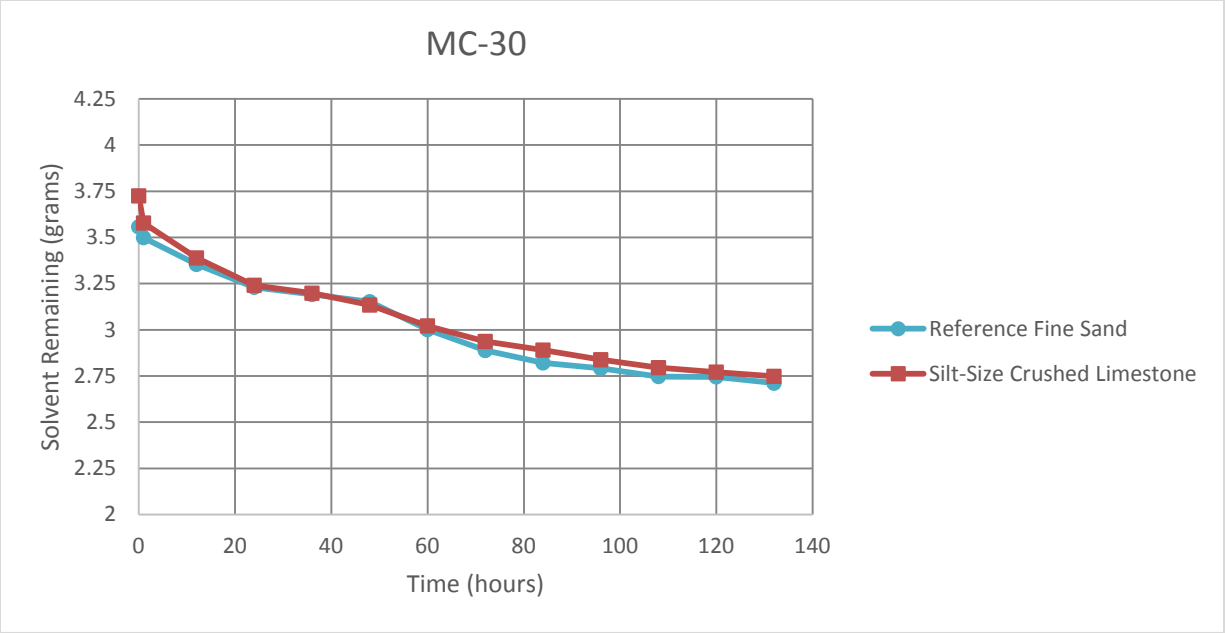


Figure 4.1 Time vs. solvent remaining for MC-30 using reference fine sand and silt-size crushed limestone during March 12th-17th testing

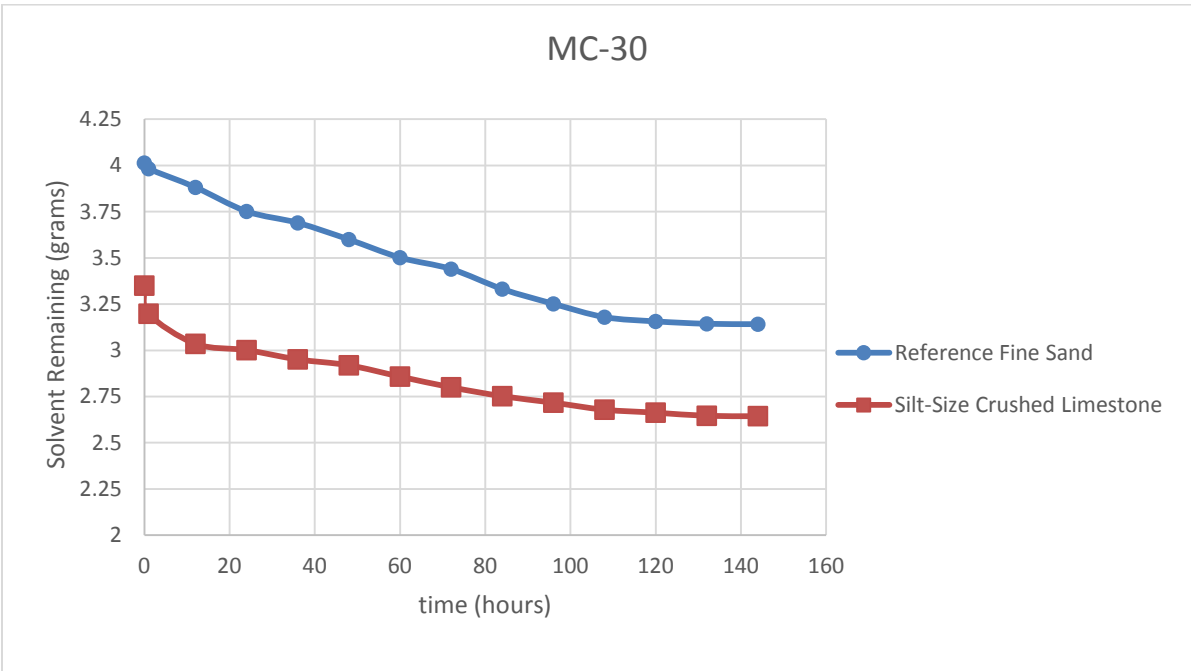


Figure 4.2 Time vs. solvent remaining using reference fine sand and silt-size crushed limestone during April 12th-17th testing

For the specimen to be completely cured the reduction in weight percentage should be less than 1% within a 12hr interval. The reduction in specimen weight relative to time can be found in Appendix B. Therefore, after careful observation, curing time can be understood to be taking place at approximately 120 hours or 5 days for both testing seasons.

For April 12th-17th testing, the evaporation percentage of silt-size crushed limestone is 20.05% and for reference fine sand 21.35%. For March 12th-17th testing, the evaporation percentages using silt-size crushed limestone were 25.61% and for reference fine sand 22.83%. It can also be observed that there is no noticeable difference between the different base materials used due to the similar trends both bases exhibit.

4.2.2 EC-30

For EC-30, the rate of evaporation is very high early. As time increases, the rate of evaporation becomes more and more negligible until it reaches the time where curing is considered to have taken place. In Table 4.2, the data between time and solvent evaporation for the months of March and April are presented. The curing days described in Table 4.2 are based on the evaporation percentage shown in the Figure 4.3 and Figure 4.4.

Table 4.2 Curing Time, Weather Parameters and Evaporation Percentage for EC-30 during field-curing

Testing Time	Curing Time (Days) Silt-Size Crushed Limestone/Reference Fine Sand	Average Daily Temp.	Average Daily Relative Humidity	Average Daily Wind Speed	Average Daily Atmospheric Pressure	Evaporation Percentage (%) Silt-Size Crushed Limestone/Reference Fine Sand
March 12 th -16 th , 2014	3.5/4	60.5°F	57.2%	7mph	30 Hg	89.39/93.13
April 12 th -17 th , 2014	5/5	62.8°F	65%	7mph	30 Hg	86.02/89.26

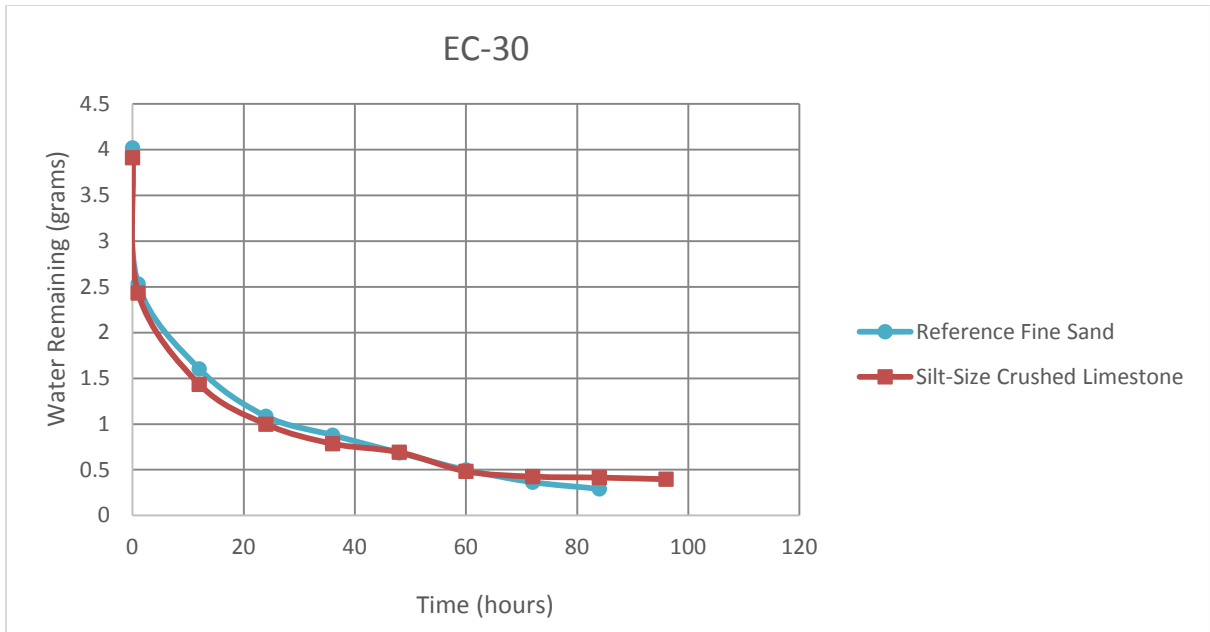


Figure 4.3 Time vs. water remaining for EC-30 using silt-size crushed limestone and reference fine sand during March 12th-16th testing

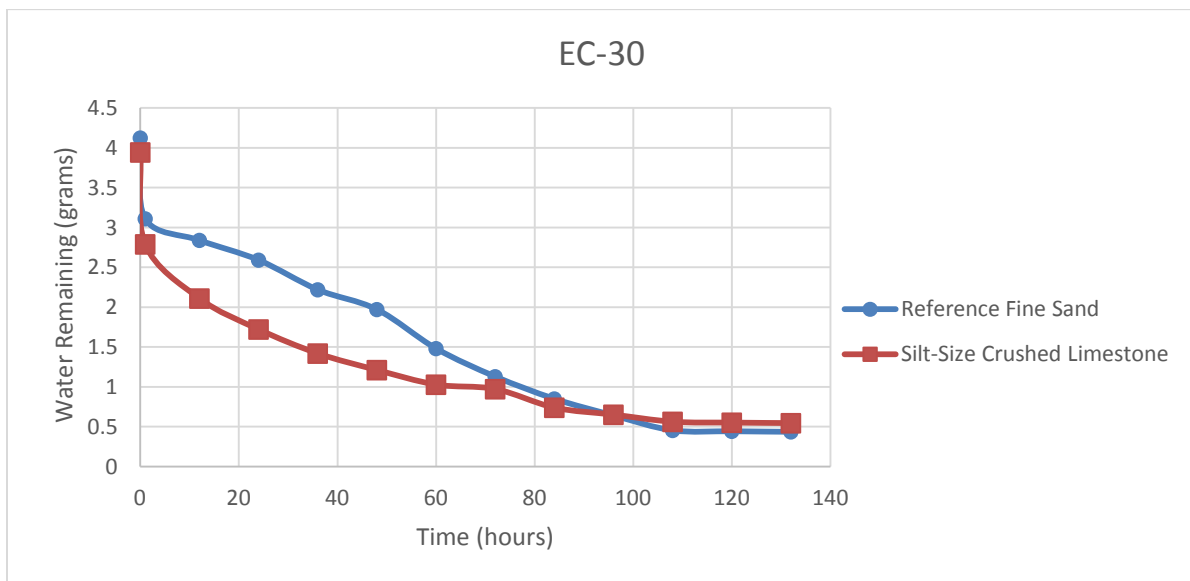


Figure 4.4 Time vs. water remaining for EC-30 using silt-size crushed limestone and reference fine sand during April 12th-17th testing

The amount of days required for curing differ between Figure 4.3 and Figure 4.4. April testing required approximately 5 days, or 120 hours, for curing to take place for both base materials. The evaporation percentage for April testing is 86.02% for silt-size crushed limestone and 89.26% for reference fine sand. March testing requires approximately 3.5 days, or 84 hours, for silt-size crushed limestone and 2.5 days for reference fine sand. The percentage of evaporation for March testing shows 89.39% for silt-size crushed limestone and 93.13% for reference fine sand. Both curves in both Figure 4.3 and Figure 4.4 show similar trends, indicating that there is no a major difference between the different base materials.

4.2.3AEP

The relationship between time, weather conditions and evaporation percentage for AEP are presented in Table 4.3, Figure 4.5 and Figure 4.6. These are the results of the field-curing procedure and are observed through the months of March 2014 and April 2014 using different base material.

Table 4.3 Curing time, weather parameters and evaporation percentage for AEP during field-curing

Testing Time	Curing Time (Days) Silt-Size Crushed Limestone/ Reference Fine Sand	Average Daily Temp.	Average Relative Humidity	Average Daily Wind Speed	Average Daily Atmospheric Pressure	Evaporation Percentage (%) Silt-Size Crushed Limestone/ Reference Fine Sand
March 12 th -17 th , 2014	4.5/4.5	58.8°F	53.7%	6.8mph	30 Hg	30.16/28.34
April 12 th -18 th , 2014	5.5/5	63.7°F	65.4%	7.3mph	30 Hg	21.68/20.35

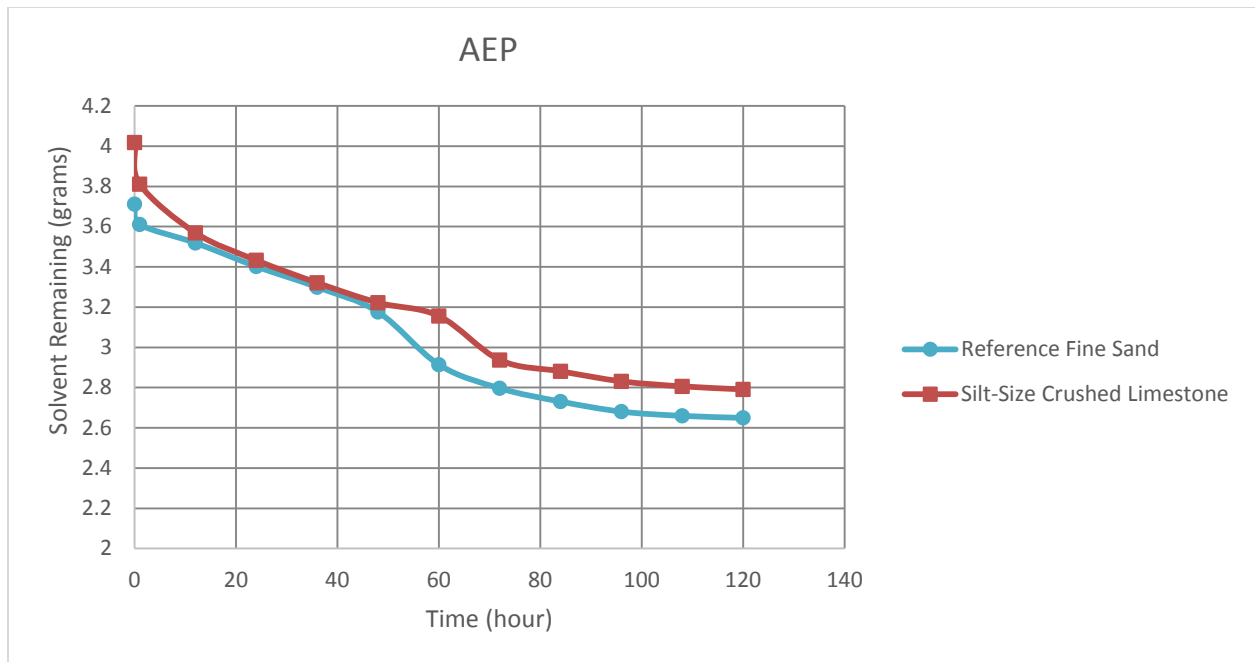


Figure 4.5 Time vs. solvent remaining for AEP using silt-size crushed limestone and reference fine sand during March 12th-17th testing

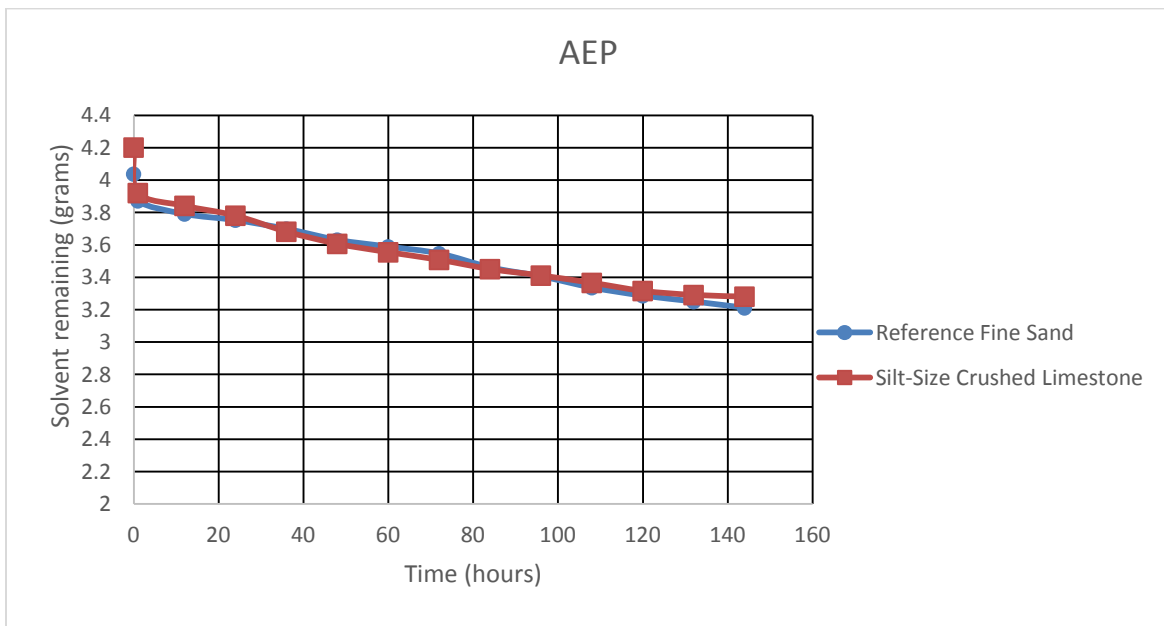


Figure 4.6 Time vs. solvent remaining for AEP using silt-size crushed limestone and reference fine sand during April 12th-18th testing

4.2.4 CSS-1H

The relationship between field-curing time, weather conditions and evaporation percentage for CSS-1H during the testing periods of March and April are presented in Table 4.4, Figure 4.7 and Figure 4.8.

Table 4.4 Curing time, weather parameters and evaporation percentage for CSS-1H during field-curing

Testing Time	Curing Time (Days) Silt-Size Crushed Limestone/ Reference Fine Sand	Average Daily Temp.	Average Relative Humidity	Average Daily Wind Speed	Average Daily Atmospheric Pressure	Evaporation Percentage (%) Silt-Size Crushed Limestone/ Reference Fine Sand
March 12 th -17 th , 2014	4.5/4.5	58.8°F	53.7%	6.8mph	30 Hg	21.3/38.39
April 12 th -17 th , 2014	5/5	62.8°F	65%	7mph	30 Hg	21.72/ 41.4

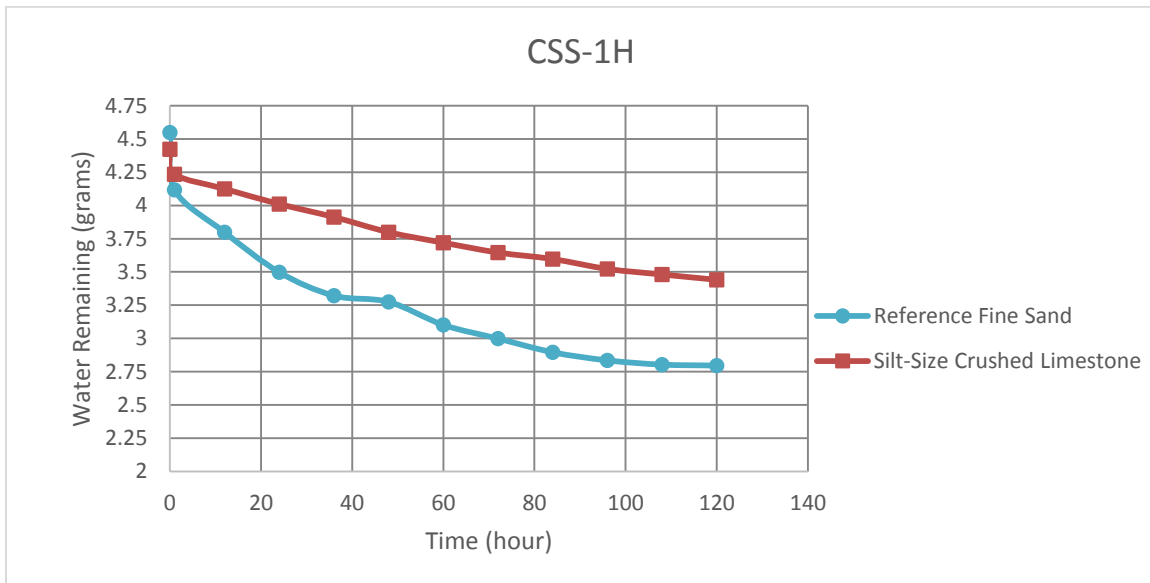


Figure 4.7 Time vs. water remaining for CSS-1H using silt-size crushed limestone and reference fine sand during March 12th-17th testing

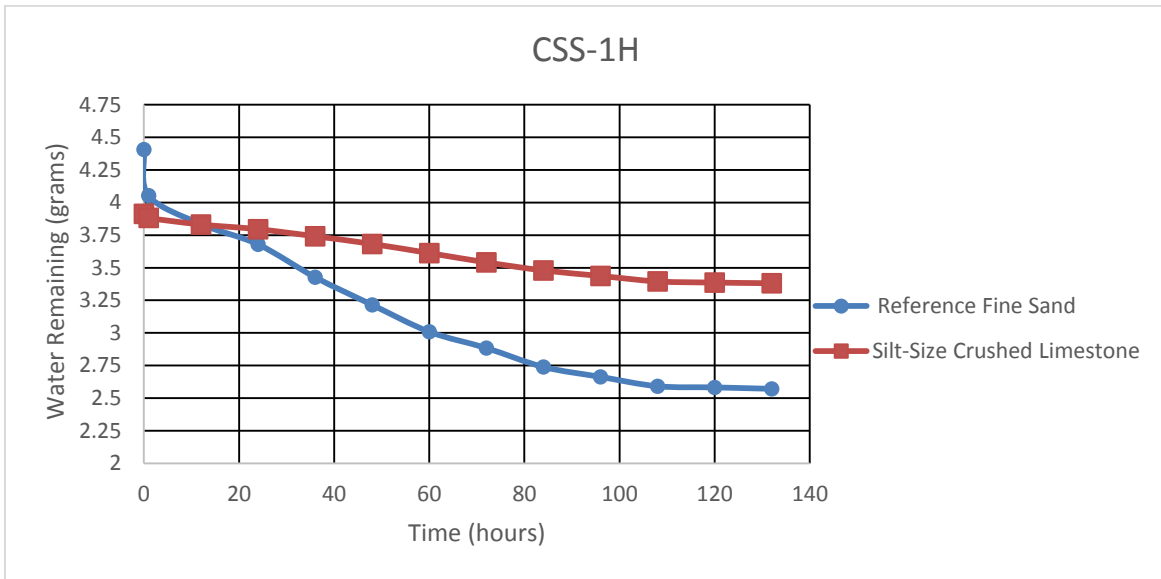


Figure 4.8 Time vs. water remaining for CSS-1H using silt-size crushed limestone and reference fine sand during April 12th-17th testing

The rate of evaporation for CSS-1H, a much higher rate with reference fine sand than with silt-size crushed limestone for April testing, can be seen in the Figure 4.8. March testing yields a similar trend in that the evaporation percentage is higher with reference fine sand than for silt-size crushed limestone.

4.2.5 SS-1H

The relationship between field-curing time, weather conditions and evaporation percentage for SS-1H using different base materials during the testing periods of April 2014 and March 2014 are presented in Table 4.5, Figure 4.9 and Figure 4.10.

Table 4.5 Curing time, weather parameters and evaporation percentages of SS-1H during field-curing

Testing Time	Curing Time (Days) Silt-Size Crushed Limestone/ Fine Reference	Average Daily Temp.	Average Relative Humidity	Average Daily Wind Speed	Average Daily Atmospheric Pressure	Evaporation Percentage (%) Silt-Size Crushed Limestone/ Reference Fine Sand
March 12 th -18 th , 2014	4.5/5.5	59.7°F	53%	7mph	30 Hg	32.06 /33.28
April 12 th -18 th , 2014	6/5	63.7°F	65.4%	7.3mph	30 Hg	17.55/30.07

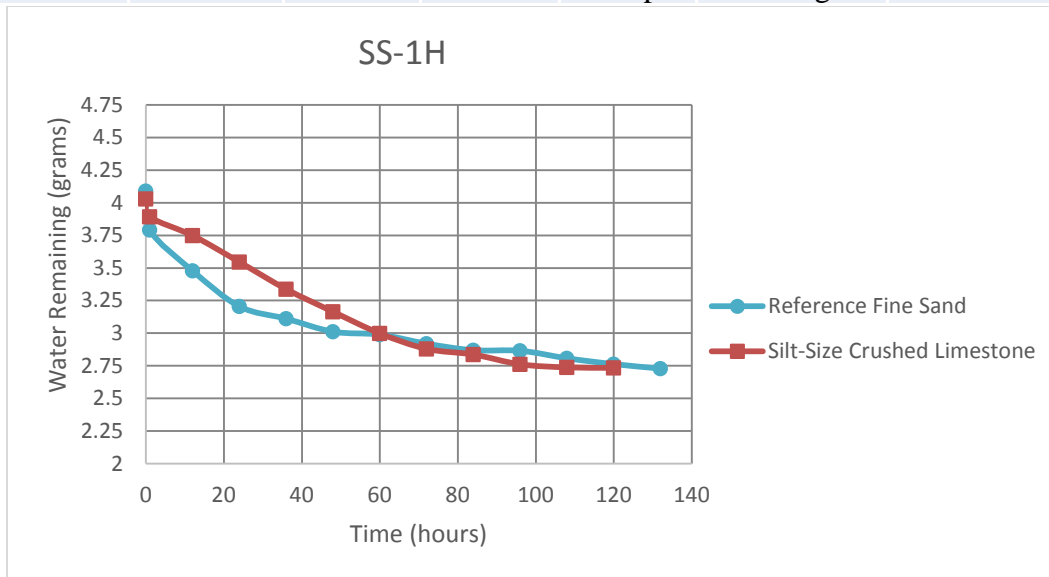


Figure 4.9 Time vs. water remaining for SS-1H using silt-size crushed limestone and reference fine sand during March 12th-18th testing

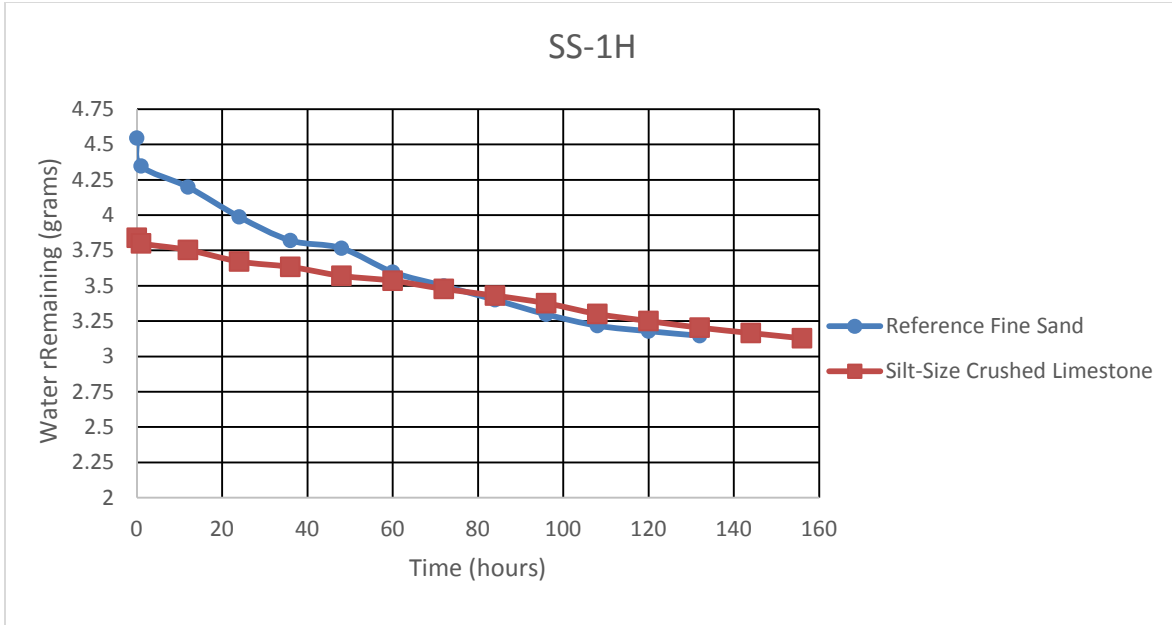


Figure 4.10 Time vs. water remaining for SS-1H using silt-size crushed limestone and reference fine sand during April 12th-18th testing

4.2.6 TP

The relationship between field-curing time, weather parameters and evaporation percentages for TP using different base materials during the testing periods of March and April are presented in Table 4.6, Figure 4.11 and Figure 4.12.

Table 4.6 Curing time, weather parameters and evaporation percentage of TP during field-curing

Testing Time	Curing Time (Days) Silt-Size Crushed Limestone/Reference Fine Sand	Average Daily Temp.	Average Relative Humidity	Average Daily Wind Speed	Average Daily Atmospheric Pressure	Evaporation Percentage (%) Silt-Size Crushed Limestone/Reference Fine Sand
March 12 th -18 th , 2014	5.5/5	59.7°F	53%	7mph	30 Hg	89.8/90.97
April 12 th -17 th , 2014	5/5	62.8°F	65%	7mph	30 Hg	90.46/92.66

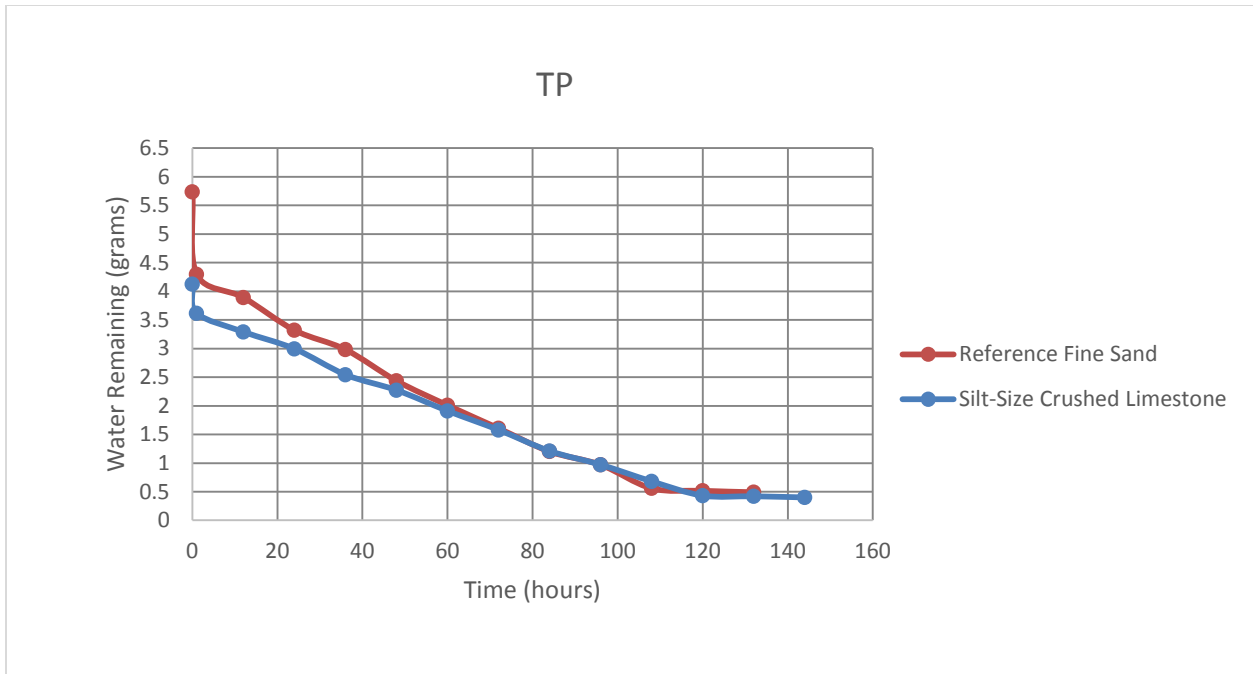


Figure 4.11 Time vs. water remaining for TP using silt-size crushed limestone and reference fine sand during March 12th-18th testing

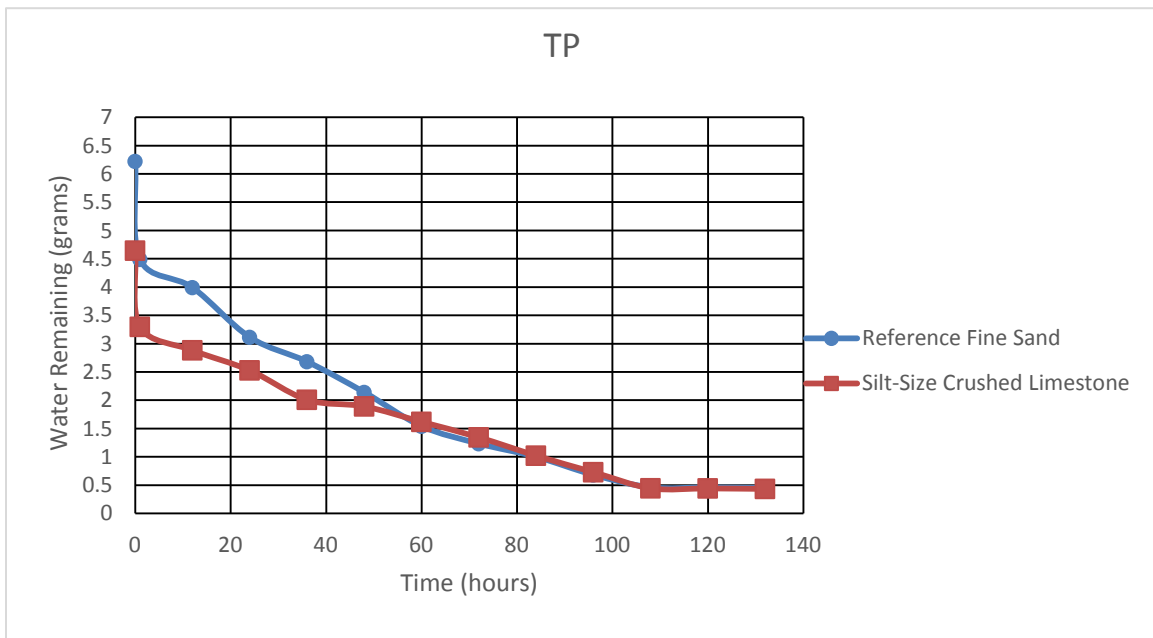


Figure 4.12 Time vs. water remaining for TP using silt-size crushed limestone and reference fine sand during April 12th-17th testing

4.3 OVEN-CURING

Oven-Curing tests are performed in the laboratory on specimens using silt-size crushed limestone and reference fine sand based on the data gathered from the field-curing tests. One group of specimens are exposed to 6 different temperature settings ranging from 50°C to 100°C using reference fine sand and the other group of specimens are exposed to 5 different temperature settings ranging from 50° C-90° C using silt-size crushed limestone.

As mentioned before, when the field specimens are left to cure, the prime coat material is considered cured when a specimen exhibits a change in solvent weight of less than 1% over consecutive 12-hour intervals. To make this concept clear, Table 4.7 below present an example of why the “consecutive” interval criteria is set using the results of MC-30 field-testing for March from 12th-17th and April from 12th-17th. Table 4.7 shows that the specimen is presumed to be cured in March at the 120 hr interval because the evaporation percentage is less than 1%. However only looking for evaporation percentages less than 1% isn’t completely reliable in that field evaporation percentages can fluctuate due to the weather. This is expressed in the April testing table where evaporation percentages are less than 1% occurring at the 48 hr interval. For the specimen to be considered cured, it must show consecutive evaporation percentages less 1% which Table 4.7 express as occurring at the 120 hr interval.

Table 4.7 Field-curing time data of MC-30 using silt-size crushed limestone

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	
March 12 th -17 th , 2014	Amount of solvent remaining (g)	3.725	3.578	3.389	3.241	3.198	3.134	3.021	2.937	2.890	2.838	2.795	2.771	2.748	
	Percentage reduction (interval based) (%)		3.946	5.074	3.973	1.154	1.718	3.034	2.255	1.259	1.399	1.154	0.644	0.617	
	Percentage reduction (cumulative) (%)		3.946	9.020	12.99	14.15	15.87	18.89	21.15	22.41	23.81	24.97	25.61	26.23	
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	144
April 12 th -17 th , 2014	Amount of solvent remaining (g)	3.35	3.198	3.035	3.001	2.951	2.919	2.858	2.800	2.752	2.717	2.679	2.663	2.646	2.644
	Percentage reduction (interval based) (%)		4.537	4.866	1.015	1.493	0.955	1.821	1.728	1.436	1.045	1.134	0.478	0.507	0.060
	Percentage reduction (cumulative) (%)	0.000	4.537	9.403	10.42	11.91	12.87	14.69	16.42	17.85	18.89	20.03	20.51	21.02	21.075

As shown in the above table, when the MC-30 specimen is cured, the total evaporation percentages for March 12th-17th is 25.6% and 20.5% for April 12th-17th. Evaporation percentages are taken from Table 4.7 and presented in Table 4.8 to determine the average evaporation percentages.

Table 4.8 Field-curing evaporation percentages and average evaporation percentage of MC-30

Silt-Size Crushed limestone			
Prime Coat Material	March 12 th -17 th , 2014 Evaporation Percentage (%)	April 12 th -17 th , 2014 Evaporation Percentage (%)	Average Evaporation Percentage (%)
MC-30	25.6	20.5	23.06

The average evaporation percentages from field-curing tests are used to determine the target percentages for oven-curing tests. The amount of time required for oven-curing is a matter of measuring the evaporation percentages of oven-cured specimens and observing how long it takes for the prime coat to reach the target evaporation percentage with oven temperatures. Table 4.9 shows an example of oven-curing evaporation percentages at 70⁰C relative to time. With the given criteria and target evaporation percentages yielded from field-curing tests, it can be presumed that curing takes place at approximately 350 minutes for oven-curing. The evaporation percentage reached at this time is approximately the same evaporation percentage reached in field-testing for MC-30.

Table 4.9 Oven-curing time data of MC-30 using silt-size crushed limestone

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360
70	Amount of solvent remaining (g)	3.632	3.379	3.268	3.206	3.169	3.121	3.071	3.019	2.971	2.921	2.879	2.815	2.789
	Percentage reduction (cumulative %)	0	6.97	10.02	11.73	12.75	14.07	15.45	16.88	18.20	19.58	20.73	22.49	23.21

Table 4.10 Field-cured prime coats evaporation percentages and average evaporation percentage using reference fine sand

Reference Fine Sand			
Prime Coat Material	March 12 th - 17 th , 2014 Evaporation Percentage (%)	April 12 th - 17 th , 2014 Evaporation Percentage (%)	Average Evaporation Percentage (%)
MC-30	22.82	21.35	22.09
EC-30	93.13	89.26	91.20
AEP	28.34	20.35	24.34
CSS-1H	38.39	41.40	39.9
SS-1H	33.28	30.07	31.68
TP	90.97	92.66	91.82

Table 4.11 Field-cured prime coats evaporation percentages and average evaporation percentage using silt-size crushed limestone

Silt-Size Crushed limestone			
Prime Coat Material	March 12 th - 17 th , 2014 Evaporation Percentage (%)	April 12 th - 17 th , 2014 Evaporation Percentage (%)	Average Evaporation Percentage (%)
MC-30	25.60	20.50	23.06
EC-30	89.39	86.02	87.71
AEP	30.16	21.68	25.92
CSS-1H	21.30	21.72	21.51
SS-1H	32.06	17.55	24.81
TP	89.80	90.46	90.13

The above tables display data gathered on the target evaporation percentages for different prime coat material testing. When left in the field to cure, these values represent the observed evaporation percentages for each material to be considered fully cured. Different specimens were tested over multiple months and an average of the evaporation percentages at the point of curing completion was calculated in order to stand as the target percentage for oven-cured testing.

The average evaporation percentages for the different prime coat and for reference fine sand are presented in Table 4.10 and for silt-size crushed limestone in Table 4.11. The target evaporation percentages, gathered from field-curing, are shown in Table 4.10 and Table 4.11. These percentages are applied to the oven-curing procedure presented for each individual prime coat in Table 4.12-Table 4.17. The curing hours are the result of the time required to observe the same target evaporation percentages gathered in the field at any of the given oven temperatures.

Table 4.12 Oven-curing hours and evaporation percentages of MC-30 using silt-size crushed limestone and reference fine sand

MC-30	Silt-Size Crushed Limestone		Reference Fine Sand	
Temperature(°C)	Approximate Curing Hours	Average Evaporation Percentage (%)	Approximate Curing Hours	Average Evaporation Percentage (%)
T=50	9.50	23.06	8.80	22.09
T=60	8.50	23.06	8.10	22.09
T=70	5.90	23.06	6.00	22.09
T=80	5.00	23.06	5.10	22.09
T=90	3.10	23.06	4.00	22.09
T=100		23.06	3.30	22.09

For MC-30, the average evaporation percentage determined from the field-curing tests done in this study is 23.06 using silt-size crushed limestone. This percentage is observed at 50° C in 9.5 hours, at 60° C in 8.5 hours, at 70° C in 5.9 hours, 80° C in 5 hours and 90° C in 3.1. The average evaporation percentage determined from the field-curing tests is 22.09 using reference fine sand. This percentage is observed at 50° C in 8.8 hours, at 60° C in 8.1 hours, at 70° C in 6 hours, 80° C in 5.1 hours, 90° C in 4 hours and 100° C 3.3 hours.

Table 4.13 Oven-curing hours and evaporation percentages of EC-30 using silt-size crushed limestone and reference fine sand

EC-30	Silt-Size Crushed Limestone		Reference Fine Sand	
Temperature(°C)	Approximate Curing Hours	Average Evaporation Percentage (%)	Approximate Curing Hours	Average Evaporation Percentage (%)
T=50	7.30	87.71	6.20	91.20
T=60	6.00	87.71	6.00	91.20
T=70	3.50	87.71	5.70	91.20
T=80	1.30	87.71	3.50	91.20
T=90	1.16	87.71	1.30	91.20
T=100		87.71	1.20	91.20

For EC-30, the average evaporation percentage determined from the field-curing tests done in this study is 87.71 using silt-size crushed limestone. This percentage is observed at 50° C in 7.3 hours, at 60° C in 6 hours, at 70° C in 3.5 hours, 80° C in 1.3 hours and 90° C in 1.16. The average evaporation percentage determined from the field-curing tests is 91.2 using reference fine sand. This percentage is observed at 50° C in 6.2

hours, at 60° C in 6 hours, at 70° C in 5.7 hours, 80° C in 3.5 hours, 90° C in 1.3 and 100° C in 1.2 hours

Table 4.14 Oven-curing hours and evaporation percentages of AEP using silt-size crushed limestone and reference fine sand

AEP	Silt-Size Crushed Limestone		Reference Fine Sand	
Temperature(°C)	Approximate Curing Hours	Average Evaporation Percentage (%)	Approximate Curing Hours	Average Evaporation Percentage (%)
T=50	8.25	25.92	8.95	24.35
T=60	6.25	25.92	8.30	24.35
T=70	5.75	25.92	5.91	24.35
T=80	3.58	25.92	5.50	24.35
T=90	2.25	25.92	3.75	24.35
T=100		25.92	3.41	24.35

For AEP, the average evaporation percentage determined from the field-curing tests done in this study is 25.92 using silt-size crushed limestone. This percentage is observed at 50° C in 8.25 hours, at 60° C in 6.25 hours, at 70° C in 5.75 hours, 80° C in 3.58 hours and 90° C in 2.25. The average evaporation percentage determined from the field-curing tests is 24.35 using reference fine sand. This percentage is observed at 50° C in 8.95 hours, at 60° C in 8.3 hours, at 70° C in 5.91 hours, 80° C in 5.5 hours, 90° C in 3.75, and 100° C in 3.41 hours.

Table 4.15 Oven-curing hours and evaporation percentages of CSS-1H using silt-size crushed limestone and reference fine sand

CSS-1H	Silt-Size Crushed Limestone		Reference Fine Sand	
Temperature(°C)	Approximate Curing Hours	Average Evaporation Percentage (%)	Approximate Curing Hours	Average Evaporation Percentage (%)
T=50	4.92	21.51	8.20	39.90
T=60	4.25	21.51	7.70	39.90
T=70	3.60	21.51	6.50	39.90
T=80	2.58	21.51	6.00	39.90
T=90	1.79	21.51	4.80	39.90
T=100		21.51	2.60	39.90

For CSS-1H, the average evaporation percentage determined from the field-curing tests done in this study is 21.51 using silt-size crushed limestone. This percentage is observed at 50° C in 4.92 hours, at 60° C in 4.25 hours, at 70° C in 3.6 hours, 80° C in 2.58 hours and 90° C in 1.79. The average evaporation percentage determined from the field-curing tests is 39.9 using reference fine sand. This percentage is observed at 50° C in 8.2 hours, at 60° C in 7.7 hours, at 70° C in 6.5 hours, 80° C in 6 hours, at 90° C in 4.8 hours and at 100° C in 2.6 hours.

Table 4.16 Oven-curing hours and evaporation percentages of SS-1H using silt-size crushed limestone and reference fine sand

SS-1H	Silt-Size Crushed Limestone		Reference Fine Sand	
Temperature(°C)	Approximate Curing Hours	Average Evaporation Percentage (%)	Approximate Curing Hours	Average Evaporation Percentage (%)
T=50	6.91	24.81	6.60	31.68
T=60	6.66	24.81	6.20	31.68
T=70	5.66	24.81	5.83	31.68
T=80	3.66	24.81	5.25	31.68
T=90	2.50	24.81	4.86	31.68
T=100		24.81	2.70	31.68

For SS-1H, the average evaporation percentage determined from the field-curing tests done in this study is 24.81 using silt-size crushed limestone. This percentage is observed at 50° C in 6.91 hours, at 60° C in 6.66 hours, at 70° C in 5.66 hours, 80° C in 3.66 hours and 90° C in 2.5. The average evaporation percentage determined from the field-curing tests is 31.68 using reference fine sand. This percentage is observed at 50° C in 6.6 hours, at 60° C in 6.2 hours, at 70° C in 5.83 hours, 80° C in 5.25 hours, at 90° C in 4.86 and at 100° C in 2.7 hours.

Table 4.17 Oven-curing hours and evaporation percentages of TP using silt-size crushed limestone and reference fine sand

TP	Silt-Size Crushed Limestone		Reference Fine Sand	
Temperature(°C)	Approximate Curing Hours	Average Evaporation Percentage (%)	Approximate Curing Hours	Average Evaporation Percentage (%)
T=50	7.41	90.13	4.08	91.82
T=60	5.90	90.13	3.20	91.82
T=70	4.30	90.13	2.58	91.82
T=80	2.66	90.13	2.25	91.82
T=90	1.90	90.13	1.58	91.82
T=100		90.13	1.10	91.82

For TP, the average evaporation percentage determined from the field-curing tests done in this study is 90.13 using silt-size crushed limestone. This percentage is observed at 50° C in 7.41 hours, at 60° C in 5.9 hours, at 70° C in 4.3 hours, 80° C in 2.66 hours and 90° C in 1.9. The average evaporation percentage determined from the field-curing tests is 91.82 using reference fine sand. This percentage is observed at 50° C in 4.08 hours, at 60° C in 3.2 hours, at 70° C in 2.58 hours, 80° C in 2.25 hours at 90° C in 1.58 and at 100° C in 1.1 hours.

CHAPTER 5 Water Absorption Tests Results

5.1 INTRODUCTION

After curing has taken place, water absorption tests are performed. This section explains the results of these tests.

Some of the specimens made for this study formed cracks. Water would be able to seep into the cracks and drastically affect the water absorption results, they are not accounted for in the results. The details of the testing procedure are given in Chapter 3.

5.2 OVEN-CURED PRIME COATS USING SILT SIZE SILT-SIZE CRUSHED LIMESTONE

Table 5.1 Water absorption for oven-cured prime coats using silt-size crushed limestone

Prime Coat Material	Water Absorption (ml)
MC 30	0.11
CSS 1H	4.71
TP	1.31
SS-1H	4.62
EC-30	13.98
AEP	0.50

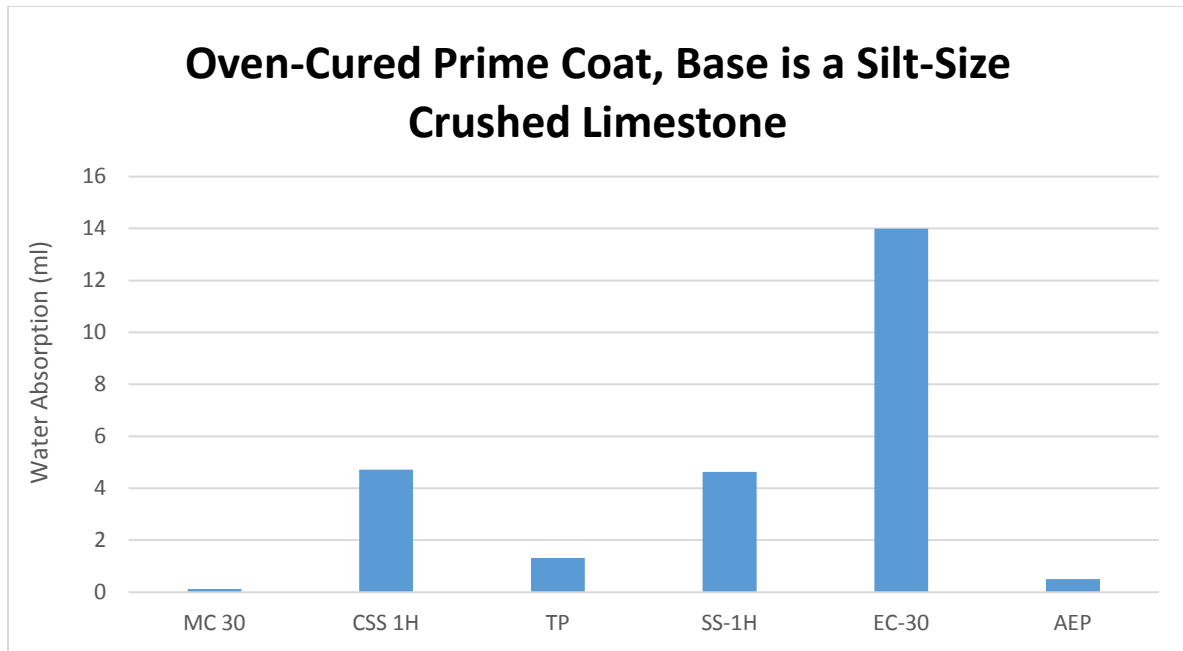


Figure 5.1 Comparison of water absorption of oven-cured prime coats using silt-size crushed limestone

In Table 5.1 and Figure 5.1, the observed levels of testing the water absorption for different prime coats using silt-size crushed limestone after oven-curing are presented. It is noted in Figure 5.1 that MC-30 has the lowest water absorption rate while EC-30 has the highest. The lowest to highest rate of water absorption of the prime coat are as follows: MC-30, AEP, TP, SS-1H, CSS-1H, EC-30. From these results, we can see that MC-30 and AEP give the best overall performance in water absorption with silt-size crushed limestone after oven-curing.

5.3 OVEN-CURED PRIME COATS USING REFERENCE FINE SAND

Table 5.2 Water absorption for oven-cured prime coats using reference fine sand

Prime Coat Material	Water Absorption(ml)
MC 30	0.15
CSS 1H	1.59
TP	4.01
SS-1H	3.12
EC-30	18.51
AEP	0.68

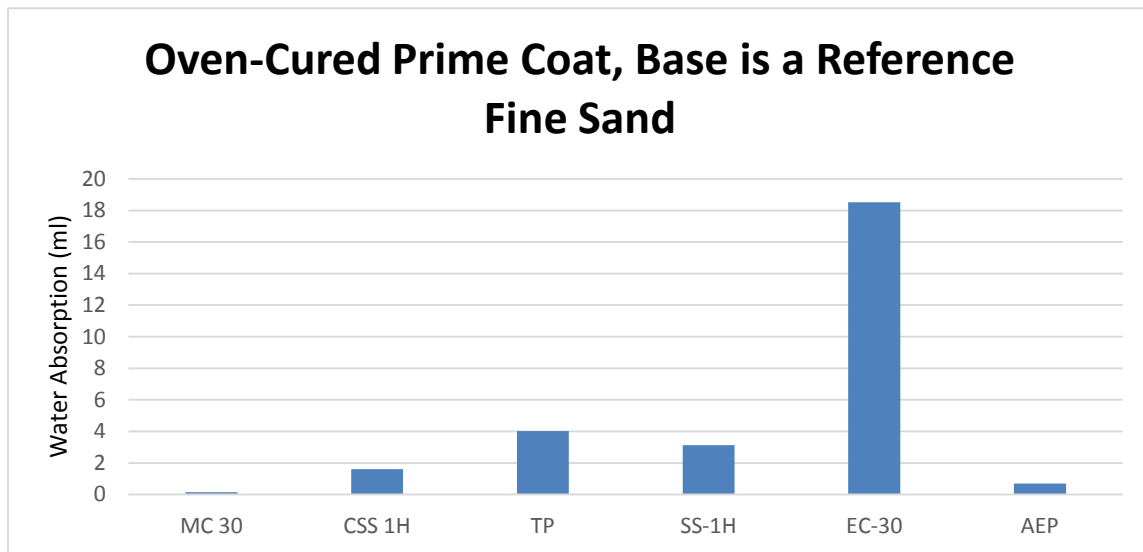


Figure 5.2 Comparison of water absorption of oven-cured prime coats using reference fine sand

In Figure 5.2 and Table 5.2, the observed levels of testing the water absorption for prime coats using reference fine sand after oven-curing are presented. It can be observed from Figure 5.2 that EC-30 has the highest rate of water absorption while MC-30 has the lowest. The values from lowest to highest of prime coat are as follows: MC-30, AEP,

CSS-1H, SS-1H, TP, and EC-30. MC-30 and AEP give the best performance using reference fine sand after oven-curing.

5.4 FIELD CURED PRIME COATS USING SILT-SIZE CRUSHED LIMESTONE

Table 5.3 Water absorption for field-cured prime coats using silt-size crushed limestone

Prime Coat Material	Water Absorption (ml)
MC 30	0.17
CSS 1H	1.00
TP	3.21
SS-1H	0.85
EC-30	19.15
AEP	0.24

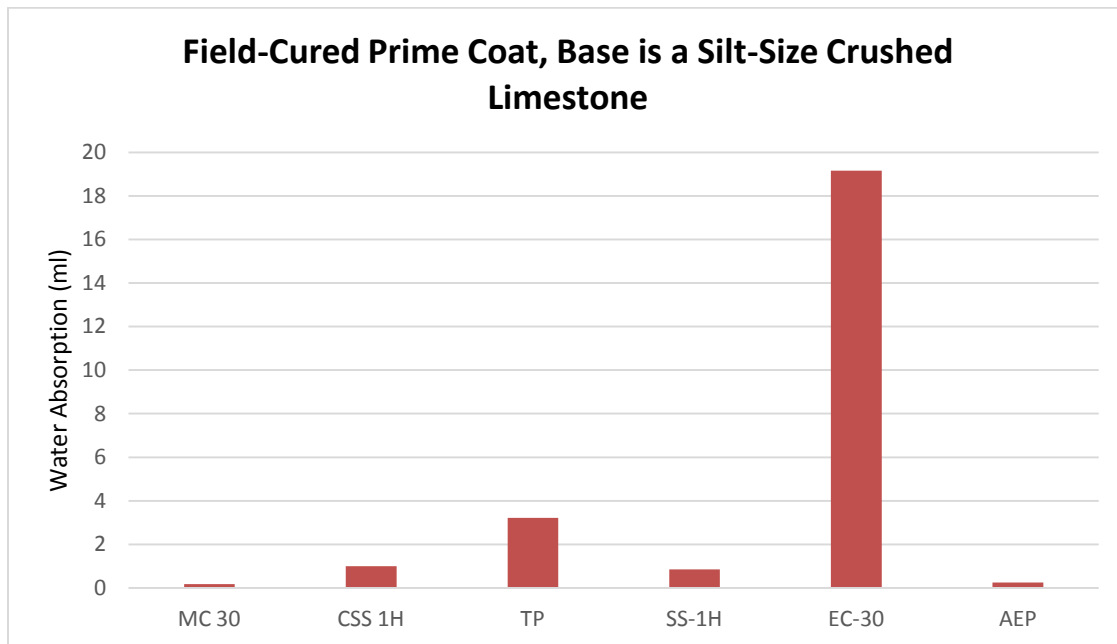


Figure 5.3 Comparison of water absorption of field-cured prime coats using silt-size crushed limestone

In Table 5.3 and Figure 5.3, the observed levels of testing the water absorption for different prime coats using the silt-size crushed limestone base after field-curing are presented. In Figure 5.3, MC-30 shows the lowest rate of water absorption while EC-30 shows the highest. The rates of lowest to highest rate of water absorption is as follows: MC-30, AEP, SS-1H, CSS-1H, TP, EC-30. MC-30 and AEP give the best performance with silt-size crushed limestone after field-curing.

5.5 FIELD-CURED PRIME COATS USING REFERENCE FINE SAND

Table 5.4 Water absorption for field-cured prime coats using reference fine sand

Prime Coat Material	Water Absorption (ml)
MC 30	0.15
CSS 1H	1.98
TP	4.41
SS-1H	2.25
EC-30	18.66
AEP	0.27

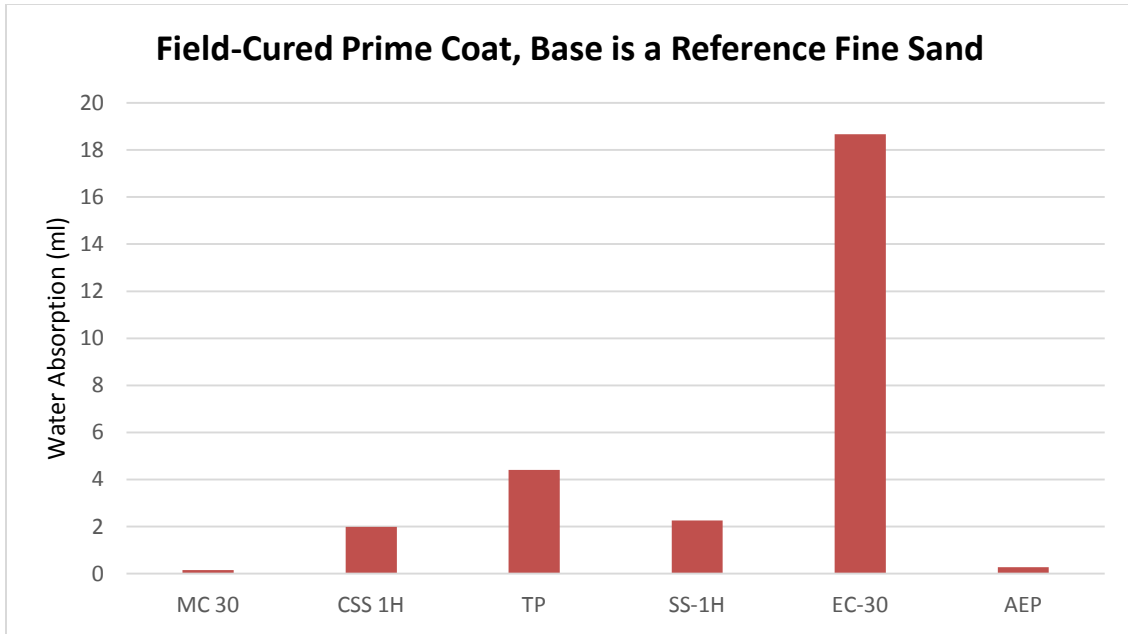


Figure 5.4 Comparison of water absorption for field-cured prime coats using reference fine sand

In Table 5.4 and Figure 5.4, the observed levels of testing the water absorption for different prime coats using a reference fine sand base after field-curing are presented. In Figure 5.4, MC-30 shows the least amount of water absorption while EC-30 shows the most amount. In order from lowest to highest rates of water absorption: MC-30, AEP, CSS-1H, SS-1H, TP, EC-30. MC-30 and AEP give the best performance using reference fine sand after field-curing.

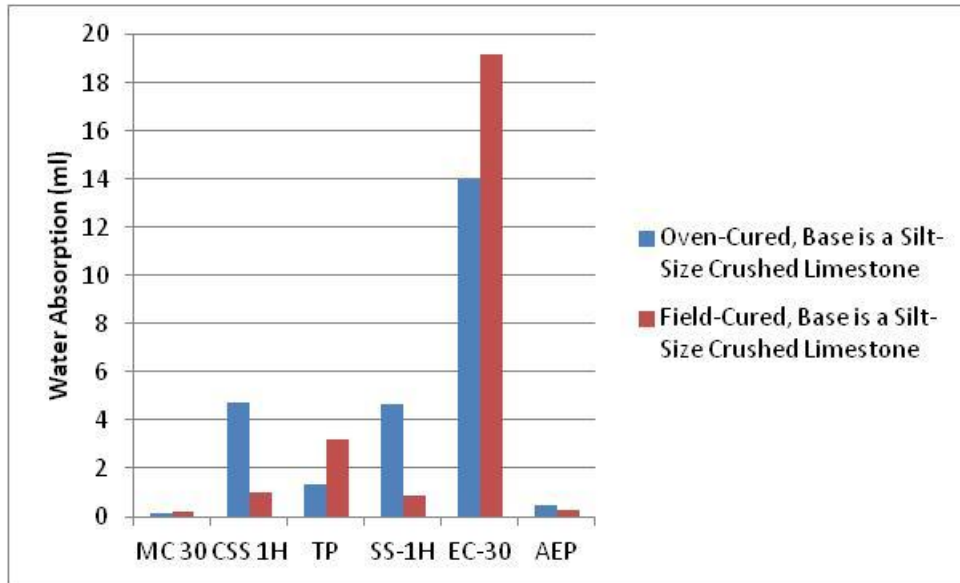


Figure 5.5 Comparison of water absorption tests for oven-cured and field-cured specimens using silt-size crushed limestone

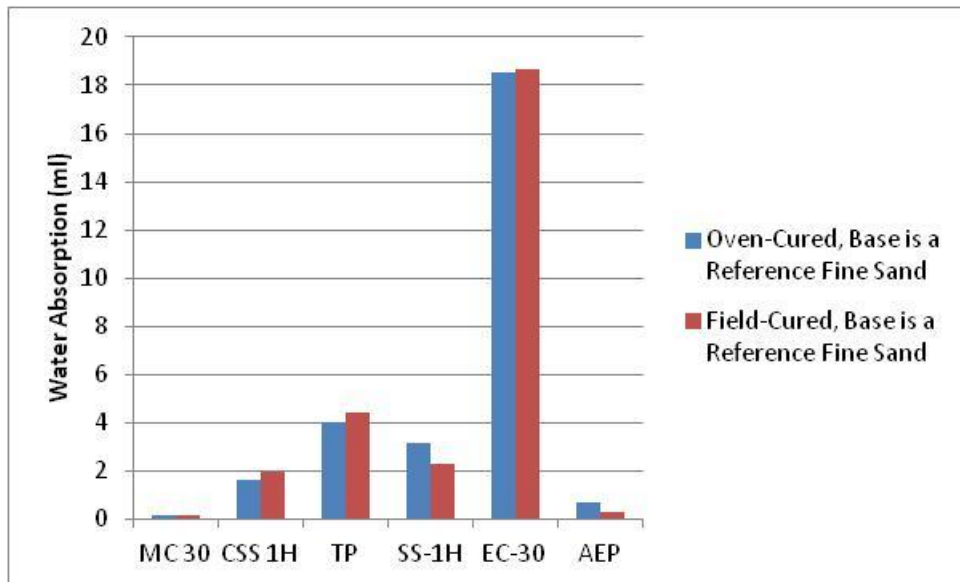


Figure 5.6 Comparison of water absorption tests for oven-cured and field-cured specimens using reference fine sand

A comparison of field-cured and oven-cured water absorption tests for all prime coat specimens using silt-size crushed limestone are presented in Figure 5.5 and reference

fine sand presented in Figure 5.6. There are minute differences between the field and oven data for Figure 5.6. As we can see in Figure 5.5 silt-size crushed limestone shows more of a difference in field-curing and oven-curing while reference fine sand in Figure 5.6 shows less of a difference. Based on Figure 5.5 and Figure 5.6, reference fine sand may be the more suitable base material for recreating field-curing data in the laboratory in terms of water absorption.

CHAPTER 6 Indirect Indicator of Relative Strength

6.1 INTRODUCTION

This section explains the results of the indirect indicator of relative strength performed in this study. One type of indirect indicator of relative strength is conducted immediately after water absorption tests while the other indirect indicator of relative strength is conducted after 5 days of drying in the field. Each test procedure also uses both a 1mm modified diameter tip and a 2mm modified diameter tip.

The effect of using different base material and different curing methods in terms of an indirect indicator of relative strength is provided in this section. An in depth explanation of the testing procedure is given in Chapter 3.

6.2 OVEN-CURED PRIME COATS USING SILT-SIZE CRUSHED LIMESTONE

Table 6.1 Average indirect indicator of relative strength of oven-cured prime coat using silt-size crushed limestone

Prime Coat Material	1mm Modified Diameter Tip (Immediately after Water Absorption Tests)(psi)	2mm Modified Diameter Tip (Immediately after Water Absorption Tests)(psi)	1mm Modified Diameter Tip (5 Days of Field-Drying after Water Absorption Tests)(psi)	2mm Modified Diameter Tip (5 Days of Field-Drying after Water Absorption Tests)(psi)
MC 30	4.12	5.36	7.81	11.72
CSS-1H	7.53	9.34	12.71	16.58
TP	12.60	15.27	41.46	47.40
SS-1H	7.17	9.19	9.66	14.13
EC-30	4.76	5.61	6.96	11.96
AEP	3.69	3.83	3.87	4.44

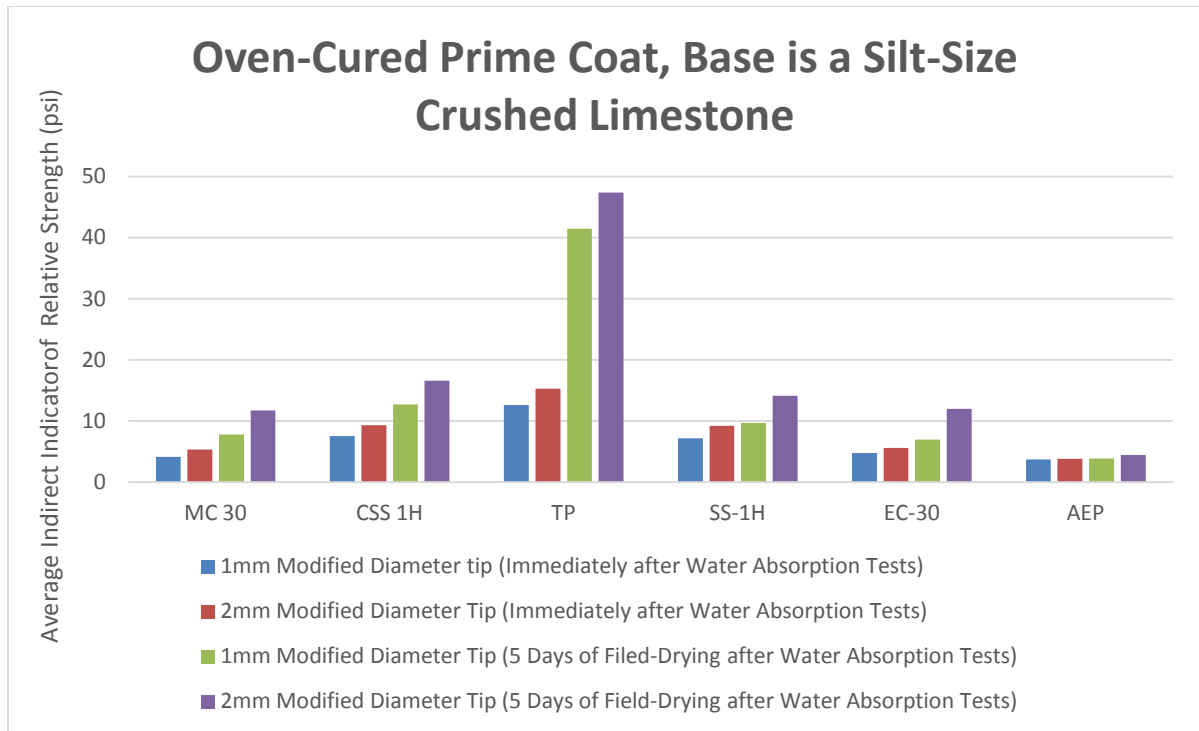


Figure 6.1 Comparison of the average indirect indicator of relative strength for oven-cured prime coats using silt-size crushed limestone

In Table 6.1 and Figure 6.1, the average indirect indicator of relative strength values of different prime coat materials with a silt-size crushed limestone base after oven-curing are presented. They also show the indirect indicator of relative strength values for samples tested immediately after water absorption tests and samples that are allowed to dry in the field for 5 days after water absorption tests. As the diameter tip is modified from 1mm to 2mm, an increase in the indirect indicator of relative strength between samples tested immediately after water absorption tests and samples that are allowed to dry in the field for 5 days after water absorption tests is observed. From the results, it is possible to determine that TP has the highest for both indirect indicator of relative

strength scenarios while AEP has the lowest. TP also shows the greatest indirect indicator of relative strength increase from tests immediately after water absorption tests to tests performed on specimens after they are allowed to dry in the field for 5 days.

The indirect indicator of relative strength of the specimens tested immediately after water absorption tests from lowest to highest using the 1mm modified diameter tip are as follows: AEP, MC-30, EC-30, SS-1H, CSS-1H, and TP. The same rankings apply to the 2mm modified diameter tip immediately after water absorption test, the 2mm modified diameter tip 5 days after water absorption test. The 1mm modified diameter tip 5 days after water absorption test ranking from lowest to highest is as follows: AEP, EC-30, MC-30, SS-1H, CSS-1H, and TP.

6.3 OVEN-CURED PRIME COATS USING REFERENCE FINE SAND

Table 6.2 Average indirect indicator of relative strength of oven-cured prime coats using reference fine sand

Prime Coat Material	1mm Modified Diameter Tip (Immediately after Water Absorption Tests)(psi)	2mm Modified Diameter Tip (Immediately after Water Absorption Tests)(psi)	1mm Modified Diameter Tip (5 Days of Field-Drying after Water Absorption Tests)(psi)	2mm Modified Diameter Tip (5 Days of Field Drying after Water Absorption Tests)(psi)
MC 30	3.85	3.88	4.35	5.21
CSS 1H	7.63	9.85	16.33	23.52
TP	15.92	19.11	43.17	57.38
SS-1H	5.98	8.82	15.68	23.08
EC-30	3.34	3.46	8.70	12.60
AEP	3.05	3.88	3.64	4.67

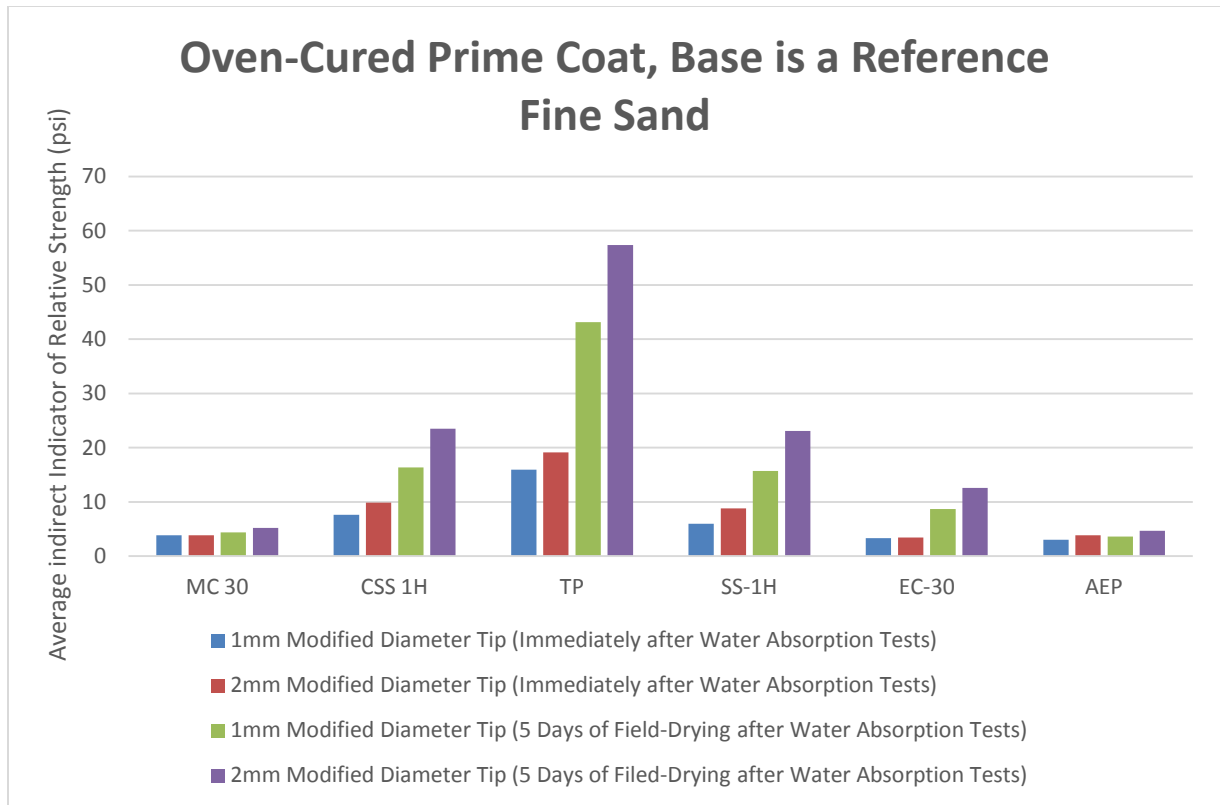


Figure 6.2 Comparison of average indirect indicator of relative strength of oven-cured prime coats using reference fine sand

In Table 6.2 and Figure 6.2, the average indirect indicator of relative strength for specimens tested immediately after water absorption tests and specimens allowed to dry in the field for 5 days after water absorption tests of different prime coat using reference fine sand after being oven-cured are presented. The values of both indirect indicator of relative strength scenarios are obtained from the 1mm modified diameter tip and the 2mm modified diameter tip are shown in Table 6.2 and Figure 6.2. TP has the best overall indirect indicator of relative strength performance while AEP has the lowest, except for

the indirect indicator of relative strength scenario test immediately after water absorption tests using the 2mm modified diameter tip, which has the same value as EC-30.

The indirect indicator of relative strength values immediately after water absorption tests from lowest to highest using the 1mm modified diameter tip are as follows: AEP, EC-30 , MC-30, SS-1H, CSS-1H, and TP. Indirect indicator of relative strength values tested immediately after water absorption tests from lowest to highest using the 2mm modified are as follows: EC-30, AEP and MC-30 are equal, SS-1H, CSS-1H, TP. Indirect indicator of relative strength values after 5 days of field-drying after water absorption tests from lowest to highest using the 1mm are as follows: AEP, MC-30, EC-30, SS-1H, CSS-1H, and TP and the same rankings apply when using the 2mm modified diameter tip.

6.4 FIELD-CURED PRIME COATS USING SILT-SIZE CRUSHED LIMESTONE

Table 6.3 Average indirect indicator of relative strength of field-cured primes coat using silt-size crushed limestone

Prime Coat Material	1mm Modified Diameter Tip (Immediately after Water Absorption Tests)(psi)	2mm Modified Diameter Tip (Immediately after Water Absorption Tests)(psi)	1mm Modified Diameter Tip (5 Days of Field-Drying after Water Absorption)(psi)	2mm Modified Diameter Tip (5 Days of Field-Drying after Water Absorption)(psi)
MC 30	3.15	3.83	8.03	12.43
CSS-1H	7.01	9.94	13.23	17.48
TP	11.80	12.78	42.60	49.41
SS-1H	6.83	9.19	11.98	18.06
EC-30	3.51	4.26	11.32	17.75
AEP	3.06	3.46	3.59	4.17

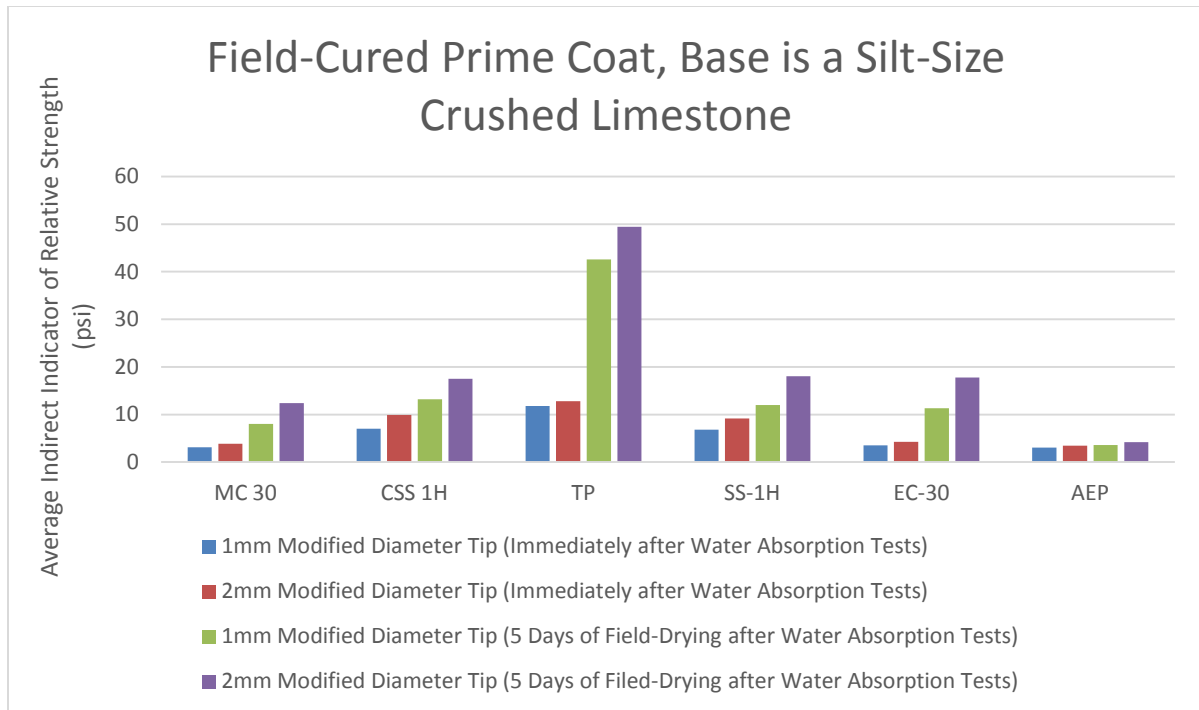


Figure 6.3 Comparison of the average indirect indicator of relative strength of field-cured prime coat using silt-size crushed limestone

In Table 6.3 and Figure 6.3, the average indirect indicator of relative strength values of different prime coat materials using silt-size crushed limestone after field-curing are presented. They also show the values of tests performed immediately after water absorption tests and tests performed 5 days of field-drying after water absorption tests using the 1mm modified diameter tip and the 2mm modified diameter tip. TP shows the best overall performance while AEP shows the overall lowest performance.

The indirect indicator of relative strength values for specimens tested immediately after water absorption tests from lowest to highest using the 1mm modified diameter tip in the following order: AEP, MC-30 , EC-30, SS-1H, CSS-1H, and TP and the same

rankings apply to the tests using the 2mm modified diameter tip. Indirect indicator of relative strength values for specimens allowed to dry in the field for 5 days after water absorption tests from lowest to highest for the 1mm modified diameter tip are as follows: AEP, MC-30, EC-30, SS-1H, CSS-1H, and TP. Increasing indirect indicator of relative strength values for specimens allowed to dry in the field for 5 days after water absorption tests from lowest to highest for the 2mm modified diameter tip are as follows: AEP, MC-30, EC-30, SS-1H, CSS-1H, and TP.

6.5 FIELD-CURED PRIME COATS USING REFERENCE FINE SAND

Table 6.4 Average indirect indicator of relative strength of of different prime coat using reference fine sand after field-cured

Prime Coat Material	1mm Modified Diameter Tip (Immediately after Water Absorption Tests)(psi)	2mm Modified Diameter Tip (Immediately after Water Absorption Tests)(psi)	1mm Modified Diameter Tip (5 Days of Field-Drying after Water Absorption Tests)(psi)	2mm Modified Diameter Tip (5 Days of Field-Drying after Water Absorption Tests)(psi)
MC 30	3.33	3.64	7.90	9.98
CSS 1H	6.92	9.50	14.47	22.63
TP	10.65	12.78	47.93	59.24
SS-1H	7.37	9.19	20.86	27.29
EC-30	3.20	4.26	17.31	22.85
AEP	3.24	3.46	3.73	4.26

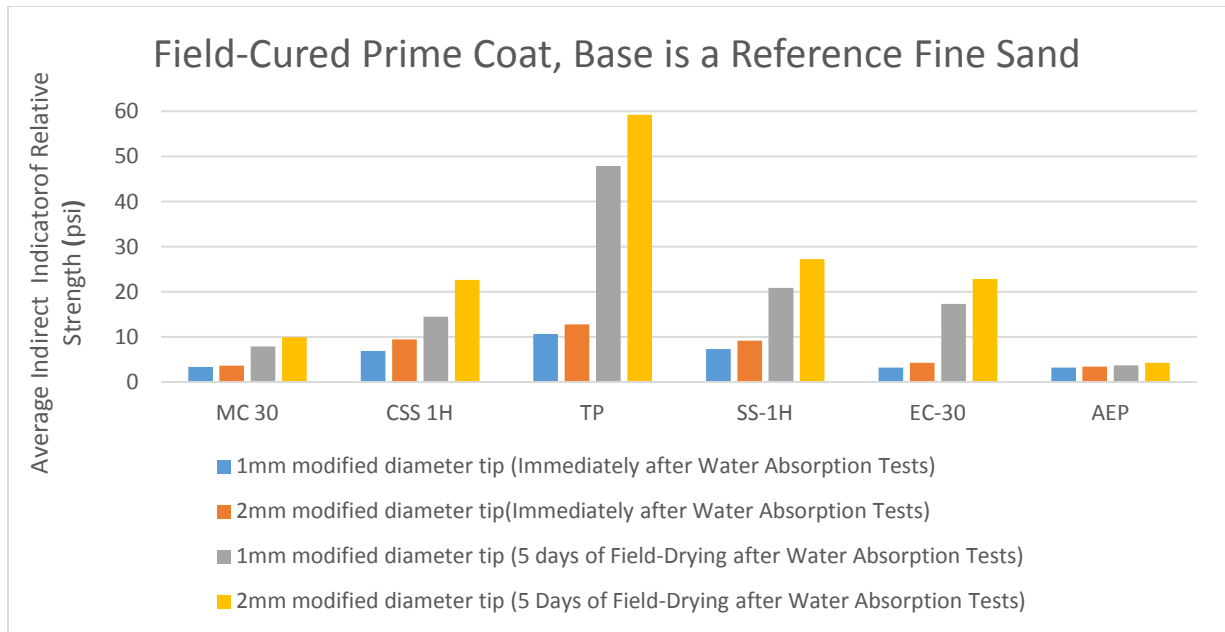


Figure 6.4 Comparison of average indirect indicator of relative strength of different prime coat using reference fine sand after field-cured

In Table 6.4 and Figure 6.4, the average indirect indicator of relative strength values of different prime coat using reference fine sand after field-curing are presented. They also show the indirect indicator of relative strength for specimens tested immediately after water absorption tests and specimens tested after 5 days of field-drying after water absorption tests using 1mm modified diameter tip and 2mm modified diameter tip. TP shows the best overall performance while AEP has the lowest overall performance except for the values from tests immediately after water absorption tests using the 1mm modified diameter tip.

The indirect indicator of relative strength rankings for specimens tested immediately after water absorption tests from lowest to highest using the 1mm modified

diameter tip are as follows: EC-30, AEP, MC-30, CSS-1H, SS-1H, and TP. Indirect indicator of relative strength rankings for the same testing scenario from lowest to highest for the 2mm modified are as follows: AEP, MC-30, EC-30, SS-1H, CSS-1H, and TP. Indirect indicator of relative strength rankings for specimens tested 5 days after water absorption tests from lowest to highest for the 1mm modified diameter tip are as follows: AEP, MC-30, CSS-1H, EC-30 SS-1H, and TP. Indirect indicator of relative strength rankings for the same testing scenario from lowest to highest for the 2mm modified diameter tip are as follows: AEP, MC-30, CSS-1H, EC-30, SS-1H, and TP.

MC-30, cutback asphalt, shows overall increasing indirect indicator of relative strength moving from testing immediately after water absorption tests to testing 5 days after field drying and moving from the 1mm modified diameter tip to the 2mm modified diameter tip. All of the other prime coat materials, regardless of base material and curing method show the same trend. AEP however is the only one that performs differently for the oven-cured prime coat using reference fine sand. The indirect indicator of relative strength using 1mm modified diameter tip after 5 days of field-drying rankings are lower than that of the 2mm modified diameter tip immediately after water absorption. TP yielded the overall best performance.

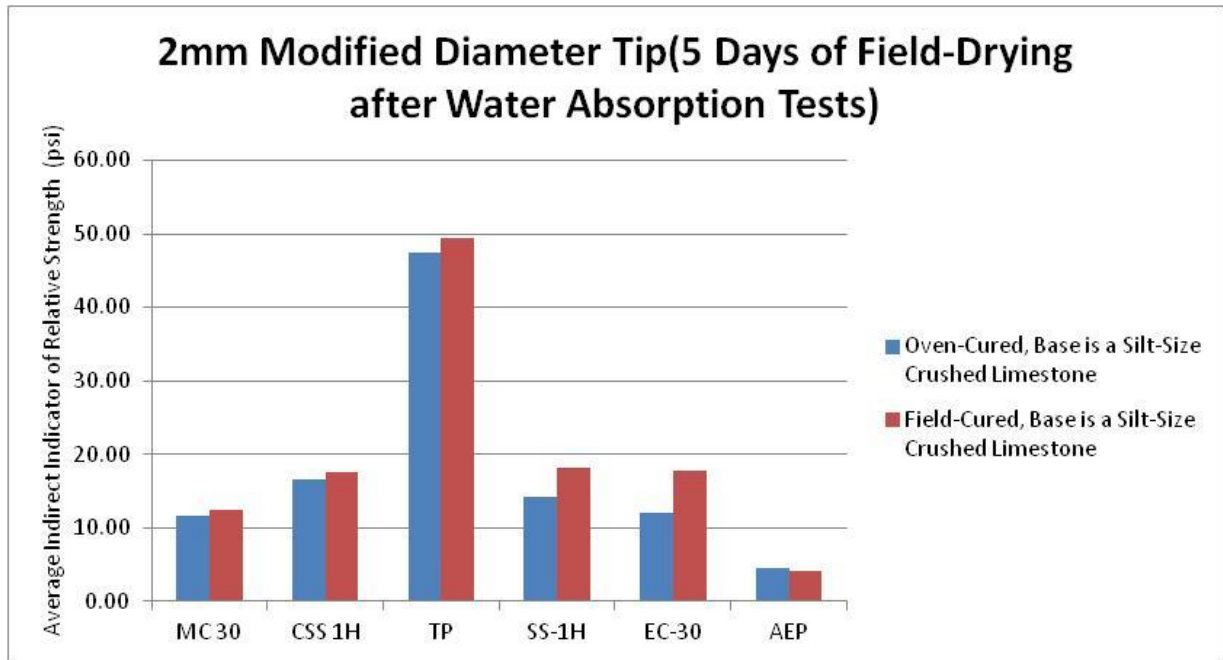


Figure 6.5 Comparison average of indirect indicator of relative strength after 5 days of field-drying using silt-size crushed limestone for oven-cured and field-cured specimens and the 2mm modified diameter tip

In Figure 6.5, a comparison of oven-cured and field-cured specimens and the indirect indicator of relative strength values of each prime coat using silt-size crushed limestone and the 2mm modified diameter tip allowed to dry for 5 days after water absorption tests are presented. In Figure 6.5, the indirect indicator of relative strength values of field-cured specimens are slightly higher than oven-cured specimens. Regardless, the difference in indirect indicator of relative strength are not substantially higher.

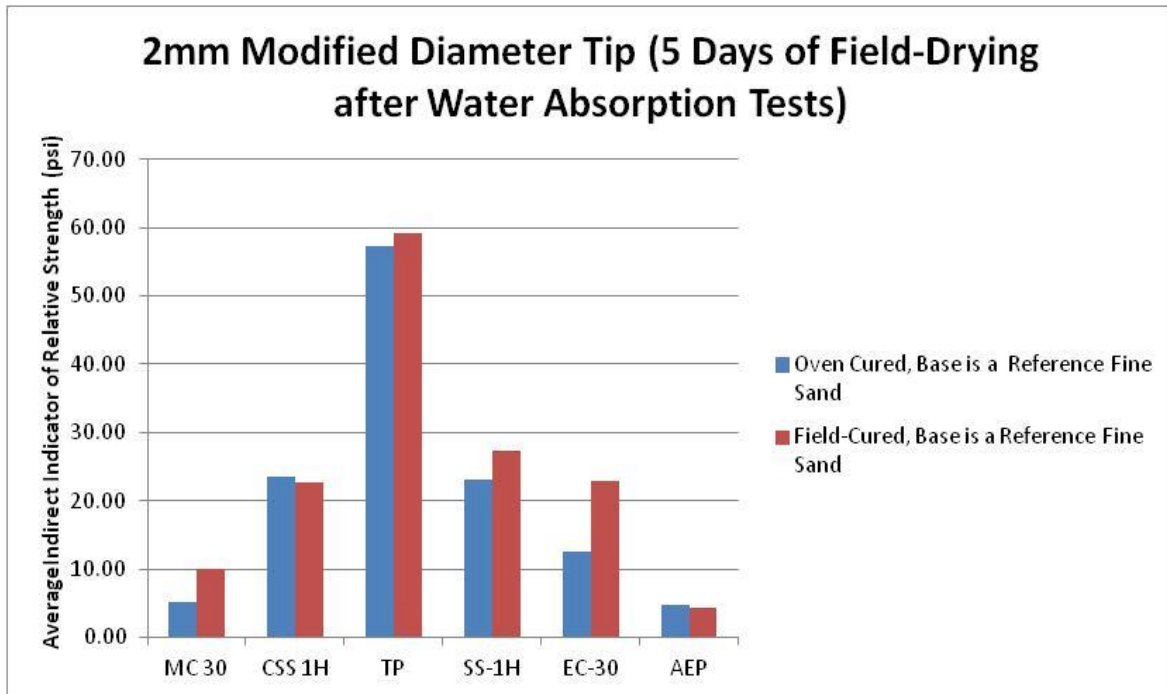


Figure 6.6 Comparison of average indirect indicator of relative strength for oven-cured and field-cured specimens allowed to dry in the field for 5 days after water absorption tests using reference fine sand and the 2mm modified diameter tip

In Figure 6.6, the indirect indicator of relative strength values for field-cured specimens tested 5 days after water absorption are slightly higher than oven-cured specimens, with the exception of CSS-1H and AEP. The difference in indirect indicator of relative strength is only substantial for EC-30.

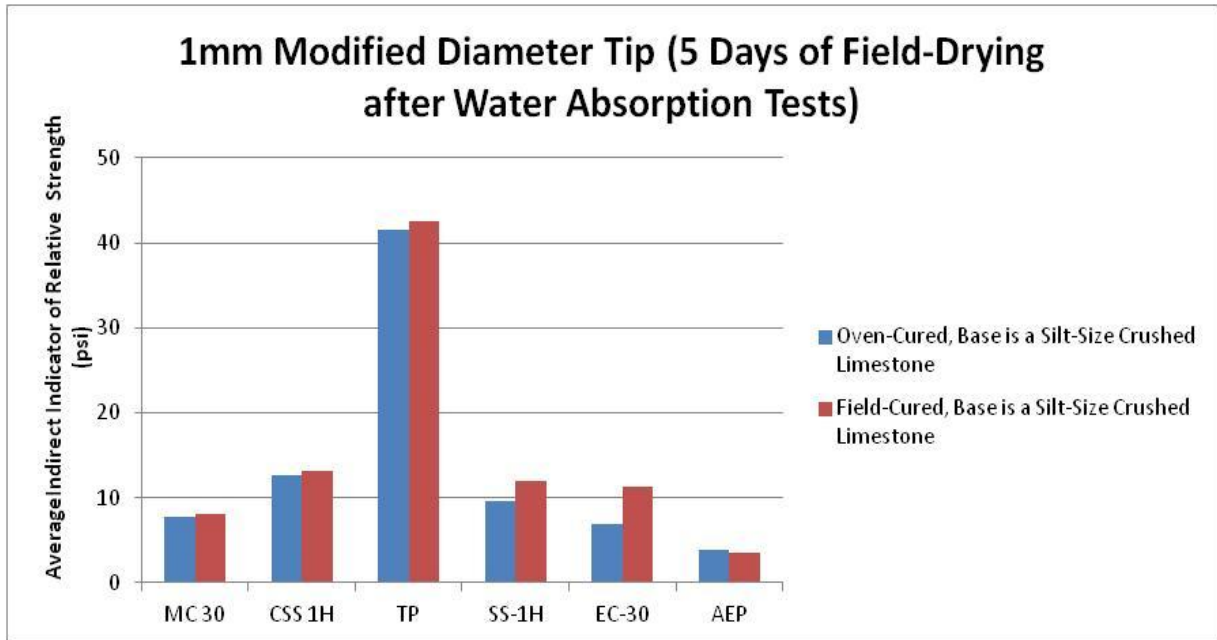


Figure 6.7 Comparison of average indirect indicator of relative strength for oven-cured and field-cured specimens allowed to dry in the field for 5 days after water absorption tests using silt-size crushed limestone and the 1mm modified diameter tip

In Figure 6.7, a comparison of the average indirect indicator of relative strength data for oven-cured and field-cured specimens allowed to dry in the field using silt-size crushed limestone and the 1mm modified diameter tip are presented. In Figure 6.7, the indirect indicator of relative strength for field-cured specimens are slightly higher, than oven-cured specimens with the exception of AEP. The difference in indirect indicator of relative strength values for field-cured compared to oven-cured are minimal, with the exception of EC-30.

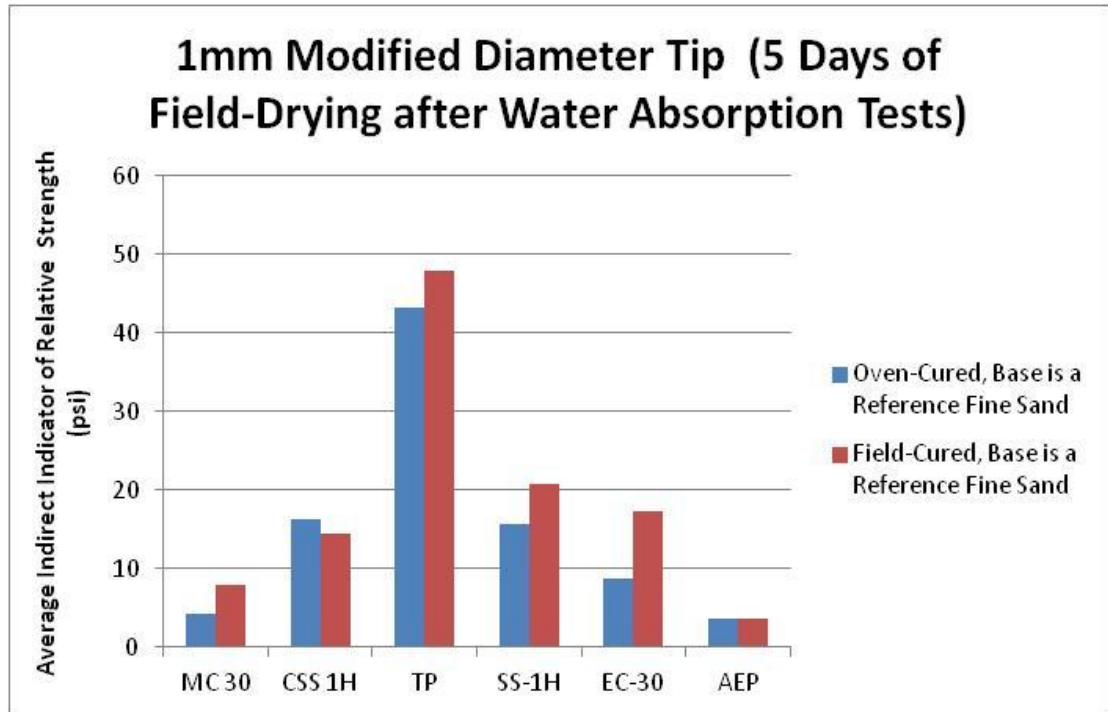


Figure 6.8 Comparison of average indirect indicator of relative strength for oven-cured and field-cured specimens allowed to dry in the field for 5 days after water absorption tests using reference fine sand and the 1mm modified diameter tip

In Figure 6.8, the indirect indicator of relative strength values for field-cured specimens are slightly higher than oven-cured specimens, with the exception of CSS-1H, and AEP shows nearly exactly the same results for field-cured and oven-cured specimens. The EC-30 field-cured specimens show an indirect indicator of relative strength value nearly twice the size of oven-cured specimens.

CHAPTER 7 Penetration Tests Results

7.1 INTRODUCTION

The results of the penetration tests done in this study are presented in this chapter. Penetration tests are performed in order to determine how well a prime coat is able to penetrate into different base materials.

7.2 OVEN-CURED PRIME COATS USING SILT-SIZE CRUSHED LIMESTONE

Table 7.1 Average penetration results for different prime coat using silt-size crushed limestone after oven-cured

Prime Coat Material	Average Penetration Depth (mm)
MC 30	6.77
CSS-1H	1.94
TP	4.08
SS-1H	2.28
EC-30	9.07
AEP	4.67

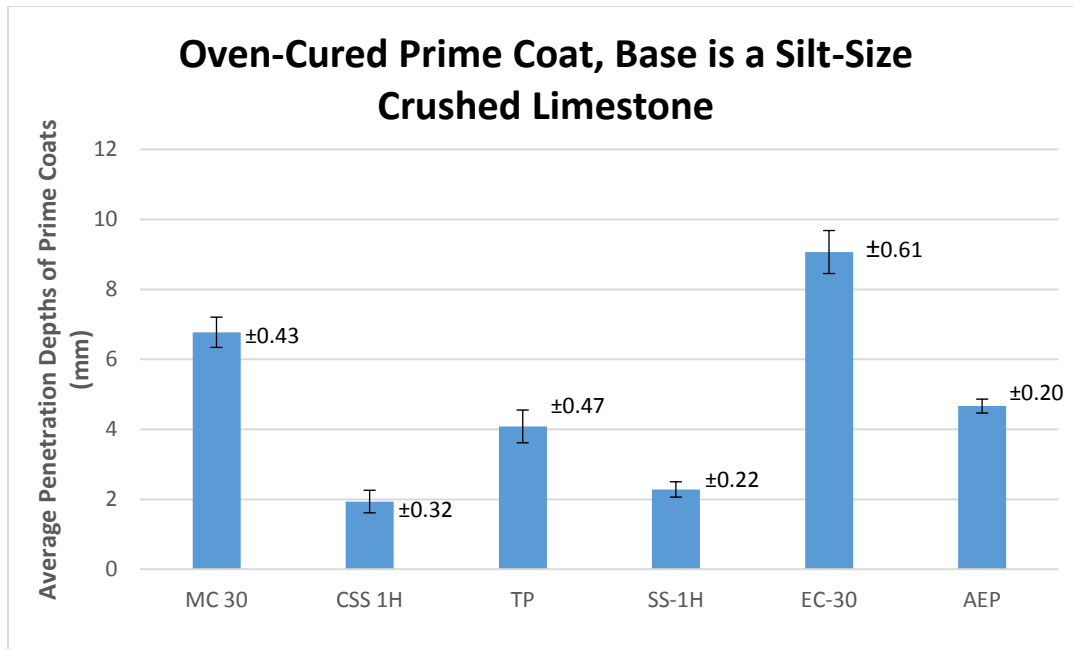


Figure 7.1 Comparison of average penetration values for different prime coat using silt-size crushed limestone after oven-cured

Table 7.1 and 7.1 show the average penetration values of different prime coat using the silt-size crushed limestone base, after oven-curing. EC-30 showed the highest amount of penetration while CSS-1H showed the lowest. These tests in order from lowest to highest are as follows: CSS-1H, SS-1H, TP, AEP, MC-30, and EC-30. It can be observed from Figure 7.1 that EC-30 and MC-30 had the best overall performance with silt-size crushed limestone after oven-curing.

7.3 OVEN-CURED PRIME COATS USING REFERENCE FINE SAND

Table 7.2 Average penetration results for different prime coat using reference fine sand after oven-cured

Prime Coat Material	Average Penetration Depth (mm)
MC 30	7.69
CSS 1H	2.95
TP	7.69
SS-1H	2.22
EC-30	6.33
AEP	4.34

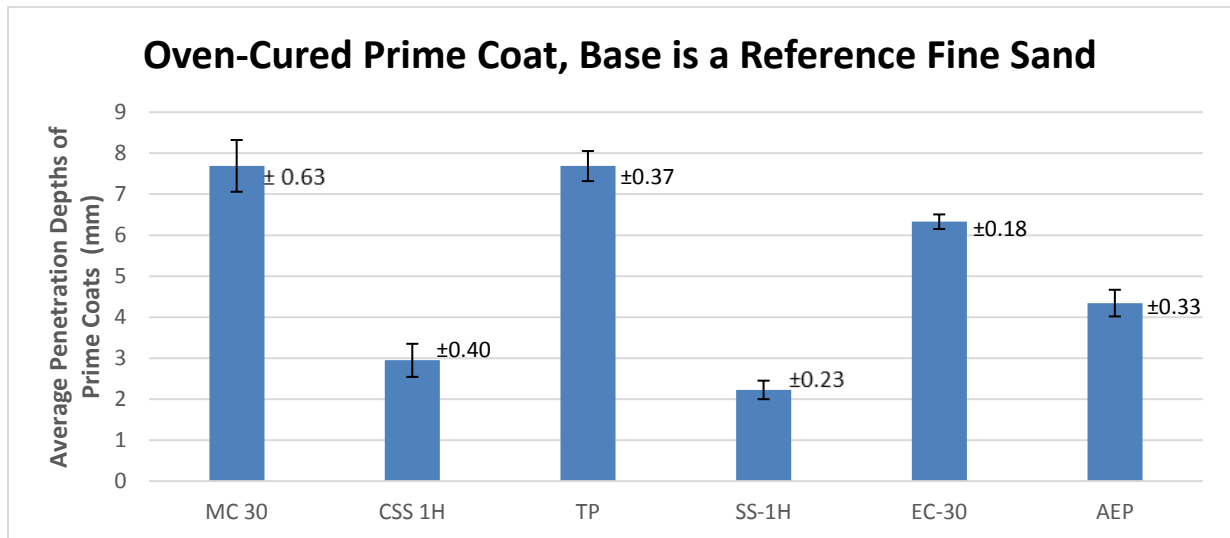


Figure 7.2 Comparison of average penetration values for different prime coat using reference fine sand after oven-cured

In Table 7.2 and Figure 7.2, the average penetration values of different prime coat materials using reference fine sand and oven-curing are presented. This testing scenario resulted in TP and MC-30 yielding the highest amount of penetration. Both had an equal value. SS-1H yielded the lowest amount of penetration. The lowest to highest amount of

penetration is as follows: SS-1H, CSS-1H, AEP, EC03, MC-30, and TP. It can be observed from Figure 7.2 that TP and MC-30 had the best overall performance with reference fine sand after oven-curing.

7.4 FIELD-CURED PRIME COATS USING SILT-SIZE CRUSHED LIMESTONE

Table 7.3 Average penetration results for different prime coat using silt-size crushed limestone after field-cured

Prime Coat Material	Average Penetration Depth (mm)
MC 30	5.45
CSS 1H	1.95
TP	4.83
SS-1H	1.68
EC-30	6.75
AEP	4.12

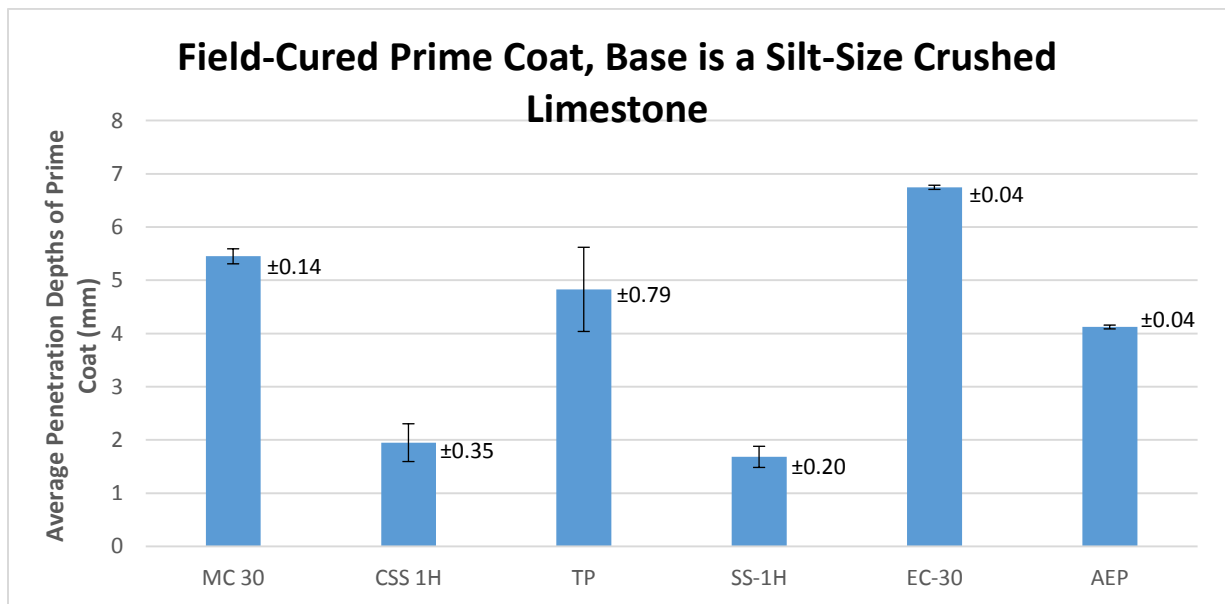


Figure 7.3 Comparison of average penetration values for different prime coat using silt-size crushed limestone after field-cured

In Table 7.3 and Figure 7.3, the average amount of penetration for different prime coat materials using silt-size crushed limestone and field-curing is presented. EC-30 showed the highest amount of penetration while SS-1H showed the lowest. The results of lowest to highest amount of penetration are as follows: SS-1H, CSS-1H, AEP, TP, MC-30, and EC-30. In Figure 7.3, it can be observed that EC-30 and MC-30 have the best overall performance with silt-size crushed limestone after field-curing.

7.5 FIELD-CURED PRIME COATS USING REFERENCE FINE SAND

Table 7.4 Average penetration results for different prime coat using reference fine sand after field-cured

Prime Coat Material	Average Penetration Depth (mm)
MC 30	7.54
CSS 1H	2.40
TP	6.84
SS-1H	2.98
EC-30	6.28
AEP	4.81

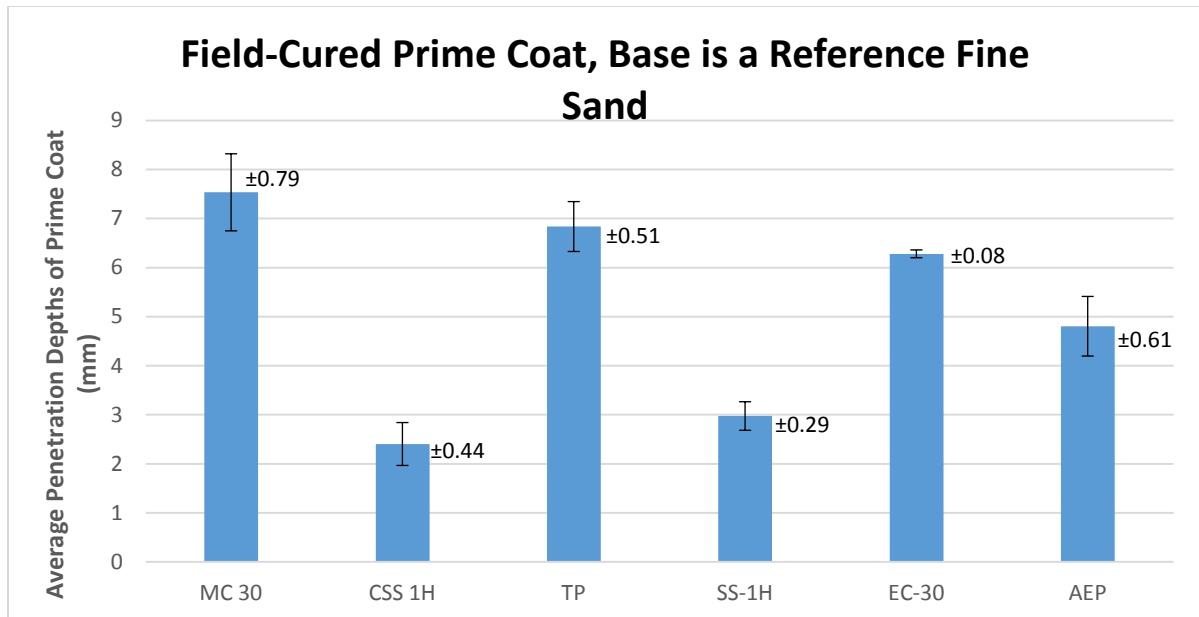


Figure 7.4 Comparison of average penetration values for different prime coat using reference fine sand after field-cured

In Table 7.4 and Figure 7.4 the average amount of penetration for different prime coat materials using reference fine sand and field-curing is presented. MC-30 showed the highest amount of penetration while CSS-1H showed the lowest. The results of lowest to highest amounts of penetration are as follows: CSS-1H, SS-1H, AEP, EC-30, TP, and MC-30. In Figure 7.4, MC-30 and TP show the best overall performance with reference fine sand after field-curing.

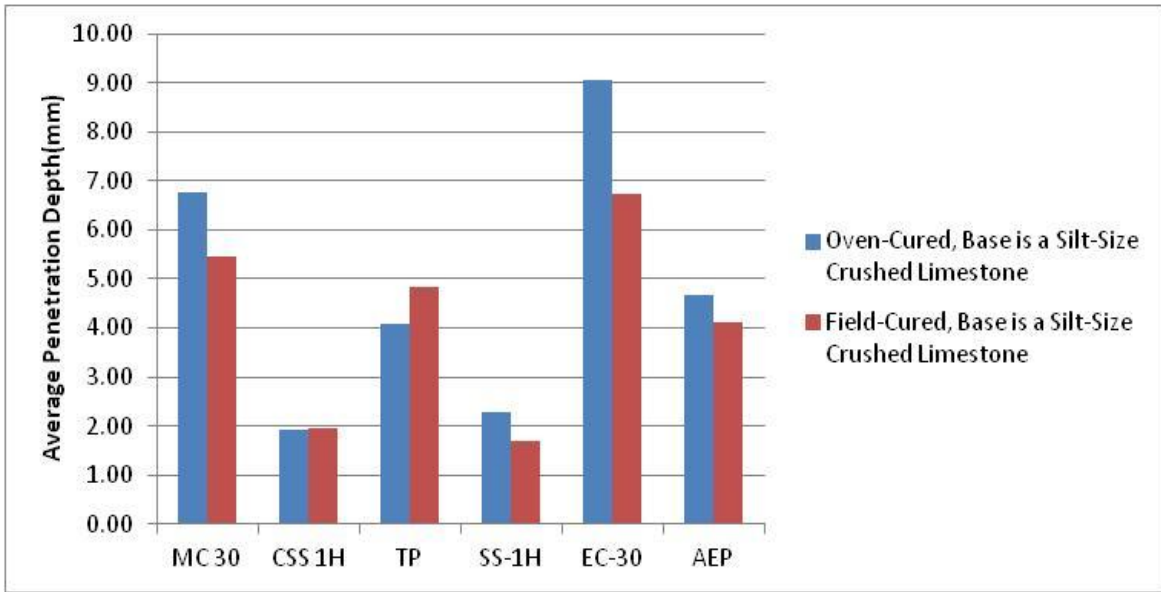


Figure 7.5 Comparison of average penetration depth for oven-cured and field-cured prime coat using silt-size crushed limestone

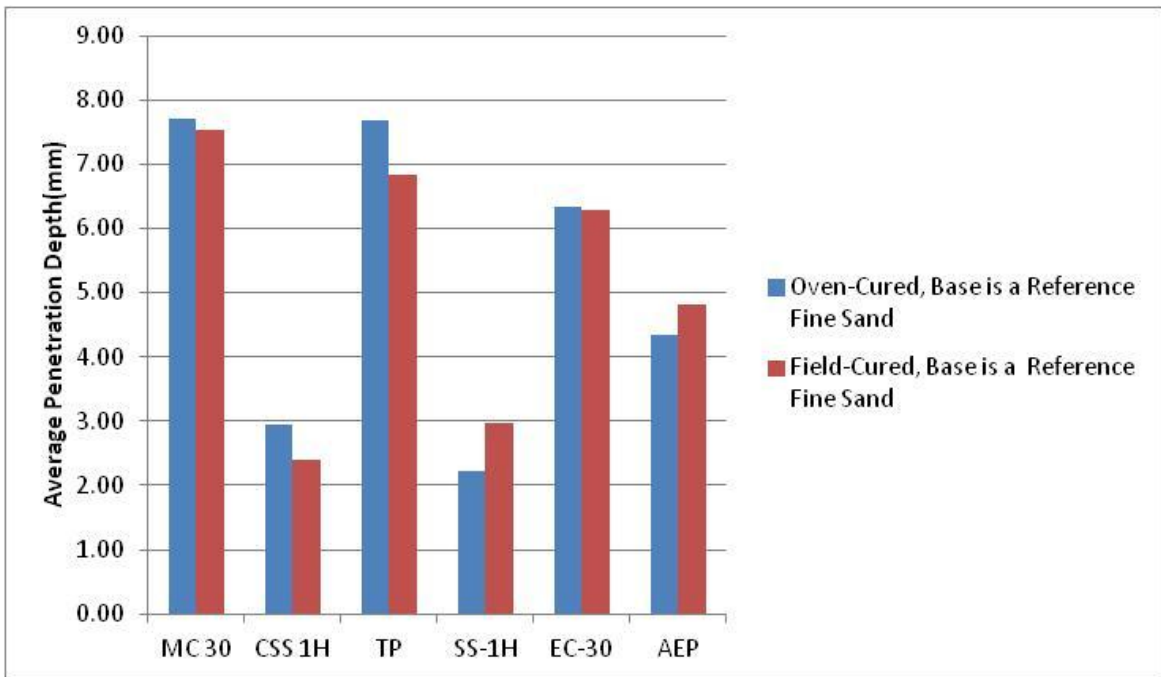


Figure 7.6 Comparison of average penetration depth for oven-cured and field-cured prime coat using reference fine sand

A comparison of penetration values based on field data and oven data with different base materials are presented in Figure 7.5 using silt-size crushed limestone and in Figure 7.6 using reference fine sand. In Figure 7.5, all prime coat material show varying results with the exception of CSS-1H using silt-size crushed limestone. The EC-30 prime coat shows a drastic difference in penetration depth in Figure 7.5 when using silt-size crushed limestone. On the other hand, in Figure 7.6, the results of penetration tests for field-and oven-curing show minute differences. Results of penetration tests show MC-30, EC-30 and TP as the overall top performers.

CHAPTER 8 Conclusions and Recommendations

8.1 SUMMARY

Field-tests were completed during the months of March 12th-18th, 2014 and April 12th-18th, 2014 in order to discern the possibility of simulating outdoor-curing of prime coat materials at an accelerated rate in a laboratory. Identical prime coat and base materials were divided into two types of testing environments, one testing field-curing environments, and one in an accelerated and controlled indoor, oven-curing environment. Once the specimens were fully cured, evaluation of the engineering properties of the specimens were carried out in order to determine if oven-cured specimens can be expected to exhibit the same engineering characteristics as the field-cured specimens. Evaluation of water absorption tests, indirect indicator of relative strength, and penetration tests were performed on all specimens for both field-cured and oven-cured specimens. Importantly, a comparison of these results shows the viability of using accelerated, laboratory curing procedures.

8.2 COMPARISONS AND RECOMMENDATIONS

All testing and comparisons of the engineering characteristics of various prime coat materials have revealed that oven-cured specimens can be expected to exhibit similar performance to field-cured specimens. For the purpose of this study, both reference fine sand and silt-size crushed limestone are used as base materials. Reference fine sand is a standard material used by TxDOT in laboratory testing for prime coat materials and silt-

size crushed limestone is a very common base material used in Texas. Both of these materials are used and compared in this study, to establish a correlation between the engineering characteristics of oven-cured and field-cured specimens. As a result, the data from this study indicate that the curing of prime coat materials in an oven is a plausible alternative.

8.2.1 Water Absorption Testing

In Figure 8.1, the results of testing the water absorption of both oven-cured and field-cured specimens with various prime coat materials are presented. In this comparison, the reference fine sand is used as the base.

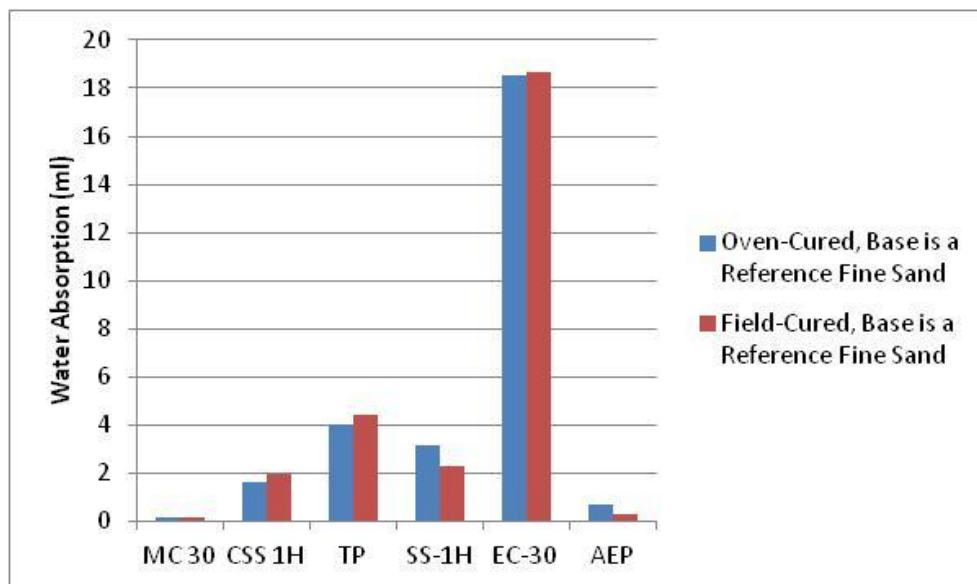


Figure 8.1 Comparison of water absorption tests for field-cured and oven-cured Specimens using reference fine sand

It can be seen that the water absorption values for field-cured specimens are mirrored by the values for the same testing completed for oven-cured specimens. The

polymer emulsion, EC-30, exhibited drastically higher absorption values than other prime coat materials for both oven-curing and field-curing procedures. Additionally, MC-30 shows much lower water absorption values than most other materials for both oven-cured and field-cured specimens. A similar relationship was found for water absorption values when comparing specimens prepared with the silt-size crushed limestone base, but the reference fine sand resulted in a closer correlation, and thus, is suggested as the preferred materials for oven-cured specimen preparation. While the water absorption data obtained are not identical for oven-cured and field-cured specimens, the results are close enough to show that when water absorption testing is performed on oven-cured specimens, the results will provide useful information on the expected field performance of materials.

8.2.2 Indirect Indicator of Relative Strength

The indirect indicator of relative strength is a new method which utilizes a pocket penetrometer with an additional modified tip at 2mm diameter. This procedure needs further development and its repeatability needs to be tested. The results of indirect indicator of relative strength for both oven-cured and field-cured specimens immediately after water absorption tests with various prime coat materials applied to the surface of the reference sand are presented in Figure 8.2.

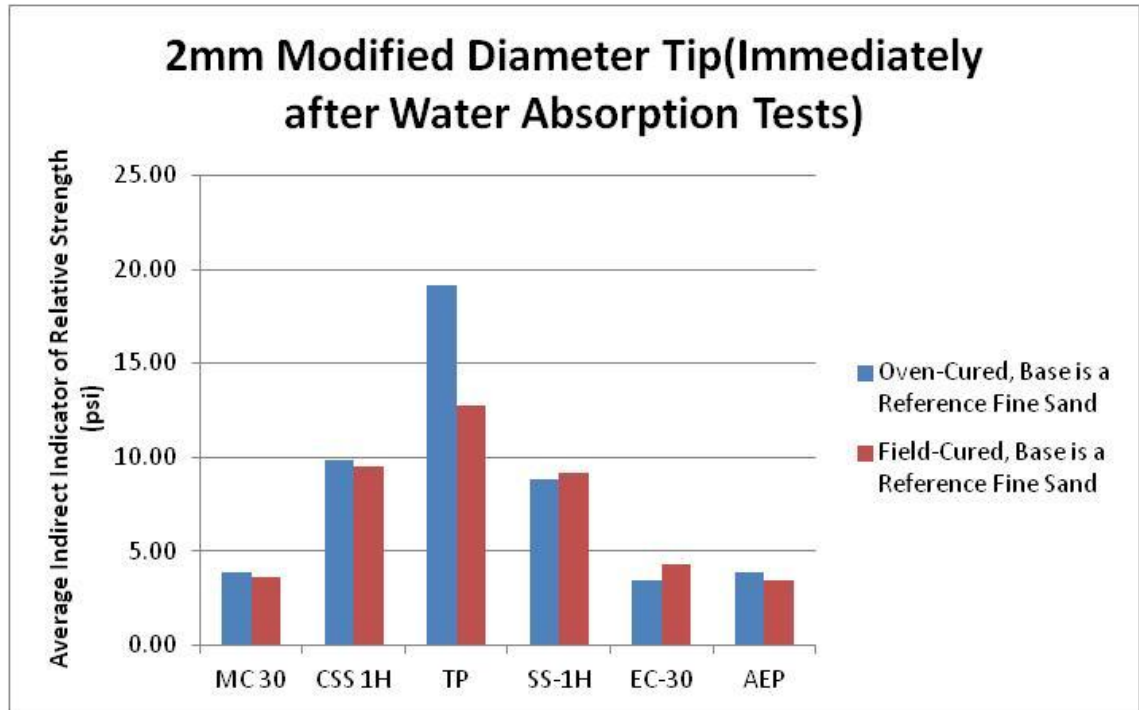


Figure 8.2 Comparison of average indirect indicator of relative strength of oven-cured and field-cured specimens tested immediately after water absorption tests using a reference fine sand and the 2mm modified diameter tip

The results of indirect indicator of relative strength for both oven-cured and field-cured specimens that dried in the field for 5 days after water absorption tests with various prime coat materials applied to the surface of the reference sand are presented in Figure 8.3.

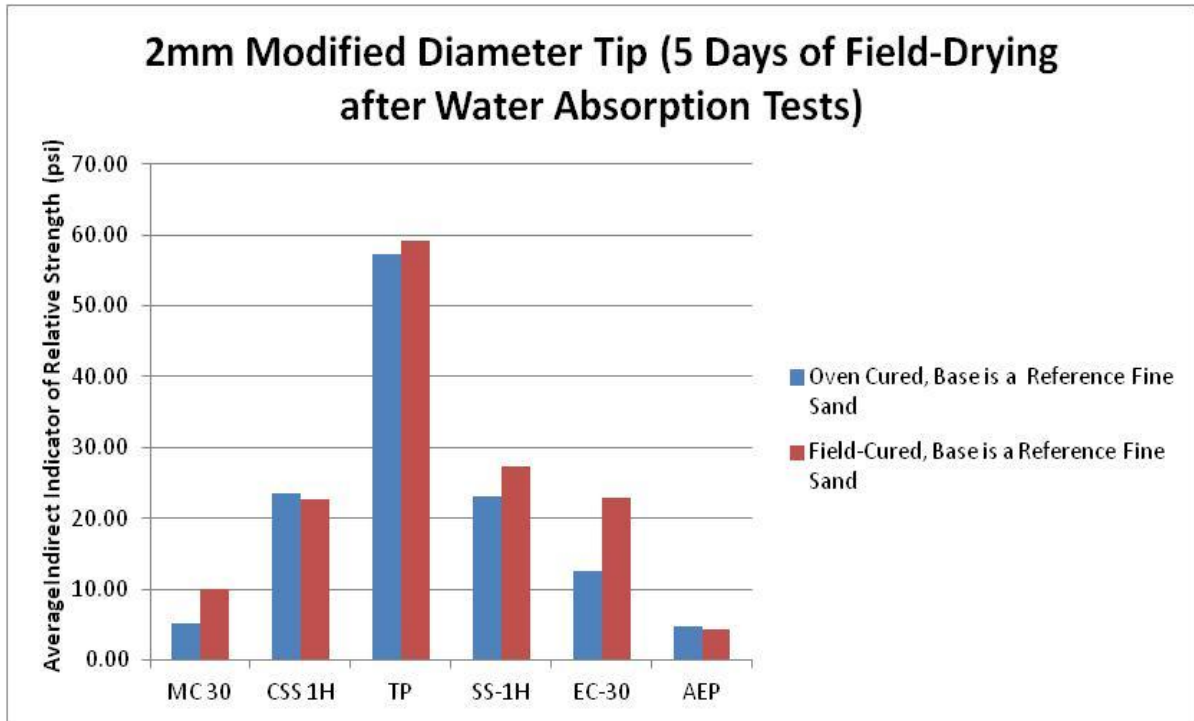


Figure 8.3 Comparison of average indirect indicator of relative strength of oven-cured and field-cured specimens allowed to dry in the field for 5 days after water absorption tests using reference fine sand and the 2mm modified diameter tip

The data show that the indirect indicator of relative strength values for field-cured specimens that dried in the field for 5 days after water absorption tests are similar to the values for the same testing completed with oven-cured specimens. As expected from previous prime coat research, the water-based polymer, TP, shows drastically higher indirect indicator of relative strength values when the specimen is allowed to dry in the field for 5 days after water absorption tests than other prime coat materials for both oven-curing and field-curing procedures. Both indirect indicator of relative strength for samples tested immediately after water absorption tests and samples tested 5 days after

field-drying produced similar performance rankings, with TP at the top and MC-30, AEP, and EC-30 all exhibiting similarly low indirect indicator of relative strength values. The specimens prepared with a silt-size limestone base produced a similar relationship for indicator of relative strength values, but reference fine sand resulted in a closer correlation, and thus, is suggested as the preferred material for oven-cured specimen preparation. While the indirect indicator of relative strength results are not identical for oven-cured and field-cured specimens, the results are close enough to show that when testing the indirect indicator of relative strength on oven-cured specimens, the results may provide useful information on the expected field performance of prime coat materials.

8.2.3 Penetration Testing

In Figure 8.4, the results of penetration testing for both oven-cured and field-cured specimens with various prime coat materials applied to the surface of the reference fine sand are presented.

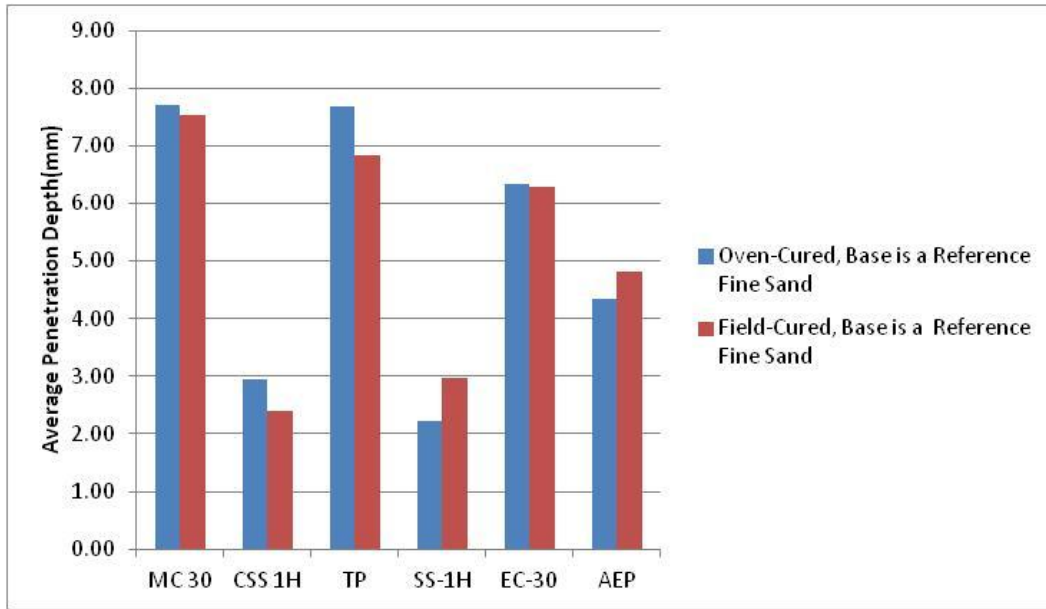


Figure 8.4 Comparison of average penetration depth for oven-cured and field-cured specimens with reference fine sand

Penetration testing for field-cured specimens are closely correlated to the values for the same testing procedure completed for oven-cured specimens. For both oven-curing and field-curing procedures, MC-30 and TP achieved the greatest penetration depths. On the other hand, the poorest penetration values were found for CSS-1H and SS-1H for both oven-cured and field-cured specimens. A similar relationship was found for penetration values when comparing specimens prepared with the silt-size crushed limestone base, but the reference fine sand resulted in a closer correlation, and thus, is a preferred material for oven-cured specimen preparation. While the penetration data obtained are not identical for oven-cured and field-cured specimens, the results are close enough to show that when penetration testing is performed on oven-cured specimens, the results will provide useful information on the materials expected field performance.

8.3 RECOMMENDATIONS FOR FUTURE STUDIES

A comparison between test data obtained with field-cured and oven-cured prime coat specimen is beneficial for setting a point of reference for creating new and more efficient prime coat testing procedures. However, because this study was limited to two testing months, March 12th-18th, 2014 and April 12th-18th, 2014, it is recommend that more testing seasons be accounted for, primarily the summer months. The averages and ranges of weather conditions observed for the field-cured prime coat used in this study, along with the testing seasons, are presented in Table 8.1.

Table 8.1 Average and range of weather conditions and testing seasons of field-cured prime coat

Testing Time	Average Daily Temp. and Range	Average Relative Humidity and Range	Average Daily Wind Speed and Range	Average Daily Atmospheric Pressure and Range
March 12 th -18 th , 2014	59.7°F 52°F -68°F	53% 36%-81%	7mph 4mph -11mph	30 Hg 29.74-30.26 Hg
April 12 th -18 th , 2014	63.7°F 52°F -75°F	65.4% 39%-85%	7.3mph 4mph-10mph	30 Hg 29.76-30.27 Hg

Additionally, this study only used the spray-on application method. It is recommended that different application methods be used. Further, future studies involving oven-cured prime coat should be conducted in order to determine the ideal oven temperature for oven-cured specimens. This study employed a range of different temperatures from 50°C to 100°C in the oven, with the target evaporation percentage

obtained from the field. The present study uses the average values obtained for indirect indicator of relative strength, water absorption and penetration testing for all testing temperatures. Future studies could focus on narrowing the temperature range, or even selecting a single temperature setting to compare the engineering properties of field-cured and oven-cured prime coat materials.

Prime coat field-testing procedures will be suggested using oven-curing rather than field-curing, reducing the amount of time required for sample preparation. Prime coat testing could conceivably be completed in a single day due to the accelerated curing rates. This advantage would reduce cost and man-hours of new prime coat material testing.

Appendix A

A-1 PROPERTIES OF PRIME COAT MATERIAL



1/1

Asphalt Material Test Report

Sample ID: C14370027 Disposition: Meets Specifications
Effective Dates: 02/12/2014 to 03/14/2014

Grade: EPC-1 (Environmental Prime Coat)	Sampled: 1/8/2014
Producer: Prime Eco Group, Inc. Wharton, TX	Received: 1/8/2014
Sample Type: Tank	Completed: 2/12/2014
Tank #: 074	Reviewed by: CIGLEHA
Seal #:	SM ID: QM301C14370027

Test No	Test Name	Result	Units	Min	Max
ASTM D 562-	Krebs Unit Viscosity at 77°F	55.9	K.U.	50	60
Tex 521-C	Sieve Test	0	%		0.1
Tex 521-C	Storage Stability	0.24	%		1
Tex SAND-	Sand Penetration Test				
	Penetration Depth	15	mm	12	
	Target Application Rate	0.1	gal/SY		
Tex 521-C	Emulsion Residue by Evaporation	12.49	%	10	

Remarks:



Asphalt Material Test Report

Sample ID: C14370478 Disposition: Meets Specifications
Effective Dates: 03/01/2014 to 03/31/2014

Grade: MC-30 (MC-30 Cutback Asphalt)
Producer: Valero Marketing and Supply
 Sunray, TX
Sample Type: Monthly
T/B #: 24
Month: Mar-14

Sampled: 2/8/2014
Received: 2/26/2014
Completed: 3/6/2014
Reviewed by: CIGLEHA
SM ID: QM301C14370478

Test No	Test Name	Result	Units	Min	Max
Tex 529-C	Kinematic Viscosity at 140°F	43.62	cSt	30	60
Tex 514-C	Specific Gravity by Hydrometer	0.9257	at 60°F		
Tex 515-C	Distillation of Cut-Back Asphalts				
	Residue by Volume	53.41	%	50	
	Portion of Total Distillate to 437°F	19.78	%	0	25
	Portion of Total Distillate to 500°F	65.93	%	40	70
	Portion of Total Distillate to 600°F	91.21	%	75	93
Tex 502-C	Penetration of Distillation Residue at 77°F	133	p.u.	120	250
Tex 528-C	Absolute Viscosity of Distillation Residue at 140°F	975.15	P	300	1200

Remarks:



Asphalt Material Test Report

Sample ID: C14370402 Disposition: Meets Specifications
Effective Dates: 03/01/2014 to 03/31/2014

Grade: AE-P (Asphalt Emulsion Prime)
Producer: Ergon Asphalt and Emulsion, Inc.
 Austin, TX
Sample Type: Monthly
T/B #: 203
Month: Mar-14

Sampled: 2/24/2014
Received: 2/24/2014
Completed: 2/25/2014
Reviewed by: CIGLEHA
SM ID: QM301C14370402

Test No	Test Name	Result	Units	Min	Max
Tex 513-C	Saybolt Viscosity at 122°F	50.9	S. sec	15	150
Tex 514-C	Specific Gravity by Gallon Weight Cup	0.9387	at 60°F		
AE-P	AE-P Emulsion Composition				
	Asphalt Content by Weight	51.24	%	40	
	Oil Content by Volume	28.84	%	25	40
Tex 519-C	Float Test on Distillation Residue				
	Float Time	135	s	50	200
	Temperature	122	°F	122	

Remarks:



Asphalt Material Test Report

Sample ID: C14370405 Disposition: Meets Specifications
Effective Dates: 03/01/2014 to 03/31/2014

Grade: SS-1H (SS-1H Emulsion)	Sampled: 2/24/2014
Producer: Ergon Asphalt and Emulsion, Inc. Austin, TX	Received: 2/24/2014
Sample Type: Monthly	Completed: 2/24/2014
T/B #: 204	Reviewed by: CIGLEHA
Month: Mar-14	SM ID: QM301C14370405

Test No	Test Name	Result	Units	Min	Max
Tex 513-C	Saybolt Viscosity at 77°F	31.9	S. sec	20	100
Tex 514-C	Specific Gravity by Gallon Weight Cup	1.0268	at 60°F		
Tex 521-C	Distillation of Emulsified Asphalts				
	Distillation Residue by Mass	65.36	%	60	
	Oil Portion of Distillate	0	%		0.5
Tex 502-C	Penetration of Distillation Residue at 77°F	90	p.u.	70	100

Remarks:



Asphalt Material Test Report

Sample ID: C14370348 Disposition: Meets Specifications
Effective Dates: 03/01/2014 to 03/31/2014

Grade: CSS-1H (CSS-1H Emulsion)
Producer: Heartland
Lubbock, TX
Sample Type: Monthly
T/B #: 216
Month: Mar-14

Sampled: 2/16/2014
Received: 2/17/2014
Completed: 2/25/2014
Reviewed by: CIGLEHA
SM ID: QM301C14370348

Test No	Test Name	Result	Units	Min	Max
Tex 513-C	Saybolt Viscosity at 77°F	43.9	S. sec	20	100
Tex 514-C	Specific Gravity by Gallon Weight Cup	1.0073	at 60°F		
Tex 521-C	Distillation of Emulsified Asphalts				
	Distillation Residue by Mass	62.18	%	60	
	Oil Portion of Distillate	0	%		0.5
Tex 502-C	Penetration of Distillation Residue at 77°F	94	p.u.	70	110

Remarks:

Appendix B

B1 – RESULT OF WATER ABSORPTION TESTS

Table B1 Water Absorption Data for Silt-Size Crushed Limestone–Based Prime Coats

	Sample	Temperature (°C)	MC -30	CSS- 1H	TP	SS-1H	EC-30	AEP
			Water absorbed (ml)					
Inside oven	1	50	0.14	4.24	1.26	3.73	14.08	0.51
	2	60	0.08	5.76	1.42	5.07	15.09	0.45
	3	70	0.09	3.99	0.99	6.33	13.01	0.36
	4	80	0.14	4.59	1.71	4.20	13.71	0.56
	5	90	0.12	4.99	1.19	3.82	14.04	0.62
	Mean		0.12	4.71	1.31	4.63	13.99	0.50
	Standard Deviation		0.03	0.69	0.27	1.09	0.75	0.10
Field	1	NA	0.20	0.65	3.31	0.57	19.94	0.34
	2	NA	0.14	1.21	3.10	1.13	19.02	0.20
	3	NA	0.16	0.78	2.54	0.87	19.29	0.21
	4	NA	0.19	1.37	3.89	0.85	18.34	0.23
	Mean		0.17	1.00	3.21	0.86	19.15	0.24
	Standard Deviation		0.03	0.34	0.56	0.23	0.66	0.06

Table B2 Water Absorption Data for Reference Fine Sand – Based Prime Coats

	Sample	Temperature (°C)	MC- 30	CSS- 1H	TP	SS-1H	EC-30	AEP
			Water absorbed (ml)					
Inside oven	1	50	0.12	1.06	4.43	2.95	18.50	0.44
	2	60	0.15	1.96	3.94	1.34	17.60	0.88
	3	70	0.15	1.06	4.52	3.00	19.04	0.75
	4	80	0.16	1.67	3.48	2.55	17.86	0.69
	5	90	0.18	2.02	3.50	3.58	19.52	0.82
	6	100	0.16	1.83	4.22	5.34	18.57	0.55
	Mean		0.15	1.60	4.01	3.12	18.51	0.69
Standard Deviation		0.02	0.44	0.45	1.32	0.72	0.17	
Field	1	NA	0.22	2.32	4.11	2.67	18.78	0.57
	2	NA	0.11	2.89	5.00	0.99	17.14	0.18
	3	NA	0.19	1.18	3.64	4.02	19.20	0.21
	4	NA	0.11	1.55	4.89	1.35	19.55	0.13
	Mean		0.16	1.99	4.41	2.26	18.67	0.27
Standard Deviation		0.06	0.77	0.65	1.38	1.07	0.20	

B2 – RESULT OF INDIRECT INDICATOR OF RELATIVE STRENGTH

Table B3 Indirect Indicator of Relative Strength Values for Silt-Size Crushed Limestone-Based Prime Coats

	Tip Characteristics	MC- 30	CSS-1H	TP	SS-1H	EC-30	AEP
		Average Strength (kg/cm ²)					
Inside oven	1mm wet	0.29	0.53	0.89	0.51	0.34	0.26
	2 mm wet	0.38	0.66	1.08	0.65	0.40	0.27
	1 mm dry	0.55	0.90	2.93	0.68	0.49	0.27
	2 mm dry	0.83	1.17	3.39	1.00	0.84	0.31
	Mean	0.51	0.81	2.07	0.71	0.52	0.28
	Standard Deviation	0.20	0.24	1.10	0.18	0.20	0.02
Field	1mm wet	0.22	0.49	0.83	0.48	0.25	0.22
	2 mm wet	0.27	0.70	0.90	0.65	0.30	0.24
	1 mm dry	0.57	0.93	3.00	0.84	0.80	0.25
	2 mm dry	0.88	1.23	3.48	1.27	1.25	0.29
	Mean	0.48	0.84	2.05	0.81	0.65	0.25
	Standard Deviation	0.26	0.27	1.20	0.30	0.41	0.03

Table B4 Indirect Indicator of Relative Strength Values for Reference Fine Sand-Based Prime Coats

	Tip Characteristics	MC- 30	CSS-1H	TP	SS-1H	EC-30	AEP
		Average Strength (kg/cm ²)					
Inside oven	1mm wet	0.27	0.54	1.12	0.42	0.24	0.21
	2 mm wet	0.27	0.69	1.35	0.62	0.24	0.27
	1 mm dry	0.31	1.15	3.04	1.10	0.61	0.26
	2 mm dry	0.37	1.66	3.97	1.63	0.89	0.33
	Mean	0.30	1.01	2.37	0.94	0.49	0.27
	Standard Deviation	0.04	0.44	1.18	0.47	0.27	0.04
Field	1mm wet	0.23	0.49	0.75	0.52	0.23	0.23
	2 mm wet	0.26	0.67	0.90	0.65	0.30	0.24
	1 mm dry	0.56	1.02	3.38	1.47	1.22	0.26
	2 mm dry	0.70	1.59	4.17	1.92	1.61	0.30
	Mean	0.44	0.94	2.30	1.14	0.84	0.26
	Standard Deviation	0.20	0.42	1.50	0.58	0.59	0.03

B3 – RESULT OF PENETRATION TESTS

Table B5 Penetration Data for Silt- Size Crushed Limestone-Based Prime Coats

	Sample	Temperature (°C)	MC- 30	CSS- 1H	TP	SS-1H	EC-30	AEP
			Average Penetration Depth (mm)					
Inside oven	1	50	6.50	2.45	3.97	2.33	9.74	4.88
	2	60	7.52	2.00	4.76	2.63	9.59	4.53
	3	70	6.76	1.61	3.59	2.14	8.91	4.40
	4	80	6.48	1.87	4.34	2.26	8.21	4.81
	5	90	6.60	1.75	3.76	2.06	8.89	4.71
	Mean		6.77	1.94	4.08	2.28	9.07	4.67
	Standard Deviation			0.43	0.32	0.47	0.22	0.61
Field	1	NA	5.31	1.85	5.57	1.82	6.73	4.14
	2	NA	5.59	2.44	5.42	1.49	6.73	4.11
	3	NA	5.56	1.60	4.37	1.88	6.81	4.16
	4	NA	5.35	1.91	3.95	1.53	6.73	4.08
	Mean		5.45	1.95	4.83	1.68	6.75	4.12
	Standard Deviation			0.14	0.35	0.79	0.20	0.04

Table B6 Penetration Data for Reference Fine Sand-Based Prime Coats

	Sample	Temperature (°C)	MC- 30	CSS- 1H	TP	SS-1H	EC-30	AEP
			Average Penetration Depth (mm)					
Inside oven	1	50	7.47	3.07	7.63	2.11	6.21	4.09
	2	60	8.19	3.39	7.81	2.21	6.55	4.51
	3	70	6.85	3.20	8.34	2.61	6.42	4.21
	4	80	8.46	2.88	7.26	2.33	6.07	4.81
	5	90	8.03	2.92	7.48	2.12	6.46	4.51
	6	100	7.16	2.22	7.62	1.96	6.27	3.93
	Mean		7.69	2.95	7.69	2.22	6.33	4.34
	Standard Deviation			0.63	0.40	0.37	0.23	0.18
Field	1	NA	8.58	2.76	6.57	3.20	6.32	3.92
	2	NA	7.48	2.77	7.59	2.63	6.16	5.14
	3	NA	7.41	2.19	6.49	2.83	6.33	4.92
	4	NA	6.67	1.89	6.70	3.23	6.31	5.24
	Mean		7.54	2.40	6.84	2.98	6.28	4.81
	Standard Deviation			0.79	0.44	0.51	0.29	0.08

B4-CURING TIME DATA

Table B7 Field -Curing Time Data for Silt-Size Crushed Limestone-Based MC-30 Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	
March 12-17, 2014	Amount of solvent remaining(g)	3.725	3.578	3.389	3.241	3.198	3.134	3.021	2.937	2.8901	2.838	2.795	2.771	2.748	
	Percentage reduction (%) (interval based)		3.946	5.074	3.973	1.154	1.718	3.034	2.255	1.259	1.399	1.154	0.644	0.617	
	Percentage reduction (%) (cumulative)		3.946	9.020	12.993	14.148	15.866	18.899	21.154	22.413	23.812	24.966	25.611	26.228	
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	144
April 12-17, 2014	Amount of solvent remaining(g)	3.35	3.198	3.035	3.001	2.951	2.919	2.858	2.8001	2.752	2.717	2.679	2.663	2.646	2.644
	Percentage reduction (%) (interval based)		4.537	4.866	1.015	1.493	0.955	1.821	1.728	1.436	1.045	1.134	0.478	0.507	0.060
	Percentage reduction (%) (cumulative)	0.000	4.537	9.403	10.418	11.910	12.866	14.687	16.415	17.851	18.896	20.030	20.507	21.015	21.075

Table B8 Oven-Curing Time Data for Silt-Size Crushed Limestone-Based MC-30 Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540
50	Amount of solvent remaining (g)	3.62	3.44	3.37	3.33	3.26	3.23	3.220	3.167	3.14	3.10	3.07	3.046	2.998	2.961	2.929	2.901	2.879	2.854	2.811
	Percentage reduction (%) (cumulative)	0.00	5.13	7.03	8.16	9.92	10.7	11.27	12.73	13.4	14.5	15.1	16.07	17.39	18.41	19.29	20.06	20.67	21.36	22.54
60	Amount of solvent remaining (g)	3.545	3.39	3.29	3.24	3.20	3.16	3.127	3.071	3.02	2.97	2.90	2.876	2.841	2.829	2.811	2.776	2.745		
	Percentage reduction (%) (cumulative)	0.00	4.20	6.97	8.35	9.70	10.8	11.79	13.37	14.8	16.2	18.1	18.87	19.86	20.20	20.71	21.69	22.57		
70	Amount of solvent remaining (g)	3.632	3.37	3.26	3.20	3.16	3.12	3.071	3.019	2.97	2.92	2.87	2.815	2.789						
	Percentage reduction (%) (cumulative)	0	6.97	10.0	11.7	12.7	14.0	15.45	16.88	18.2	19.5	20.7	22.49	23.21						
80	Amount of solvent remaining(g)	3.761	3.39	3.27	3.20	3.13	3.09	3.049	2.992	2.94	2.90									
	Percentage reduction (%) (cumulative)	0	9.74	13.0	14.7	16.5	17.8	18.91	20.45	21.7	22.8									
90	Amount of solvent remaining(g)	3.661	3.12	2.98	2.97	2.96	2.91	2.854	2.80											
	Percentage reduction (%) (cumulative)	0.00	14.5	18.3	18.6	19.0	20.3	22.04	23.52											

Table B9 Field-Curing Time Data Reference Fine Sand-Based MC-30 Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	
March 12-17, 2014	Amount of solvent remaining(g)	3.557	3.499	3.354	3.23	3.191	3.152	3.001	2.888	2.821	2.791	2.747	2.745	2.711	
	Percentage reduction (%) (interval based)		1.631	4.076	3.486	1.096	1.096	4.245	3.177	1.884	0.843	1.237	0.056	0.956	
	Percentage reduction (%) (cumulative)		1.631	5.707	9.193	10.290	11.386	15.631	18.808	20.692	21.535	22.772	22.828	23.784	
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	144
April 12-17, 2014	Amount of solvent remaining(g)	4.013	3.982	3.881	3.751	3.689	3.599	3.501	3.439	3.331	3.251	3.179	3.156	3.143	3.141
	Percentage reduction (%) (interval based)		0.772	2.517	3.239	1.545	2.243	2.442	1.545	2.691	1.994	1.794	0.573	0.324	0.050
	Percentage reduction (%) (cumulative)		0.772	3.289	6.529	8.074	10.316	12.759	14.304	16.995	18.988	20.782	21.356	21.680	21.729

Table B10 Oven-Curing Time Data for Reference Fine Sand-Based MC-30 Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	
50	Amount of solvent remaining(g)	3.62	3.49	3.44	3.40	3.36	3.32	3.29	3.26	3.212	3.17	3.13	3.09	3.05	2.981	2.96	2.921	2.882	2.845	2.823	
	Percentage reduction (%) (cumulative)	0.00	3.61	5.02	6.23	7.20	8.35	9.26	10.09	11.44	12.5	13.6	14.5	15.8	17.81	18.2	19.47	20.54	21.56	22.17	
60	Amount of solvent remaining(g)	4	3.83	3.73	3.68	3.64	3.61	3.57	3.531	3.492	3.45	3.43	3.40	3.35	3.314	3.26	3.214	3.146	3.093	3.065	
	Percentage reduction (%) (cumulative)	0.00	4.14	6.73	7.80	8.97	9.63	10.5	11.72	12.70	13.7	14.0	14.9	16.0	17.15	18.4	19.65	21.35	22.67	23.38	
70	Amount of solvent remaining(g)	3.36	3.12	2.99	2.96	2.92	2.87	2.83	2.801	2.760	2.72	2.68	2.64	2.62	2.581						
	Percentage reduction (%) (cumulative)	0.00	7.11	10.77	11.9	12.9	14.4	15.7	16.68	17.90	19.0	20.0	21.3	22.0	23.23						
80	Amount of solvent remaining(g)	3.87	3.61	3.45	3.40	3.35	3.30	3.24	3.189	3.136	3.07	3.02	2.97								
	Percentage reduction (%) (cumulative)	0.00	6.56	10.95	12.1	13.4	14.7	16.1	17.66	19.03	20.6	21.9	23.1								
90	Amount of solvent remaining(g)	3.58	3.39	3.27	3.18	3.09	3.00	2.92	2.857	2.795	2.74										
	Percentage reduction (%) (cumulative)	0.00	5.30	8.64	11.1	13.8	16.3	18.4	20.37	22.10	23.4										
100	Amount of solvent remaining(g)	3.74	3.42	3.30	3.21	3.11	3.05	2.96	2.905												
	Percentage reduction (%) (cumulative)	0.00	8.54	11.95	14.2	16.8	18.5	20.8	22.51												

Table B11 Field-Curing Time Data for Silt-Size Crushed Limestone-Based EC-30 Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96			
March 12-16, 2014	Amount of water remaining(g)	3.912	2.432	1.434	0.998	0.785	0.692	0.483	0.426	0.415	0.397			
	Percentage reduction (%) (interval based)	0	37.83	25.51	11.15	5.44	2.38	5.34	1.46	0.28	0.46			
	Percentage reduction (%) (cumulative)		37.83	63.34	74.49	79.93	82.31	87.65	89.11	89.39	89.85			
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132
April 12-17, 2014	Amount of water remaining(g)	3.942	2.789	2.109	1.721	1.419	1.211	1.028	0.972	0.739	0.651	0.562	0.551	0.545
	Percentage reduction (%) (interval based)		29.25	17.25	9.84	7.66	5.28	4.64	1.42	5.91	2.23	2.26	0.28	0.15
	Percentage reduction (%) (cumulative)	0.00	29.25	46.50	56.34	64.00	69.28	73.92	75.34	81.25	83.49	85.74	86.02	86.17

Table B12 Oven-Curing Time Data for Silt-Size Crushed Limestone-Based EC-30 Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	
50	Amount of Water remaining(g)	3.852	2.61	2.204	2.0182	1.838	1.653	1.507	1.463	1.337	1.233	1.102	0.999	0.85	0.729	0.545	0.421	
	Percentage reduction (%) (cumulative)	0.00	32.24	42.78	47.61	52.28	57.09	60.88	62.02	65.29	67.99	71.39	74.07	77.93	81.07	85.85	89.07	
60	Amount of water remaining (g)	3.991	2.521	2.189	1.893	1.717	1.591	1.257	1.106	0.894	0.795	0.671	0.561	0.499				
	Percentage reduction (%) (cumulative)	0.00	36.83	45.15	52.57	56.98	60.14	68.50	72.29	77.60	80.08	83.19	85.94	87.50				
70	Amount of water remaining (g)	3.605	2.391	1.428	1.109	0.891	0.642	0.542	0.461	0.4097								
	Percentage reduction (%) (cumulative)	0.00	33.68	60.39	69.24	75.28	82.19	84.97	87.21	88.64								
80	Amount of water remaining (g)	3.757	1.6233	0.666	0.3793	0.312	0.297											
	Percentage reduction (%) (cumulative)	0.00	56.79	82.27	89.90	91.70	92.09											
90	Amount of water remaining (g)	3.819	1.558	0.541	0.419	0.402												
	Percentage reduction (%) (cumulative)	0.00	59.20	85.83	89.03	89.47												

Table B13 Field-Curing Time Data for Reference Fine Sand-Based EC-30 Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108		
March 12-16, 2014	Amount of water remaining (g)	4.019	2.532	1.603	1.085	0.878	0.685	0.498	0.364	0.291	0.276	0.241		
	Percentage reduction (%) (interval based)		37.00	23.12	12.89	5.15	4.80	4.65	3.33	1.82	0.37	0.87		
	Percentage reduction (%) (cumulative)		37.00	60.11	73.00	78.15	82.96	87.61	90.94	92.76	93.13	94.00		
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132
April 12-17, 2014	Amount of water remaining (g)	4.123	3.109	2.839	2.591	2.219	1.971	1.481	1.129	0.85	0.641	0.454	0.443	0.436
	Percentage reduction (%) (interval based)		24.59	6.55	6.02	9.02	6.02	11.88	8.54	6.77	5.07	4.54	0.27	0.17
	Percentage reduction (%) (cumulative)		32.61	31.14	37.16	46.18	52.20	64.08	72.62	79.38	84.45	88.99	89.26	89.43

Table B14 Oven-Curing Time Data for Reference Fine Sand-Based EC-30 Specimen

Temp(°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390
50	Amount of water remaining(g)	4.021	2.819	2.29	1.989	1.749	1.591	1.3494	1.191	0.934	0.7985	0.567	0.4964	0.3954	0.289
	Percentage reduction (%) (cumulative)	0.00	29.89	43.05	50.53	56.50	60.43	66.44	70.38	76.77	80.14	85.90	87.65	90.17	92.81
60	Amount of water remaining(g)	4	2.5546	1.9801	1.6525	1.468	1.321	1.172	1.092	0.998	0.8002	0.601	0.498	0.355	0.294
	Percentage reduction (%) (cumulative)	0.00	36.14	50.50	58.69	63.30	66.98	70.70	72.70	75.05	79.99	84.98	87.55	91.12	92.65
70	Amount of water remaining(g)	3.873	2.503	1.998	1.694	1.412	1.124	0.998	0.7948	0.6493	0.501	0.387	0.262		
	Percentage reduction (%) (cumulative)	0.00	35.37	48.41	56.26	63.54	70.98	74.23	79.48	83.24	87.06	90.01	93.24		
80	Amount of water remaining(g)	3.884	2.1428	1.2407	0.9491	0.784	0.532	0.421	0.342						
	Percentage reduction (%) (cumulative)	0.00	44.82	68.05	75.56	79.81	86.30	89.16	91.19						
90	Amount of water remaining(g)	3.504	2.098	0.535	0.267	0.175	0.125								
	Percentage reduction (%) (cumulative)	0.00	40.13	84.73	92.38	95.01	96.43								
100	Amount of water remaining(g)	3.985	1.319	0.511	0.281										
	Percentage reduction (%) (cumulative)	0	0.669	0.8718	0.9295										

Table B15 Field -Curing Time Data for Silt-Size Crushed Limestone-Based AEP Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120		
March 12-17, 2014	Amount of solvent remaining(g)	4.018	3.811	3.569	3.433	3.321	3.222	3.156	2.937	2.881	2.831	2.806	2.791		
	Percentage reduction (%) (interval based)		5.15	6.02	3.38	2.79	2.46	1.64	5.45	1.39	1.24	0.62	0.37		
	Percentage reduction (%) (cumulative)		5.15	11.17	14.56	17.35	19.81	21.45	26.90	28.30	29.54	30.16	30.54		
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	144
April 12-18, 2014	Amount of solvent remaining (g)	4.202	3.921	3.842	3.781	3.682	3.607	3.555	3.508	3.451	3.411	3.366	3.316	3.291	3.281
	Percentage reduction (%) (interval based)		6.69	1.88	1.45	2.36	1.78	1.24	1.12	1.36	0.95	1.07	1.19	0.59	0.24
	Percentage reduction (%) (cumulative)	0.00	6.69	8.57	10.02	12.38	14.16	15.40	16.52	17.87	18.82	19.90	21.09	21.68	21.92

Table B16 Oven-Curing Time Data for Silt- Size Crushed Limestone-Based AEP Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	
50	Amount of solvent remaining (g)	3.735	3.478	3.352	3.322	3.302	3.283	3.258	3.228	3.204	3.167	3.139	3.078	2.999	2.958	2.916	2.885	2.809	2.736	
	Percentage reduction (%) (cumulative)	0.00	6.88	10.25	11.06	11.59	12.10	12.77	13.57	14.22	15.21	15.96	17.59	19.71	20.80	21.93	22.76	24.79	26.75	
60	Amount of solvent remaining (g)	3.93	3.639	3.569	3.477	3.439	3.393	3.306	3.262	3.203	3.172	3.142	3.086	3.002	2.947	2.879				
	Percentage reduction (%) (cumulative)	0.00	7.40	9.19	11.53	12.49	13.66	15.88	17.00	18.50	19.29	20.05	21.48	23.61	25.01	26.74				
70	Amount of solvent remaining (g)	4.167	3.767	3.529	3.409	3.378	3.356	3.297	3.275	3.259	3.205	3.178	3.158	3.041						
	Percentage reduction (%) (cumulative)	0.00	9.60	15.31	18.19	18.93	19.46	20.88	21.41	21.79	23.09	23.73	24.21	27.02						
80	Amount of solvent remaining (g)	3.892	3.3983	3.178	3.057	3.032	2.993	2.9381	2.895	2.845										
	Percentage reduction (%) (cumulative)	0.00	12.68	18.35	21.45	22.10	23.10	24.51	25.62	26.90										
90	Amount of solvent remaining (g)	3.954	3.295	3.069	2.996	2.962	2.901	2.792												
	Percentage reduction (%) (cumulative)	0.00	16.67	22.38	24.23	25.09	26.63	29.39												

Table B17 Field -Curing Time Data for Reference Fine Sand-Based AEP Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120		
March 12-17, 2014	Amount of solvent remaining(g)	3.712	3.611	3.519	3.402	3.299	3.176	2.914	2.797	2.731	2.681	2.66	2.65		
	Percentage reduction (%) (interval based)		2.72	2.48	3.15	2.77	3.31	7.06	3.15	1.78	1.35	0.57	0.27		
	Percentage reduction (%) (cumulative)		2.72	5.20	8.35	11.13	14.44	21.50	24.65	26.43	27.77	28.34	28.61		
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	144
April 12-18, 2014	Amount of solvent remaining (g)	4.038	3.8721	3.791	3.753	3.699	3.631	3.589	3.547	3.461	3.4052	3.336	3.286	3.2499	3.211
	Percentage reduction (%) (interval based)		4.11	2.01	0.94	1.34	1.68	1.04	1.04	2.13	1.38	1.71	1.24	0.89	0.96
	Percentage reduction (%) (cumulative)		4.28	6.38	7.36	8.75	10.51	11.60	12.68	14.90	16.34	18.13	19.42	20.35	21.36

Table B18 Oven-Curing Time Data for Reference Fine Sand-Based AEP Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540
50	Amount of solvent remaining(g)	3.87	3.73	3.63	3.59	3.56	3.53	3.48	3.43	3.38	3.33	3.29	3.24	3.199	3.159	3.112	3.067	3.011	2.981	2.931
	Percentage reduction (%) (cumulative)	0.00	3.64	6.15	7.20	8.15	8.98	10.03	11.4	12.7	14.08	15.1	16.4	17.49	18.52	19.73	20.89	22.34	23.11	24.40
60	Amount of solvent remaining(g)	4	3.84	3.69	3.60	3.54	3.51	3.47	3.42	3.39	3.36	3.31	3.28	3.244	3.201	3.171	3.128	3.068	3.001	
	Percentage reduction (%) (cumulative)	0.00	3.96	7.55	9.78	11.4	12.2	13.03	14.2	15.2	15.93	17.2	18.0	18.88	19.98	20.72	21.80	23.30	24.97	
70	Amount of solvent remaining(g)	3.70	3.53	3.40	3.32	3.28	3.21	3.19	3.14	3.06	2.96	2.88	2.82	2.783						
	Percentage reduction (%) (cumulative)	0.00	4.62	8.14	10.0	11.2	12.9	13.56	15.1	17.2	19.85	22.2	23.6	24.82						
80	Amount of solvent remaining(g)	3.96	3.77	3.62	3.52	3.43	3.39	3.33	3.27	3.21	3.13	3.04	2.99							
	Percentage reduction (%) (cumulative)	0.00	4.95	8.73	11.2	13.4	14.6	16.14	17.4	19.0	21.11	23.2	24.4							
90	Amount of solvent remaining(g)	3.95	3.74	3.54	3.41	3.31	3.21	3.14	3.04	2.97										
	Percentage reduction (%) (cumulative)	0.00	5.26	10.42	13.7	16.2	18.7	20.47	22.9	24.6										
100	Amount of solvent remaining(g)	4.00	3.67	3.53	3.42	3.34	3.24	3.15	3.01											
	Percentage reduction (%) (cumulative)	0.00	8.16	11.86	14.4	16.4	19.0	21.34	24.7											

Table B19 Field-Curing Time Data for Silt-Size Crushed Limestone-Based CSS-1H Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	
March 12-17, 2014	Amount of water remaining (g)	4.422	4.234	4.124	4.01	3.912	3.798	3.719	3.645	3.596	3.522	3.48	3.4401	
	Percentage reduction (%) (interval based)		4.25	2.49	2.58	2.22	2.58	1.79	1.67	1.11	1.67	0.95	0.90	
	Percentage reduction (%) (cumulative)		4.25	6.74	9.32	11.53	14.11	15.90	17.57	18.68	20.35	21.30	22.20	
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132
April 12-17, 2014	Amount of water remaining (g)	3.913	3.832	3.7131	3.625	3.541	3.506	3.43612	3.3541	3.274	3.1874	3.099	3.063	3.0281
	Percentage reduction (%) (interval based)		2.07	3.04	2.25	2.15	0.89	1.79	2.10	2.05	2.21	2.26	0.92	0.89
	Percentage reduction (%) (cumulative)	0.00	2.07	5.11	7.36	9.51	10.40	12.19	14.28	16.33	18.54	20.80	21.72	22.61

Table B20 Oven-Curing Time Data for Silt- Size Crushed Limestone-Based CSS-1H Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330
50	Amount of water remaining (g)	3.692	3.502	3.381	3.299	3.251	3.198	3.12	3.057	2.999	2.934	2.894	2.867
	Percentage reduction (%) (cumulative)	0.00	5.15	8.42	10.64	11.92	13.38	15.49	17.20	18.77	20.53	21.61	22.32
60	Amount of water remaining (g)	3.748	3.598	3.431	3.381	3.302	3.236	3.130	3.059	2.978	2.898	2.837	
	Percentage reduction (%) (cumulative)	0.00	4.00	8.46	9.79	11.90	13.64	16.47	18.38	20.52	22.67	24.30	
70	Amount of water remaining (g)	3.899	3.558	3.394	3.3569	3.291	3.239	3.173	3.107	3.006			
	Percentage reduction (%) (cumulative)	0.00	8.75	12.95	13.90	15.59	16.93	18.62	20.31	22.90			
80	Amount of water remaining (g)	3.696	3.275	3.132	3.044	2.991	2.917	2.846					
	Percentage reduction (%) (cumulative)	0.00	11.39	15.26	17.64	19.07	21.08	23.00					
90	Amount of water remaining (g)	3.672	3.241	3.014	2.943	2.845							
	Percentage reduction (%) (cumulative)	0.00	11.74	17.92	19.85	22.52							

Table B21 Field -Curing Time Data for Reference Fine Sand-Based CSS-1H Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	
March 12-17, 2014	Amount of water remaining (g)	4.548	4.117	3.798	3.497	3.321	3.274	3.101	2.998	2.895	2.834	2.802	2.795	
	Percentage reduction (%) (interval based)		9.48	7.01	6.62	3.87	1.03	3.80	2.26	2.26	1.34	0.70	0.15	
	Percentage reduction (%) (cumulative)		9.48	16.49	23.11	26.98	28.01	31.82	34.08	36.35	37.69	38.39	38.54	
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132
April 12-17, 2014	Amount of water remaining (g)	4.406	4.053	3.834	3.679	3.427	3.215	3.009	2.884	2.739	2.663	2.591	2.582	2.571
	Percentage reduction (%) (interval based)		8.01	4.97	3.52	5.72	4.81	4.68	2.84	3.29	1.72	1.63	0.20	0.25
	Percentage reduction (%) (cumulative)	0.00	8.01	12.98	16.50	22.22	27.03	31.71	34.54	37.83	39.56	41.19	41.40	41.65

Table B 22 Oven-Curing Time Data for Reference Fine Sand-Based CSS-1H Specimen

Temp(°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480
50	Amount of water remaining (g)	4.058	3.677	3.415	3.296	3.223	3.178	3.125	3.053	2.986	2.932	2.873	2.827	2.7327	2.687	2.602	2.544	2.457
	Percentage reduction (%) (cumulative)	0.00	9.39	15.85	18.78	20.58	21.68	22.99	24.76	26.42	27.73	29.20	30.31	32.66	33.79	35.88	37.31	39.45
60	Amount of water remaining (g)	3.6	3.268	3.039	2.967	2.901	2.848	2.767	2.691	2.633	2.581	2.502	2.462	2.411	2.321	2.247	2.171	
	Percentage reduction (%) (cumulative)	0.00	9.22	15.57	17.56	19.42	20.86	23.14	25.25	26.86	28.31	30.50	31.61	33.03	35.53	37.58	39.67	
70	Amount of water remaining (g)	4.054	3.592	3.363	3.252	3.175	3.087	2.994	2.856	2.779	2.701	2.633	2.559	2.502	2.435			
	Percentage reduction (%) (cumulative)	0.00	11.40	17.04	19.78	21.68	23.84	26.15	29.55	31.45	33.37	35.05	36.88	38.28	39.94			
80	Amount of water remaining (g)	4.3475	3.846	3.586	3.471	3.373	3.270	3.191	3.111	3.002	2.925	2.806	2.724	2.619				
	Percentage reduction (%) (cumulative)	0.00	11.53	17.52	20.16	22.42	24.77	26.60	28.44	30.95	32.72	35.46	37.34	39.76				
90	Amount of water remaining (g)	4.066	3.628	3.354	3.201	3.1055	3.001	2.874	2.7811	2.6085	2.5009	2.424	2.411					
	Percentage reduction (%) (cumulative)	0.00	10.77	17.51	21.27	23.62	26.19	29.32	31.60	35.85	38.49	40.38	40.70					
100	Amount of water remaining (g)	4.429	3.569	3.130	2.897	2.7704	2.667											
	Percentage reduction (%) (cumulative)	0.00	19.42	29.31	34.59	37.45	39.77											

Table B23 Field -Curing Time Data for Silt-Size Crushed Limestone-Based SS-1H Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120			
March 12-18, 2014	Amount of water remaining (g)	4.029	3.892	3.748	3.545	3.337	3.164	2.998	2.879	2.836	2.760	2.737	2.733			
	Percentage reduction (%) (interval based)		3.40	3.57	5.04	5.16	4.29	4.12	2.95	1.07	1.86	0.58	0.09			
	Percentage reduction (%) (cumulative)		3.40	6.97	12.01	17.18	21.47	25.59	28.54	29.61	31.47	32.06	32.15			
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	144	156
April 12-18, 2014	Amount of water remaining (g)	3.84	3.800	3.754	3.672	3.634	3.571	3.536	3.478	3.431	3.377	3.301	3.251	3.204	3.166	3.129
	Percentage reduction (%) (interval based)		1.03	1.21	2.14	0.99	1.64	0.91	1.51	1.22	1.41	1.98	1.30	1.22	0.99	0.96
	Percentage reduction (%) (cumulative)	0.00	1.03	2.24	4.38	5.36	7.01	7.92	9.43	10.65	12.06	14.04	15.34	16.56	17.55	18.52

Table B24 Oven-Curing Time Data for Silt-Size Crushed Limestone-Based SS-1H Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450
50	Amount of water remaining (g)	3.997	3.841	3.739	3.695	3.627	3.559	3.501	3.461	3.387	3.3297	3.274	3.1975	3.1375	3.078	2.99	2.931
	Percentage reduction (%) (cumulative)	0.00	3.90	6.45	7.56	9.26	10.96	12.41	13.41	15.26	16.70	18.09	20.00	21.50	22.98	24.96	26.67
60	Amount of water remaining (g)	4.019	3.842	3.723	3.6792	3.618	3.551	3.461	3.405	3.344	3.286	3.213	3.158	3.112	3.048	2.981	
	Percentage reduction (%) (cumulative)	0.00	4.40	7.37	8.45	9.98	11.64	13.88	15.28	16.80	18.24	20.05	21.42	22.57	24.16	25.83	
70	Amount of water remaining (g)	4.087	3.829	3.697	3.598	3.524	3.462	3.382	3.339	3.274	3.211	3.147	3.092	2.984			
	Percentage reduction (%) (cumulative)	0.00	6.31	9.54	11.96	13.78	15.29	17.25	18.30	19.89	21.43	23.00	24.35	26.99			
80	Amount of water remaining (g)	3.909	3.7734	3.572	3.445	3.223	3.117	3.024	2.9474	2.8743							
	Percentage reduction (%) (cumulative)	0.00	3.47	8.62	11.87	17.55	20.26	22.64	24.60	26.47							
90	Amount of water remaining (g)	3.892	3.642	3.369	3.221	3.031	2.924	2.828	2.742								
	Percentage reduction (%) (cumulative)	0.00	6.42	13.44	17.24	22.12	24.87	27.34	29.55								

Table B25 Field -Curing Time Data for Reference Fine Sand-Based SS-1H Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	144
March 12-18, 2014	Amount of water remaining (g)	4.089	3.791	3.478	3.205	3.111	3.011	2.989	2.919	2.869	2.865	2.807	2.7621	2.728	2.688
	Percentage reduction (%) (interval based)		7.29	7.65	6.68	2.30	2.45	0.54	1.71	1.22	0.10	1.42	1.10	0.83	0.98
	Percentage reduction (%) (cumulative)		7.29	14.94	21.62	23.92	26.36	26.90	28.61	29.84	29.93	31.35	32.45	33.28	34.26
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	
April 12-18, 2014	Amount of water remaining (g)	4.546	4.348	4.199	3.988	3.821	3.766	3.597	3.499	3.401	3.298	3.2179	3.179	3.1467	
	Percentage reduction (%) (interval based)		4.36	3.28	4.64	3.67	1.21	3.72	2.16	2.16	2.27	1.76	0.86	0.71	
	Percentage reduction (%) (cumulative)	0.00	4.36	7.63	12.27	15.95	17.16	20.88	23.03	25.19	27.45	29.21	30.07	30.78	

Table B26 Oven-Curing Time Data for Reference Fine Sand-Based SS-1H Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420
50	Amount of water remaining (g)	3.826	3.513	3.325	3.259	3.198	3.1299	3.058	2.971	2.909	2.837	2.774	2.699	2.651	2.618	2.583
	Percentage reduction (%) (cumulative)	0.00	8.18	13.09	14.81	16.41	18.19	20.07	22.35	23.94	25.85	27.48	29.46	30.71	31.57	32.49
60	Amount of water remaining (g)	4.1	3.662	3.498	3.422	3.391	3.322	3.241	3.215	3.142	3.053	2.979	2.903	2.845	2.7801	
	Percentage reduction (%) (cumulative)	0.00	10.68	14.68	16.54	17.29	18.98	20.95	21.59	23.37	25.54	27.34	29.20	30.61	32.19	
70	Amount of water remaining (g)	4.096	3.712	3.523	3.4517	3.416	3.3019	3.198	3.1298	3.079	2.995	2.945	2.864	2.784		
	Percentage reduction (%) (cumulative)	0.00	9.38	13.99	15.73	16.59	19.39	21.92	23.59	24.83	26.88	28.10	30.08	32.03		
80	Amount of water remaining (g)	4.088	3.776	3.6435	3.512	3.423	3.295	3.161	3.083	2.997	2.932	2.867	2.7803			
	Percentage reduction (%) (cumulative)	0.00	7.63	10.89	14.10	16.28	19.41	22.69	24.60	26.70	28.29	29.88	32.00			
90	Amount of water remaining (g)	4.165	3.769	3.509	3.429	3.365	3.279	3.205	3.085	2.9701	2.8707	2.7822				
	Percentage reduction (cumulative)	0.00	9.50	15.75	17.67	19.21	21.27	23.05	25.93	28.69	31.08	33.20				
100	Amount of solvent remaining(g)	3.918	3.3301	3.003	2.9094	2.8276	2.734	2.624								
	Percentage reduction (cumulative)	0.00	15.01	23.35	25.74	27.83	30.22	33.03								

Table B27 Field -Curing Time Data for Silt-Size Crushed Limestone-Based TP Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	144
March 12-18, 2014	Amount of water remaining (g)	4.126	3.617	3.291	2.995	2.543	2.273	1.911	1.578	1.211	0.971	0.681	0.432	0.421	0.401
	Percentage reduction (%) (interval based)		12.34	7.90	7.17	10.95	6.54	8.77	8.07	8.89	5.82	7.03	6.03	0.27	0.48
	Percentage reduction (%) (cumulative)		12.34	20.24	27.41	38.37	44.91	53.68	61.75	70.65	76.47	83.49	89.53	89.80	90.28
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132	
April 12-17, 2014	Amount of water remaining (g)	4.645	3.298	2.884	2.529	2.009	1.892	1.619	1.345	1.021	0.729	0.445	0.443	0.434	
	Percentage reduction (%) (interval based)		29.00	8.91	7.64	11.19	2.52	5.88	5.90	6.98	6.29	6.11	0.04	0.19	
	Percentage reduction (%) (cumulative)	0.00	29.00	37.91	45.55	56.75	59.27	65.15	71.04	78.02	84.31	90.42	90.46	90.66	

Table B28 Oven-Curing Time Data for Silt-Size Crushed Limestone-Based TP Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450
50	Amount of water remaining (g)	4.902	3.395	2.675	2.383	2.169	2.093	1.881	1.675	1.545	1.304	1.145	0.963	0.789	0.664	0.569	0.475
	Percentage reduction (%) (cumulative)	0.00	30.74	45.43	51.39	55.75	57.30	61.63	65.83	68.48	73.40	76.64	80.35	83.90	86.44	88.39	90.31
60	Amount of water remaining (g)	3.733	2.641	2.091	1.836	1.582	1.335	0.998	0.798	0.643	0.489	0.426	0.377	0.359			
	Percentage reduction (%) (cumulative)	0.00	29.25	43.99	50.82	57.62	64.24	73.27	78.60	82.78	86.90	88.59	89.90	90.38			
70	Amount of water remaining (g)	3.964	2.519	1.619	1.339	1.0869	0.859	0.6949	0.5191	0.432	0.334						
	Percentage reduction (%) (cumulative)	0.00	36.45	59.16	66.22	72.58	78.33	82.47	86.90	89.10	91.57						
80	Amount of water remaining (g)	4.168	2.0893	1.099	0.8943	0.626	0.496	0.342									
	Percentage reduction (%) (cumulative)	0.00	49.87	73.63	78.54	84.98	88.10	91.79									
90	Amount of water remaining (g)	4.118	1.843	0.8812	0.522	0.369											
	Percentage reduction (%) (cumulative)	0.00	55.25	78.60	87.32	91.04											

Table B29 Field -Curing Time Data for Reference Fine Sand-Based TP Specimen

Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132
March 12-18, 2014	Amount of water remaining (g)	5.738	4.298	3.8919	3.322	2.984	2.438	2.011	1.609	1.204	0.972	0.561	0.518	0.493
	Percentage reduction (%) (interval based)		25.10	7.08	9.93	5.89	9.52	7.44	7.01	7.06	4.04	7.16	0.75	0.44
	Percentage reduction (%) (cumulative)		25.10	32.17	42.11	48.00	57.51	64.95	71.96	79.02	83.06	90.22	90.97	91.41
Testing Season	Time (hrs)	0	1	12	24	36	48	60	72	84	96	108	120	132
April 12-17, 2014	Amount of water remaining (g)	6.222	4.489	3.991	3.113	2.681	2.139	1.539	1.231	0.998	0.679	0.459	0.457	0.449
	Percentage reduction (%) (interval based)		27.85	8.00	14.11	6.94	8.71	9.64	4.95	3.74	5.13	3.54	0.03	0.13
	Percentage reduction (%) (cumulative)	0.00	27.85	35.86	49.97	56.91	65.62	75.27	80.22	83.96	89.09	92.62	92.66	92.78

Table B30 Oven-Curing Time Data for Reference Fine Sand-Based TP Specimen

Temp (°C)	Time (min)	0	30	60	90	120	150	180	210	240	270
50	Amount of water remaining (g)	4.515	2.871	1.876	1.598	1.244	0.901	0.678	0.501	0.376	0.278
	Percentage reduction (%) (cumulative)	0.00	36.41	58.45	64.61	72.45	80.04	84.98	88.90	91.67	93.84
60	Amount of water remaining (g)	3.9	2.7186	1.6802	1.2792	0.991	0.728	0.395	0.205		
	Percentage reduction (%) (cumulative)	0.00	30.29	56.92	67.20	74.59	81.33	89.87	94.74		
70	Amount of water remaining (g)	6.131	3.901	2.399	1.755	1.347	0.5359	0.230			
	Percentage reduction (%) (cumulative)	0.00	36.37	60.87	71.37	78.03	91.26	96.25			
80	Amount of water remaining (g)	6.7079	3.5433	1.5271	1.021	0.689	0.405	0.292			
	Percentage reduction (%) (cumulative)	0.00	47.18	77.23	84.78	89.73	93.96	95.65			
90	Amount of water remaining (g)	6.077	3.721	0.988	0.598	0.223					
	Percentage reduction (%) (cumulative)	0.00	38.77	83.74	90.16	96.33					
100	Amount of water remaining (g)	5.884	1.812	0.611	0.291						
	Percentage reduction (cumulative)	0	0.69	0.90	0.95						

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