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# Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance

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Prepared for  
Mississippi Department of Transportation

State Study No. 271

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Thompson Engineering, Inc.

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<b>16. Abstract</b> <p>The Mississippi Department of Transportation is in the process of implementing the Mechanistic-Empirical Pavement Design procedure for designing rigid and flexible pavements. This implementation effort includes developing a manual, "Mississippi DOT Pavement ME Design User Input Guide." The current draft manual will be enhanced with the addition of a chapter focused on various problematic soils located throughout the state. This chapter of the guide will capture available institutional knowledge on the general properties of various geological units of soil deposits and their effects on the performance of pavements constructed thereon.</p> <p>In the 30 years following the implementation of the 1986 Mississippi AHEAD Construction Program, over 1,000 miles of formerly two-lane highways have been upgraded to four-lane arterial standards. A large number of these construction projects involved construction of two new parallel lanes, and then the existing lanes were upgraded to the current safety standards. The pavement design and/or reconstruction of these old existing lanes presented many more challenges than the construction of the new lanes, because the materials used within the roadway prism of the new lanes were much more easily controlled. It is the experiences of the soils encountered and unusual lessons learned during construction of new lanes and reconstruction of the old lanes during this construction program, as well as current design and construction issues, that this research was focused on.</p>			
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Daniel Cauthen, Brad Watson, and Durwood Graham – District 3

Graham Clarke and Freddie Stokes – District 5

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Steve Smith, Ken Morris, and Dalton Williams – District 7

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## **List of Abbreviations**

AASHTO – American Association of State Highway and Transportation Officials

HVC – High Volume Change

MDOT – Mississippi Department of Transportation

PI – Plasticity Index

SOP – Standard Operating Procedure



## Executive Summary

The Mississippi Department of Transportation (MDOT) is in the process of implementing the Mechanistic-Empirical Pavement Design procedure for designing rigid and flexible pavements. This implementation effort includes providing the agency with a manual, “Mississippi DOT Pavement ME Design User Input Guide.” MDOT has considered enhancing the current draft manual with the addition of a chapter focused on various problematic soils located throughout the state. This chapter of the guide will capture available institutional knowledge on the general properties of various geological units and types of soil deposits and their effects on the performance of pavements constructed thereon.

In the 30 years following the implementation of the 1986 Mississippi AHEAD Construction Program, over 1,000 miles of formerly two-lane highways have been upgraded to four-lane arterial standards. A large number of these construction projects involved construction of two new parallel lanes, and then the existing lanes were upgraded to the current safety standards. The pavement design and/or reconstruction of these old existing lanes presented many more challenges than the construction of the new lanes, because the materials used within the roadway prism of the new lanes were much more easily controlled. It is the experiences of the soils encountered and unusual lessons learned during construction of new lanes and reconstruction of the old lanes, that this research primarily attempted to capture.

This research focused on a series of interviews with experienced MDOT materials and construction personnel with familiarity of the problematic soils in their respective districts of the state, to determine how they addressed the problems at the time and what they would do differently to address them today. The conclusions from these experiences are addressed by submittal of recommended changes for MDOT Standard Operating Procedures, as well as recommendations for the additional chapter in the Mississippi DOT Pavement ME Design User Input Guide.

## Introduction/Background

The Mississippi Department of Transportation (MDOT) has for many years used an empirical process to design pavements. Various versions of the American Association of State Highway and Transportation Officials (AASHTO) Design Guide have been used, utilizing structural layer coefficients of the various pavement layers based upon local experience and results from research projects. In essence, however, most pavement designs are predicated upon the controlling California Bearing Ratio (CBR), which is converted through empirical formulas into a resilient modulus, of the subgrade soils along the roadway alignment. Mississippi has an abundance of low CBR ( $\leq 5$ ) soils, which are typically fine grained materials. Some, but not all, of these fine grained soils become problematic due to sensitivity to moisture content. These sensitivities manifest themselves in the form of subgrade instability which inhibit proper construction of subsequent pavement layers, shrinking and swelling which destroy the smoothness of the finished pavement, or simply the difficulty of processing the materials during earthmoving operations.

MDOT is in the process of implementing the Mechanistic-Empirical Pavement Design procedure for designing rigid and flexible pavements. Various research efforts over the past decade have been undertaken to develop the materials libraries, traffic inputs, and climate data to establish the local calibration factors which are used in the design process. Another part of the implementation effort includes developing an agency manual, "Mississippi DOT Pavement ME Design User Input Guide."

In the 30 years following the implementation of the 1986 Mississippi AHEAD construction program, over 1,000 miles of formerly two-lane highways have been upgraded to divided four-lane arterial standards. A large number of these construction projects involved construction of two new parallel lanes, and then the existing lanes were upgraded to the current safety standards. The pavement design and/or reconstruction of these old existing lanes presented many more challenges than the construction of the new lanes, because the materials used within the roadway prism of the new lanes were much more easily controlled.

With the completion of the AHEAD program, the MDOT construction program primarily has shifted towards pavement maintenance (overlays) and rehabilitation work. Some of the recent rehabilitation projects in urban areas have involved providing additional capacity (lanes) and total reconstruction of the existing pavement structure. Thus, the problematic soils issues often associated with reconstruction of the existing lanes during the AHEAD program continue to surface in the design and construction of these rehabilitation projects.

MDOT recognized a need to enhance the draft design user input guide manual with the addition of a chapter focused on various problematic soil deposits located throughout the state.

This chapter of the guide will capture available institutional knowledge on the general properties of various geological units and types of soil deposits and their effects on the performance of pavements constructed thereon. It is the experiences of the soils encountered, and unusual lessons learned during construction of new lanes and reconstruction of the old lanes, that this research attempts to capture.

## Literature Review

The Mississippi Department of Environmental Quality, Office of Geology has published a *Geologic Map of Mississippi*. It is used to identify the various major soil formations that can be anticipated at the surface or near surface of the ground. This map is the primary basis for identifying areas within the state where problematic soils can be expected on a particular project. The map, presented here as Figure 1, can be accessed at the following link:

[https://www.mdeq.ms.gov/wp-content/uploads/2017/05/MS\\_Geology1969.pdf](https://www.mdeq.ms.gov/wp-content/uploads/2017/05/MS_Geology1969.pdf)

During the course of the research task devoted to District interviews, the *Geologic Map of Mississippi* was consulted and used as a starting point to initiate discussions.

MDOT commissioned State Study No. 224 “Summary of Lessons Learned from the MDOT MEPDG Materials Library Study”.<sup>(2)</sup> The final report, authored by Robert James, Allen Cooley, and Randy Ahlrich of Burns Cooley Dennis, Inc. (BCD), primarily discusses the experiences BCD obtained with resilient modulus testing of various soils around the State of Mississippi for the MDOT’s MEPDG materials library. Of particular interest from their report, it was noted that BCD obtained some of their higher resilient modulus values measured in the laboratory, for two of the more problematic soil materials and types which were revealed in the course of this study.

## Methodology/Research Approach

On a general basis, the major geological units in Mississippi which are known to be problematic to design and construction efforts are common knowledge. With the abundance of soft soils, shrinking and swelling expansive clays, silts, and fine sands in this state, property owners and construction people alike are well aware of local earth working conditions which can present issues when they simply want to build something. The fraternity of people who have had to get into the details of how the presence of these soils are determined in the design process, or what to do with them in the construction process, is quite limited. This applies even to the Mississippi Department of Transportation, which is tasked with designing, building, and maintaining infrastructure facilities for the public.

During the scoping of this research effort, it was determined that interviews with current or former MDOT personnel, who had experiential knowledge of specific construction issues related to problematic soils, could provide a wealth of information in regards to specific locations of these soils. An agenda was developed to be used in a series of interviews with the appropriate MDOT District and Central Office personnel. This agenda is presented as Figure 2.

The personnel selected to take part in these interviews, as a general rule, have been involved with materials testing, pavement design recommendations, or construction for many years. The process attempted to capture their experiences with the 1987 4-lane AHEAD program as well as more recent pavement reconstruction projects regarding issues related to problematic soils. These personnel were then questioned about their opinion of particular MDOT policies or standard operating procedures which could be modified to circumvent future construction problems.

Over the course of the process, identifiable trends began to appear as not only common in the areas in which these individuals work but also on a statewide basis.

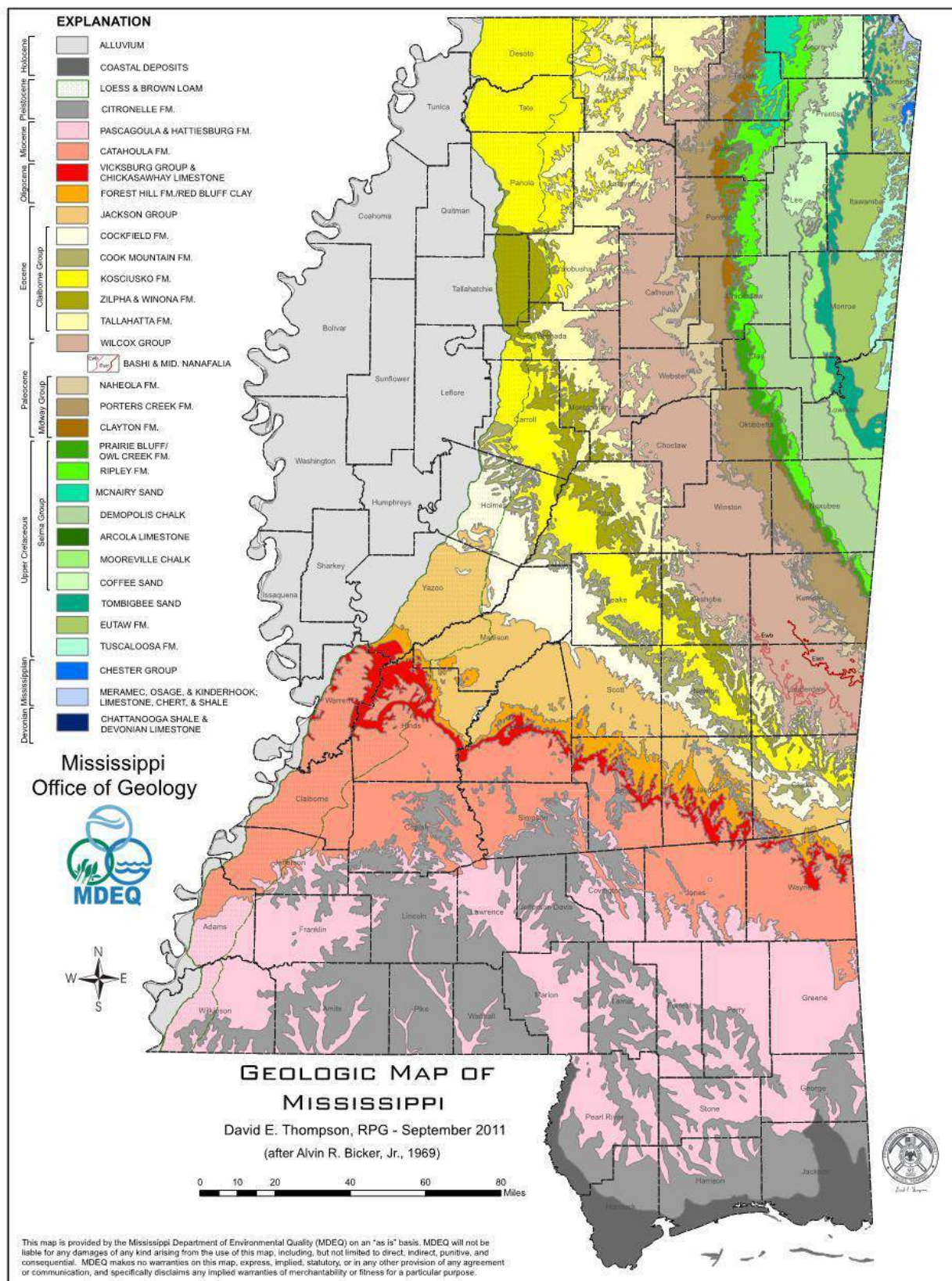


Figure 1

## **DISTRICT INTERVIEWS**

### **SS #271 Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance**

**District:**

**Attendees:**

- **Purpose of Research**
- **Identification of problem soils in the District**
- **Types of construction affected**
- **Treatment or Remediation methods used**
- **Maintenance issues**
- **Recommendations (how you would do it differently based on past experiences)**
- **Suggestions for changing Department SOPs**
  - a. **Overlays**
  - b. **Widening**
  - c. **Rehabilitation**
  - d. **New construction**
- **Closing Remarks**

Figure 2



## Research Findings and Applications

### HEAVY CLAYS –

The *Geologic Map of Mississippi* lists several geological formations which are known to the locals to exhibit shrinking and swelling tendencies. In no particular order, the major formations with these tendencies include:

- Black Prairie Soils of the Selma Group
- Owl Creek Formation
- Porters Creek Formation
- Zilpha Formation
- Yazoo Clay of the Jackson Group
- Pascagoula and Hattiesburg Formations
- “Gumbo” clays of the Mississippi River Delta Alluvium

The MDOT has been attempting to mitigate the effects of active clays on pavements for approximately 50 years.<sup>(1)</sup> These early attempts included identifying active clays by performing shrinkage limit tests\* to determine the volume change potential of the material. For several years, clays that exhibited a volume change of greater than 74% were considered “high volume change” (HVC), and there were procedures in place that were used to try and offset the shrink/swell effects of HVC soils.

In the 1970’s, for example, it was thought that “remolding” of Yazoo clay in the subgrade disrupted the natural shrinkage cracks in the material which would eventually allow rain water to infiltrate down to certain depths, and prevent swelling of the clay as it tried to reach equilibrium when water entered those cracks. Several high traffic roadways were constructed in the Jackson area using this technique. The technique basically consisted of scarifying or excavating the Yazoo clay material, placing it back into the subgrade or within an embankment (in a drier condition), and compacting it to the specified density.

The use of lime, particularly the hydrated variety, has been shown to be very effective in reducing the plasticity index (PI) of clay materials. Properly blended, clay soils mixed with lime are much more friable and easier to work with during earthwork construction. It was presumed that a subgrade consisting of shrinking and swelling expansive clays that had been treated with lime would inhibit or even prevent additional shrinking and swelling. This method was used with HVC soils on a statewide basis for a period of time for this purpose, and it is still used today as a chemical treatment in certain design soils (defined below).

**\*NOTE:** The standard test method to determine the shrinkage limit and volume change of soils was a now discontinued procedure AASHTO T 92 – Determining the Shrinkage Factors of Soils. It is presented in Appendix D for reference.

Neither of these methods proved in the long term to work very well for HVC clays, and pavement failures in areas of Mississippi with these types of soils and constructed using these methods on the subgrade continued to appear. In the 1980's, MDOT began trying different methods of controlling the in-situ moisture content of the clay subgrade soils. Some examples included application of a bituminous coating directly on the subgrade; use of an impermeable membrane directly on top of the subgrade similar to those used in landfill applications; and significant undercutting of the subgrade (up to 3 feet) and backfilling with a fine-grained material of low to medium plasticity (AASHTO A-6 classification).

The best success in regards to inhibiting shrink/swell of the subgrade to reduce bumpy pavements was found to be with the undercut/backfill procedure, especially in roadway cut sections when the undercut extended from ditchline to ditchline. By nature the procedure is costly, for three major reasons. One, rarely is quality backfill material readily available in most areas of the state where the HVC soils exist, such that there is usually a considerable haul distance involved from a pit that has material with the desired properties. Two, the undercut heavy clay material is of relatively no use on a highway construction project, and must be hauled off and wasted somewhere off the project. And three, even though the A-6 type material used for backfill is a "better" material than the underlying subgrade, it is still a fine-grained material with a less than desirable CBR and must be chemically treated to provide a stable subgrade.

In the past 20 years, the MDOT pavement policy has been modified several times to address the problem of clay subgrades. Virtually all new construction projects are now built with controls on the design soil. Design soil is defined as "that portion of the roadbed consisting of the top three feet of untreated or treated soils in excavated sections and embankment."<sup>(3)</sup> Limitations on the volume change have been reduced to 60% - meaning, soil materials with a volume change of 60% or more are prohibited from being used in the design soil prism. In addition, with rare exception, all subgrades are now chemically treated with either lime or cement, depending on the classification of the subgrade soil.

This current policy necessitates more engineering insight both in the preconstruction design stage and during the actual construction. HVC soils must be identified, if possible, during the design stage by drilling for subsurface samples to a depth of up to 5 feet below the anticipated subgrade elevation. Considerable effort must be expended in the laboratory to test these samples for HVC characteristics. The extent and limits of HVC soils which would be in the subgrade must be identified and listed, so that roadway designers can modify the construction plans accordingly to insure that adequate quantities of excess excavation (waste) and borrow excavation are established in the bid documents. Similarly, inspection personnel must be vigilant during the construction operations to insure that HVC soils do not end up in the design soil and that slopes are properly constructed.



During the interview process with select MDOT personnel, it was noted that the procedures described in the two preceding paragraphs have evolved. These procedures were originally developed for construction along new alignments, whether a part of the 1987 4-lane AHEAD program or other “new construction” projects. At the time of this research undertaking, there is little new construction being performed, as MDOT’s primary mission has moved towards maintaining existing roadways (overlays), or upgrading and adding capacity (rehabilitation projects). In the course of designing these type projects, the MDOT District personnel have become increasingly aware of the need to verify all types of in-situ materials they will be working with during construction. Instances were noted where roadways in tolerably good working condition were being upgraded or widened for safety reasons or to add capacity, and it was found that the soils on the outside of the existing pavement (shoulder areas) were very poor. The existing as-built construction plans gave little or no indication that poor subgrade soils from the roadway section had been pushed to the side to form the shoulders or side slopes.

Other instances were noted with design of simple overlay projects, where the Districts went to retrieve cores of the existing pavement to determine the structure thickness and found very poor, saturated subgrades beneath the pavement. These problems probably would have never been known had they not taken full-depth cores of the existing pavement. The existence of poor subgrade material would likely affect the design thickness of the overlay or the depth of the milling required.

#### **OTHER PROBLEMATIC SOILS –**

The MDOT District interviews yielded many locations around the state where problematic soils were encountered (see Appendix A), and most were related to highly plastic or HVC soils. “Highly plastic” was a term loosely used, and there were various opinions as to what constituted a “highly plastic” designation. There seemed to be general consensus that any clay material with a plasticity index of 23 or higher was going to present issues during construction, *regardless of the volume change measured in the laboratory*, and it had to be dealt with accordingly.

In an unexpected discovery, there were some other types of non-plastic or low PI soils that were identified by the Districts as materials which had caused difficulties during construction. In particular, certain soils given an AASHTO classification of A-4 were singled out.

Along the bluffs of the Mississippi Delta and the Mississippi River, massive wind-blown deposits of silt known as loess exist. This material consists of 90% or more silt size particles, and has little to no plasticity. It is highly erodible. As long as the moisture content is approximately 3% below the optimum moisture at maximum dry density, the material can be excavated, shaped and compacted with relative ease. However, when the material gets wet and saturated, it has very little stability. This limits earthwork operations to being performed when the prevailing

weather pattern is dry. As a subgrade material, it must be quickly chemically treated with cement and primed with bituminous material to avoid excessive moisture intrusion and loss of stability.

Similar A-4 materials not associated with the loess bluffs are prevalent within the southern 1/3 of the state. These are usually found as very wet and soft, and are sometimes mis-categorized as muck even though the organic content of the material does not bear that out. District 6 (Hattiesburg) notes that often they are able to excavate these materials, stockpile them in a place where they can naturally drain and dry out, then use it as a good unclassified excavation material in embankment construction below the design soil. The material, when used in this manner, is also highly erodible and slopes must be vegetated quickly.

Three of the Districts noted that they had recently had issues with materials which traditionally have been used with great success in their roadway construction projects. The first is their Class 9 granular material, used extensively across the state as a sub-base beneath pavements (“topping”) and chemically treated with cement before the base lift of hot mix asphalt is placed. MDOT’s standard specifications define a Class 9 granular material as a material with 30 - 100% passing the No. 10 sieve. Of the material passing the No. 10 sieve, the following gradation limitations apply:

Sieve Size	% Passing
No. 10	100
No. 40	20 – 100
No. 60	15 – 85
No. 200	6 - 40

Historically most pit sources of Class 9 granular material have fallen into the median range of the percent passing specified. For many years, when the material was available, the Districts preferred Class 9 granular material with a Group C designation (limiting the PI of the material to a maximum of 10). This insured they were getting a good sandy material with just enough fines to help hold the sand sized particles together. Nowadays, Class 9 granular material is often specified with a Group E designation, *requiring* it to have a plasticity index between 6 and 15. This material would categorize as an AASHTO A-2-4 classification. As good sources for Class 9 granular material have become more difficult to find, the materials which do meet the specification limits (regardless of Group designation) are at the upper end of the gradation bands for the No. 60 and No. 200 sieves, and there is also very little plasticity – i.e., the material is fine and silty. The fineness of the material makes it difficult for the laboratory to determine the optimum cement content for chemical treatment. Designing strictly on a compressive strength basis, excessive application rates of cement (>7%) are determined to be necessary. However, these high cement applications are difficult to manage in the construction process, due to excessive water demand with the short time limitations required in achieving

proper density. It also lends itself to excessive cracking of the blended and compacted materials, even when the bituminous prime coat is placed in a reasonable time after compaction to prevent moisture loss. Two of the districts noted that they have begun limiting the cement application to 6% or less, regardless of compressive strength constraints, whenever the Class 9 granular material tends towards a fine gradation.

Another material which historically has worked well as a design soil is Class B9-6 Borrow Excavation. It has been used extensively statewide to backfill undercut subgrades in HVC areas. MDOT's standard specifications allow up to 100% of the B9-6 material to pass the No. 200 sieve, but the liquid limit cannot exceed 40 and the plasticity index must be between 6 and 20. This insures that "lean clay" is being placed over the HVC undercut subgrade in an attempt to keep the moisture content of the HVC subgrade at a constant level. Most of the Districts noted that on several of their projects, the B9-6 material was difficult to locate within a reasonable haul distance, and the material they did have was so silty or sandy that it was at the lower limit of the plasticity index requirement. These Districts also noted that the B9-6 borrow excavation did not always respond well to the usual chemical treatment methods. They did not feel they were getting the desired moisture barrier over the undercut HVC soils, based upon swelling which manifested itself in a short period of time after opening the completed pavements to traffic.

For both situations described above, these "marginal" earthwork construction materials are trending towards an AASHTO A-4 classification, in which the silt content seems to be the common thread.

## Conclusions

The information provided by the MDOT Districts in the interview process indicated that the experienced, seasoned veterans of the Department were very much aware of where the problematic soils are located in their respective Districts. As geologically complex as the State of Mississippi is, there were really no surprising revelations noted concerning locations of less than desirable subgrade soils for new roadway construction. The *Geologic Map of Mississippi* provides sufficient detail of the locations of these soils. The District laboratories have become well versed in what to look for whenever a soils investigation begins for some new roadway alignment, based on the general area of the project. They use the data collected and plan accordingly.

The surprises that were most mentioned were ones encountered during subgrade investigations for overlay or rehabilitation projects. The MDOT Districts are finding that materials used in the original roadway construction are often of poor quality, which was unexpected before construction or a site investigation for a new project was begun. Sometimes these poor quality materials are not discovered until issues arise during an active construction project, which result in overruns and extra cost. These issues have forced the Districts to look more closely at the existing roadway conditions in the pre-construction stage, instead of relying strictly on “as-built” plans on file whenever they package an overlay or widening project for construction bids.

MDOT has Standard Operating Procedures (SOPs) which prescribe the procedures to be used with a soils investigation. One of these SOPs, specifically TMD-20-14-00-00, not only describes the procedures to be used for developing centerline soil profiles, it also lists the procedures to be used when HVC soils are encountered. Each of the districts indicated that the procedures for developing centerline soil profiles should be enhanced to include investigations for overlays and widening or rehabilitation projects. They also indicated that procedures for addressing HVC soils should be in a separate standalone SOP.

With now over 100 years of construction administered by the Mississippi Department of Transportation, there remains only a slim chance of discovering new sources of high quality road construction soil materials. Economical sources of the better materials have already been used. By default, MDOT is tasked with developing new economical ways to use the natural resources in the form of earthen materials which do remain. This will require more site research, investigation, and engineering on the front end of planned projects to determine the soil materials at hand. It may also require some changes, either in construction procedures or material specifications, to allow the use of the soil materials that are still available. With the emergence of the Mechanistic-Empirical Pavement Design Procedures, it is imperative that the pavement designers are aware of the soil conditions which are prevalent in the project limits as

well as the limitations associated with the soil construction materials which will likely be used on the project.

## **Recommendations**

There are three draft Standard Operating Procedures included in Appendix B of this report presented for consideration. The drafts are based upon the author's experience and recommendations suggested by the MDOT staff during the interviews conducted for this research effort. A listing and description of the edited SOPs is as follows:

**ADM-02-21-00-000 SUBSURFACE INVESTIGATIONS** – This SOP is updated to clarify the type and extent of soil investigations, in accordance with current MDOT methods and procedures.

**TMD-20-14-00-000 CENTERLINE SOIL PROFILES** – This SOP is completely revised to address investigation of soil materials for roadways. It removes the procedures for addressing high volume change materials (moved to a standalone SOP), has an updated listing of laboratory test procedures needed, and prescribes investigation methods for various types of construction projects.

**TMD-20-14-01-000 STANDARD DESIGN PROCEDURES FOR CONSTRUCTION OF ROADWAYS THROUGH HIGH VOLUME CHANGE SOILS** – This new SOP consists of the portion removed from the previous TMD-20-14-00-000, with updated and enhanced details.

There is a draft of a recommended chapter for inclusion into the MDOT Pavement ME Design User Input Guide. It is presented in Appendix C of this report. This draft discusses experiences with various soil materials as well as cautions, gleaned from the details presented in this research report, which a pavement designer should consider when using the mechanistic-empirical design procedures.

It is also recommended that MDOT continue to gather samples of the materials identified in this research as a problematic soil, for further resilient modulus testing and enhancement of the materials library used with Pavement ME Design.

## References

1. Experimental Work for Active Clays in Mississippi - by T. C. Paul Teng, (A.M.ASCE), Research and Development Engr.; Mississippi State Highway Dept., Jackson, Miss., M. Barrett Clisby, Prof. of Civ. Engrg.; Mississippi State Univ., Mississippi State, Miss., as published in *Transportation Engineering Journal of ASCE*, 1975, Vol. 101, Issue 1, Pg. 77-95
2. Summary of Lessons Learned from the MDOT MEPDG Materials Library Study – by Robert S. James, PE, L. Allen Cooley, Jr., Ph.D, and R. C. Ahlrich, Ph.D, PE; Burns Cooley Dennis, Inc.; MDOT State Study No. 224, June 2010
3. *Mississippi Standard Specifications for Road and Bridge Construction*, 2017 Ed., Subsection 101.02 – Mississippi Department of Transportation

## **Appendix A**

### **Notes from Interviews with MDOT District and Materials Personnel**

## DISTRICT INTERVIEWS

### SS #271 Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance

**District:** 1 – October 6, 2016

**Attendees:** Nan Mitchell (Materials), Jamie McDonald (Construction)

- **Purpose of Research**

- **Identification of problem soils in the District**

HVC clay pockets – Pontotoc, Lee, Noxubee, Lowndes, and Clay counties. US 45 – Brooksville to US 82; SR 6 from US 45 to SR 342; SR 9 from SR 6 to Sherman; SR 15 south of New Albany; anything south of US 78 in Lee County (Mooreville, Shannon, Nettleton); SR 25 south of Aberdeen; Northeast corner of Itawamba County; South Entrance to MSU; the “flubber” soil on SR 25 south of Amory

- **Types of construction affected**

Mostly new construction, occasionally rehabilitation projects

- **Treatment or Remediation methods used**

The 3’ undercut of HVC soils is often not very effective when backfilled with B9-6 borrow excavation. 0.0 grade points need to be undercut. Subgrades should be treated deeper than 6” – a 12” or 14” Class A lime treatment covered with crushed stone works better than the usual methods.

- **Maintenance issues**

Scrub seals and chip seals on secondary roads. Pavement must be very clean with scrub seals.

- **Recommendations (how you would do it differently based on past experiences)**

Don’t use 3:1 median ditches.

With the amount of bad soils in the District, they need to have grading plans to begin investigation and recommendation phase of design. All this to say, PDPM dates and letting dates are too compressed to make good recommendations.



**Suggestions for changing Department SOPs** – split TMD 20-14-00-000 into a separate SOP for HVC soils. For a, b, and c below, investigation will depend on performance of the existing pavement:

- a. **Overlays** – core full depth for existing thickness and condition if at all possible, but definitely in known bad soil areas
- b. **Widening** – drill and sample the shoulders!
- c. **Rehabilitation** - Drill the shoulders as well as existing lanes
- d. **New construction**

Need to address “reclaimed HMA” pavement designs – structural coefficients?  
Standards?

- **Closing Remarks**

If we had more money available, we would almost always add more structure on overlays – probably mill one lift and add back two lifts.

Jamie recommended that MDOT should look at mix designs and materials in Pavement Analysis/Management, and should pick some good performers and bad performers. It is his opinion that limestone mixes perform much better in their District.

## DISTRICT INTERVIEWS

### SS #271 Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance

**District:** 2 – November 1, 2016

**Attendees:** Mackenzie Fountain (Materials), Daniel Norris, Tony Sheffield (Construction), Trey Bullock (Maintenance), Mitch Turner (District Engineer)

- **Purpose of Research**

- **Identification of problem soils in the District**

HVC soils intermittent in the District – Zilpha Fm, Porter’s Creek Fm, some Delta gumbos. SR 3, SR 6, and US 61 are worst with gumbo clay and soft saturated soils. US 51 Yalobusha River bottom, and usually any river bottom in the hills area (settlement issues). SR 35 between Kosciusko and Vaiden – HVC clays? I-269 Lauder Road interchange; US 78 Pott’s Camp interchange; Calhoun County in general.

- **Types of construction affected**

New construction – 0.0 grade points – some contractors do not undercut, and those that do often do not cut it to drain until they get it backfilled.

District has a lot of recent experience on rehab projects in which old concrete pavement is being removed and there is a “rotten subgrade” left. Several instances of this where up to 5 feet of the existing subgrade has to be undercut.

- **Treatment or Remediation methods used**

For HVC soils, undercut 3 feet and backfill with B9-6. Sometimes even more undercut is warranted.

Prefer to use limestone instead of soil cement topping – must use a geotextile beneath limestone if subgrade is not treated. Minimum limestone thickness should be 8”, not 6”.

The District also uses a lot of sand blankets over soft wet areas before constructing embankments, to help with roadbed stability and post-construction settlement issues.

- **Maintenance issues**

District suggests that for maintenance overlays of existing HMA over old concrete pavement, DO NOT mill down to the original concrete pavement.

- **Recommendations (how you would do it differently based on past experiences)**

For certain construction situations, District already obtains soil samples from existing shoulder but rarely cuts a corehole to sample materials under the pavement. If the construction calls for grade changes or the cross section profile is to be changed, they recommend full depth coreholes and subgrade sampling under the existing pavement.

**Suggestions for changing Department SOPs –**

- a. **Overlays**

- b. **Widening**

- c. **Rehabilitation**

- d. **New construction** - Bridge replacement projects – usually on a new alignment – need a centerline soils profile as would be obtained on any new construction.

District prefers to use the old AASHTO T92 volume change determination (using mercury) – seems to be more accurate than wax method. Soil profiles should be more definitive of all problem areas.

- **Closing Remarks**

There should be more emphasis on identifying bad soils at the 60% design plan phase – PDPM/letting schedule issue?

## DISTRICT INTERVIEWS

### SS #271 Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance

**District:** 3 - January 25, 2017

**Attendees:** Daniel Cauthen, Brad Watson (Materials), Durwood Graham (Construction)

- **Purpose of Research**
- **Identification of problem soils in the District**

Delta gumbo clays – US 49, US 82 bypass from SR 1 to Leland, SR 16 at Sunflower River. US 61 where they removed the old concrete – temporary traffic destroyed the stability due to insufficient HMA thickness. “Sugar sands” used for Class9 Group C topping is always a problem – District uses Class 5 Group D for topping now. Occasionally problems along the Loess bluffs
- **Types of construction affected**

Removal of old concrete pavement ALWAYS causes problems
- **Treatment or Remediation methods used**

Have to soil cement the loess subgrades – District is more interested in obtaining stability than density. They have to use sand cone density tests to calibrate the nuclear gauges.

Interestingly, the District specifies B9 borrow excavation for backfill in undercut areas – BUT – they know where the B9 is coming from and that it has the properties they are looking for.

They have lime treated loess soils, with limited success.
- **Maintenance issues**

Erosion issues with loess soils.
- **Recommendations (how you would do it differently based on past experiences)**
- **Suggestions for changing Department SOPs** – split TMD 20-14-00-000 into a separate SOP for HVC soils.

- a. **Overlays**
  - b. **Widening**
  - c. **Rehabilitation** – core lanes and shoulders
  - d. **New construction**
- **Closing Remarks**

Interstates require FWD analysis for pavement recommendations.

For maintenance overlays, try to avoid milling if possible. If you know you must mill, cut cores full depth and check the subgrade.

## DISTRICT INTERVIEWS

### SS #271 Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance

**District:** 5 - September 13, 2016

**Attendees:** Graham Clarke (Materials), Freddie Stokes (Construction)

- **Purpose of Research**

- **Identification of problem soils in the District**

Generally, the Yazoo and Porter's Creek clays, as well as weathered chalk (Black Prairie) soils in the northeast part of the district. Particularly US 45 Porterville/Scooba/Suqualak/Brooksville was troublesome.

- **Types of construction affected**

Rehabilitation/reconstruction

- **Treatment or Remediation methods used**

For HVC soils, undercut & replace with B9-6 borrow excavation, and soil cement. On I-55 south of I-20, had to undercut, treat top of undercut, backfill, treat the borrow, then place topping and treat. Three separate operations to achieve stability.

- **Maintenance issues**

Chip seals on low volume (< 1500 vpd) "three digit" roads helps ride immensely. Performed every 4 years. District does about 120 miles per year. They do not overlay chip sealed roads.

The Yazoo Clay has destroyed SR 501 in Scott County.

- **Recommendations (how you would do it differently based on past experiences)**

No A+B bidding! Forces "shortcuts in both design and construction. Rehabilitation/reconstruction projects need to have the best plans possible.

## **Suggestions for changing Department SOPs**

- a. **Overlays** – core for existing thickness and condition if at all possible
  - b. **Widening** – consider adding slopes
  - c. **Rehabilitation** – get soil samples under existing pavement, run moisture and Atterberg limits. For I-20 in Scott County, their investigation paid a lot of dividends by being able to core the centerline
  - d. **New construction** – need more time in preconstruction to explore soils.
- **Closing Remarks**

When designing in HVC clay areas, check the as-built plans to see if any embankment prisms include “cores” constructed of bad clays as a means of reducing excess excavation.

## **DISTRICT INTERVIEWS**

### **SS #271 Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance**

**District:** 6 – October 11, 2016

**Attendees:** Wilson Ruff, Zach Lott (Materials), Gabe Thaggard (Construction)

- **Purpose of Research**

- **Identification of problem soils in the District**

HVC soils - SR 503 and SR 15 in north Jasper County; US 84 Wayne County (very high VC); SR 57 Jackson County. Wet organic materials overlying the Pascagoula Fm on the coast, generally called “muck”. SR 67 Harrison County – some HVC soils but the wet silty A-4 materials (muck) were tough to deal with. Hydraulic fills on US 90 and I-10. US 49 SB widening project Forrest County – poor soils on the shoulders

- **Types of construction affected**

Mostly widening or safety projects, some new construction. Also punchout repairs on old concrete pavement.

- **Treatment or Remediation methods used**

For the silty A-4 materials in the coastal counties, they just excavate it and let it dry out, it makes good unclassified material (but sometimes have to pay for it twice). District really likes to control the design soils if at all possible, and use B7-6 backfill in undercuts. Pavements are always designed for CBR=5, even though sometimes there is better subgrade material available.

- **Maintenance issues**

Landslides! Heave problems are very isolated. District mentions that a lot of A-7 soils have been used to construct embankments, without the usual heaving associated with those soils, but they do experience a lot of slides.

- **Recommendations (how you would do it differently based on past experiences)**

Don't use A-7 soils in embankments – haul the material off the project.



**Suggestions for changing Department SOPs** – split TMD 20-14-00-000 into a separate SOP for HVC soils.

- a. **Overlays**
  - b. **Widening**
  - c. **Rehabilitation**
  - d. **New construction** – they prefer the undercut/replace option for HVC clays
- 
- **Closing Remarks**

Chemical treatment of subgrades and subbases is not very well liked, they prefer to use geotextile/crushed stone bases. However, they do treat the design soil if crushed stone bases are not used.

Estimates for lime or soil cement in the plans should be emphasized “as necessary” and not a requirement.

## DISTRICT INTERVIEWS

### SS #271 Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance

**District:** 7 - January 24, 2017

**Attendees:** Steve Smith (Materials), Ken Morris (Construction), Dalton Williams (Maintenance)

- **Purpose of Research**
- **Identification of problem soils in the District**

HVC clay pockets – SR 588 Covington County only roadway mentioned. Lab only sees 1 or 2 HVC samples per year!

Loess soils along the bluffs; real fine silty sands near the Pearl River (esp. Monticello area) which erode badly; US 49 “muck” materials. No areas on US 98, and just a few on US 84 in which they “bladed off to the side” some questionable materials.
- **Types of construction affected**

Real fine B9-6 material is difficult to achieve density for soil cement operations
- **Treatment or Remediation methods used**

3’ undercut of high PI clay areas – there is always good backfill material available close by. For rehab projects, they always cut a core and get a subgrade sample if the pavement is being removed
- **Maintenance issues**

Homochitto River bottom – sometimes get pumping pavements in embankment sections.
- **Recommendations (how you would do it differently based on past experiences)**

Don’t seal old asphalt before overlays.
- **Suggestions for changing Department SOPs** – split TMD 20-14-00-000 into a separate SOP for HVC soils. TMD 20-14 should address how to perform investigation for a, b, and c below
  - a. **Overlays** – core full depth for existing thickness and condition if at all possible, but definitely in known bad soil areas
  - b. **Widening** – drill and sample the shoulders!

- c. **Rehabilitation** - Drill the shoulders as well as existing lanes
  - d. **New construction** – TMD 20-14 already addresses this
- **Closing Remarks**

## **Appendix B**

### **Draft Recommendations for MDOT Standard Operating Procedures**

ADM-02-21-00-000 Subsurface Investigations

TMD-20-14-00-000 Centerline Soil Profiles

TMD-20-14-01-000 Standard Design Procedures for Construction of  
Roadways Through High Volume Change Soils

Approved by:

S.O.P. No.: **ADM-02-21-00-000**

Mississippi Department of Transportation - Standard Operating Procedures

Subject: **SUBSURFACE INVESTIGATIONS**

Effective Date:

Issued Date:

Original Issue Date: **October 1, 1970**

Supersedes S.O.P.  
**ADM-02-21-00-000**

Dated  
**April 1, 2004**

**PURPOSE:** To define the responsibilities vested in the Roadway Design Division, Bridge Design Division, Materials Division, and Districts as related for subsurface investigations for design purpose on preliminary engineering and construction projects.

## **1. DEFINITION OF SUBSURFACE INVESTIGATIONS BY TYPE**

Due to limitation of facilities, it is necessary to subdivide and define the various types of subsurface investigations to be conducted:

### **1.1 Type A**

Subsurface investigation of all soil conditions existing on a project to determine embankment stability, consolidation and settlement, subsurface drainage and structural foundation design criteria. Type A investigation will usually be in addition to or in conjunction with Type C investigation.

### **1.2 Type B**

Subsurface investigation at some locations of major structures will include standard penetration tests (SPT) and/or cone penetrometer tests (CPT). Boring logs will be recorded. Laboratory testing and analysis may or may not be conducted for Type B investigations.

### **1.3 Type C**

Type C investigations will include development of a generalized soil profile and a soil classification of all subsurface strata encountered during the course of the drilling operations. Supplemental laboratory tests for further identification of engineering characteristics of subsurface strata will be conducted as required. Reference TMD-20-14-00-000 for additional details.

### **1.4 Type D**

Special cases involving critical soil conditions, roadway failures, unusual structures, or design features which require further investigation not covered under Type A, B, or C.

## **2. DETERMINATION OF TYPE INVESTIGATION**

Type of investigation will be determined under guidelines as follows:

### **2.1 Type A**

To be determined by the State Materials Engineer (via the Geotechnical Branch) based on the Schedule of Proposed Projects and known geological conditions at each project location. The capabilities of the Geotechnical Branch will be considered in determining the number or scope of Type A investigations.

### **2.2 Type B**

Annotations:  
Commission Order:

Mississippi Department of Transportation S.O.P. No. **ADM-02-21-00-000**

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To be determined by the State Materials Engineer (via the Geotechnical Branch) based on the Schedule of Proposed Projects and known geological conditions at each project location. The capabilities of the Geotechnical Branch will be considered also in determining the number of Type B investigations.

### **2.3 Type C**

To be determined by the District Materials Engineer for those projects in which the districts normally furnish a soil profile and other soil data for design purposes. The District Construction Engineer may work in conjunction with the District Materials Engineer for coordinating any necessary soils investigations of overlay, widening, or rehabilitation projects which are not for an original centerline soil profile.

### **2.4 Type D**

Geotechnical Branch capabilities will be made available for Type D investigations. The determination of Type D investigation will be based on the scope of the requested work, the critical nature of the work as related to design, and time available. Each Type D investigation will require authorization by the Assistant Chief Engineers - Preconstruction and Operations.

## **3. RESPONSIBILITIES**

### **3.1 State Materials Engineer (via Geotechnical Engineer)**

- 3.1.1 Determine projects requiring Type A and Type B investigations.
- 3.1.2 Prepare schedule for Types A and B investigations by projects.
- 3.1.3 Attend regular review meetings to obtain information for establishing a schedule for projects requiring Types A, B and requested D investigations.
- 3.1.4 Conduct subsurface investigations and prepare reports and recommendations based on results of investigations.
- 3.1.5 Assimilation of all data to be used in a soil and foundation report including type, location and depth of borings.
- 3.1.6 Test soil samples as necessary to determine the soil parameters for proper design.
- 3.1.7 Coordinate investigations with District Materials Engineer, when necessary.

### **3.2 District Materials Engineer**

- 3.2.1 Type C investigations
  - 3.2.1.1 Schedule and conduct Type C investigations and reports.
  - 3.2.1.2 Establish a Type C investigation schedule using the three year project schedule, stage of plan development, data from regular project reviews, and instructions from the District Engineer and District Construction Engineer.
- 3.2.2 Report critical soil conditions which may require Type D investigation to District Engineer.
- 3.2.3 Cooperate with Geotechnical Branch in Type A, B, and D investigations, when required.

- 3.2.4 Determine locations and depth of centerline soil profile borings according to TMD-20-14-00-000.

### **3.3 District Engineers, Roadway Design Division, Bridge Design Division**

- 3.3.1 Submit written request for Type D investigations to Assistant Chief Engineers Preconstruction and Operations, with details of nature and magnitude of problems, apparent alternate solutions and information required for each.
- 3.3.2 Under emergency conditions a request to the Assistant Chief Engineers for Type D may be made verbally.
- 3.3.3 Special maintenance problems may be handled as outlined above.
- 3.3.4 Refer approved requests for Type D investigations to Geotechnical Engineer for scheduling.

## **4. REPORTS**

### **4.1 Type A investigation reports are to include:**

- 4.1.1 Generalized soil profile for each site.
- 4.1.2 Boring logs with pertinent design parameters, including ground water measurements.
- 4.1.3 Test results for shear strength, gradation, physio-chemical, and consolidation, and any other parameters required for proper design.
- 4.1.4 Specific recommendations when applicable for:
- a. Settlement analysis, including amount and time required for consolidation to occur, and remedial measures to be considered.
  - b. Embankment stability, including slopes for cut and embankment sections, the relative slope stability safety factor, and remedial measures to alleviate unstable conditions when deemed necessary.
  - c. Foundation design for bridges.
  - d. Retaining wall analysis and criteria for retaining wall design.
  - e. Distribution:
    - (1) Bridge Division (2 copies)
    - (2) Roadway Design Division
    - (3) Construction Division
    - (4) District Engineer (2 copies)
    - (5) Materials Division (2 copies)
    - (6) Federal Highway Administration (applicable to Interstate and all other NHS projects)
    - (7) Central File
    - (8) Miss. Dept. of Environmental Quality, Office of Geology
    - (9) U.S. Geological Survey

### **4.2 Type B investigation reports are to include:**

**Annotations:**  
**Commission Order:**

4.2.1 Results of boring logs, standard penetration tests and/or cone penetrometer probe results.

4.2.2 Distribution:

- a. Bridge Division
- b. Roadway Design Division
- c. Construction Division
- d. Materials Division
- e. Federal Highway Administration (applicable to Interstate and all other NHS projects)
- f. Central File

**4.3** Specific guidelines for Type C investigation reports are given in TMD-20-14-00-000, but include:

4.3.1 Generalized soil profile

- a. Major strata encountered
- b. Water table location

4.3.2 Boring logs

4.3.3 Results of laboratory tests

- a. Atterberg limits
- b. Gradations
- c. Other data necessary to define engineering characteristics
- d. Field moisture content

4.3.4 Recommendations of District Materials Engineer

- a. Any deemed pertinent to project

4.3.5 Distribution:

- a. Bridge Division (if project includes bridge)
- b. Roadway Design Division
- c. Construction Division
- d. Materials Division
- e. Federal Highway Administration (applicable to Interstate and all other NHS projects)
- f. Central File
- g. Geotechnical Branch

**4.4** Type D investigation reports are to include:

4.4.1 All information requested. Use format as outlined for Type A investigation.

4.4.2 Distribution:

- a. Requesting District or Division
- b. Others as needed



Approved by:

S.O.P. No.: **TMD-20-14-00-000**

Mississippi Department of Transportation - Standard Operating Procedures

Subject: **CENTERLINE SOIL PROFILES**

Effective Date:

Issued Date:

Original Issue Date: **September 1, 1991**

Supersedes S.O.P.  
**TMD-20-14-00-000**

Dated  
**November 9, 2005**

**PURPOSE:** To establish procedures and guidelines for conducting centerline soil profiles in accordance with ADM-02-21-00-000, and to characterize the soil conditions along a proposed roadway centerline.

## 1. GENERAL

The centerline soil profile and associated testing shall be a Type C Investigation as defined in ADM-02-21-00-000. The centerline soil profile shall provide classification and testing of the soils to identify the types of soil present along the roadway, evaluate their potential use as fill materials, and locate any undesirable soils which may require undercutting or other remedial measures during construction of the roadway subgrade. Undesirable soils may be characterized as "low strength" due to high plasticity index, high volume change, organic content, or other grain size factors.

## 2. DEFINITIONS

**2.1 High Plasticity Index** – Soils with a plasticity index of greater than 23 as determined by AASHTO T 89 and T 90 are considered high PI soils, especially if the liquid limit exceeds 40. These soils generally fall into the A-6, A-7-5, and A-7-6 classification, and sometimes qualify as high volume change soils. When the Group Index exceeds 15, they are unsuitable as a subgrade material, and chemical stabilization techniques usually add little value in regards to subgrade support.

**2.2 High Volume Change Soil** - A high volume change soil is defined as a soil having a volume change of 60 percent or higher when determined from shrinkage limit testing using the formula

$$VC = (w_1 - S) R$$

The most economical means for controlling the problems associated with shrinking and swelling of a high volume change soil can be challenging. With this in mind, the replacement materials should always be the materials closest to the replacement site that possess the highest CBR available, and will keep the underlying high volume change material at constant moisture content. Acceptable treatment methods of high volume change soils are described in TMD-20-14-01-000.

**2.3 Muck** – A muck is defined as a saturated soil having an organic content of at least 6 percent as determined by Mississippi Test Method MT-29 or AASHTO T 267. The depth and extent of the muck shall be determined in the field to calculate the amount of material to be removed as muck excavation. Muck, having an organic content between 6 and 20 percent, may be tested for pH to determine whether it is suitable for use as plating or topsoil along the roadway. Muck having an organic content greater than 20 percent should be wasted.

**2.4 Unstable Soil** – An unstable soil is defined as a soft, low CBR, or saturated soil having an organic content less than 6 percent as defined by Mississippi Test Method MT-29 or AASHTO T 267. Several soils which classify as A-4 or A-5 can fall into this type. The depth and extent of the unstable soil shall be determined in the field to calculate the amount of material that must be removed as excess excavation.

Annotations:

Commission Order:

Mississippi Department of Transportation S.O.P. No. **TMD-20-14-00-000**

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### **3. SOIL PROFILE DEVELOPMENT – NEW ALIGNMENTS**

- 3.1** As soon as possible after completion of the centerline survey and establishment of the centerline profile grades, the District Laboratory shall complete soil borings to aid in the development of a centerline soil profile.
- 3.2** Boring spacing along the centerline of the survey shall be a maximum of 100 feet apart in cut sections and 200 feet apart in fill sections. For original soil profiles, it may be necessary to vary from these spacings due to field constraints (poor access, physical features, etc.), but every effort should be made to get representative samples from any omitted section as soon as field conditions permit.
- 3.3** Boring depths shall be a minimum of five (5) feet below the proposed subgrade elevation in cut sections and at grade points. Boring depths shall be a minimum of five (5) feet below the existing ground surface for the fill sections.
- 3.4** The spacing and depth of the soil borings should vary if unusual conditions such as rock layers or weak deposits (muck or unstable soil) are encountered. The auger method of drilling for disturbed samples is generally suitable for identification and testing; however, if it becomes apparent that adequate samples are not being obtained from the auger method, the Geotechnical Branch of Materials Division may be contacted to schedule a Type D investigation as defined in ADM-02-21-00000.
- 3.4.1 When unusual soil conditions are encountered, such as rock or any unsuitable soils, every effort shall be made to identify the limits of these soil conditions (lateral, horizontal, and vertical) beyond the usual samples taken at the regular drilling intervals. Contact the Geotechnical Branch if assistance is needed in determining these limits, or in determining possible construction alternatives for mitigating these conditions.
- 3.5** The borings, as nearly as possible, shall be sampled on one (1) foot intervals. From these samples the boring crew supervisor shall obtain a representative sample for each class soil encountered.
- 3.6** The boring crew supervisor shall prepare a boring log that describes and classifies the soil and lists the depth where changes occur.
- 3.7** Each day the boring crew supervisor shall obtain representative soil samples of each soil class encountered. These soil samples are to be used when the boring crew supervisor prepares the boring log for each boring. The boring crew supervisor should use extreme caution when obtaining representative soil samples, to insure that the samples are not contaminated. This is especially true when a sand or silt overlies a clay soil.
- 3.8** Each day the boring crew supervisor shall deliver the representative soil samples to the district laboratory for drying and testing. The samples shall be prepared for testing according to AASHTO R 58.

### **4. INVESTIGATIONS ALONG EXISTING ROADWAYS**

- 4.1** Depending upon the nature of the project – overlay, widening, or roadway reconstruction – it is usually necessary to determine the existing subgrade conditions, especially if the existing roadway shows signs of subgrade related distress.
- 4.2** Overlays – If the project involves milling of the existing upper one or two courses, typically a limited number of cores are taken to examine the as built thicknesses of the asphalt courses

and condition of the underlying layers (i.e., is the asphalt stripping). When these cores reveal that there is stripping of the underlying courses, or if the roadway exhibits considerable faulting and numerous leveling patches, there exists a good probability that the base and/or subgrade are saturated. In this instance, further investigation of the soils beneath the pavement is warranted.

To define the limits of the saturated subgrade areas, full depth cores through the existing pavement shall be taken. These should be done at a frequency of no less than 200 feet along the roadway throughout the affected section. Samples of the granular base (if present) and subgrade should be taken down to the point where it is obvious that saturated conditions no longer exist. The samples should be sealed in a moisture tight container for subsequent moisture content testing, plasticity index, and any other classification testing needed. If at all possible, Dynamic Cone Penetrometer (DCP) readings shall be taken every 6 inches of depth through the core hole to determine relative CBR and consistency. The DCP readings are the best indicator of the suitability of the material.

- 4.3 Widening** – Projects involving widening of the existing roadway, particularly to shift traffic to the existing outside shoulder, require a soil profile investigation to be performed in a similar manner as for a new alignment. Boring spacing shall be 200 feet or less. Depth of the borings may terminate after three feet, if no saturated soils are found within the boring.

Sometimes this type of investigation may require coring through a paved shoulder to obtain the requisite samples for testing. If the alignment being investigated does have an existing paved shoulder, then the investigation should follow the same protocol as for an overlay. This includes the DCP readings.

- 4.4 Roadway Reconstruction** – If the project involves complete removal of the existing roadway structure for the purpose of reconstructing a new roadway, the protocols used for both overlay and widening projects shall be used to determine the subgrade conditions beneath the existing pavement and along the existing shoulders. This will, by necessity, involve lane closures to perform the work and may require night time investigations if the traffic levels dictate.

## **5. LABORATORY TESTING**

- 5.1** Laboratory testing shall be conducted for the purpose of classifying each soil type in accordance with AASHTO M 145 and the Unified Soil Classification System.

- 5.2** As a minimum, the following tests and calculations shall be completed by the District Laboratory.

AASHTO T 11 — Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO T 27 — Sieve Analysis of Fine and Coarse Aggregates

AASHTO R 58 — Dry preparation of Disturbed Soil and Soil Aggregate Samples for Test

AASHTO T 88 — Particle Size Analysis of Soils (with MT-23 Methods for Testing Soils)

AASHTO T 89 — Determination of the Liquid Limit of Soils

AASHTO T 90 — Determining the Plastic Limit and Plasticity Index of Soils

— Determining the Shrinkage Factors of Soils

MT-30 – pH Determination

MT-47 – Soil Resistivity (if alternate pipe culverts are proposed)

Note: Additional test methods may be assigned by the District Materials Engineer as deemed necessary in preparing the centerline soil profile. For example, at cross drain or

box culvert locations, it may be necessary to determine the soluble sulfates of the surface soils. Also, moisture content tests are necessary for samples taken beneath existing pavements. The District Materials Engineer shall have the discretion as to the necessity of running hydrometer analyses (T 88) on some types of soils, if it is certain that the test results would have no bearing as to the proper classification of the particular soil.

**5.3** All test results shall be reported on form TMD-683.

## 6. FINAL REPORT

The results of the centerline soil investigation shall be reported by the District Materials Engineer in the form of a report. The report shall contain the following:

**Soil Profile** - The soil profile shall be prepared on grid sheets with a logical horizontal and vertical scale to show the necessary detail. The soil profile shall clearly delineate differing soil types. Each soil type shall have an identification number to reference it to the laboratory test results, the AASHTO Classification, Unified Soils Classification, estimated CBR value, Plasticity Index, and Percent Volume Change (if applicable).

**Laboratory Test Results** - All test results shall be reported on TMD-683 clearly identifying the sample number, location, depth, Station Number, and date. If the DCP was used in an investigation, the results shall be tabularized separately and shall indicate the corresponding in-situ moisture content at each DCP reading.

**Conclusions and Recommendations** - Areas along the roadway requiring special consideration during construction shall be delineated by Station and offset. As a minimum, the recommendations shall include areas that require undercut (or other construction considerations) due to the presence of high plasticity index material, high volume change clay, muck, or unstable material. Recommendations regarding cut and fill slopes in potentially unstable areas should be addressed. Additionally, recommendations as to type of chemical treatment of subgrades (soil-lime-water, lime-fly ash, or soil cement) should be delineated by Station limits.

**Distribution of Report** - Once the final report is complete, it shall be distributed by the District Materials Engineer according to the following schedule:

<b>Original</b> - On file in the District Materials Laboratory	
<b>Central Records (via 71-01)</b> -	1 copy
<b>District Engineer</b> -	2 copies
<b>Roadway Design Engineer</b> -	4 copies
<b>Bridge Engineer</b> -	2 copies (when bridges are included)
<b>State Construction Engineer</b> -	1 copy
<b>State Materials Engineer</b> -	1 copy
<b>Geotechnical Engineer</b> -	1 copy

Approved by:

S.O.P. No.: **TMD-20-14-01-000**

Mississippi Department of Transportation - Standard Operating Procedures

Subject: **STANDARD DESIGN PROCEDURES FOR CONSTRUCTION OF ROADWAYS THROUGH HIGH VOLUME CHANGE SOILS**

Effective Date:  
Issued Date:  
Original Issue Date:

Supersedes S.O.P. Dated  
INITIAL DISTRIBUTION

**PURPOSE:** To establish procedures, guidelines, and to specify treatment methods for high volume change soils.

## 1. GENERAL

A centerline soil profile and associated testing, per a Type C Investigation as defined in ADM-02-21-00-000, is conducted by the District Materials Laboratory. This centerline soil profile often identifies undesirable high volume change or low strength surface soils which may require undercutting or other remedial measures during construction. This Standard Operating Procedure addresses treatment methods for locations with high volume change soils. These methods can also be applied to soils with a plasticity index exceeding 23, regardless of volume change, depending upon local experience with the soil.

## 2. BACKGROUND

**2.1 Definition** - A high volume change (HVC) soil is defined as a soil having a volume change of 60% or higher when determined in accordance with laboratory test procedures for shrinkage limit testing using the formula

$$VC = (w_1 - S) R$$

Where:

VC = the volumetric change

$w_1$  = a given water content

S = the shrinkage limit – the maximum calculated water content at which a reduction in water content will not cause a decrease in the volume of the soil mass.

R = the shrinkage ratio – the ratio between a given volume change and the corresponding change in water content above the shrinkage limit

Procedures for the determination of the shrinkage limit and shrinkage ratio are described in AASHTO T 92 (see Section 2.3 below).

**2.2 Background** - Volume change of a soil sample is measured in the laboratory as change in volume of a specimen from a “prescribed moisture content” ( $w_1$  in the equation) to a completely dry specimen. The “prescribed moisture content” for MDOT purposes is at or slightly above the liquid limit of the soil. HVC soils are typically clays, with a liquid limit greater than 50 and a plasticity index exceeding 23. The higher the plasticity index, the greater the chance the soil exhibits HVC tendencies.

**2.3 Test Procedure** – The formula presented in Section 2.1 originated in standard test procedure AASHTO T 92 – Determining the Shrinkage Factors of Soils (or ASTM D 4943). This test

Annotations:  
Commission Order:

standard has been dropped by the AASHTO Subcommittee on Materials due to the dependence on using mercury, and other methods for determining the shrinkage limit were experimented with using wax sprays. However, there is no recognizable AASHTO or ASTM test standard at this time. In general, the deleted AASHTO T 92 test standard is still utilized to determine the shrinkage limit and volume change of soils. If available, this test standard can be found in AASHTO Methods of Sampling and Testing books, 2010 (30<sup>th</sup> Edition) or prior. A copy is also provided in the report for MDOT State Study No. 271 *Knowledge of Effects of Different Mississippi Soil Deposits on Pavement Performance*.

### 3. SOIL PROFILE DEVELOPMENT

It is the intent of this procedure to establish the most economical means for controlling the problems associated with a shrinking and swelling soil. With this in mind, any replacement materials should always be the materials closest to the replacement site and possessing the highest CBR available. Controlling surface water is also a key feature in decreasing the harmful effects of shrinking and swelling soils. Other key features in design are good drainage ditch grades and an impermeable layer of soil over the high volume change clay.

**3.1** As soon as possible in the project development process, the District Laboratory shall complete soil borings to aid in the development of a soil profile in accordance with TMD-20-14-00-000.

**3.2** When high plasticity clays are encountered during the field investigation, every effort shall be made to identify the limits of these soil conditions (lateral, horizontal, and vertical) beyond the usual samples taken at the regular drilling intervals. Contact the Geotechnical Branch if assistance is needed in determining these limits, or for determining possible construction alternatives for mitigating these conditions and the additional field investigation which would be required.

### 4. LABORATORY TESTING

**4.1** Laboratory testing shall be conducted in accordance with those methods specified in TMD-20-14-00-000. When these tests indicate fine grained soils with a liquid limit greater than 40 and a plasticity index greater than 23, additional tests shall be conducted to determine the volume change characteristics. In areas of the state where poor subgrade soils are known to exist, at the District Materials Engineer's discretion, volume change testing may be performed on any plastic soils.

### 5. REPORTING

During development of the soils profile report, any areas along the roadway with HVC soils requiring special consideration during construction shall be delineated by Station and offset. As a minimum, the report recommendations shall include specific areas that require undercut (or other construction considerations) due to the presence of high volume change material. Recommendations regarding cut and fill slopes in potentially unstable areas should be addressed. Additionally, recommendations as to type of chemical treatment of subgrades (soil-lime-water or soil cement) should be delineated by Station limits.

### 6. DESIGN IN AREAS OF HIGH VOLUME CHANGE SOILS

**6.1** The District Materials Engineer has responsibility for reviewing and evaluating the soil profile along the project, and providing the centerline soil profile report. Especially in the case of areas with known HVC soil issues, communication and coordination between the District and the Roadway Design Division shall occur as early in the design process as possible. If the soil

profile contains HVC soils identified through the field and laboratory investigation, the centerline soil profile report shall additionally contain recommendations for mitigating the HVC soils located along the project. These recommendations should be discussed and vetted through the Geotechnical Branch before furnishing the written report to Roadway Design Division. The location(s) of HVC soil shall be well defined or delineated within this report.

Recommendations concerning HVC soil areas shall take into consideration the construction budget, availability of right of way, type of roadway and anticipated traffic (which directly impacts the structure thickness for the project), and any other economic or safety considerations. Roadway Design Division shall prepare construction plans based on their review of the District Materials Engineer's recommendations and the general guidelines listed below.

- 6.2** Back slopes of cut sections containing high volume change soils shall be 6H:1V to minimize the risk of future slope failure. This necessitates large takes of right of way in deeper cut sections, which may not be practical or available. In these cases, it may be necessary to get the Geotechnical Branch to conduct a Type D investigation in accordance with ADM-02-21-00-000 to determine if steeper slopes or special design slopes are more feasible.
- 6.3** Embankments constructed with HVC soils used as unclassified excavation should be avoided at all costs if possible. If this is not practical, then the HVC material shall be encapsulated by a minimum of three feet (3') of relatively impervious material (A-6), including the top three feet of design soil beneath the roadway structure. The side slope of the embankment, as well as the encapsulated HVC material, shall be no steeper than 5H:1V.
- 6.4** The design soil roadway section in areas delineated as containing high volume change soils shall be designed according to one of the two methods listed below.

#### **6.4.1 Method 1 - Replacement Method**

6.4.1.1 The Replacement Method shall be used where high volume change soils exist and belong to the geologic units listed below. Any questions concerning the geologic classification of the soil should be directed to the Geotechnical Branch of Materials Division.

Yazoo Clay Formation  
 Porters Creek Clay  
 Formation Zilpha  
 Formation  
 Prairie Bluff / Owl Creek  
 Formation Ripley Formation\*  
 Demopolis Chalk  
 Formation\* Mooreville  
 Chalk Formation\*  
 Hattiesburg/Pascagoula Formation

**\* Note:** These "Black Prairie" soils may be suitable for Method 2, at the District Materials Engineer's discretion, for alignments constructed parallel to existing roadways that exhibit no signs of active clays. In general, however, these soils should require Method 1 if suitable replacement materials are available.

The Mississippi Department of Environmental Quality, Office of Geology's *Geologic Map of Mississippi* shall be used for soil formation identification. This map can be found at the following link:

[http://www.deq.state.ms.us/MDEQ.nsf/pdf/Geology\\_MSGeology1969Map/\\$File/MS\\_Geology1969.pdf](http://www.deq.state.ms.us/MDEQ.nsf/pdf/Geology_MSGeology1969Map/$File/MS_Geology1969.pdf)

6.4.1.2 The roadway typical section (cut or fill sections) shall be constructed in such a manner that the Design Soil (top 3 feet) contains no high volume change soil. The cut sections shall be undercut 3 feet below the profile grade and backfilled with select materials. The undercutting shall extend from ditchline to ditchline. Undercut HVC material shall be wasted as excess excavation if at all possible.

6.4.1.3 Material used as backfill within the Design Soil prism shall conform to one of the two types listed below. Suitable material that is to be excavated along the roadway alignment should be utilized where practical.

(a) Granular Material, Class 1 through Class 10, Group D or E

(b) Borrow Excavation, Classes B5-6, B6-6, B9-6, B15 or B16

6.4.1.4 The appropriate chemical treatment shall be established for the type of material used to replace the undercut sections.

#### **6.4.2 Method 2 – Lime Treatment Method**

6.4.2.1 High volume change soil areas not requiring Method 1 treatment shall be treated by soil-lime-water mixing.

6.4.2.2 The top 8 inches of the subgrade shall be treated with a Class A or Class B Lime Treatment (as determined by the Soils Laboratory of the Materials Division). The treatment shall extend to the outside of the shoulders.

6.4.2.3 A base consisting of 6 inches of Cement Treated Course, or 8 inches of crushed stone, shall be placed over the lime treated subgrade as a portion of the pavement structure as soon as practical.



## **Appendix C**

### **Draft of a “Chapter X – Problematic Soil Materials and Considerations” for Inclusion into the Mississippi DOT Pavement ME Design User Input Guide**

# CHAPTER X—PROBLEMATIC SOIL MATERIALS AND CONSIDERATIONS

## X.1 SUBGRADES

Section 8.5 discusses the general physical properties and recommendations for resilient modulus of various soil types for Pavement ME Design. There were 34 different subgrade materials from around the state which were subjected to resilient modulus testing, and ranges of values are provided for the designer. Though the range of material *types* was well represented during this testing, there are still many *areas* of the state which were not represented, and thus the designer needs to consider past historical issues with soils in certain areas of Mississippi.

Mississippi has an abundance of low CBR soils, which either directly or indirectly can have an impact upon the subgrade resilient modulus used in a pavement design. These soils are typically fine grained materials with an AASHTO classification of A-7-6 or sometimes A-7-5. Some, but not all, of these fine grained soils become problematic due to sensitivity to moisture content. These sensitivities manifest themselves in the form of subgrade instability which inhibit proper construction of subsequent pavement layers, shrinking and swelling which destroy the smoothness of the finished pavement, or simply the difficulty of processing the materials during earthmoving operations.

### X.1.1 High Volume Change Soils

The Mississippi Department of Environmental Quality, Office of Geology has published a *Geologic Map of Mississippi*. It is used primarily to identify the various soil formations that can be anticipated at the surface or near surface of the ground. This map is the primary basis for identifying areas within the state where problematic soils can be expected on a particular project. The map, presented as Figure 1, can be accessed full size at the following internet link:

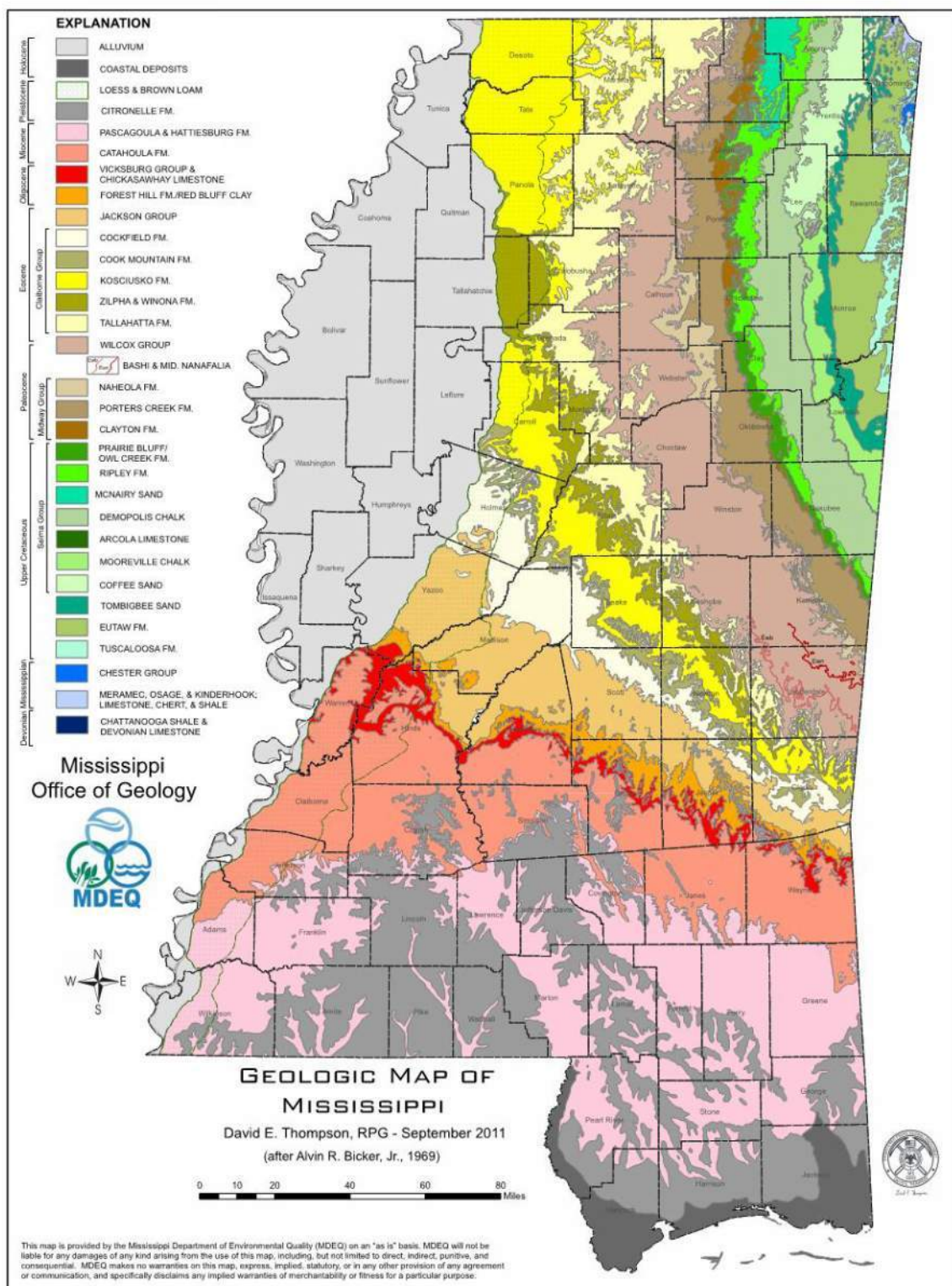
[https://www.mdeq.ms.gov/wp-content/uploads/2017/05/MS\\_Geology1969.pdf](https://www.mdeq.ms.gov/wp-content/uploads/2017/05/MS_Geology1969.pdf)

The *Geologic Map of Mississippi* lists several geological formations which are known to exhibit the high volume change shrinking and swelling tendencies. In no particular order, the major formations with these tendencies include:

- Black Prairie Soils of the Selma Group
- Owl Creek Formation
- Porters Creek Formation
- Zilpha Formation
- Yazoo Clay of the Jackson Group
- Pascagoula and Hattiesburg Formations
- “Gumbo” clays of the Mississippi River Delta Alluvium

Each MDOT District has areas of high volume change soils. The eastern ½ of the state, in Districts 1, 5, and 6, has an *abundance* of HVC soils. One can simply drive from Waynesboro to Corinth on US 45 to cross several of the listed formations and experience the effects of HVC clays on the pavement.

Figure 1



Some of the geological formations listed above cover massive areas, such as the Yazoo clay, the Porters Creek clay, and the Hattiesburg clay. Others such as the Zilpha clay and Owl Creek clay are “hit or miss”, and are not as extensive but nonetheless very detrimental to road construction.

Chalk formations that are a part of the Selma Group are not necessarily active insofar as shrinking and swelling is concerned. However, the weathered portions of these formations, which are found at the ground surface, are known as “Black Prairie Soils”. They have high plasticity and often exhibit HVC characteristics. Because of the extensive area these soils are found, it can be very challenging to locate suitable borrow excavation within a reasonable distance on projects developed in these areas.

The area of the state known as the “Delta” consists of alluvial soils deposited by the Mississippi River and its tributaries. Districts 2 and 3 can attest that the alluvium can be sandy, or silty, but sometimes it can be “gumbo” clay which is highly plastic and has HVC characteristics. Though not quite to the same extent as the Black Prairie Soils, it is sometimes difficult to locate suitable borrow excavation for projects in areas with the gumbo clay prevalent.

#### **X.1.1.1 History of HVC Construction**

MDOT has been attempting to mitigate the effects of active clays on pavements since the 1960's. These early attempts included identifying active clays by performing shrinkage limit tests to determine the volume change potential of the material. For several years, clays that exhibited a volume change of greater than 74% were considered “high volume change”, and there were procedures in place that were used to try and offset the shrink/swell effects of HVC soils.

In the 1970's, for example, it was thought that “remolding” of Yazoo clay in the subgrade disrupted the natural shrinkage cracks in the material which would eventually allow rain water to infiltrate down to certain depths, and prevent swelling of the clay as it tried to reach equilibrium when water entered those cracks. Several high traffic roadways were constructed in the Jackson, Mississippi area using this technique. The technique basically consisted of scarifying or excavating the Yazoo clay material, placing it back into the subgrade or within an embankment (in a drier condition), and compacting it to the specified density.

During construction of SR 475 in Rankin County (Airport Road) an experimental section was excavated below the subgrade elevation. A series of small borings in a grid pattern was excavated, and the boreholes filled with clean sand. The entire area was flooded, and readings from moisture probes were obtained until the Yazoo clay had reached its maximum natural moisture content. The water was released and the clay was sealed by placing an impervious borrow excavation over the area. The entire experiment was an attempt to limit the future “activity” of the underlying HVC clay by keeping the moisture content at a constant level. Unfortunately, almost 50 years later that section of the roadway is one of the worst riding areas along the alignment.

The use of lime, particularly the hydrated variety, has been shown to be very effective in reducing the plasticity index (PI) of clayey materials. Properly blended, clay soils mixed with lime are much more friable and easier to work with in earthwork construction. It was presumed that a subgrade consisting of shrinking and swelling expansive clays that had been treated with lime would inhibit or even prevent additional shrinking and swelling. This method was used with

HVC soils on a statewide basis for a period of time for this purpose. It is still used today as a chemical treatment in certain design soils, particularly the afore-mentioned "Black Prairie Soils".

None of these methods proved in the long term to work very well for HVC clays, and pavement failures in areas of Mississippi with these types of soils and constructed using the various preventative methods on the subgrade continued to appear.

In the 1980's, MDOT began trying different methods of controlling the in-situ moisture content of the clay subgrade soils. Some examples included application of a bituminous coating directly on the subgrade; use of an impermeable membrane directly on top of the subgrade similar to those used in landfill applications; and significant undercutting of the subgrade (up to 3 feet) and backfilling with a fine-grained material of low to medium plasticity (AASHTO A-6 classification). The best success in regards to inhibiting shrink/swell of the subgrade and reducing bumpy pavements was found to be with the undercut/backfill procedure, especially in roadway cut sections when the undercut extended from ditchline to ditchline. By nature the procedure is costly, for three major reasons. One, rarely is quality backfill material readily available in most areas of the state where the HVC soils exist, such that there is usually a considerable haul distance involved from a pit that has material with the desired properties. (The exception to this observation is in District 7, where there is almost always a suitable material nearby.) Two, the undercut heavy clay material is of relatively no use on a highway construction project, and must be hauled off and wasted somewhere off the project. And three, even though the A-6 type material used for backfill is a "better" material than the underlying subgrade, it is still a fine-grained material with a less than desirable modulus and must be chemically treated to provide a stable subgrade.

#### **X.1.1.2 Recent Policies**

In the past 20 years, the MDOT pavement policy has been modified several times to address the problem of clay subgrades. Virtually all new construction projects are now built with controls on the design soil. Limitations on the volume change potential in the design soil have been reduced to 60% - meaning, soil materials with a volume change of 60% or more are prohibited from being used in the design soil prism. In addition, with rare exception, all subgrades are now chemically treated with either lime or cement, depending on the classification of the subgrade soil.

This current policy necessitates more engineering insight both in the preconstruction design stage and during the actual construction. HVC soils must be identified, if possible, during the design stage by drilling for subsurface samples to a depth of up to 5 feet below the anticipated subgrade elevation. Considerable effort must be expended in the laboratory to test these samples for HVC characteristics. The extent and limits of HVC soils which would be in the subgrade must be identified and listed, so that roadway designers can modify the construction plans accordingly to insure that adequate quantities of excess excavation (waste) and borrow excavation are established in the bid documents. The type of borrow excavation used to backfill undercut subgrade areas should be determined as soon as possible. Pavement designers should be keenly aware of the existence of HVC clays, and what the projected plans are to mitigate the effects of HVC clays, which will affect the design assumptions used in the design process. Similarly, inspection personnel must be vigilant during the construction operations to insure that HVC soils do not end up in the design soil and that the design criteria are not compromised.

### **X.1.2 Other Clayey Soils**

As noted, there are many locations around the state where problematic soils are encountered, and most are related to highly plastic or HVC soils. Again, HVC soils will usually have an AASHTO classification of A-7-6. “Highly plastic” is a term loosely used, and there are various opinions as to what constitutes a “highly plastic” designation. There appears now to be general consensus among MDOT materials engineers that any clay material with a plasticity index of 23 or higher is going to present issues during construction, *regardless of the volume change measured in the laboratory*, and must be dealt with accordingly. These materials may classify as AASHTO A-7-5 or A-6.

From strictly a pavement design perspective, subgrades consisting of “highly plastic” soils should be presumed to have basically the same material characteristics as any HVC soil.

The implications here are immense. There are few locations in the state of Mississippi where one could design or construct a section of roadway without encountering a highly plastic material. The economic considerations (project budget) must by necessity prevail when determining the effects of these soils on a project. The moduli for the pavement structure must be carefully selected, with knowledge of the proposed mitigation measures.

### **X.1.3 Other Fine Grained Soils**

There are certain soils in Mississippi, given an AASHTO classification of A-4, which are singled out as being problematic.

On the western side of the state, along the bluffs leading to the Mississippi Delta and the Mississippi River, massive wind-blown deposits of silt known as loess exist. This material consists of 90% or more silt size particles, and has little to no plasticity. As Districts 2, 3, and 7 can affirm, it is highly erodible. As long as the moisture content is at approximately 3% below the optimum moisture at maximum dry density, the material can be excavated, shaped and compacted with relative ease. From review of the values reported from the resilient modulus testing, one would expect an A-4 material to provide a substantially good subgrade. However, when this loess material gets wet and saturated, it has very little stability. This limits earthwork operations to being performed when the prevailing weather pattern is dry. As a subgrade material, it must be quickly chemically treated with cement and primed with bituminous material to avoid excessive moisture intrusion and loss of stability.

Since a designer usually has no control over the season of earthwork construction, how should a designer account for this loess material with the Pavement ME Design? Reference Section 6.2 concerning depth to the water table – for cut sections, it should be assumed that the depth to the water table is at or within one foot of the surface. Also reference Section 8.1 Stabilized Subgrade and Embankment/Foundation Layers or Subgrade. A resilient modulus selected from the tables for A-4 materials should take into account whether the material is this loess silt, and if so, should be lowered accordingly.

Similar A-4 materials not associated with the loess bluffs are prevalent within the southern 1/3 of the state. These are usually found in a natural condition as very wet and soft, and are sometimes mis-categorized as muck even though the organic content of the material does not bear that out. District 6 (Hattiesburg) notes that often they are able to excavate these materials, stockpile them in a place where they can naturally drain and dry out, then use it as a good unclassified excavation material in embankment construction but below the design soil.

Since a pavement designer in most instances cannot anticipate the presence of this material in an embankment, or in the design soil, the District Materials and Construction personnel must insure that any material of this type is processed accordingly and not allowed into the design soil.

## **X.2 BORROW EXCAVATION DESIGN SOILS**

Class B9-6 Borrow Excavation is a material which historically has worked well in the design soil prism. It has been used extensively statewide to backfill undercut subgrades in HVC areas. MDOT's standard specifications allow up to 100% of the B9-6 material to pass the No. 200 sieve, but the liquid limit cannot exceed 40 and the plasticity index must be between 6 and 20. This insures that "lean clay" is being placed over the HVC undercut subgrade in an attempt to keep the moisture content of the HVC subgrade at a constant level. Quality B9-6 borrow excavation will classify as an AASHTO A-6 material.

Most of the Districts have noted that on several of their projects, a quality B9-6 material was difficult to locate within a reasonable haul distance, and the material they did have available was so silty or sandy that it was at the lower limit of the plasticity index requirement. These Districts also noted that the B9-6 borrow excavation did not always respond well to the usual chemical treatment methods. They did not feel they were getting the desired moisture barrier over the undercut HVC soils, based upon swelling which exhibited itself in a short period of time after opening the completed pavements to traffic.

For the situation described above, these B9-6 materials are trending towards an AASHTO A-4 classification. If the source can be determined with some confidence in the design process, and the material only marginally exceeds the specified minimum PI of 6, it should be more prudent to select a design resilient modulus for an A-6 material even though test results indicate an A-4.

## **X.3 GRANULAR BASE LAYERS**

Some MDOT Districts report that they have recently had issues with Class 9 granular material. It has traditionally been used with great success in roadway construction projects statewide. It is used extensively across the state as a sub-base beneath pavements ("topping"), and is usually chemically treated for a cement treated base before placement of hot mix asphalt or concrete pavements.

MDOT's standard specifications define a Class 9 granular material as a material with 30 - 100% passing the No. 10 sieve. Of the material passing the No. 10 sieve, the following gradation limitations apply:

<b>Sieve Size</b>	<b>% Passing</b>
No. 10	100
No. 40	20 – 100
No. 60	15 – 85
No. 200	6 - 40

Historically most pit sources of Class 9 granular material have fallen into the median range of the percent passing specified. This material would classify as an AASHTO A-2-4 material.

For many years, when it was available, the Districts preferred Class 9 granular material with a Group C designation (limiting the PI of the material to a maximum of 10). This insured they were getting a good sandy material with just enough clay fines to help hold the sand sized particles together. Nowadays, some Districts are finding that their sources of Class 9 granular material must often be specified with a Group E designation, *requiring* it to have a plasticity index between 6 and 15. As good sources for Class 9 granular material have become more difficult to find, the materials which do meet the specification limits (regardless of Group designation) are at the upper end of the gradation bands for the No. 60 and No. 200 sieves, and there is also very little plasticity – i.e., the material is fine and silty. Here again, the material is trending towards an AASHTO A-4 classification.

When the Class 9 granular material has a fine gradation, it becomes difficult for the laboratory to determine the optimum cement content for chemical treatment. With the laboratory designing strictly on a compressive strength basis, excessive application rates of cement (>7%) are often determined to be necessary. There becomes a point at which there is little to no difference in compressive strength with the addition of more cement.

These high cement applications are difficult to manage in the construction process, due to excessive water demand with the short time limitations required in achieving proper density. It also lends itself to excessive cracking of the blended and compacted materials, even when the bituminous prime coat is placed in a reasonable time after compaction to prevent moisture loss. This situation results in pavement failures which occur quickly, because the resilient modulus of the material does not meet the design assumptions.

One remedy is to limit the cement application to 6% or less, regardless of compressive strength constraints, whenever the Class 9 granular material tends towards a fine gradation. Pavement designers should ascertain, with some confidence, the gradation quality of the expected source of material before selecting the resilient modulus for the cement treated base.



## **Appendix D**

### **Discontinued AASHTO Standard Method of Test T 92 - Determining the Shrinkage Factors of Soils**

**(For Information Only and not for Reproduction)**

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## Standard Method of Test for

# Determining the Shrinkage Factors of Soils



AASHTO Designation: T 92-97 (2005)

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## 1. SCOPE

- 1.1. This procedure furnishes data from which the following soil characteristics may be calculated: (a) shrinkage limit, (b) shrinkage ratio, (c) volumetric change, and (d) lineal shrinkage.
- 1.2. The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limited value, in accordance with E 29, Using Significant Digits in Test Data to Determine Conformance with Specifications.
- 1.3. The values stated in SI units are to be regarded as the standard.
- 1.4. Refer to R 16 for regulatory information for chemicals.

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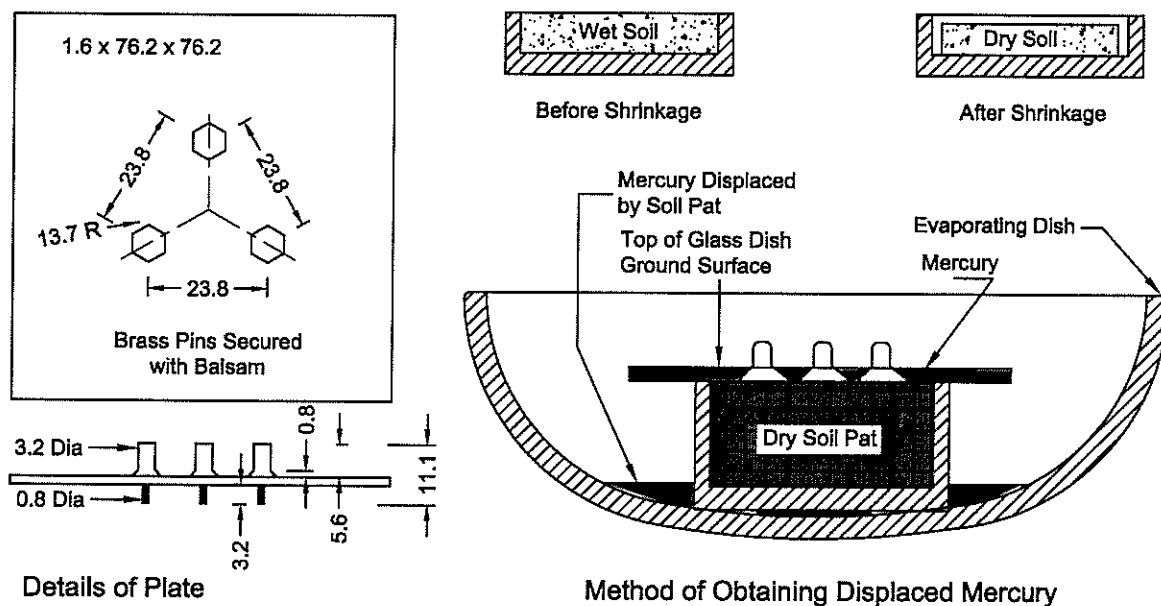
## DETERMINATION OF THE VOLUMETRIC SHRINKAGE

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## 2. APPARATUS

- 2.1. The apparatus shall consist of the following:
  - 2.1.1. *Dishes:*
    - 2.1.1.1. A porcelain evaporating dish, or similar mixing dish, about 115-mm ( $4\frac{1}{2}$ -in.) diameter.
    - 2.1.1.2. A porcelain evaporating dish about 150 mm (6 in.) in diameter.
  - 2.1.2. *Spatula*—A spatula or pill knife having a blade about 75 mm (3 in.) long and about 20 mm ( $\frac{3}{4}$  in.) wide.
  - 2.1.3. *Milk Dish*—A porcelain or monel metal milk dish having a flat bottom and being about 45 mm ( $1\frac{3}{4}$  in.) in diameter by about 12.7 mm ( $\frac{1}{2}$  in.) high.
  - 2.1.4. *Straightedge*—A steel straightedge 100 mm (4 in.) or more in length.
  - 2.1.5. *Glass Cup*—A glass cup about 50 mm (2 in.) in diameter by 25 mm (1 in.) high, the top rim of which is ground smooth and parallel with its base.

- 2.1.6. *Transparent Plate*—A transparent plate with three metal prongs for immersing the soil pat in mercury as shown in Figure 1.



#### Dimensional Equivalents

mm	in.
0.8	1/32
1.6	1/16
3.2	1/8
5.6	7/32
11.1	7/16
13.7	0.54
23.8	15/16
76.2	3

Note: All dimensions shown in millimeters unless otherwise noted.

**Figure 1**—Apparatus for Determining the Shrinkage Factors of Subgrade Soils

- 2.1.7. *Glass Graduate*—A glass graduate having a capacity of 25 mL and graduated to 0.2 mL.
- 2.1.8. *Balance*—The balance shall have sufficient capacity and conform to M 231, Class G 1.
- 2.1.9. *Mercury*—Sufficient mercury to fill the glass cup to overflowing.
- 2.1.10. *Oven*—A thermostatically controlled drying oven capable of maintaining temperatures of  $110 \pm 5^\circ\text{C}$  ( $230 \pm 9^\circ\text{F}$ ) for drying soil samples.

### 3. SAMPLE

- 3.1. A sample with a mass of about 30 g shall be taken from the thoroughly mixed portion of the material passing the 0.425-mm (No. 40) sieve prepared in accordance with the Standard Method of

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## 4. PROCEDURE

- 4.1. The sample shall be placed in the 115-mm (4½-in.) mixing dish and thoroughly mixed with water in amount sufficient to fill the soil voids completely and to make the soil pasty enough to be readily worked into the milk dish without inclusion of air bubbles. The amount of water required to produce the desired consistency in friable soils is equal to or slightly greater than the liquid limit, and the amount necessary to produce the desired consistency in plastic soils may exceed the liquid limit by as much as 10 percent.
- 4.2. The inside of the milk dish shall be coated with a thin layer of vaseline or some other heavy grease to prevent the adhesion of the soil to the dish. An amount of the wetted soil equal to about one-third of the volume of the milk dish shall be placed in the center of the dish, and the soil shall be caused to flow to the edges by tapping the dish on the firm surface cushioned by several layers of blotting paper or similar material. An amount of soil, approximately equal to the first portion, shall be added and the dish tapped until the soil is thoroughly compacted and all included air has been brought to the surface. More soil shall be added and the tapping continued until the dish is completely filled and excess soil stands out about its edge. The excess soil shall then be struck off with a straightedge and all soil adhering to the outside of the dish shall be wiped off.
- 4.3. The dish when filled, struck off, and wiped clean shall be weighed immediately and the mass recorded as the mass of dish and wet soil. The soil pat shall be allowed to dry at room temperature until the color of the pat turns from dark to light. It shall then be oven-dried to constant mass at  $110 \pm 5^{\circ}\text{C}$  ( $230 \pm 9^{\circ}\text{F}$ ) and the mass recorded as the mass of dish and dry soil. The mass of the empty dish shall be determined and recorded. The capacity of the dish in mL which is also the volume of the wet soil pat shall be determined by filling the dish to overflowing with mercury, removing the excess by pressing a glass plate firmly over the top of the dish, and measuring the volume of the mercury held in the dish in the glass graduate. The volume of the mercury shall be determined by the value at the top of the meniscus. Alternatively, determine the volume of the dish by weighing the mercury held in the dish to the nearest 0.1 g and calculate the volume in mL using the formula  $V = M/D$ , where  $M$  = mass of displaced mercury in grams and  $D = 13.5 \text{ g/mL}$  (the density of mercury). This volume shall be recorded as the volume of the wet soil pat,  $V$ .
- 4.4. The volume of the dry soil pat shall be determined by removing the pat from the milk dish and immersing it in the glass cup full of mercury in the following manner:
- 4.4.1. The glass cup shall be filled to overflowing with mercury and the excess mercury shall be removed by pressing the glass plate with the three prongs (Figure 1) firmly over the top of the cup. Any mercury that may be adhering to the outside of the cup shall be carefully wiped off. The cup filled with mercury shall be placed in the 150-mm (6-in.) evaporating dish and the soil pat shall be placed on the surface of the mercury. The pat shall then be carefully forced under the mercury by means of the glass plate with the three prongs (Figure 1) and the plate shall be pressed firmly over the top of the cup. It is essential that no air be trapped under the soil pat. Determine the volume in mL of the dry soil pat,  $V_o$ , by measuring the mercury so displaced in the glass graduate or by determining the mass of the mercury to the nearest 0.1 g and calculating the volume in mL using the formula  $V_o = M/D$ , where,  $M$  = mass of mercury in grams and  $D = 13.5 \text{ g/mL}$  (density of mercury).

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## 5. CALCULATION OF WATER CONTENT

- 5.1. The water content of the soil at the time it was placed in the dish expressed as a percentage of the dry mass of the soil shall be calculated as follows:

$$w = \frac{W - W_o}{W_o} \times 100 \quad (1)$$

where:

- $w$  = water content of the soil when placed in the dish,  
 $W$  = mass of wet soil obtained by subtracting the mass of the shrinkage dish from the mass of the dish and wet pat, and  
 $W_o$  = mass of dry soil pat obtained by subtracting the mass of the shrinkage dish from the mass of the dish and dry pat.

- 5.1.1. Calculate the water content to the nearest 0.1 percent.

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## 6. CALCULATION OF THE SHRINKAGE LIMIT

- 6.1. *Definition:*

- 6.1.1. The shrinkage limit of a soil is defined as the maximum calculated water content, at which a reduction in water content will not cause a decrease in the volume of the soil mass.

- 6.2. *Calculation:*

- 6.2.1. The shrinkage limit,  $S$ , shall be calculated from the data obtained in the volumetric shrinkage determination by the following formula:

$$S = w - \frac{V - V_o}{W} \times 100 \quad (2)$$

where:

- $S$  = shrinkage limit;  
 $w$  = water content of wet soil, in percentage of the mass of oven-dried soil;  
 $V$  = volume of wet soil pat;  
 $V_o$  = volume of oven-dried soil pat; and  
 $W$  = mass of oven-dried soil pat.

- 6.2.1.1. Calculate the shrinkage limit to the nearest 0.1 percent.

- 6.3. *Optional Method:*

- 6.3.1. When both the true specific gravity,  $G$ , and the shrinkage ratio,  $R$ , are known, the shrinkage limit may be calculated from the following formula:

$$S = (1/R - 1/G) \times 100 \quad (3)$$

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## 7. CALCULATION OF THE SHRINKAGE RATIO

### 7.1. *Definition:*

- 7.1.1. The shrinkage ratio of a soil is the ratio between a given volume change and the corresponding change in water content above the shrinkage limit.

### 7.2. *Calculation:*

- 7.2.1. The shrinkage ratio,  $R$ , shall be calculated from the data obtained in the volumetric shrinkage determination by the following formula:

$$R = \frac{W_o}{V_o} \quad (4)$$

- 7.2.1.1. Calculate the shrinkage ratio to the nearest 0.1.

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## 8. CALCULATION OF THE VOLUMETRIC CHANGE

### 8.1. *Definition:*

- 8.1.1. The volumetric change of a soil is the decrease in volume of the soil mass when the water content is reduced from a given percentage to the shrinkage limit.

### 8.2. *Calculation:*

- 8.2.1. The volumetric change,  $VC$ , shall be calculated from the data obtained from the volumetric shrinkage determination by the following formula:

$$VC = (w_1 - S)R \quad (5)$$

where:

$VC$  = the volumetric change, and

$w_1$  = a given water content.

- 8.2.1.1. Calculate the volumetric change to the nearest 0.1 percent.

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## 9. CALCULATION OF THE LINEAL SHRINKAGE

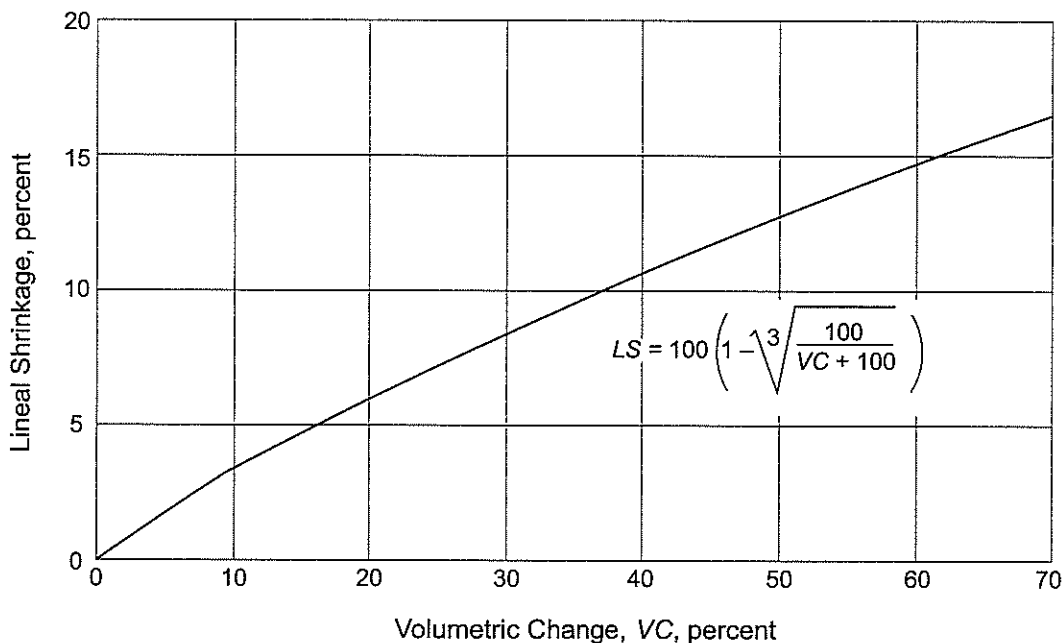
### 9.1. *Definition:*

- 9.1.1. The lineal shrinkage of a soil is defined as the decrease in one dimension of the soil mass when the water content is reduced from a given percentage to the shrinkage limit.

- 9.1.2. The lineal shrinkage,  $LS$ , shall be obtained either by means of the formula:

$$LS = 100 \left( 1 - \sqrt[3]{\frac{100}{VC + 100}} \right) \quad (6)$$

or by means of the curve in Figure 2, which represents this relation.



**Figure 2**—Relation between Volumetric Change and Lineal Shrinkage

9.1.2.1. Determine the lineal shrinkage to the nearest whole percent.

## 10. PRECISION

10.1. Criteria for judging the shrinkage factors of soils are as follows:

**Note 1**—The figures in Column 2 are the standard deviations that have been found to be appropriate for the tests described in Column 1. The figures in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

10.1.1. *Single-Operator Precision:*

**Table 1**—Single-Operator Precision

	Type of Test	Standard Deviation <sup>a</sup>	Acceptable Range of Two Results <sup>a</sup>
10.1.1.1	Water Content	no data	no data
10.1.1.2	Shrinkage Limit	0.91	2.6
10.1.1.3	Shrinkage Ratio	0.020	0.06
10.1.1.4	Volumetric Change	no data	no data
10.1.1.5	Lineal Shrinkage	no data	no data

<sup>a</sup> These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Recommended Practice C 670 for Preparing Precision Statements for Test Methods for Construction Materials.

10.1.2. *Multilaboratory Precision:*

**Table 2—Multilaboratory Precision**

	Type of Test	Standard Deviation <sup>a</sup>	Acceptable Range of Two Results <sup>a</sup>
10.1.2.1	Water Content	no data	no data
10.1.2.2	Shrinkage Limit	2.42	6.8
10.1.2.3	Shrinkage Ratio	0.055	0.16
10.1.2.4	Volumetric Change	no data	no data
10.1.2.5	Lineal Shrinkage	no data	no data

<sup>a</sup> These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Recommended Practice C 670 for Preparing Precision Statements for Test Methods for Construction Materials.