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EFFECTS OF FREEZE-THAW AND OVERLOAD CONDITIONS ON THE RESILIENT MODULUS OF LOW-PLASTICITY SOILS

by

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16. Abstract

The resilient modulus (M_r) of frost-susceptible soils was evaluated for effects of freeze-thaw, moisture imbibition, and overloading. Substantial stiffness reductions were observed for both the freeze-thaw and imbibition conditioning regimes. Most reduction occurred during the first two cycles of freezing or wetting. The effects of freeze-thaw on a subgrade material can be approximated through conditioning of samples with moisture imbibition cycles only. Recommendations for modifying the AASHTO T274 test are provided.

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DISCLAIMER

PREFACE

The 1986 AASHTO Guide for Design of Pavement Structures requires an "effective" Resilient Modulus (M_r) of a subgrade soil as the definitive material property to be used in pavement design. This effective M_r is determined by utilizing M_r values expected during seasonal variations of the year when subgrade soils experience fluctuations in water content and structural strength. The standard test used in determining M_r is described in AASHTO T 274.

Many agencies in the MPC region are experiencing difficulty in determining the appropriate M_r values to use for the critical periods during spring thaw. This difficulty is primarily because many subgrade soils in the western states are susceptible to moisture imbibition during the winter months, creating a substantial reduction in M_r while the soil is thawing.

This study investigates sample conditioning methods and the effects of freeze-thaw and overloading on frost-susceptible soils in the MPC region. Limitations and recommendations for modifying AASHTO T 274 are also provided.

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EXECUTIVE SUMMARY [1]

OBJECTIVES

The primary objective of this study was to investigate the effects of freeze-thaw conditioning and overloading on the resilient modulus (M_r) of subgrade soils susceptible to frost penetration. The M_r values of conditioned samples were compared to unconditioned samples. All M_r values were determined in accordance with AASHTO T 274 test procedure.

TECHNIQUES

Seventy-seven samples were prepared from four frost-susceptible soils compacted to various selected water contents. Samples were prepared for testing using no treatment, open-celled freezing and imbibition only based on techniques developed for this project and easily reproducible in DOT laboratories. Most of the samples were freeze-thawed cycled from one to eight times before testing and the results were compared to values obtained from normally prepared samples.

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CONCLUSIONS

Results from laboratory testing of various frost-susceptible soil types, water contents and conditioning indicate identifiable trends in conditioning stages, conditioning methods and testing procedures. These trends are:

1. Reduction of M_r values occurs through imbibition and freeze-thaw conditioning, as indicated by subgrade failures during critical spring-thaw periods.
2. Most reduction of M_r occurs during the first freeze-thaw or imbibition conditioning cycle.
3. Little decrease of M_r occurs after 2 freeze-thaw cycles.
4. The reduction of M_r can be reasonably predicted through imbibition conditioning only.
5. Overloading of soft samples resulted in large plastic deformations. This influenced the final M_r values which produced an apparent increase in M_r.
6. Greatest percent loss of M_r for a given soil and typically the lowest final M_r occured in conditioned samples prepared at lower moisture contents.
7. Values of M_r obtained from the AASHTO T 274 test can be accurately predicted over a wide range of soil types and conditioning using a condensed regime such as the Asphalt Institute test method.
8. AASHTO T 274 does not specifically address testing of non-cohesive fine-grained soils. The conditioning sequence specified for both cohesive and non-cohesive soils is too severe for soft specimens conditioned for M_r reduction due to freeze-thaw. This may also be true of many non-conditioned samples in these type ranges.

CHAPTER I

INTRODUCTION

Background and Statement of Problem

The American Association of State Highway and Transportation Officials (AASHTO) has stated in the 1986 AASHTO Guide for Design of Pavement Structures that the resilient modulus (M_r) is to be the definitive material property to be used in pavement design. Under the previous Guide, soils were evaluated on an arbitrary "soil support" scale, which was not based on any particular method of test or evaluation (Elliott and Thornton, 1988). Each highway agency adopted it's own test and relationship to determine an appropriate soil support number for pavement design. Tests commonly used to characterize soil support were the Hveem Resistance-value, or R-value, and the California Bearing Ratio, or CBR test.

The presence of excessive moisture beneath a roadbase during spring thaw conditions has long been recognized as a significant factor in producing large deflections that eventually lead to fatigue failure of asphalt road surfaces. If an overload condition occurs due to heavy truck traffic during this vulnerable period of spring thaw, severe damage to the surface and roadbase could occur.

Effects of freeze-thaw and overloading on a subgrade soil can be determined by defining the M_r values for samples conditioned to simulate in-service conditions.

Definition of Resilient Modulus

The resilient modulus (M_r) is the relationship of stress to elastic strain of a material subjected to cyclic loading. Materials considered in this report are restricted to bases and subgrade materials used in highway construction. The resilient modulus can be computed by the formula:

$$M_r = \frac{\sigma_d}{\epsilon_r} \qquad (1)$$

where: M_r = Resilient Modulus
σ_d = repeated deviator stress
ε_r = recoverable axial strain

A graphical representation of M_r by Thompson (1989) is shown in Figure I-1, which depicts both the plastic (non-recoverable) strain and elastic (resilient) strain to a deviator stress applied as a haversine wave. A schematic representation of M_r by Seim (1989) is shown in Figure I-2.

Objectives

The primary objective of this study was to investigate the effects of freeze-thaw conditioning and overloading on the stiffness (M_r) of subgrade soils susceptible to frost penetration. The M_r values of conditioned samples were determined in accordance with AASHTO T 274 test procedure.

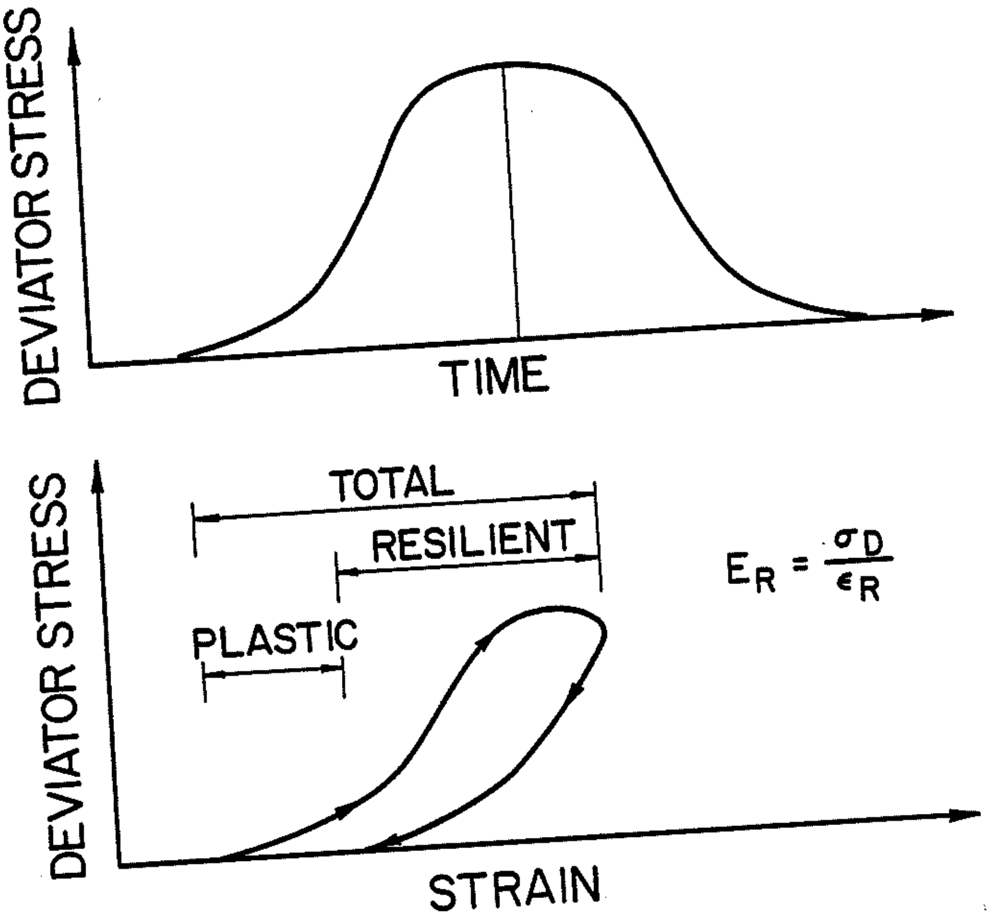
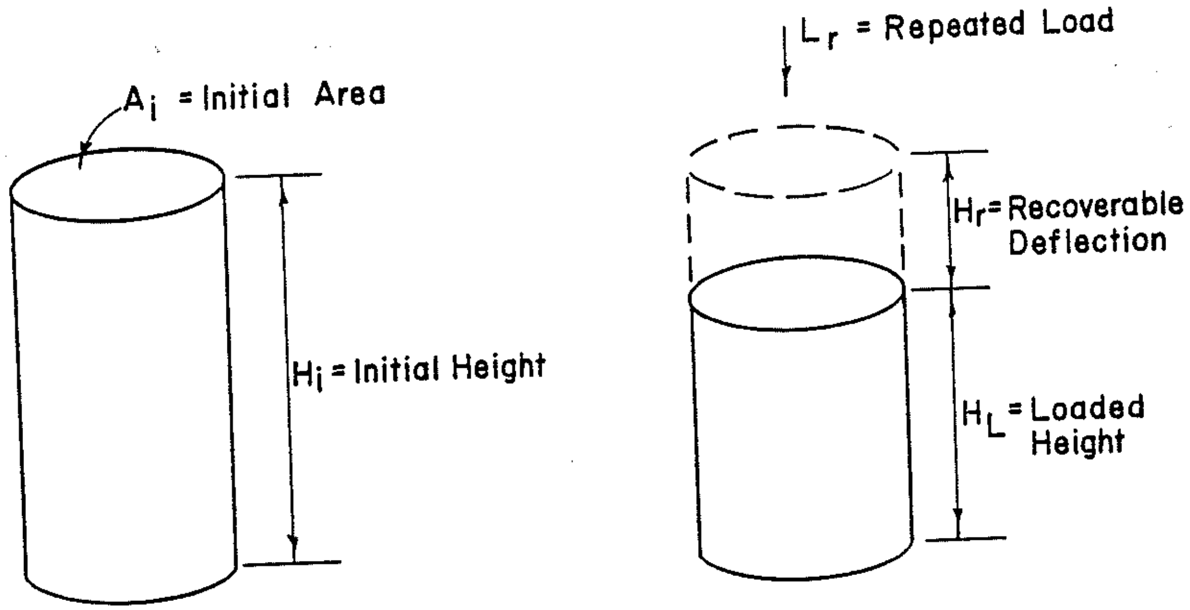


Figure I-1. Definition of Resilient Modulus ($E_r = M_r$), (Thompson, 1989).



$$\frac{L_r}{A_i} = \sigma_r = \text{Repeated Deviator Stress}$$

$$\frac{H_r}{H_i} = \epsilon_r = \text{Recoverable Strain}$$

$$\text{Resilient Modulus} = M_r = \frac{\sigma_r}{\epsilon_r}$$

Figure I-2. Definition of Resilient Modulus (Seim, 1989).

Scope of Project

Seventy-seven samples in 4 categories representing AASHTO M 145 classifications A-2-6(1), A-4(5), A-6(2) and A-7-6(14) were conditioned and tested in this study. This range of classifications covers the fine-grained soils that are most susceptible to moisture retainment (imbibition) during the freeze-thaw process.

The matrix of conditioned samples is discussed in Chapter IV. The A-4(5) and A-6(2) soils were investigated throughout a range of water contents around optimum. The A-2-6(1) soil was tested at optimum water content only. The A-7-6(14) soil was tested at +1% optimum and -1.5% optimum. A further comparison between freeze-thaw conditioning and imbibition only (no freeze-thaw) was performed on the A-6(2) and A-4(5) soils.

Soils not investigated in this study are the coarse-granular and cohesive clays.

Organization of Study

Chapter II describes the freeze-thaw process and moisture imbibition of soils and the effects of overloading on subgrade materials. Use of spring overload restrictions throughout local states and methods of working with frost-susceptible soils in new construction are also covered. Chapter III describes the basic resilient modulus test and how it is used in the AASHTO pavement design procedure. The M_r testing setup at the University of Wyoming is also discussed. Chapter IV details the soil collection, sample construction, conditioning and testing procedure used in this study. Chapter V discusses the results of the testing regime. Correlations between freeze-thaw and imbibition only conditioning are also presented. Overloading effects and a comparison between the AASHTO T 274 and the Asphalt Institute testing sequences are also discussed. Chapter V also discusses the limitations of the

AASHTO T 274 test. Chapter VI summarizes the study and suggests recommendations for future research.

CHAPTER II

FREEZING AND THAWING OF FROST-SUSCEPTIBLE SOIL AND OVERLOAD RESTRICTIONS

Introduction

Frost action in soils has long been considered a substantial problem in both design and maintenance of load-bearing structures. The problem is not specific to just the northern states. A questionnaire presented by the Highway Research Board asked the question: "Is damage caused by freezing of roadbases, subbases, and/or subgrade soils a problem in your state?" The response of Highway Departments in 40 states was positive (Jumikis, 1955).

This chapter details the process of freezing and thawing of frost-susceptible subgrade soils. Spring overload restrictions used by state agencies and their effectiveness are also discussed.

The Freezing Process in Soil

Highway engineers have long recognized the phenomena of moisture accumulation beneath a roadbase as a consequence of frost action. It has also been observed that heaving occurs in magnitudes far greater than would be expected if only the existing moisture within the soil expanded by the 9% exhibited by open water upon freezing (Jumikis, 1955; Tsytovich, 1960, and others).

As the winter months bring average temperatures below 0° C., the roadbase freezes from the top down. As the frostline penetrates downward, moisture between the soil particles freezes. This, in effect, dries the soil because the frozen moisture no longer satisfies the attractive forces of the soil for capillary water held adjacent to the soil particles by surface tension (Spangler and Handy, 1973). The voids within the soil accumulate ice lenses that effectively decrease the pore diameters and make the soil appear as if it were finer-grained. This causes the capillary stress to increase (or capillary potential to decrease) for a given degree of saturation. The decrease in capillary potential creates a hydraulic gradient, which results in moisture flow from the layers beneath the frostline where the capillary potential is greater (Jumikis, 1955; Spangler and Handy, 1973).

The free bulk water in the voids of the soil is the first type of soil moisture to freeze. Bound water, which may be chemically bound, adsorbed water, or water experiencing capillary forces, freezes at temperatures below 0° C. (Jumikis, 1966; Khakimov, 1966).

Capillary water can be characterized as a series of film layers surrounding a soil particle. The outer layers of the capillary film begin to freeze at about -1.4° C. Freezing of capillary layers continues inward towards the soil particle with lowering temperatures. Tsytovich (1960) and other Soviet researchers found that tightly bound moisture can remained unfrozen at temperatures down to -186° C. The unfrozen water provides a film around the soil particles which allows the moisture to move through the soil at temperatures below freezing (Jumikis, 1966; Tsytovich, 1975). Figure II-1 illustrates the upward flow of soil moisture film toward an ice crystal.

Soil moisture can be translocated as vapor, liquid or both. The manner in which moisture migrates through the soil medium during the freezing process is referred to as the "mechanism" of moisture transfer.

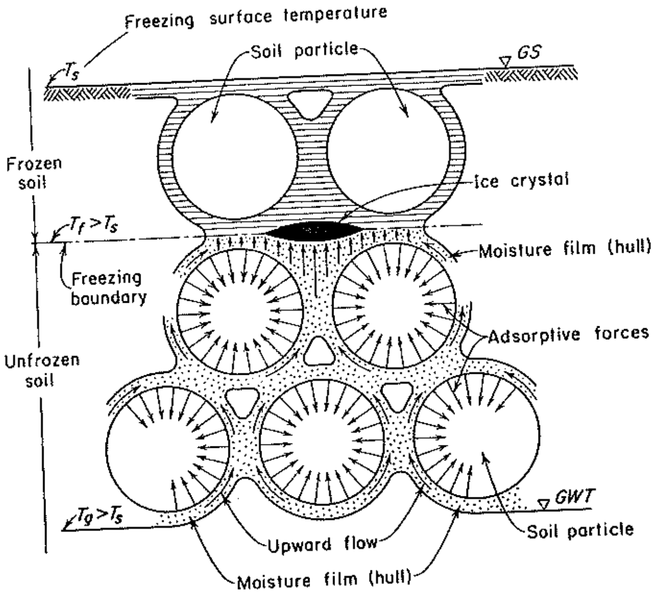


Figure II-1. Concept of Upward Flow of Soil Moisture Towards an Ice Crystal (Jumikis, 1984).

Vapor diffusion occurs in coarse and uniform soils containing large voids with little moisture continuity upwards from the groundwater. This diffusion is driven by the difference in vapor pressure between the warmer saturated condition at the groundwater table and the colder, drier condition at the freezing level. The change in vapor pressure is nonlinear, decreasing from the groundwater table to the freezing level.

If the soil is more dense with small porosity, the moisture surrounding the soil particles creates uninterrupted liquid films through which liquid water can flow. This provides a more effective mechanism than vapor diffusion. Although the rate of transfer may be slow, a substantial amount of moisture can be translocated during the winter months (Jumikis, 1984).

When moisture reaches the freezing zone, it freezes preferentially to existing ice grains, forming ice lenses parallel to the road surface. These lenses cause upward heaving of the roadbase and the road surface. This process continues until equilibrium is reached and the growth stops. If conditions such as soil type, density, availability of groundwater, type of road surface and soil conductivity are uniform, the moisture imbibition and consequential frost heaving will be uniform. This is usually not the case and differential heaving occurs where non-homogeneous conditions exist. This may cause considerable (and expensive) damage to road surfaces (Johnston, 1981; Phukan, 1985).

The Thawing Process in Soil

Unlike the freezing process, thawing of a roadbase occurs inward from both the bottom and top of the frozen layer. The rate of thaw from the top is ordinarily several times higher than from the bottom due to the heat transfer from the road surface, which is subjected to solar radiation and warming air temperatures (Andersland and Anderson, 1978). As thawing from the top progresses downward, the ice lenses melt and create void spaces in the soil due to the decrease in volume occupied by the moisture. These void spaces reduce the interlocking soil structure which lowers both the cohesive and the interlocking components of the soil shear strength.

Also, the largely impervious frozen soil layer beneath the thawed layer prevents gravity drainage of the meltwater. Lateral drainage is often hampered by frozen soils adjacent to the roadbase that are insulated beneath a layer of snow often created by winter plowing. This creates a saturated, undrained subgrade soil. Wheel loads applied by traffic cause the water pressure in the saturated soil to vary with the total stress changes, thereby maintaining a constant effective stress. The combination of voids left from ice lensing and increased soil water content ultimately decrease the bearing capacity of the soil. This decrease of bearing capacity is often referred to as "thaw-weakening".

Frost Susceptibility of Soils

The silty A-4 soils are most susceptible to imbibition and frost-heave because they exhibit the critical combination of moderately high capillary forces and high permeability to transfer moisture. This causes a rapid saturation of the voids which results in reduced bearing capacity upon thawing. The clayey soils possessing high capillary potential are also susceptible, however, low permeability hinders moisture movement. The granular A-1-a, A-1-b, and A-3 soils show the least amount of heaves and loss in bearing capacity upon thawing (Jumikis, 1984).

Casagrande (1932) stated the following criteria for identifying frost- susceptible soils:

> *"under natural freezing conditions and with a sufficient water supply one should expect considerable ice segregation in non-uniform soils containing more than 3% of grains smaller than 0.02 mm. No ice segregation was observed in soils containing less than 1% of grains smaller than 0.02 mm. even if the groundwater was at the frost line."*

A frost design soil classification system has been developed by the U.S. Corps of Engineers based on the Casagrande grain size criterion, and is shown in Table II-1 for both Unified and AASHTO soil classifications. The soil types are listed in order of increasing frost-susceptibility and thaw-weakening. It should be noted that the amount of fines < 0.02 mm. criterion can vary. Laboratory studies have shown that some gravelly soils with only 1% of particles smaller than 0.02 mm. heave significantly more than sandy materials having up to 20% finer than 0.02 mm. (Johnson, 1981). This variation is likely due to a combination of gradation and density.

Table II-1. U.S. Corps of Engineers Frost Design Soil Classification (Johnston, 1981). (Typical AASHTO classification added)

Frost group	Soil Type	Percentage finer than 0.02 mm, by weight	Typical soil types, Unified Soil Classification System	Typical AASHTO Soil Classification
F1	Gravelly soils	3 to 10	GW, GP, GW-GM, GP-GM	A-1-a, A-2-4, A-2-5
F2	(a) Gravelly soils	10 to 20	GM, GW-GM, GP-GM	A-1-a, A-2-4, A-2-5
	(b) Sands	3 to 15	SW, SP, SM, SW-SM, SP-SM	A-1-b, A-2-4, A-2-5, A-3
F3	(a) Gravelly soils	> 20	GM, GC	A-2
	(b) Sands, except very fine silty sands	> 15	SM, SC	A-2
	(c) Clays, PI > 12	-	CL, CH	A-6, A-7
F4	(a) All silts	-	ML, MH	A-2-4, A-2-5, A-4, A-5
	(b) Very fine silty sands	> 15	SM	A-2-4, A-2-5, A-4, A-5
	(c) Clays, PI < 12	-	CL, CL-ML	A-2, A-4, A-5
	(d) Varved clays and other fine-grained, banded sediments	-	CL ML; CL, ML, SM; CL, CH, ML;	A-2 thru A-7

Spring Load Restrictions

Purpose of Spring Load Restrictions

Many regions of the northern United States experience moderate to severe seasonal freezing which subjects pavement subgrades to freeze-thaw conditions. This freeze-thaw cycling, which may occur several times during a winter, increases the soil moisture content while decreasing the soil density. Thaw-weakening of pavement subgrades results in premature pavement cracking and deterioration. This deterioration may be prevented by:

1. Placing restrictions on heavy loads during periods of severe thaw-weakening.

2. Designing and constructing roadbases with materials not susceptible to frost action.

Since many frost-susceptible pavements are in service today, item 2 is not a viable solution except during construction or reconstruction. Item 1 appears to be the best alternative for public transportation agencies faced with budget constraints.

Types of Roads Receiving Load Restrictions

A recent survey of state agencies by Rutherford (1987) queried users regarding current practices used for load restrictions. Some general responses are itemized below:

1. Most state agencies place restrictions on both primary and secondary roads, but mostly to secondary roads. Few states place restrictions on Interstate highways.

2. Generally, state agencies place load restrictions on roads with average daily traffic (ADT) less than 2,500 and 10% or less trucks. Local governments such as cities or counties apply restrictions on roads with ADT levels up to 30,000 and up to 10% trucks.

3. Load restrictions are generally applied to aggregate or asphalt roads. Portland cement pavement structures reportedly have adequate strength to withstand the critical thaw period.

4. Load restrictions are primarily placed on roads with moisture-susceptible silt or clay subgrades. Granular subgrades were generally not restricted.

5. Ranges and normal thicknesses of pavement cross sections on which load restrictions are currently being applied are as follows:

	Range (in.)	*Normal (in.)*
Asphalt Surface	1½ - 5	2 to 4
Aggregate Base	4 to 18	6 to 12

Magnitude of Load Restrictions

A recent survey addressed the current load limits and how they are determined (Rwebangira, et al.; 1987). Significant findings are:

1. Normal service load limits range from 18,000 to 20,000 lb. on a single axle and 34,000 lb. on tandem axles.

2. Spring load restrictions generally range from 10,000 to 14,000 lb. for single axles and 18,000 to 28,000 lb. for tandem axles.

3. Spring load restrictions correlate to a 30 to 50 percent reduction for single axle loads, and 18 to 47 percent reduction for tandem axle loads.

4. Most load limits are established from experience. Only three states (Alaska, Minnesota and Washington) make some use of deflection measuring techniques to determine necessary load restrictions on specific road sections.

Results of this survey are listed in Table II-2.

Effectiveness of Spring Load Restrictions

A recent computer simulation by Rutherford (1987) compared thirty-two pavement structures representing "typical" restricted pavements. On each section, a layered elastic analysis was performed to calculate tensile and vertical subgrade strains. Spring thaw-weakening was simulated by reducing the subgrade resilient modulus. The effectiveness of spring load restrictions was evaluated by comparing the strains and asphalt fatigue produced under spring thaw conditions to the pavement response during the summer.

Rutherford considered the benchmark pavement performance to be the normal rate of consumption of pavement service life during the summer months. The increased rate of consumption of service life was determined at various levels of load restrictions.

Table II-2. Summary From Agencies Interviewed (Rwebangira et al., 1987).

Location	Types of Pavement Failure Associated with Spring Thaw	Extent of Problem	How Are Locations for Load Restrictions Determined?
Alaska DOT	Alligator cracking, rutting, frost boils	Statewide	FWD, visual observations, measurements of thaw depth, experience
Idaho DOT	Foundation, deep base, surface	15 percent of system	Experience
Iowa DOT	Spring breakup	Low-volume roads	Selected by district engineers
Bremer County, Iowa	Pavement breakup, rutting	Up to 50 percent on aggregate-surfaced, up to 10 percent on paved	Visual observation of heaving or pumping, or both
Maine DOT	Alligator cracking	Low-volume roads statewide	Selected by district engineers
Minnesota DOT	Rutting, alligator cracking	Limited	Experience of maintenance engineer and deflection measurements with road rater and FWD
Anoka County, Minnesota	Alligator cracking, potholes	Not too extensive due to restrictions	Construction history and design, and Benkelman beam deflections
Maple Grove, Minnesota	Frost boils, alligator cracking	Citywide	Uniform load restriction policy for all streets
Wright County, Minnesota	Rutting, alligator cracking	Variable from year to year	Road rater deflections
Montana DOT	Frost boils	Statewide to minimum structure roads	Judgment of maintenance personnel
New Hampshire DOT, Division 2	Alligator cracking, rutting, frost heave	Modest	Judgment of maintenance personnel based on whether heavy hauling is occurring
North Dakota DOT	Surface break, potholes	Varies yearly depending on frost penetration	Experience
Nova Scotia DOT	Varies depending on structure and loads	Not extensive	Benkelman beam testing
Oregon DOT	Heave, cracking, pavement breakup	Central, eastern part of state	Experience and visual observation
Benton County, Oregon	Alligator cracking and breakup	All road construction types	Experience
South Dakota DOT	Potholes, edge failure, alligator cracking	Highways with thin mats typically restricted statewide	Experience
Washington State DOT	Alligator cracking, pavement breakup	Central and eastern Washington on a few low-volume roads	Judgment of maintenance personnel
Benton County, Washington	Pavement breakup, frost heave, base failure	Moderate	Observation of road conditions

Her study determined pavement response could be classified into two categories, thin pavements with asphaltic concrete thicknesses of two inches and thick pavements with asphalt concrete thicknesses of four inches. Thin pavements typically deteriorate during the initial thawing periods due to tensile strain in the pavement. This strain results in fatigue-based "alligator" cracking and eventual destruction of the road surface. Figure II-2 shows the relationship between the rate of consumption of fatigue life in spring compared to summer consumption as a function of spring load restrictions for thin pavements. Conversely, thick pavements deteriorate later in the thawing cycle when the subgrade weakening allows excessive vertical subgrade strain.

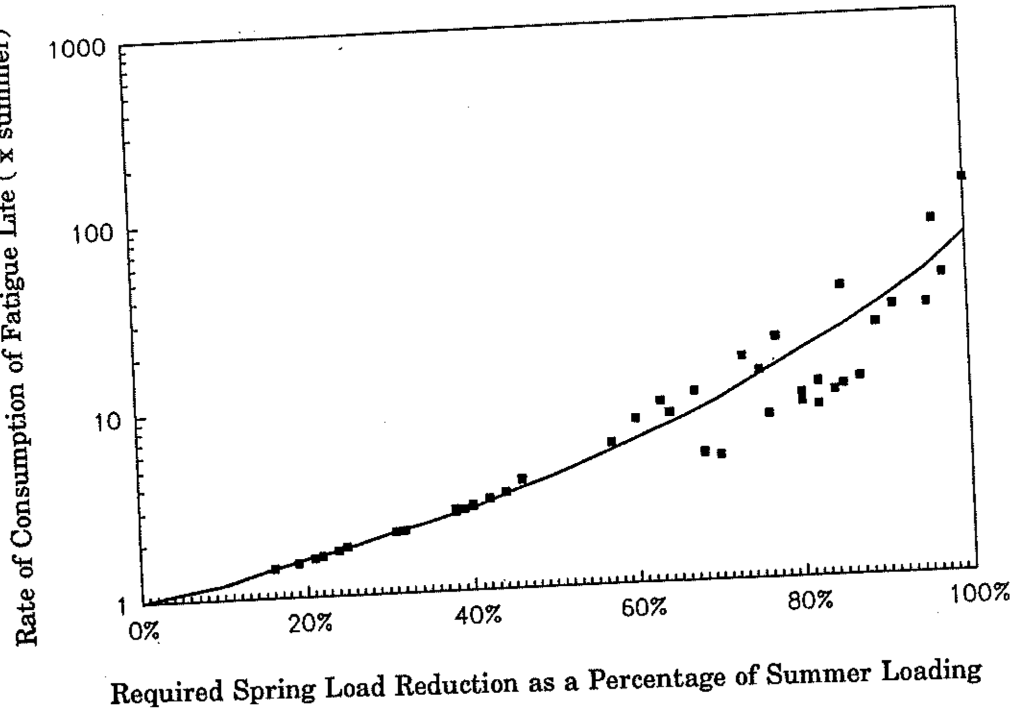


Figure II-2. Rate of Consumption of Fatigue Life Relative to Summer Versus Required Spring Load Restrictions for Thin Pavements (Rutherford, 1987).

This leads to rutting of the travel surface. Figure II-3 shows ratio of the rate of consumption of pavement rut life in spring compared to summer consumption as a function of the spring load reduction.

The results of the analysis indicate that substantial weight reductions are necessary to maintain consumption rates in the spring at the same level as those during the summer. Social and political pressures to maintain road usage make this level of reduction unacceptable to most local agencies. Restrictions are generally applied to reduce the need for major road rehabilitation and increase service life, but not to a degree that eliminates excessive subbase strains and/or asphalt fatigue entirely.

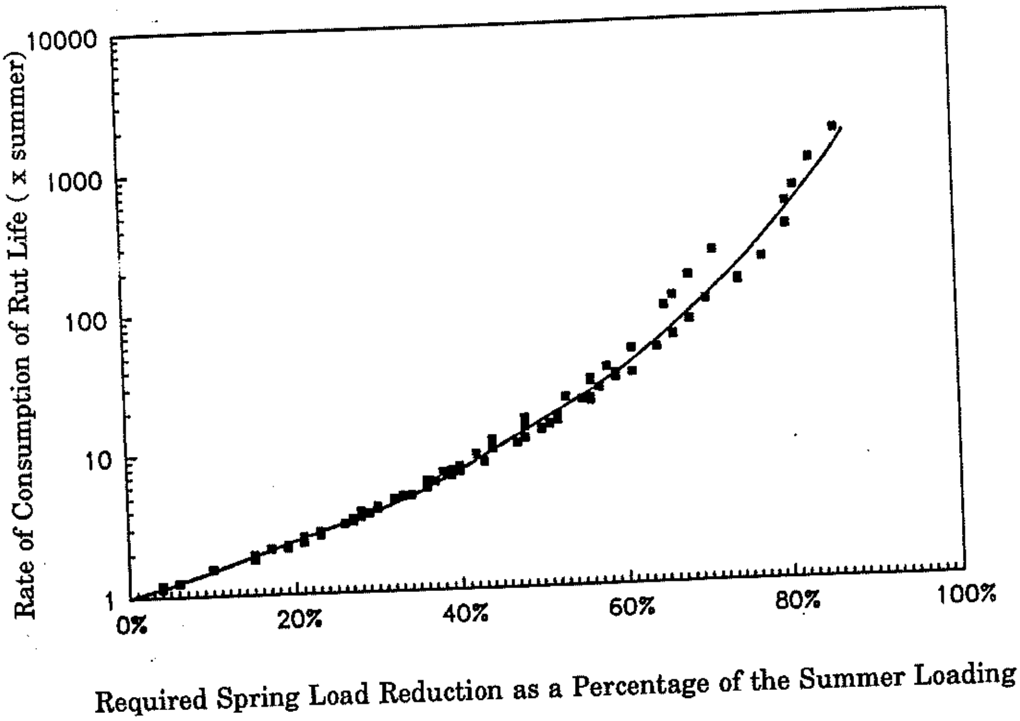


Figure II-3. Rate of Consumption of Fatigue Life Relative to Summer Versus Required Spring Load Restrictions for Thick Pavements (Rutherford, 1987).

Methods of Working with Frost-Susceptible Soils in New Construction

Restricting heavy traffic may be a viable deterrent to destructive usage of a secondary road facility where alternative routes are available. On primary roads, which perform at a high level of serviceability throughout the year under high traffic volumes, it is necessary to minimize the detrimental effects of the thaw-weakening process during initial construction.

The three components necessary for the frost-heave/thaw-weakening process to evolve are:

1. A frost susceptible soil,
2. Temperatures low enough to initiate freezing of the soil, and
3. Availability of moisture to the soil during freezing.

The alternatives available to the designer of a new road to alleviate freeze-thaw damage are based on eliminating one of the necessary components.

Removal of Frost-Susceptible Soil

If the existing roadbase consists of primarily frost-susceptible soils, removal of the soil and replacing it with a less frost-susceptible soil could be a viable option. Based on criteria presented earlier, this would normally require using an A-1-a or A-1-b soil. Design considerations are availability of a non-frost susceptible soil and disposal of the removed soil.

Insulating the Soil from Freezing Temperatures

Minimizing the extent of soil freezing may reduce the effects of problem soils. A common method used is placing an insulating layer of foamed polystyrene beneath the base or subbase layer. Caution should be taken to assure the insulating layers are not subjected to excessive moisture because its effectiveness is greatly reduced when water in the cells increases its thermal conductivity. (Lindroth, P.H., 1973).

Some problems associated with insulating layers, such as polystyrene, are:

1. Special placement procedures.
2. A thicker base course is necessary to offset increased subsurface deflections created by the plastic layer, which has a lower modulus of elasticity than common subbase materials.
3. Heavy construction traffic during and after construction must be limited due to the reduced capacity of the foam layer.

An alternative to plastic slabs is subbase materials that have low thermal conductivity, such as polystyrene foam concrete or frost-resistent gravels or sands. These materials provide insulating qualities while maintaining the bearing capacity of the subbase (Orama, 1973; Behr, 1973).

Salt Migration Through Leaching

For transportation systems that do not require a capped surface, such as a railroad bed, salt leaching can reduce the freezing point of frost-susceptible soils. If salt is applied to the surface of a soil, it leaches downward with subsequent rainfall. Salt movement occurs due to temperature gradients, self diffusion, and coupling with fluid flow. The salt not only lowers the critical freezing point, but also depresses the thickness of the diffuse layer of ions and water surrounding the soil particles, providing the mechanism of fluid transport through liquid films discussed earlier in this chapter (Yong, Sheeran and Janiga, 1973). Environmental effects of salt leaching must be considered as well.

Removal of Available Moisture

If moisture is prevented access to the frost-susceptible soil, effects of the moisture movement described previously will be minimized. Procedures available are:

1. Provide adequate positive drainage away from the road.
2. Use of geomembranes or other impervious materials to insulate the soil from the moisture source.
3. Provide wicking paths for positive moisture movement away from the susceptible soil.

Obviously most of the processes discussed involve both special considerations during design and construction as well as additional capital resources. A careful economic analysis of the benefit-cost ratio must precede any decision in working with frost-susceptible soils.

CHAPTER III

RESILIENT MODULUS TESTING

Introduction

This chapter provides a background and description of the resilient modulus test as it is used in modern practice. Previous studies on freeze-thaw effects are also presented. A brief summary on the use of results from the resilient modulus test in the design of pavements, and resilient modulus testing at the University of Wyoming is also discussed.

The Basic Resilient Modulus Test

Historical Background

Prior to the 1940's, pavement thickness design was based on empirical knowledge of the local soil conditions and results from static load tests such as the California Bearing Ratio (CBR) test or plate load testing. Pavement thickness design often was based on limiting plastic deformations as the only design criterion.

It has long been known that extensive cracking of asphalt concrete pavements results from excessive elastic deflections of the roadbed soil. Researchers and designers realized the significance of elastic behavior in the subgrade, including Professor A. Casagrande (Burmister, 1943) who wrote:

> *"Irrespective of the theoretical method of evaluation of load tests, there remains the important question as to what extent individual static load tests reflect the results of thousands of dynamic load repetitions under actual traffic. Experience and large-scale traffic tests have already indicated that various types of soils react differently, and that the results of static load tests by no means bear a simple relation to pavement behavior."*

In the late 1940's, several studies (McLeod, 1947; Phillipe 1947) used plate load tests on model pavements to determine the effect of load repetition on deformation. These tests were costly and time consuming, and a transition from static load testing in the field to cyclic triaxial tests in the laboratory was developed. Early tests by Seed and McNeill (1958) indicated a substantial difference between tangent moduli determined using normal unconfined compression tests and resilient moduli determined by repeated load testing. These results, shown in Figure III-1, indicate that soil behavior under traffic loading should only be investigated using repeated load (cyclic) tests. Other tests by Hveem (1955) also indicated a marked difference in pavement deflections between static and moving wheel loads. Further investigations with repeated load testing continued in the 60's and 70's to primarily determine the effects of mix characteristics on the fatigue life of asphalt concrete.

In the early 1980's, the New York Department of Transportation Soil Mechanics Bureau acquired a cyclic load testing system to investigate the Westway Project soils for possible liquefaction. Alaska began resilient modulus testing of asphalt pavement, base coarse, crushed aggregate base and subbase samples in 1981. Other states (Minnesota, Colorado and Oregon) implemented resilient modulus testing of various design materials, however, a standard testing and analysis procedure was not available until AASHTO Standard T 274-82 was published (Carmichael and Stuart, 1985).

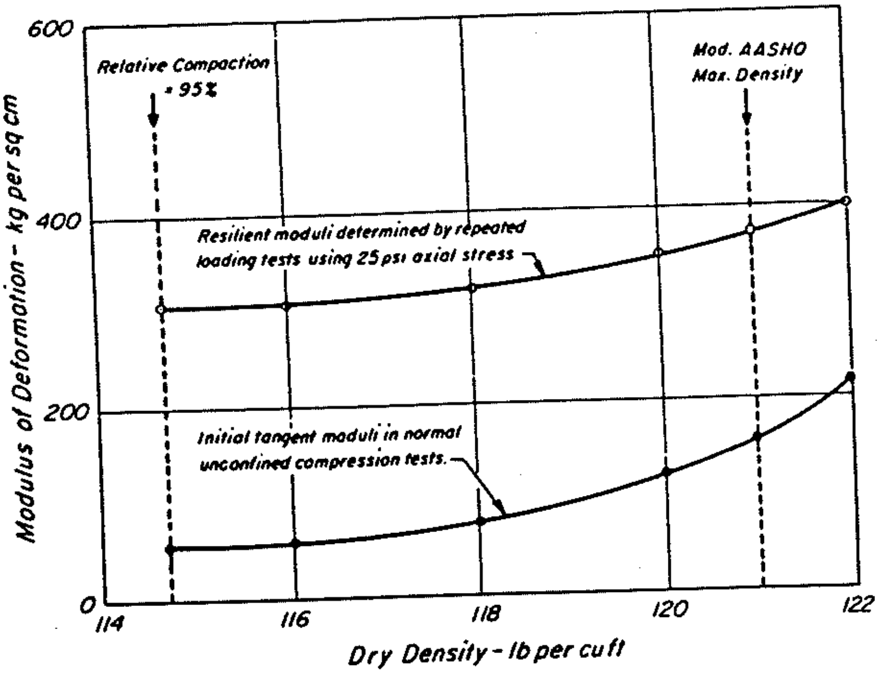


Figure III-1. Comparison of Moduli of Deformation by Normal Unconfined Compression and Repeated Loading Tests (Seed and McNeill, 1958).

Along with this publication, the "AASHTO Guide for Design of Pavement Structures" (1986) recommends the resilient modulus as "the method of choice" to characterize subgrade soils and assigns "layer coefficients" to granular base and subbase layers. Many state agencies are presently experiencing difficulty in establishing the appropriate "resilient modulus" input into the design procedure. Some of these difficulties were expressed in the Oregon Department of Transportation Workshop on Resilient Modulus Testing held at Oregon State University in Corvallis, Oregon on March 28-30, 1989.

AASHTO Standard T274-82 (1986)

This Standard covers procedures for sample preparation and testing for resilient (dynamic elastic) modulus to "be used in the available linear-elastic and non-linear elastic layered system theories to calculate the physical response of pavement structures." Procedures for sample preparation and testing of both undisturbed samples of natural and compacted subgrade and lab-prepared samples are covered. Procedures are specified for sample preparation and testing of both granular and cohesive soils. Preparation and testing of silty soils is not addressed specifically. This research utilized procedures specified for cohesive soils. Sample preparation in accordance with AASHTO 274-82 is addressed in Chapter IV of this report.

Testing cohesive and granular soils requires a modified triaxial cell as detailed in Figure III-2. The cell is similar to most standard triaxial cells except it is somewhat larger to accommodate the load and deflection measuring devices. A compressed air source is recommended to provide confining pressure, however water or a water/alcohol mixture can also be used.

The external loading source can be any device capable of providing variable cyclic loading of fixed duration and frequency. Axial deformation-measuring equipment for use on materials with maximum resilient modulus greater than 15,000 p.s.i. consists of 2 linear variable differential transformers (LVDT's) mounted directly on the specimen with clamps. Specimens with maximum resilient modulus less than 15,000 p.s.i. may either have LVDT's mounted directly onto the load piston rod outisde the test chamber, or on the specimen as required for the stiffer samples. This study utilized LVDT's mounted on the specimen. AASHTO recommends cyclic loading of 100 msec duration and 1 to 3 sec frequency. These values are generally accepted to represent transient pavement loading and provide adequate time for the specimen to rebound to equilibrium. For each stress condition, 200 cycles are applied with recovered deformations recorded on the last cycle. This study utilized a loading of 200 msec to allow for feedback control adjustments of the loading stress to become stabilized. Other studies have shown the time of loading has little consequence on the determined M_r values (Thompson, 1989). Average values for the last five cycles were used in calculating the M_r. Analysis of data to determine M_r is covered in Chapter V of this report.

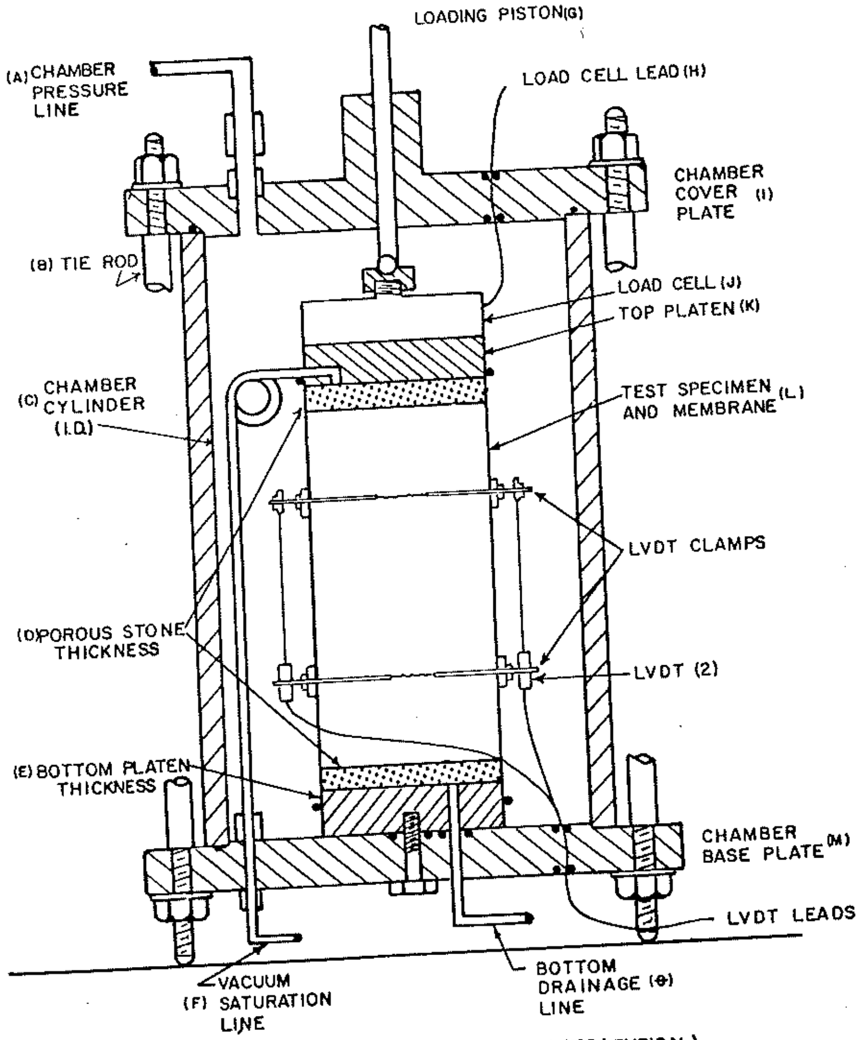


TABLE OF MEASUREMENTS (TYPICAL)

DIMENSION	A	B	C	D	E	F	G	H	I	J	K	L	M	N
METRIC, mm.	6.4	12.7	152.4	6.4	38.1	6.4	12.7	Note 1	19.1	Note 1	38.1	Note 2	25.4	6.4
ENGLISH in.	0.25	0.50	6.00	0.25	1.50	0.25	0.50		0.75		1.50		1.0	0.25

NOTE:
1. Dimensions varies with manufacturer
2. Dimensions varies with specimen size

Figure III-2. Typical Triaxial Testing Chamber (AASHTO, 1986).

AASHTO specifications for confining and deviator stress conditions for cohesive soils are given in Table III-1. The initial five stress conditions allow for sample conditioning. This conditioning is provided to eliminate the effects of residual stresses after sample preparation and provide for a steady-state hysterisis loop in the deviator stress vs. elastic deformation curve. Load conditioning also aids in minimizing the effects of initially imperfect contact between the specimen and the end platens. The conditioning cycles also induce an initial plastic strain which represents in-service conditions under long term loading.

ASTM Procedures

ASTM is presently producing a standard procedure for evaluation of M_r, but information is not available at this time.

Asphalt Institute Procedures

Detailed procedures for determination of M_r are described in The Asphalt Institute publication, Soils Manual (1988). This procedure is identical to AASHTO in all aspects of sample preparation and testing apparatus. The Asphalt Institute test procedure varies from the AASHTO test in which data collection is taken only at a deviator stress of 6 psi and confining stress of 2 psi. Conditioning sequences are identical in both procedures.

Table III-1. Stress State Sequences for AASHTO T 274.

Deviator Stress (psi)	Confining Stress (psi)
1	6
2	6
4	6
8	6
10	6
End of Conditioning Begin Data Collection	
1	6 3 0
2	6 3 0
4	6 3 0
8	6 3 0
10	6 3 0

Previous Studies of Freeze-Thaw Effects On Resilient

A comprehensive literature search revealed little information from past studies of freeze-thaw effects on fine-grained frost-susceptible soils using laboratory-prepared samples. Early studies by Broms and Yao (1964) on the shear strength of a silty clay soil after freezing and thawing used a 24" square freezing "capsule" containing compacted soil. The compacted soil was open-cell (moisture provided to the soil) conditioned, and cores of frozen material were extracted and tested after thawing. Their study revealed core samples subjected to several freeze-thaw cycles had an ultimate strength of 10% to 20% of control samples not subjected to freeze-thaw conditioning.

Studies by Bergan and Monismith (1973) investigated the effects of freeze-thaw on the M_r of fine-grained cohesive soils using closed-cell (no moisture provided to the soil) conditioning techniques on laboratory prepared samples. A study by Bergan and Fredlund (1973) characterized the effects of freeze-thaw on unsaturated clay soils, comparing M_r values during fall and spring between undisturbed samples and samples conditioned in a closed system. They determined that spring in-service conditions can be depicted after two freeze-thaw cycles of the conditioned samples. Studies by CRREL (1978) on the effects of freeze-thaw on the M_r of subgrade silty soils utilized frozen cores taken in-situ and allowed to thaw. Upon thawing, they found most of the samples to be too soft and weak to test, and had to be either partially or fully consolidated before testing. As with the other studies cited, this study determined the resilient modulus is greatly reduced by freeze-thaw activity.

A recent study by Hardcastle, Lottman and Buu (1983) recognized the degree of saturation of a subgrade soil would be very close to 100% during critical spring-thaw periods, and the strength of the soil is significantly reduced with increased saturation. They utilized closed-cell conditioning of samples constructed by combining the dry material necessary to produce the desired dry density with water sufficient to completely fill the voids of the compacted material.

Resilient Modulus Testing in Pavement Design

As discussed in Chapter I, the "Guide for Design of Pavement Structures" (AASHTO, 1986) requires that the resilient modulus to be used to characterize the material properties instead of the soil support number as used in previous design procedures (AASHTO, 1981). This discussion presents the AASHTO pavement design process and how the M_r is utilized.

AASHTO requires laboratory resilient modulus tests of roadbed materials on representative samples subjected to stress and moisture conditions simulating those of the primary moisture seasons. The design manual also suggests correlations of seasonal resilient modulus that are based on soil properties; i.e., clay content, water content, plasticity index, etc. The purpose of identifying seasonal resilient moduli is to quantify the relative damage a pavement structure is subjected to during each season of the year and determine an "effective" resilient modulus equivalent to the combined effect of all seasonal modulus values.

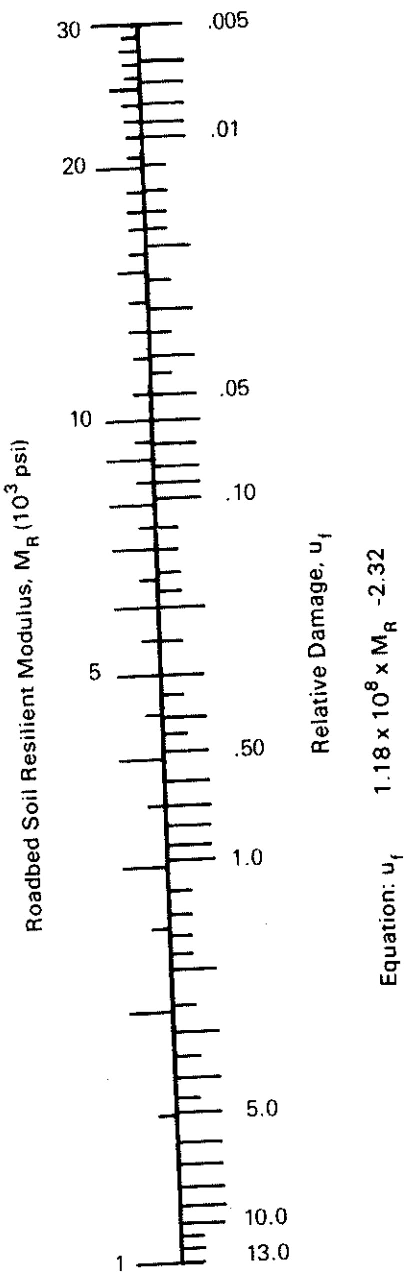
AASHTO recommends two procedures for determining seasonal resilient moduli. The first method requires a laboratory relationship between water content and resilient modulus of the roadbase material. Estimates of the in situ water content beneath the pavement then are used to provide estimates of seasonal resilient modulus.

An alternate method requires back-calculation of resilient modulus based on observed deflections of in-service pavements. This alternate method is described in Part III of the AASHTO design manual.

Roadbeds with varying moduli should be designed with small sections that have equivalent representation of strengths. AASHTO recommends a coefficient of variation within a section be no greater than 0.15.

To find the effective resilient modulus for flexible pavement section design, seasonal values must be determined and input into a chart such as to Figure III-3. Periods of months or half months may be used so long as the period is consistent throughout the year. A relative damage value (u_f) is then determined for each seasonal value of resilient modulus listed on the chart. The u_f is determined by use of the vertical nomograph also shown on Figure III-3. The values of u_f are then summed, and an effective resilient modulus is determined from the vertical nomograph correlating to the summed u_f value. This effective resilient modulus value is used in the design equation nomograph on Figure III-4 which determines a "structural number" to be used in the pavement design. Design procedures beyond determination of the structural number are similar in the 1986 manual to the previous manual procedures.

Month	Roadbed Soil Modulus, M_R (psi)	Relative Damage, u_f
Jan.	20,000	0.01
Feb.	20,000	0.01
Mar.	2,500	1.51
Apr.	4,000	0.51
May	4,000	0.51
June	7,000	0.13
July	7,000	0.13
Aug.	7,000	0.13
Sept.	7,000	0.13
Oct.	7,000	0.13
Nov.	4,000	0.51
Dec.	20,000	0.01
Summation: Σu_f =		3.72



Average: $\bar{u}_f = \dfrac{\Sigma u_f}{n} = \dfrac{3.72}{12} = 0.31$

Effective Roadbed Soil Resilient Modulus, M_R (psi) = 5,000 (corresponds to $\bar{u}_f$)

Figure III-3. Chart for Estimating Effective Roadbed Soil Resilient Modulus for Flexible Pavements Designed Using Serviceability Criteria (AASHTO Figure 2.4, 1986).

NOMOGRAPH SOLVES:

$$\log_{10}W_{18} = Z_R{*}S_o + 9.36{*}\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\dfrac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \dfrac{1094}{(SN+1)^{5.19}}} + 2.32{*}\log_{10}M_R - 8.07$$

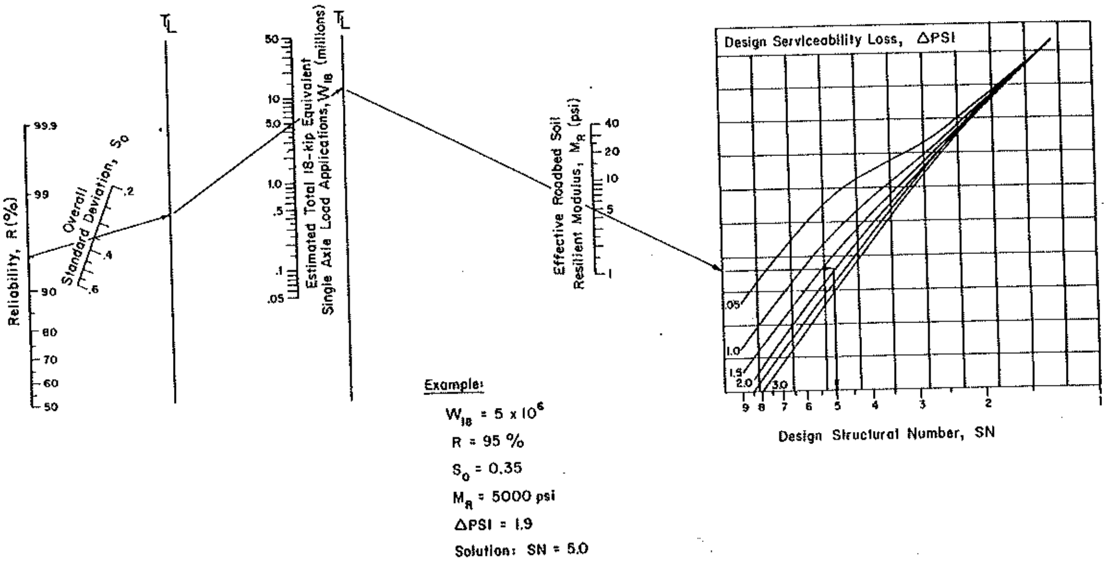


Figure III-4. Design Chart for Flexible Pavements Based on Using Mean Values for Each Input (AASHTO Figure 3.1, 1986).

Rigid pavement design determines an effective modulus of subgrade reaction by utilizing the seasonal resilient modulus of the roadbed and other factors (subbase moduli, composite k-value and k-value on rigid foundation) as inputs into the chart in Table III-2. An average relative damage factor is determined using the nomograph in Figure III-3 similar to the method for flexible pavements. The modulus of subgrade reaction is then utilized with the roadbed resilient modulus and other factors are then used in the design nomograph in Figure III-5 to determine the composite modulus of subgrade reaction (k_{∞}). Further design procedures in the 1986 manual are similar to previous manuals.

Table III-2. Example Application of Method for Estimating Effective Modulus of Subgrade Reaction (AASHTO Table 3.3).

TRIAL SUBBASE: TYPE: Granular
THICKNESS (inches) 6
LOSS OF SUPPORT, LS 1.0
DEPTH TO RIGID FOUNDATION (feet) 5
PROJECTED SLAB THICKNESS (inches) 9

(1) MONTH	(2) ROADBED MODULUS, M_R (psi)	(3) SUBBASE MODULUS, E_{SB} (psi)	(4) COMPOSITE k-VALUE (pci) (Fig. 3.3)	(5) k-VALUE (pci) ON RIGID FOUNDATION (Fig. 3.4)	(6) RELATIVE DAMAGE u_r (Fig. 3.5)
Jan.	20,000	50,000	1100	1350	0.35
Feb.	20,000	50,000	1100	1350	0.35
Mar.	2,500	15,000	160	230	0.86
April	4,000	15,000	230	300	0.78
May	4,000	15,000	230	300	0.78
June	7,000	20,000	410	540	0.60
July	7,000	20,000	410	540	0.60
Aug.	7,000	20,000	410	540	0.60
Sept.	7,000	20,000	410	540	0.60
Oct.	7,000	20,000	410	540	0.60
Nov.	4,000	15,000	230	300	0.78
Dec.	20,000	50,000	1100	1350	0.35
				Summation: Σu_r =	7.25

Average: $\bar{u}_r = \frac{\Sigma u_r}{n} = \frac{7.25}{12} = 0.60$

Effective Modulus of Subgrade Reaction, k (pci) = 540

Corrected for Loss of Support: k (pci) = 170

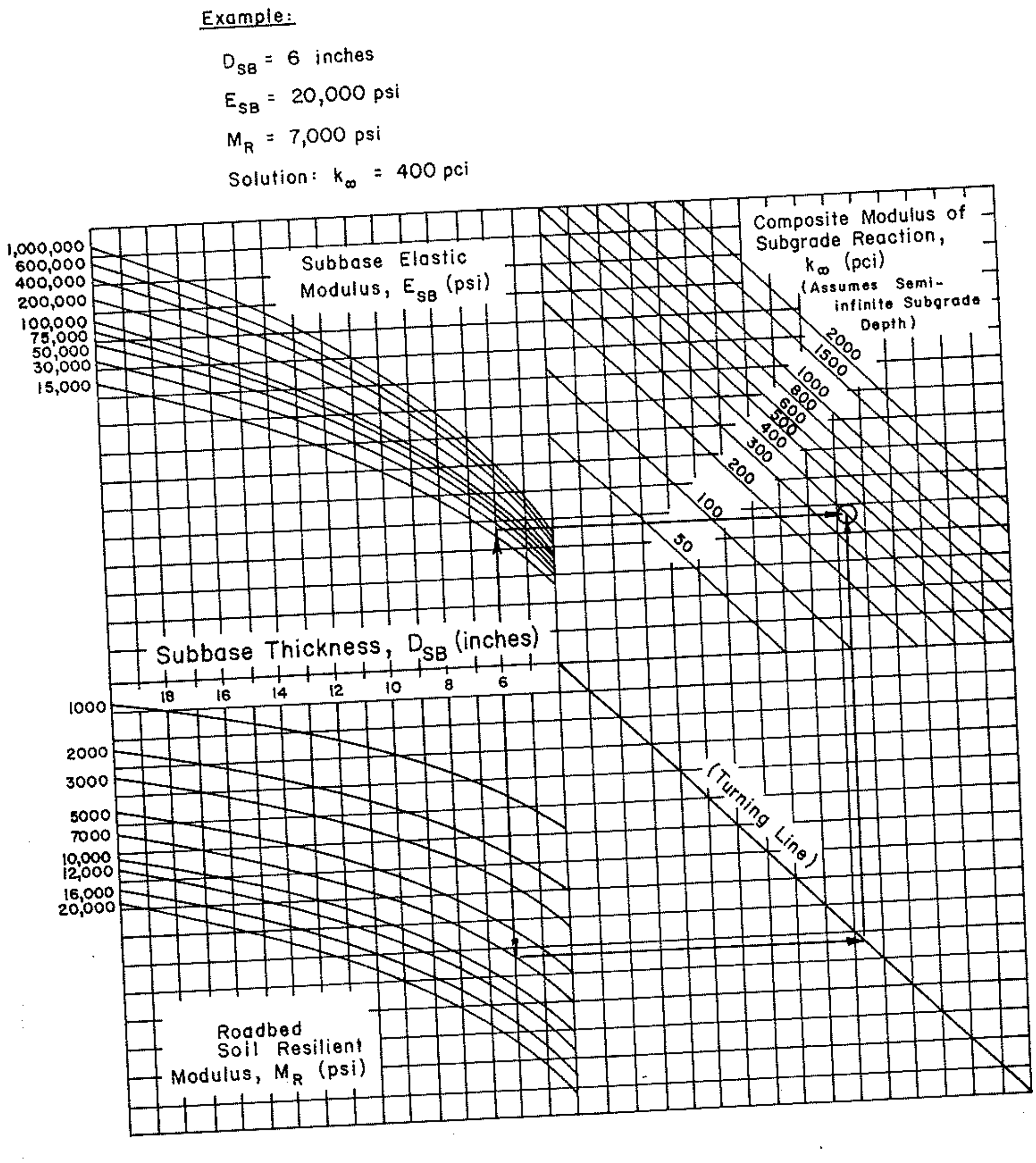


Figure III-5. Chart for Estimating Composite Modulus of Subgrade Reaction, k_∞ (AASHTO Figure 3.3, 1986).

Resilient Modulus Testing at the University of Wyoming

Initial tests of resilient modulus for this research used a system developed for an earlier study performed at the University of Wyoming. The purpose of this earlier study was to correlate the resilient modulus of typical Wyoming soils to an "R-value" or "Resistance value," which describes the relative tendency of a subgrade material to transmit lateral stresses (Turner and Farrar, 1991). This earlier study used an Instron servohydraulic closed-loop loading system, and purchased a triaxial cell and other peripheral hardware to perform resilient modulus testing.

This study tested twenty samples using the system developed for the previous study. The 55-kip Instron system proved inadequate to respond to the large deformations developed under this phase of testing, thus requiring an in-house loading system to be designed to overcome the deficiencies of the Instron system. Design and construction of the new testing and data acquisition system began in April, 1990. Equipment order delays prevented this system from becoming operational until October, 1990. The remainder of testing was performed on this new system. The results presented in subsequent chapters are based only on data obtained from this developed loading system and do not include the previous twenty samples.

The University of Wyoming system uses a 4" air piston manufactured by Bellofram Industries for application of deviator stresses. The triaxial cell was manufactured by Research Engineering Inc. and is similar to Figure III-2. A 600 pound load cell is mounted on the load piston inside the triaxial chamber. Sample deflections are measured by two LVDT's mounted on opposite sides of the specimen with rings set at 4.000" from ring center to ring center. Signals from both LVDT's are averaged before recording. Confining stresses are provided with compressed air. The confining stress and the air pressure applied to the

Bellofram cylinder are regulated by Fairchild electric-to-pneumatic pressure transducers. Data acquisition and test monitoring are accomplished with a United Electronic Industries Inc. data acquisition board and software developed by Professor Thomas V. Edgar at the University of Wyoming.

The testing system is pictured in Figure III-6 and represented schematically in Figure III-7. A computer program was developed for calibration, test monitoring and data acquisition. Test procedures are discussed in Appendix A.

Calibration of the LVDT's was performed by comparing actual ring deflections measured using a dial indicator to the signal output. The load cell was calibrated by comparing the signal output of a dead weight calibrated load cell to the signal output of the load cell. Both calibrations were checked periodically to assure consistent and accurate test results. Overall testing consistency was monitored by performing a condensed stress regime test on a rubber specimen purchased from Research Engineering Inc.

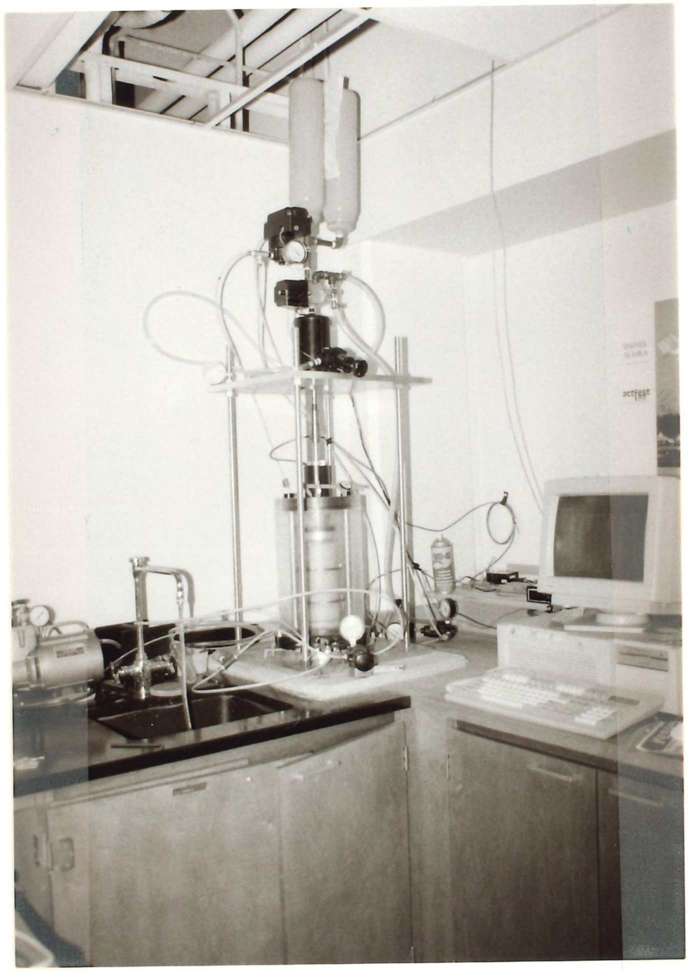


Figure III-6. Developed U.W. Resilient Modulus Testing System.

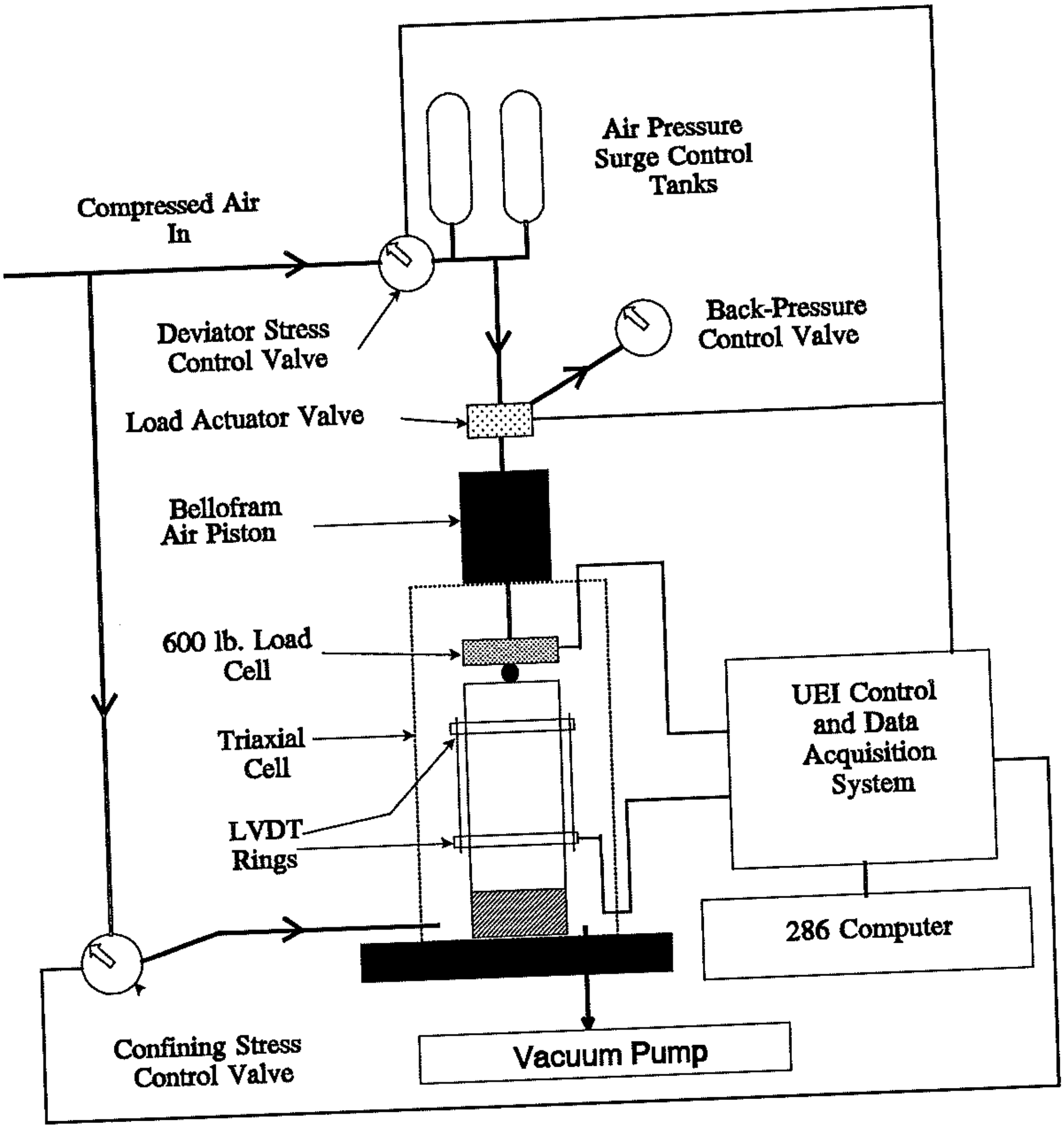


Figure III-7. Schematic of Developed U.W. Resilient Modulus Testing System.

CHAPTER IV

TEST PROCEDURES

Standard Testing Procedures

Soil Collection

Samples from various locations statewide were evaluated to select those generally considered susceptible to water content changes due to environmental effects, the clayey sands to silty clays. All samples collected were classified in accordance with AASHTO M 145.

Four soils were selected from this group. An A-4(5) soil was located within a large stockpile north of Laramie, Wyoming. An A-6(2) soil was located approximately 18" beneath the existing soil surface and 250' west of centerline close to milemarker 26 of Interstate 25. An A-2-6(1) soil was located in a construction borrow area at surface elevation, 150' west of centerline at approximately milemarker 24 of Interstate 25. An A-5 soil was not located, therefore a soil close to A-5 (A-7-6(14)) soil was prepared in the lab by blending. Testing for classification and compaction characteristics of the soils tested was performed in accordance with the methods listed in Table IV-1. Index properties of the investigated soils are listed in Table IV-2. A comparison between the AASHTO and Unified Soil Classification systems is presented in Table IV-3 for soils tested.

Soil Preparation

All soils were carefully mixed using the methods described below to provide the most uniform mixture possible. After blending,

Table IV-1. Procedures for Determination of Soil Properties.

Property	Procedure
Soil Classification	AASHTO M 145
Sieve Analysis	AASHTO T 88
Atterberg Limits	
Liquid Limit	AASHTO T 89
Plastic Limit	AASHTO T 90
Optimum Water Content	AASHTO T 99
Maximum Dry Density	AASHTO T 99
Resilient Modulus	AASHTO T 274

Table IV-2. Soil Index and Compaction Properties.

Soil Type AASHTO M 145 Class	Maximum Dry Density (pcf)	Optimum Water Content (%)	Liquid Limit (LL) (%)	Plasticity Index (PI) (%)	Percent Passing # 200 Sieve
A-2-6(1)	125	11.0	32	16	26
A-4(5)	114	14.4	27	8	80
A-6(2)	112	14.5	37	17	37
A-7-6(14)	101	22.4	41	14	88

Table IV-3. AASHTO and Unified Soil Classifications of Soils Tested. (McCarthy, 1988)

AASHTO	Unified
A-2-6(1)	SC
A-4(5)	CL
A-6(2)	SC
A-7-6 (14)	ML

soils were passed through a 4.75 mm sieve. The material retained on the 4.75 mm sieve was discarded according to AASHTO T 99. To assure consistency, water contents for all soils were achieved in bulk quantities (50 lbs. minimum) sufficient to produce all necessary samples within that category. Complete dispersion of moisture throughout the soil was assured by allowing a minimum of 24 hours between water mixing and water content determination. Water contents with deviations of ± 0.2% from targeted values were adjusted.

A comparison of oven-dried water contents and microwave-dried water contents was performed on all soils, with less than 0.1% variation noted. This comparison allowed microwave-dried water contents to be used throughout this study. A minimum sample of 100 grams of soil was used for all water content determinations. Water contents used in preparing samples are listed in Table IV-4.

A-4(5) Soil After sieving, the minus 4.75 mm material was carefully blended using a Riffler splitter. The soil was then mixed to targeted water contents listed in Table IV-4. A +1% of optimum water content was selected for study initially, however the reduction of soil cohesion at this water content caused the specimens to fracture severely during the extrusion process.

A-6(2) Soil As stated above, the A-6(2) soil was located beneath approximately 18 inches of topsoil, requiring hand excavation of topsoil within an 8' X 8' area to expose the desired soil. To achieve maximum possible field blending of material, ten 5-gallon buckets were placed around the perimeter of the excavation, and soil was collected by placing one small shovelful in each bucket successively until all buckets were full. Lab blending was achieved by passing all minus 4.75 mm material through a Riffler splitter. The soil was

Table IV-4. Water Contents of Samples Used in Testing.

Soil Classification	Prepared Water Contents (Deviation from optimum water content, %)
A-2-6(1)	Optimum
A-4(5)	-1.0 Optimum +0.8
A-6(2)	-1.0 Optimum +0.9
A-7-6(14)	-1.4 +1.1

then mixed to targeted water contents listed in Table IV-4. As with the A-4(5) soil, a +1% of optimum water content was selected for initial the investigation, however reduced cohesive strength at this water content prevented sample extrusion without fracturing.

A-2-6(1) Soil To achieve complete dispersion of clays through the sands, the A-2-6(1) soil was blended using a slurry technique developed at U.W. Soil was placed in a water bath for a minimum of 12 hours, then carefully sieved through a 4.75 mm sieve during transfer from the bath to a 35 gallon plastic container. This process continued until all the soil was in the common container. The soil was then mixed with a plunger to assure complete blending. Soil was then transferred into drying pans and placed into a controlled 120 degree F. environment with two circulating fans. After drying, the soil was passed again through a 4.75 mm sieve, placed in a wheel barrow and mixed to a water content of approximately 7%.

Samples of this mixture were used for moisture-density determination. The remaining soil was placed in 5 gallon buckets and sealed to maintain moisture. After the moisture-density relationship was determined, soil was mixed to the optimum water content of 11% using the method described above. The soil was then stored in closed containers until the compacted samples were prepared.

Careful attention was taken to prevent loss of fines by washing all utensils, hands and drying trays in a large bucket of clean water. The water was allowed to sit until all fines had settled, then the clean water was decanted off. The remaining fines were air-dried and blended into the soil during the wheel barrow mixing process.

A-7-6(14) Soil A mixture of 33% silts (A-4(5)) and 67% clay (kaolonite) by dry weight was used to provide a soil with a high liquid limit and low plasticity index. To assure complete distribution of silts within the clays, blending was accomplished using the slurry method described for the A-2-6(1) soil. To assure that clay clods were completely dissolved, the slurry was passed through a 2.00 mm sieve as it was transferred from the wash buckets into the 35 gallon plastic container.

Mixing of the highly plastic A-7-6(14) soil was achieved by using a layered hydration procedure. Soil was placed in thin (1/2") lifts while moisture was added with a misting spray bottle. The layered soil was allowed to hydrate for a minimum of 24 hours to assure moisture distribution before hand mixing and passing through a 2.00 mm sieve. This process was repeated until the desired water contents were achieved.

Sample Preparation

Two soils representing AASHTO M 145 soil classifications A-4(5) and A-6(2) were used for extensive testing over the range of water contents as listed in Table IV-4. A condensed testing regime at optimum water content was performed on the A-2-6(1) soil. The A-7-6(14) soil was investigated at -1.4% and +1.1% of optimum.

Sample Compaction

A standard specimen of 4" diameter and 8" height was constructed using an electro-hydraulic kneading compactor, Model CN-425A, manufactured by Soiltest Incorporated of Lake Bluff, Illinois (Figure IV-1). Footer pressures and number of blows necessary to achieve desired densities were found by trial and error. This study determined that more consistent M_r results were achieved with samples prepared at dry densities slightly higher than maximum.

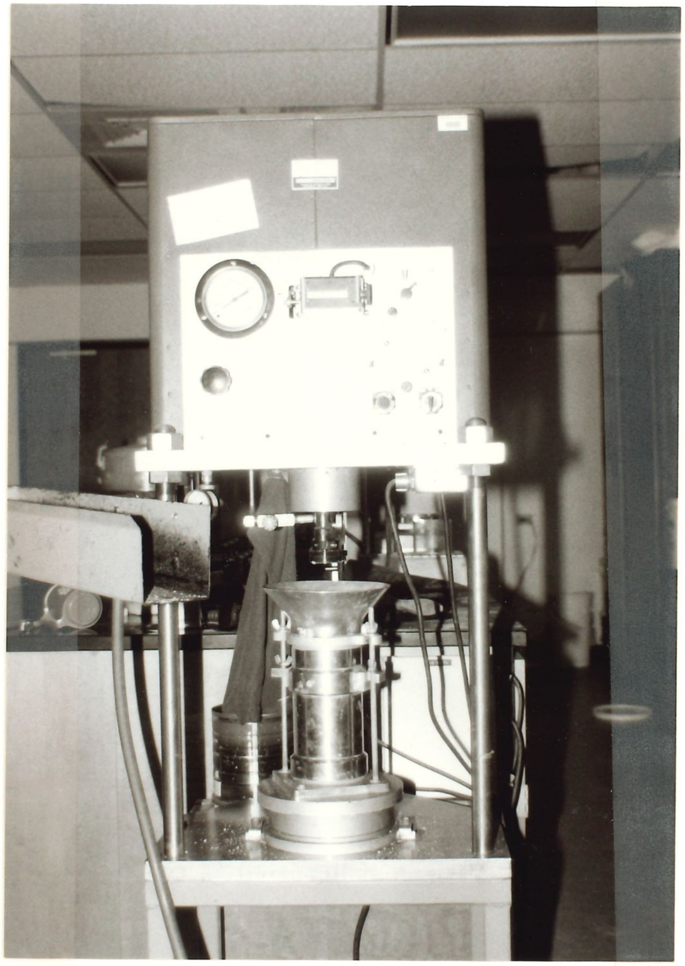


Figure IV-1. Soiltest Kneading Compactor.

Table IV-5 lists the kneading compaction settings used in sample construction. A detailed description on sample preparation is provided in Appendix A.

Sample Conditioning

The present study initially utilized a closed-cell conditioning of samples. Twenty samples were constructed, carefully wrapped in plastic and placed in two plastic bags sealed tightly against the sample with masking tape. The samples were subjected to freezing conditions in an environmental chamber at -10° C. then allowed to thaw in a 100% moisture room.

Table IV-5. Sample Preparation Data.

Soil Type (AASHTO)	Nominal Dry Density (pcf)	Footer Pressure (psi)	Number of Strokes
A-2-6(1)	126	160	250
A-4(5)	117	150	225
A-6(2)	114	160	250
A-7-6(14)	101	160	250

Water content determinations after testing indicated moisture movement towards the outer edges of the sample, with as much as 3% variation between the center of the sample and the edges. This lateral moisture movement does not depict actual moisture movement described in Chapter II of this report, so an open system of conditioning was developed imitate actual field conditions of subgrade soils. Freezing occurs from the top down in winter, and thaws from both the top and bottom surfaces. Moisture is commonly imbibed from the bottom during freezing, and is available from the bottom during thawing. These processes are discussed in Chapter 2. A laboratory technique used to simulate these processes during sample freezing is referred to as an "open cell" method. This method provides water to the base of the samples during freezing, which allows imbibition. The open cell chamber used in this study is shown in Figure IV-2. Four samples on 1/2" porous stones were placed in an 11" x 15" x 2" Plexiglass tray. Water was then placed in the tray to a depth of approximately 3/8". A common heat tape was placed around the stones to prevent the water from freezing.

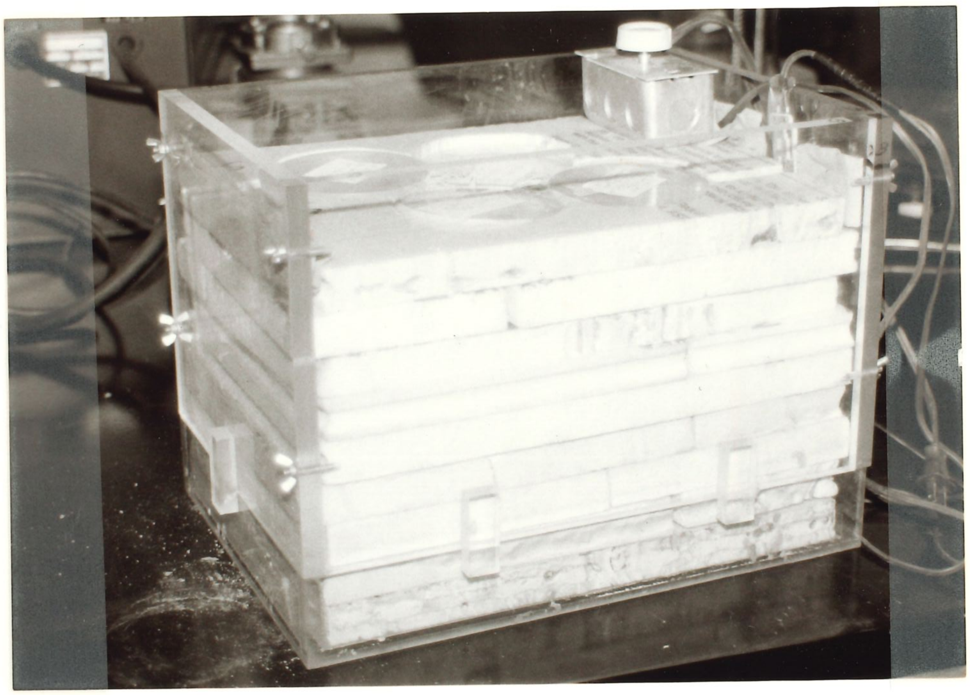


Figure IV-2. Freeze-Thaw Chamber for Open-Cell Conditioning.

Placement of heat tape around the porous stones is shown in Figure IV-3. It was found by trial and error that the heat tape must be supplied by a rheostat at 50% power to prevent excessive heat from being transferred to the samples and thus hindering freezing at the lower zone.

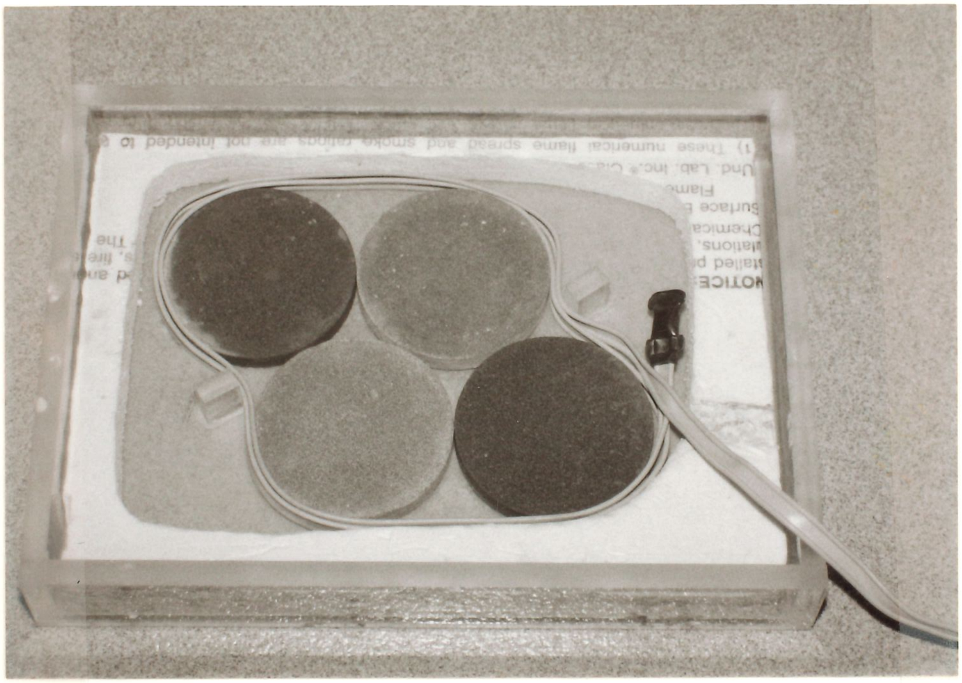


Figure IV-3. View of Placement of Heat Tape Around Porous Stones in Conditioning Chamber.

Closed-cell styrofoam insulation was placed in layers around the samples to assure freezing from the top only and not from the sides. Plexiglass sides were placed around the insulation, and the chamber was placed in a freezer at -10° Celsius for a period of 24 hours. The chamber was then removed from the freezer, covered with plastic and placed on a rack to allow thawing from the bottom for a period of 24 hours. If cycling was desired, water level was checked prior to re-freezing.

Verification of the system was performed to ensure freezing occurred from the top down by removing several samples after 12 and 18 hours. The 12 hour sample was frozen to a depth of 5", while the 18 hour sample was frozen to a depth slightly above the porous stone. After 24 hours, samples are completely frozen to the porous stone. Water remained fluid in the tray throughout the freezing cycle.

Samples from each soil classification and water content were also conditioned for moisture imbibition with no freeze-thaw cycling by placing them on a 1/2" porous stone in 3/8" of water for 24 hours. The samples were then removed from the water and allowed to drain through the porous stone for 24 hours before testing. Samples were continuously kept within an environment of 75% minimum relative humidity during this type of conditioning in accordance with AASHTO T 274.

A more detailed study of sample imbibition was performed on the A-4(5) soil at optimum water content and the A-6(2) soil at -1% of optimum water content. Samples were allowed to imbibe continuously for 24, 48 and 96 hours.

To assure continuous moisture availability to the samples during extended periods, a moisture imbibition tray was developed to provide a constant level of water to the porous stones (Figure IV-4). An 11" x 15" x 2" Plexiglas tray was used for the base. Inlet and outlet ports for water were placed at 3/8" above the bottom of the tray. A constant supply of water to the inlet was provided from a faucet, while the overflow from the outlet was drained into a sink. A Plexiglas cover was placed over the tray to maintain humidity.

Sample Testing

Procedures used for testing of samples in this study were performed according to AASHTO T 274 with some modifications. The AASHTO T 274 procedure was discussed in Chapter III, and Table III-1 outlines the standard stress sequence. The stress sequence used in this study is shown in Table IV-6.

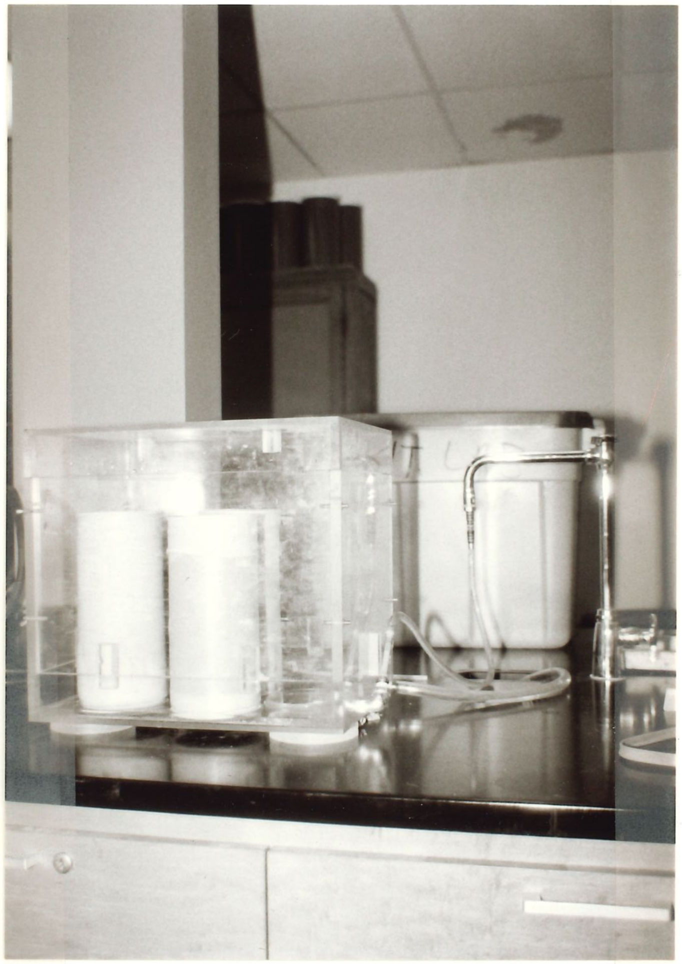


Figure IV-4. Moisture Imbibition Tray.

An extra cycle of 6 psi deviator stress and 2 psi confining stress was performed after the conditioning cycling to perform the M_r testing method outlined by The Asphalt Institute (1988). A stress condition of 20 psi deviator stress and 15 psi confining stress was also added at the end of the standard ASSHTO test to simulate overload conditions. Two more cycles of 6 psi deviator stress and 2 psi confining stress were added immediately prior to and after the overload condition to identify changes in M_r due to overloading.

Testing equipment developed at the University of Wyoming was described in Chapter III.

During testing, a minimum contact pressure of 0.1 psi to 0.2 psi was maintained on the load ram to assure contact between the load cell and the sample. If contact was lost, overloading could occur, resulting in damage to the sample. Immediately following each test, water contents was determined at the sample mid-section.

Table IV-6. Stress State Sequences Used in Testing.

Deviator Stress (psi)	Deviator Stress (psi)
1	6
2	6
4	6
8	6
10	6
End of Conditioning Begin Data Collection	
6	2
1	6 3 0
2	6 3 0
4	6 3 0

Deviator Stress (psi)	Deviator Stress (psi)
8	6 3 0
10	6 3 0
6	2
20	15
6	2

CHAPTER V

TEST RESULTS

Introduction

A total of 77 samples were evaluated for M_r throughout a range of soil types, water contents and conditioning as described in Chapter IV. Data output from each sample is listed in Appendix B.

Samples were investigated for reduction of M_r as a function of freeze-thaw cycling, imbibition with no freeze-thaw and overloading. A comparison of values obtained using AASHTO T 274 and the Asphalt Institute M_r test is also presented.

Calculation of Resilient Modulus

The AASHTO T 274 test does not specifically identify a method of determining a single M_r value from the 15 stress states requiring data collection. This situation was addressed in the Workshop on Resilient Modulus Testing in Corvallis, Oregon by speakers such as Baladi (1989), Jackson (1989) and others who were concerned about defining a single value to be used in design of pavement structures.

Researchers have previously investigated typical soils to determine a single M_r value to represent the range specified by AASHTO. Elliot and Thornton (1988) identified one test at 8 psi deviator stress and 3 psi confining stress as a representative value for cohesive Arkansas subgrade soils. Thompson and Robnett (1976) concluded that the M_r of Illinois soils could be reasonably determined by testing at a deviator stress of 6 psi.

This study utilized an average M_r determined from the stress states listed in Table V-1. The deviator stresses of 1 psi and 2 psi within the AASHTO test were not used in the average due to frequent sample deflections lower than the resolution of the LVDTs. This observation is consistent with agencies such as the Florida Department of Transportation (Ho, 1989) and the New York Department of Transportation (Seim, 1989).

Table V-1. Stress State Sequences Used in Determining Average M_r Values.

Deviator Stress (psi)	Confining Stress (psi)
6	2
4	6 3 0
8	6 3 0
10	6 3 0
6	2

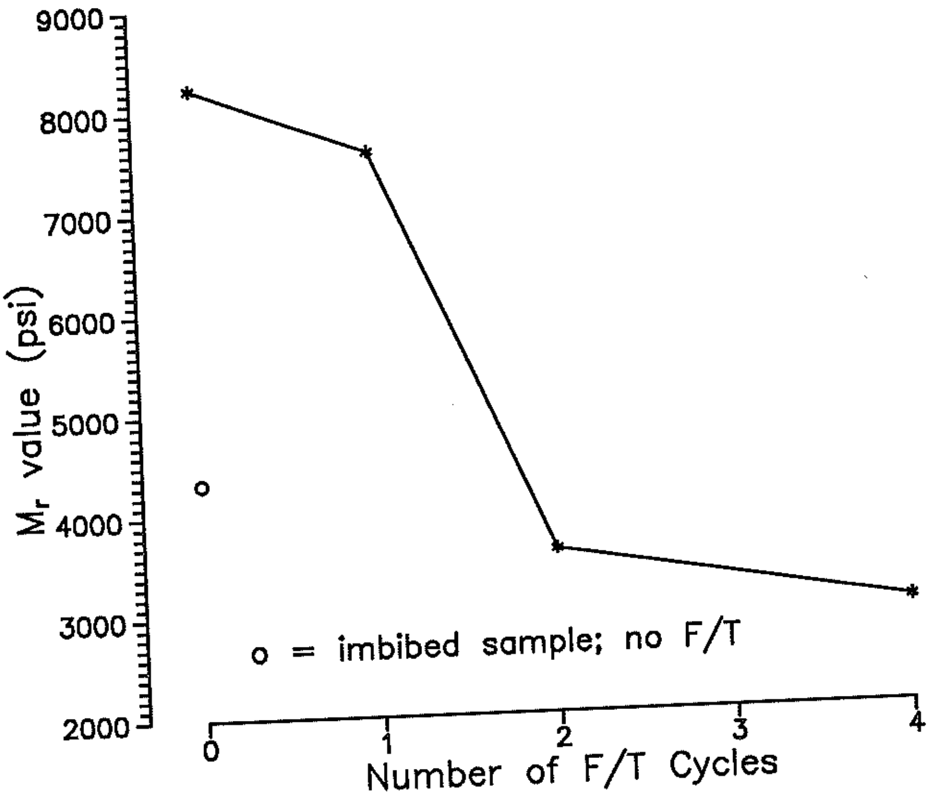
Discussion of Results

Effects of Freeze-Thaw Cycling

All soils investigated indicated significant M_r reductions with freeze-thaw cycling. The first freeze-thaw cycle reduced the M_r as much as 80% for the A-6(2) soil. For the soils investigated to 8 freeze-thaw cycles, little reduction of M_r was observed after the fourth cycle. Water contents taken at the sample mid-sections after testing revealed significant increases with freeze-thaw cycling. The highly saturated samples drained moisture through the lower platen during testing, making a detailed analysis of moisture imbibition with freeze-thaw cycling meaningless. A more specific discussion of the effects of freeze-thaw on soils investigated follows.

A-2-6(1) Soil The A-2-6(1) soil was investigated at optimum water content (11%) with 0, 1, 2 and 4 freeze-thaw conditioning cycles. An imbibed sample was also tested. Results of the tests are shown in Figure V-1. The effects of freeze-thaw appear to be insignificant beyond the second cycle. The imbibed sample showed a significant M_r reduction (50%) from the non-imbibed sample, and is approximately representative of the sample after 2 freeze-thaws. The 1 freeze-thaw sample appears to be higher than expected when compared to the M_r of imbibition only. This could be due to moisture variations in the sample.

A-4(5) Soil The A-4(5) soil was the first soil type investigated. Thirty-six samples were initially prepared over the range of water contents listed in Table IV-3. Samples were conditioned and tested at 0, 1, 2, 4, and 8 freeze-thaw cycles for each water content listed. Samples for imbibition only were also conditioned and tested.



Non-Imbibed	Imbibed	1 F/T	2 F/T	4 F/T
8,236	4,332	7,589	3,606	3,019

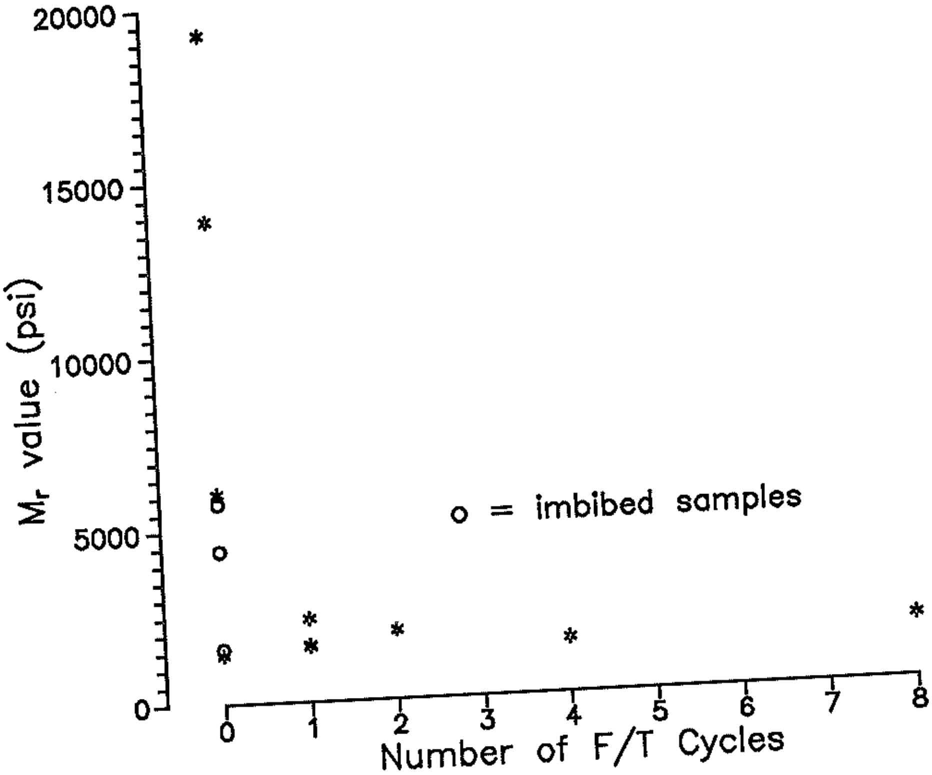
Figure V-1. Average M_r Values (psi) for A-2-6(1) Soil. w = 11% (optimum).

Initial test results of the A-4(5) samples produced inconsistent results. Replication of samples and tests was necessary to verify results. Using a trial and error procedure, minor changes in the hardware, software and sample construction were made to produce more consistent test results. Reconstruction, conditioning and testing of 4 additional samples were performed at optimum water content to identify trends with the revised procedures.

Test results for -1% of optimum water content of the initial samples are shown in Figure V-2. Figure V-3 and V-4 show results for the optimum and +0.8% initial samples respectively. Average values of all initial samples tested for each conditioning phase and water content are shown in Figure V-5. The retest samples at optimum water content are shown in Figure V-6.

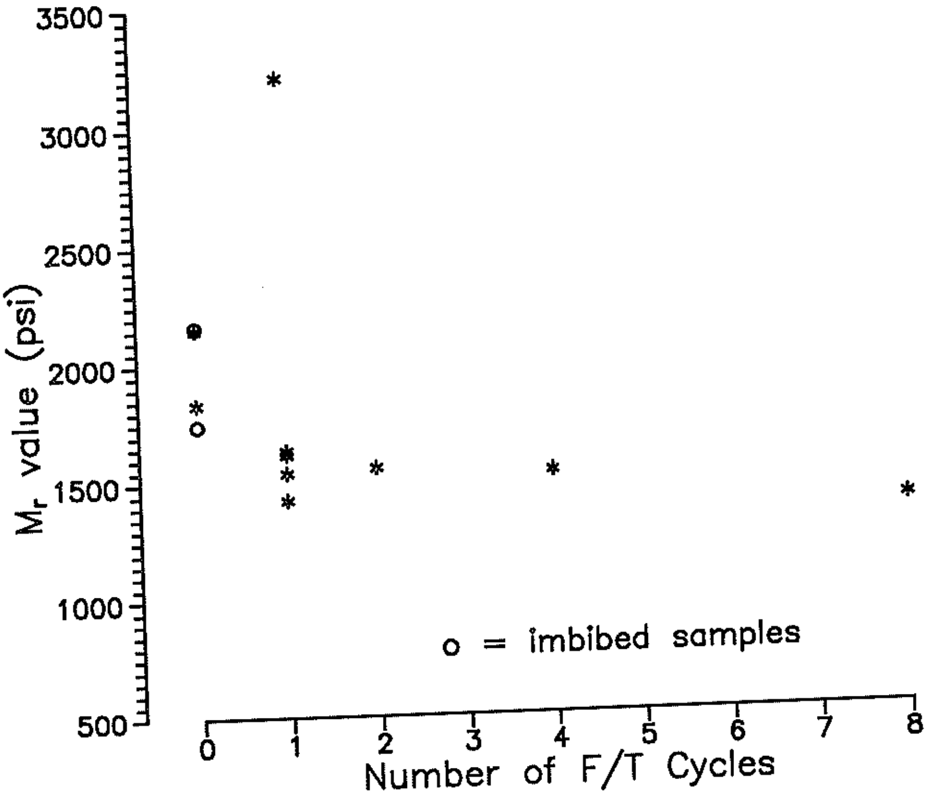
Although variations of M_r were observed, specific trends are noticeable. As with the A-2-6(1) soil, significant reduction of M_r is apparent after 1 conditioning cycle of either freeze-thaw or imbibition. The -1% and optimum samples indicate that most of the reductions of M_r occur by the second cycle, with little reduction occurring between the second and eighth cycle. Wide variations of data occur with the +0.8% samples, probably due to the inconsistencies addressed earlier.

Samples tested at 8 cycles of freeze-thaw were difficult to test due to the sample softness and large plastic deformations occurring during testing. The 8 F/T sample constructed at +0.8% of optimum (15.2%) failed during the test conditioning sequence with plastic deformation beyond the range of the LVDTs.



Non-Imb.	Imbibed	1 F/T	2 F/T	4 F/T	8 F/T
13,894 19,261 6,079	5,787 4,416 1,587	2,408 1,639 1,604	1,993	1,562	1,800

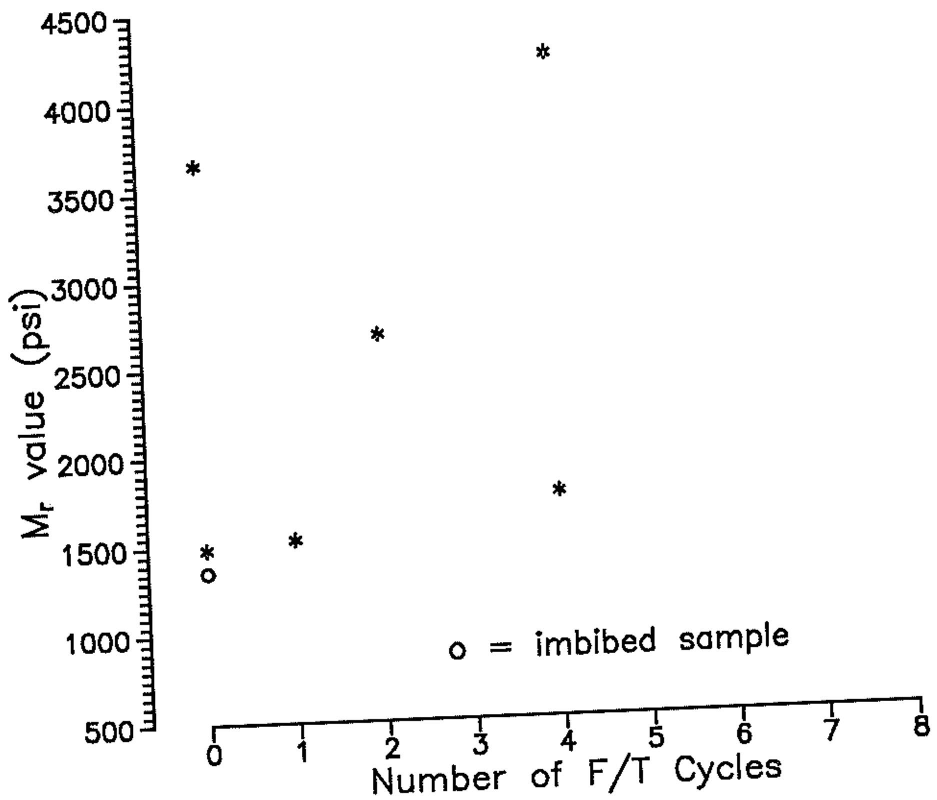
Figure V-2. Average M_r Values (psi) for Initial A-4(5) Soil. (w = 13.4%; -1% of optimum).



Non-Imb.	Imbibed	1 F/T	2 F/T	4 F/T	8 F/T
1,834 2,152 12,055*	1,743 2,161	1,635 1,617 1,539 1,425 3,211	1,556	1,529	1,382

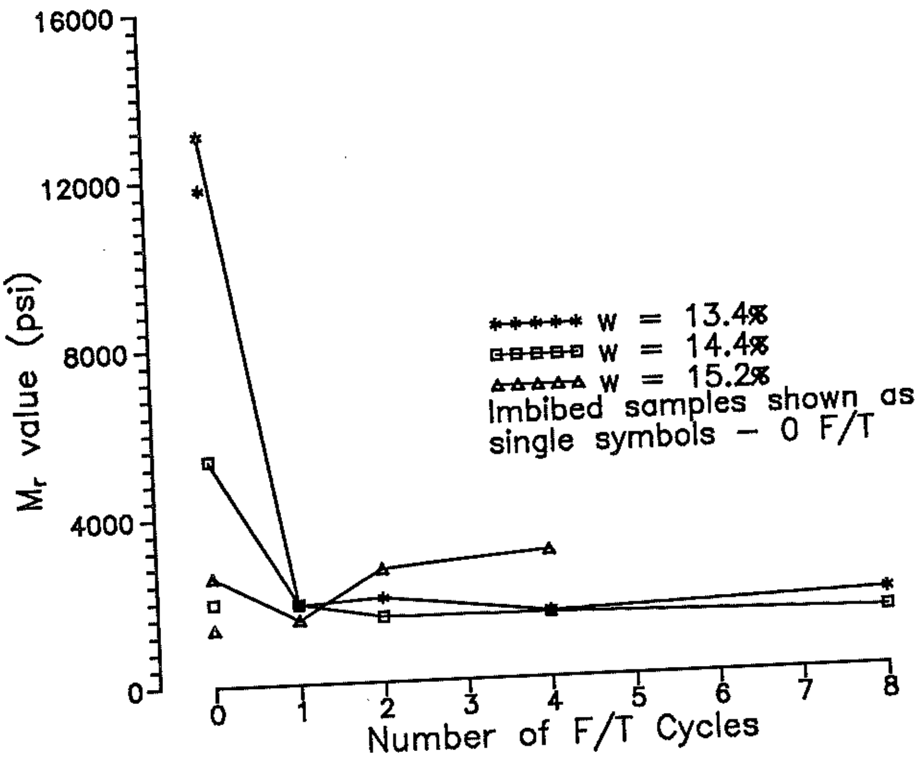
(* - Value not shown)

Figure V-3. Average M_r Values (psi) for Initial A-4(5) Soil. (w = 14.4%; optimum).



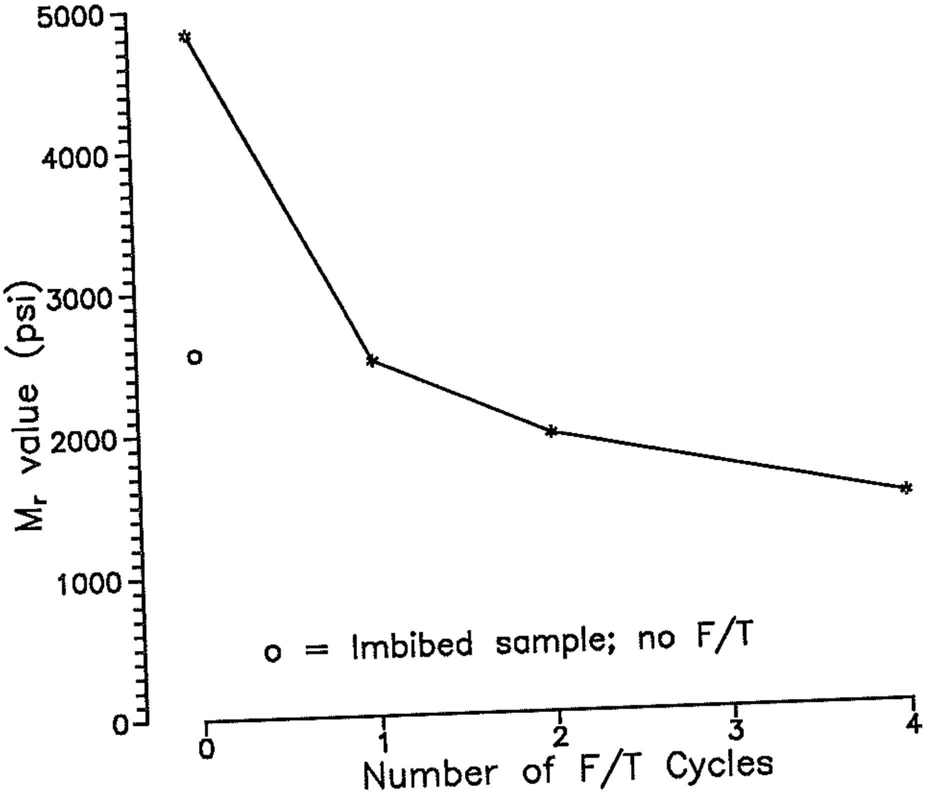
Non-Imb.	Imbibed	1 F/T	2 F/T	4 F/T	8 F/T
3,660 1,486	1,356	1,531	2,680	4,234 1,760	Failed

Figure V-4. Average M_r Values (psi) for Initial A-4(5) Soil. (w = 15.2%; +0.8% of optimum).



w	0 F/T	Imbibed	1 F/T	2 F/T	4 F/T	8 F/T
13.4%	13,078	11,790	1,884	1,993	1,562	1,800
14.4%	5,347	1,952	1,885	1,556	1,529	1,382
15.2%	2,573	1,356	1,531	2,680	2,997	Failed

Figure V-5. Averaged M_r Values (psi) of All Initial Samples Tested in Each Phase of Conditioning for A-4(5) Soil.



Non-Imbibed	Imbibed	1 F/T	2 F/T	4 F/T
4,830	2,567	2,496	1,954	1,467

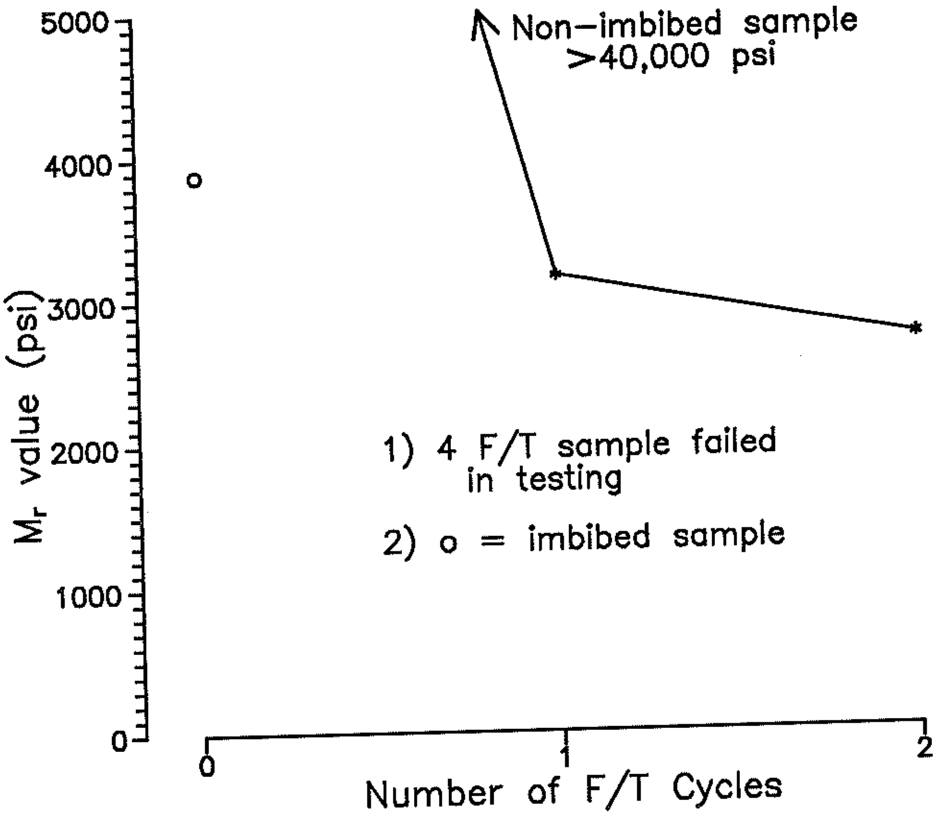
Figure V-6. Average M_r Values (psi) for Retest A-4(5) Soil. (w = 14.4%; optimum).

The A-4(5) retest samples at optimum water content show a consistent trend of decreasing M_r with conditioning cycles. As observed earlier, most reduction of M_r occurs after the first cycle of either freeze-thaw or imbibition conditioning, and little reduction of M_r occurring after the second cycle.

A-7-6(14) Soil This soil was investigated at water contents of -1.4% (21%) and +1.1% (23.5%) of optimum. The conditioning matrix was presented in Table IV-3. The results are shown in Figures V-7 and V-8.

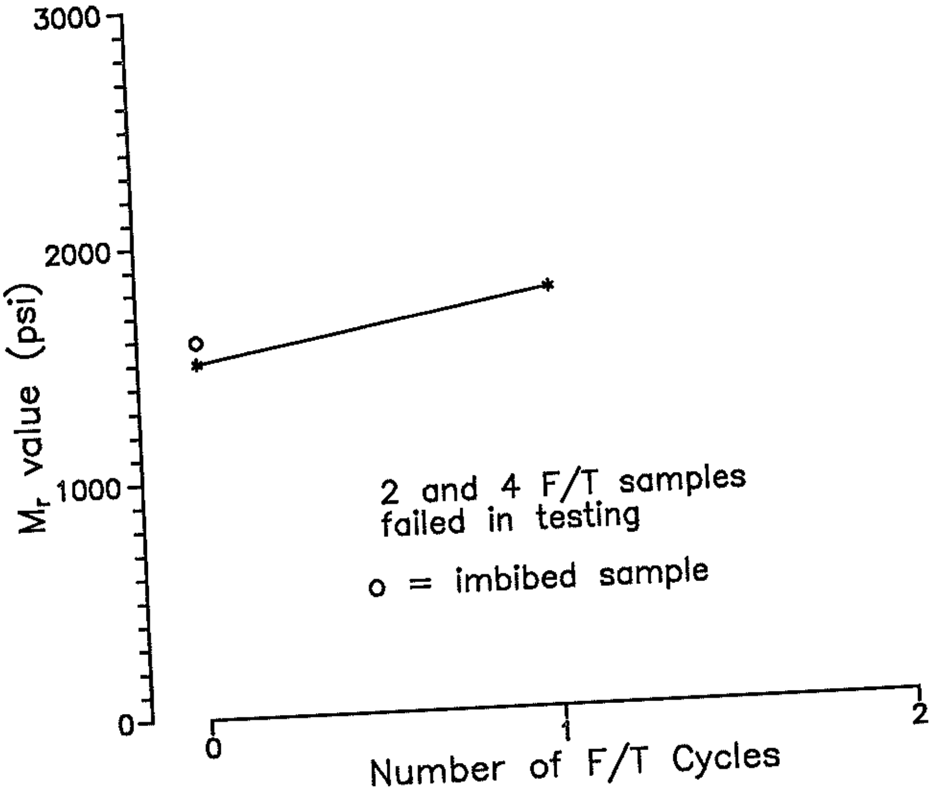
The -1.4% sample tested without any freeze-thaw or imbibition conditioning was too stiff to have deflections measured by the LVDTs, indicating an M_r greater than 40,000 psi. The conditioned samples were much softer, however little reduction of M_r occurred after the first cycle of freeze-thaw or imbibition. This is probably due to high capillary stresses causing imbibition. Small changes in water content occurring after 1 conditioning cycle. Large plastic deformations were observed with all of the conditioned samples during both the load conditioning phase and testing phase of the test. These deformations possibly lead to erroneous results in the calculation of M_r due to the reduced distance between the initial placement of the LVDT rings. To keep the LVDTs within the measuring range, the test was stopped after load conditioning and the stems of the LVDTs repositioned (screwed into the top ring) to allow for further deformations. The sample after 4 freeze-thaw cycles deformed beyond the limit of the loading ram from the load cylinder, ending the test.

The +1.1% samples exhibited the same behavior as observed with the -1.4% samples during testing, however the plastic deformations observed were much more extensive.



Non-Imbibed	Imbibed	1 F/T	2 F/T	4 F/T
Out of Range	3,880	3,159	2,712	Failed

Figure V-7. Average M_r Values (psi) for A-7-6(14) Soil. (w = 21%; -1.4% of optimum).



Non-Imbibed	Imbibed	1 F/T	2 F/T	4 F/T
1,500	1,591	1,772	Failed	Failed

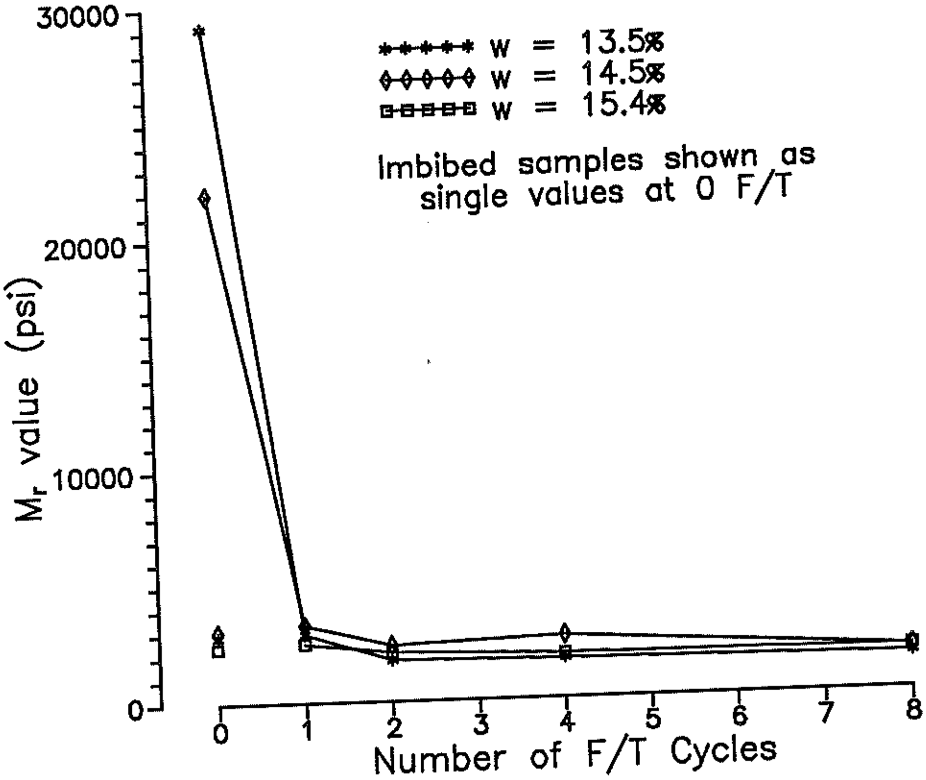
Figure V-8. Average M_r Values (psi) for A-7-6 Soil.
(w = 23.5%; +1.1% of optimum).

more extensive. The data in Figure V-8 indicate an increase M_r with conditioning, which again is probably due to erroneous calculations caused by the reduction of the gage length between the LVDT rings. The sample conditioned to 2 freeze-thaw cycles deformed beyond the range of the loading ram from the load cylinder during the 8 deviator stress sequence. The sample conditioned to 4 freeze-thaw cycles deformed beyond the range of the loading ram from the load cylinder during the conditioning sequence.

A-6(2) Soil The A-6(2) soil was investigated with water contents of -1% (13.5%), optimum (14.5%) and +0.9% (15.4%) of optimum. Conditioning of the A-6(2) soils consisted of 0, 1, 2, 4 and 8 freeze-thaw cycles and imbibition only at each water content. Results of all A-6(2) tests are shown in Figure V-9. Figure V-10 shows M_r values < 4,000 psi.

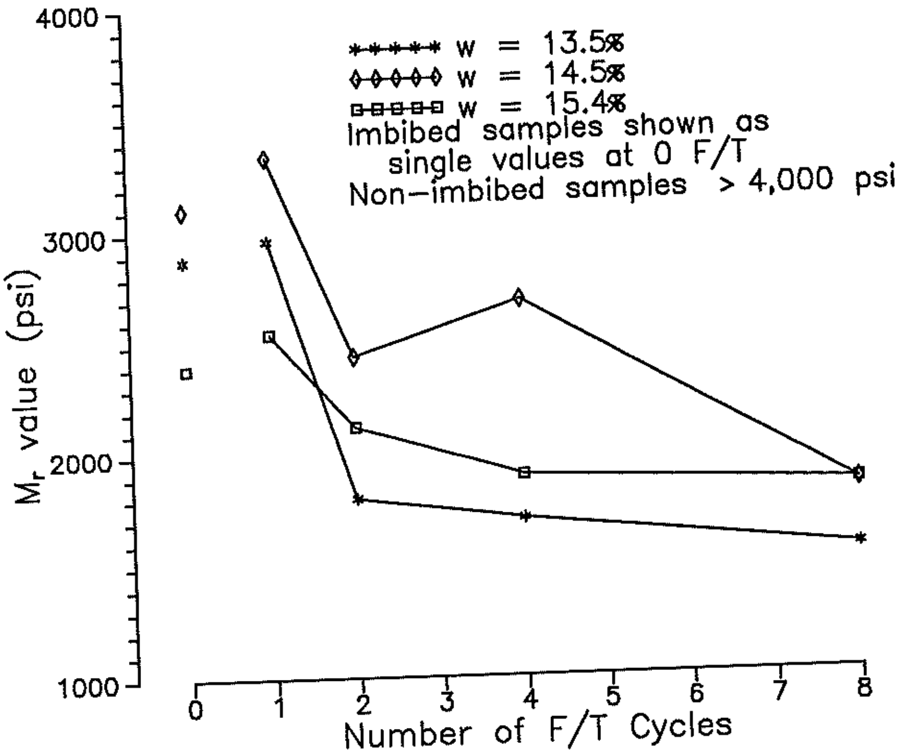
The non-imbibed A-6(2) samples were very stiff, resulting in M_r values in the range between 20,000 and 30,000 psi. The +0.9% non-imbibed sample failed during testing due to loss of contact between the loading ram and the specimen, resulting in overloading and severe plastic deformation.

Significant reduction of M_r resulted from the first cycle of either freeze-thaw or imbibition. Little reduction of M_r occurred after the second freeze-thaw cycle of conditioning. The largest reduction of M_r occurred with the -1% samples, probably due to loss of the cohesive bonding between soil particles that is apparent with the more cohesive soils during compaction. A cohesive soil compacted dry of optimum will compact in a flocculated state while soil compacted wet of optimum will generally have a dispersed structure (Monismith, 1989). In general, flocculated soil structures exhibit higher permeabilities and lower compressibility characteristics than dispersed structures (Lambe and Whitman, 1969).



w	Non-imb	Imb.	1 F/T	2 F/T	4 F/T	8 F/T
13.5%	29,190	2,879	2,965	1,799	1,700	1,549
14.5%	21,972	3,103	3,334	2,441	2,685	1,835
15.4%	Failed	2,393	2,547	2,124	1,895	1,840

Figure V-9.Average M_r Values (psi) for A-6(2) Soil.



w	Imb.	1 F/T	2 F/T	4 F/T	8 F/T
13.5%	2,879	2,965	1,799	1,700	1,549
14.5%	3,103	3,334	2,441	2,685	1,835
15.4%	2,393	2,547	2,124	1,895	1,840

Figure V-10. Average M_r Values (psi) for A-6(2) Soil ($M_r < 4,000$ psi).

In a flocculated structure, the effects of freezing tends to reduce the effectiveness of the edge to face bonds.

Comparison Between AASHTO T274 and the Asphalt Institute M_r Test

As discussed in Chapter IV, the test regime used in this study incorporated both the AASHTO T 274 test and the M_r test used by the Asphalt Institute. The purpose of this was to compare results between the lengthy AASHTO T 274 test utilizing 15 stress states for data collection and the Asphalt Institute M_r test which utilizes 1 stress state value.

A comparison of values obtained from 51 samples in the range of M_r up to 4,000 psi is shown in Figure V-11. A comparison of 59 samples with M_r values to 20,000 psi is shown in Figure V-12. Both graphs show a definite correlation between the two tests. A linear best fit analysis was performed on both data. The samples of $M_r < 4{,}000$ psi correlates with a slope of 1.01 and an Y axis intercept of 220. The samples of $M_r < 20{,}000$ correlates with a slope of 1.05 and also has Y axis intercept of 220. The data used in this comparison is from all of the samples that tested without failing. As discussed previous, permanent plastic deformations were observed in many of the samples during the AASHTO T 274 test, which quite possibly resulted in higher M_r values due to a reduced distance between LVDT rings.

These correlations are significant considering the following:

1. All samples which tested within the accuracy range of the system were included in the comparison.

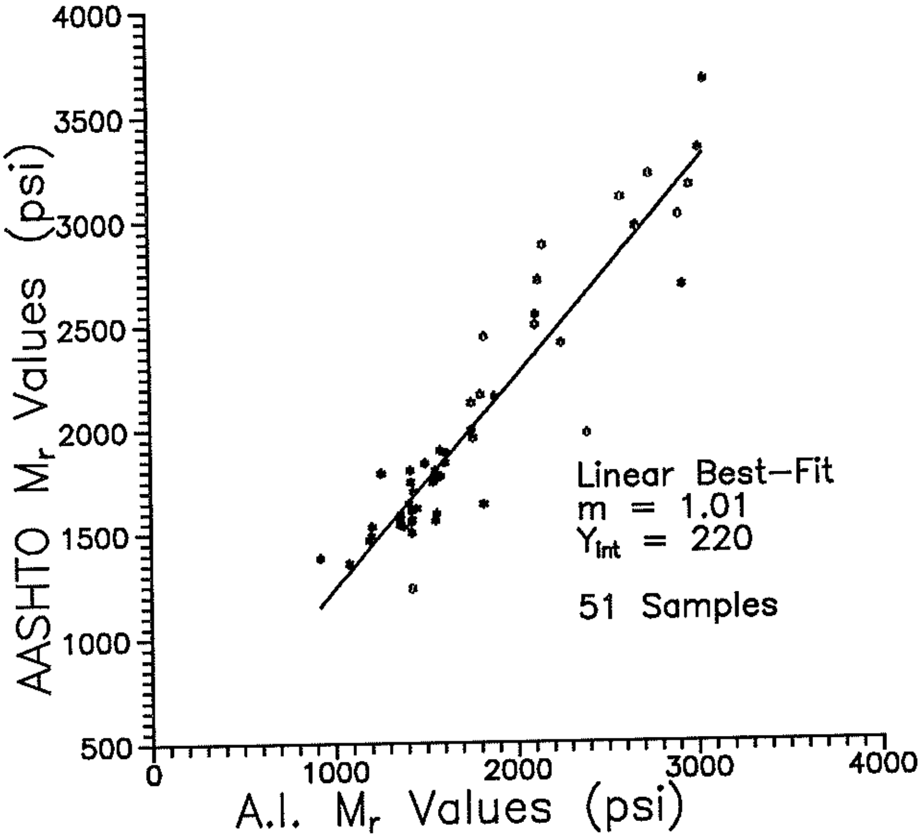


Figure V-11. AASHTO M_r vs. Asphalt Institute M_r for Samples < 4,000 psi.

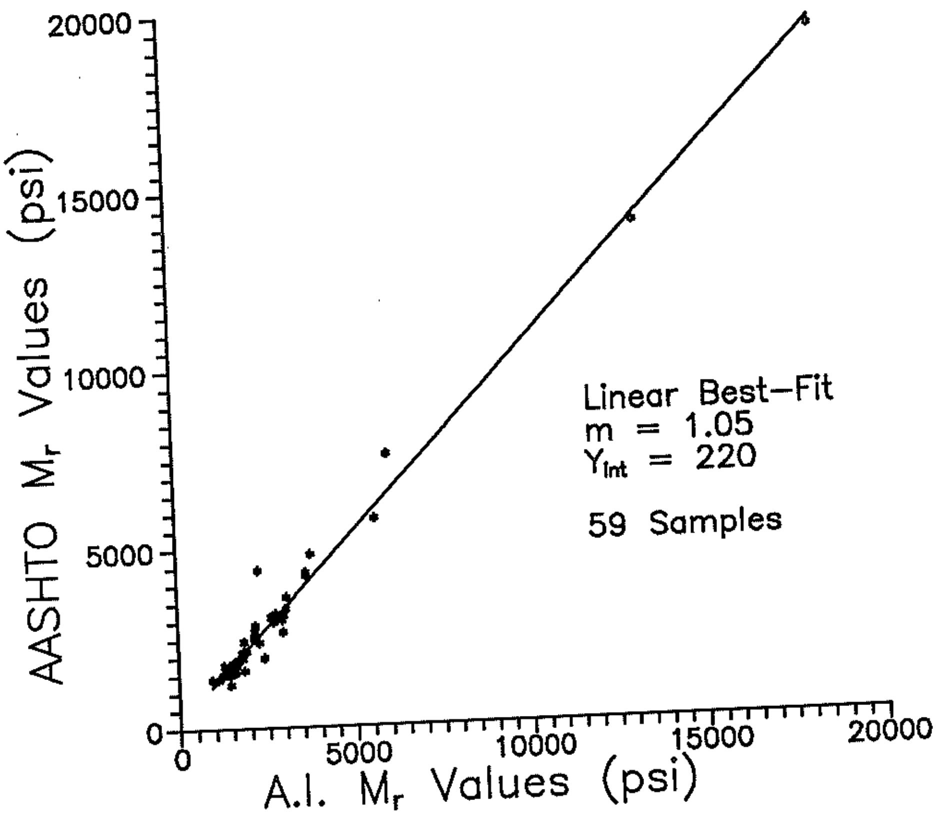


Figure V-12. AASHTO M_r vs. Asphalt Institute M_r for Samples < 20,000 psi.

2. The data is representative of various conditioning phases and water contents.

3. The data is obtained from 4 different soil classes.

The advantages of the Asphalt Institute test are:

1. Length of test including conditioning is 40 minutes, versus 140 minutes for AASHTO T 274.

2. A single value of M_r is obtained instead of the 15 values with AASHTO T 274.

Comparison Between Imbibition and Freeze-Thaw Conditioning

Data from the four soils tested exhibited a distinct correlation between the first freeze-thaw and the imbibition cycle. An investigation of the A-4(5) soil and the A-6(2) soil revealed that this correlation exists beyond the first cycle. Figure V-13 compares M_r with freeze-thaw and imbibition only for the A-4(5) soil at optimum water content up to 4 cycles. Figure V-14 compares the M_r between freeze-thaw and imbibition only at -1% of optimum water content, also up to four cycles. The imbibed samples were placed on porous stones in a constant water level for periods identical to the length of time the freeze-thaw samples were conditioned (i.e. 2 F/T = 48 hours). Both figures show that the effects of freeze-thaw conditioning can be reasonably predicted by subjected the samples to imbibition only over the same time period. The significance of this finding is that a testing agencies such as State Highway Departments can investigate the effects of freeze-thaw without conducting a time-consuming and possibly expensive conditioning regime.

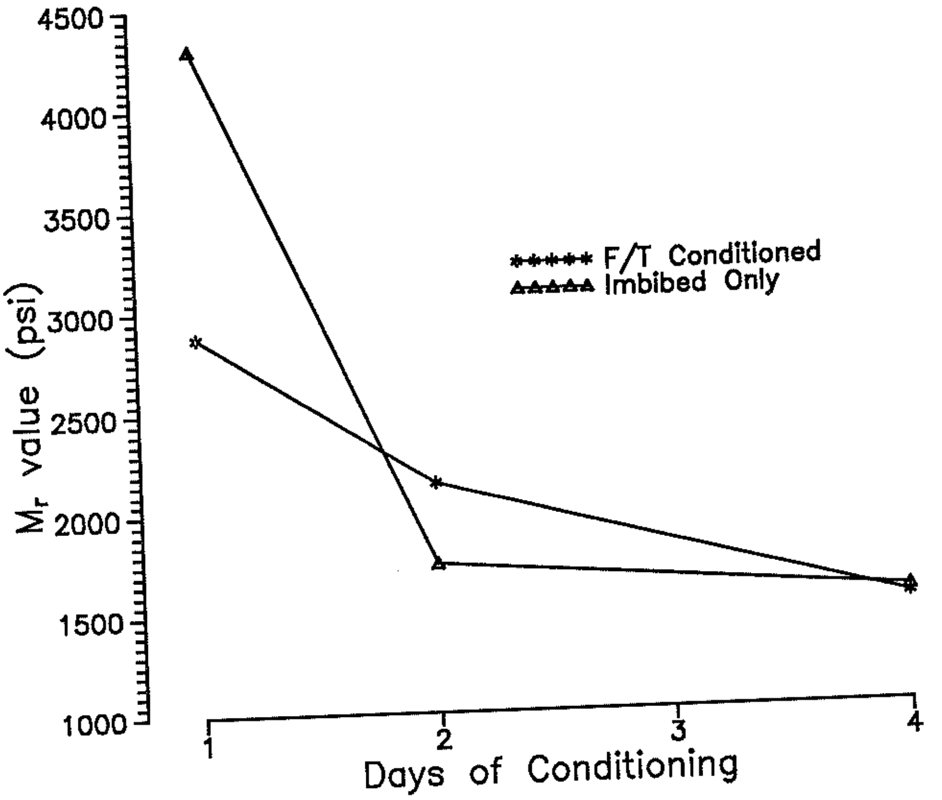


Figure V-13. Comparison Between Imbibition Only and Freeze-Thaw Conditioning. A-4(5) Soil; (w = 14.4% optimum).

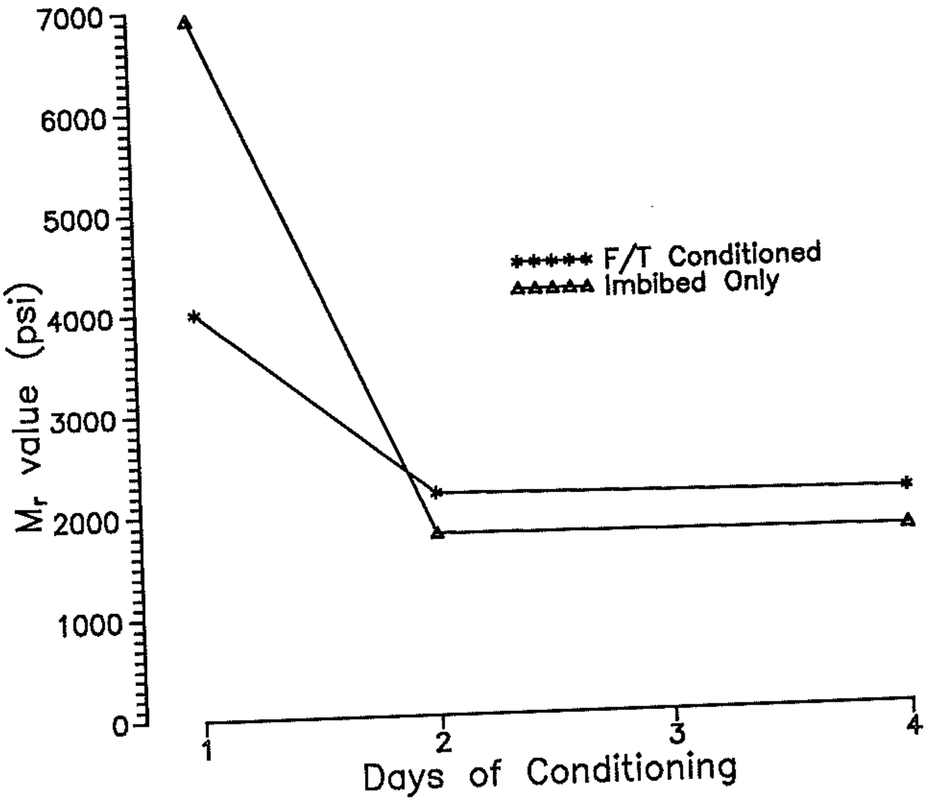


Figure V-14. Comparison Between Imbibition Only and Freeze-Thaw Conditioning. A-6(2) Soil, w = 13.5% (-1% of optimum).

Overload Conditions

This study incorporated an overload stress sequence after the standard AASHTO T 274 test to identify soil behavior to overloading during critical spring-thaw by heavy traffic. A deviator stress of 20 psi and confining stress of 15 psi was chosen as a representative stress state of overloading. This value was also chosen because it is a specified stress condition in the AASHTO T 274 conditioning sequence of granular soils. The stresses were applied to the samples for 10 cycles only to avoid severe deformations observed with earlier samples tested. A 6 psi deviator and 2 psi confining stress cycle was applied immediately prior to and after the overloading cycles to identify changes in soil M_r.

In all soil classes tested, large plastic deformations were observed during the overloading stress sequence. This created an apparent increase in M_r when comparing values between the 6 and 2 psi sequences added before and after overloading. This apparent M_r increase is probably due to the reduced distance between the LVDT rings as discussed earlier, which created subsequent increased lateral area over which the force was applied. Soil failure due to overloading was not observed in any test. These findings indicate that pavement failure during heavy truck traffic in critical spring-thaw periods is due to plastic deformation of the subgrade material and not from soil failure. These deformations would lead to alligator cracking or rutting (Rutherford, 1987).

Limitations of AASHTO T 274

Lack of Definitive M_r Calculation

The AASHTO T 274 test was developed to provide M_r values to be used in pavement design. Unfortunately, AASHTO has not specified how to apply the 15 data values from each stress state to calculate a single autonomous value. It is left to the testing agency to determine which stress state or grouping of stress states best identifies the soils being investigated. It might be suggested that a comparison of M_r values between lab tested samples and back-calculations using field deflection tests would yield some reasonable values to be utilized in deriving a single M_r. These comparisons have been performed by the Oregon Department of Transportation (Sorenson, 1989) and other agencies represented at the Workshop on Resilient Modulus Testing at Oregon State University in Corvallis, Oregon in March of 1989. Many agencies expressed difficulty in obtaining comparable results between back-calculated and lab-observed M_r values (Cochran, 1989; Thompson, 1989). This would appear to indicate that defining an accurate stress state sequence from AASHTO T 274 by comparing field and lab M_r values to be used as a representative value would also be difficult.

Time Consuming Procedure

The 200 cycles applied for 20 stress states during the conditioning and testing procedure of AASHTO T 274 would take over 2 hours if the cycles were applied continuously. Considering setup and adjustments, during the test, it is reasonable to assume AASHTO T 274 to be a 3 hour test. Additional time to prepare and compact the sample is necessary. For agencies testing over a range of water contents representing yearly fluctuations, the time consumed would be prohibitive to allow several tests over a range of soils.

Severity of Test Sequence

In AASHTO T 274, test sequences for both cohesive and granular soils are specified. In Section 6.4 of T 274, cohesive soils are defined as those in AASHTO M 145 classifications A-2-6, A-2-7, A-6 and A-7. All other soils are considered granular if the specification is taken literally. The granular test uses a 20 psi deviator and 15 psi confining stress condition for 200 cycles in the conditioning and testing phase. As discussed earlier, these stresses induced severe plastic deformation with most of the samples tested.

The samples used in this study were tested using specified sequences for cohesive soils, because they were less severe than for granular soils. Using the cohesive test procedure, a maximum stress of 10 psi deviator and 6 psi confining stress was applied for 200 repetitions during the conditioning phase. A 10 psi deviator and 0 psi confining stress was used in the testing phase.

Many of the samples tested in this study exhibited severe plastic deformation during the conditioning sequence, particularly in the A-4(5) and A-7-6(14) soil classes. Figure V-15 shows deformation of an A-7-6(14) sample after the conditioning sequence and prior to the testing sequence. It is difficult to justify test results from a sample after such deformations. The silty and more permeable A-4(5) soils exhibited more of a "barrelling" effect throughout the entire sample, creating the reduced distance between initial setting of the LVDT rings and increased diameter as discussed earlier. It appears obvious that if testing of silty soils is to be performed, a specific, less severe conditioning and testing sequence should be addressed by AASHTO T 274.

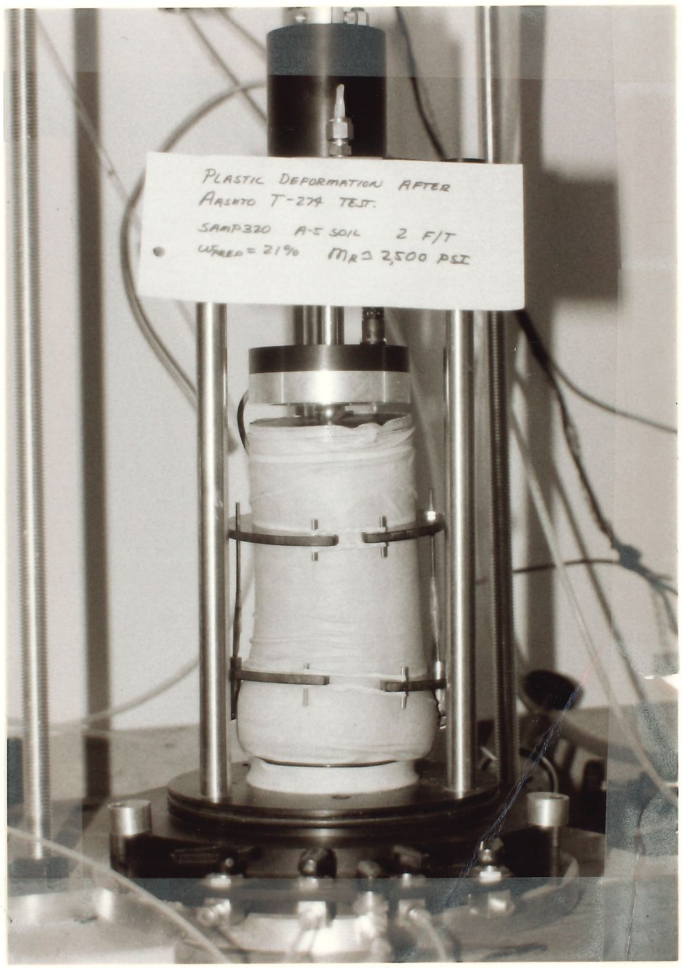


Figure V-15. Plastic Deformation of an A-7-6(14) Soil After Conditioning Sequence of AASHTO T 274. (Soil was re-classified after photo was taken)

CHAPTER VI

CONCLUSIONS

Testing Results

Results from laboratory testing of various frost-susceptible soil types, water contents and conditioning indicate identifiable trends in conditioning stages, conditioning methods and testing procedures. These trends are:

1. Reduction of M_r values occurs through imbibition and freeze-thaw conditioning, as indicated by subgrade failures during critical spring-thaw periods.

2. Most reduction of M_r occurs during the first freeze-thaw or imbibition conditioning cycle.

3. Little decrease of M_r occurs after 2 freeze-thaw cycles.

4. The reduction of M_r can be reasonably predicted through imbibition conditioning only.

5. Overloading of soft samples resulted in large plastic deformations. This influenced the final M_r values which produced an apparent increase in M_r.

6. Values of M_r obtained from the AASHTO T 274 test can be accurately predicted over a wide range of soil types and conditioning using a condensed regime, such as the Asphalt Institute test method.

7. AASHTO T 274 does not specifically address testing of non-cohesive fine-grained soils. The conditioning sequence specified for both cohesive and non-cohesive soils is too severe for soft specimens conditioned for M_r reduction due to freeze-thaw. This may also be true of many non-conditioned samples in these type ranges.

Necessity for Standard Comparison Sample

In the early stages of this study, it was evident that standard specimens suitable for verification and comparison between testing systems have not been developed. Some agencies using resilient modulus testing systems have an in-house standard constructed of rubber or other resilient material, however no universally accepted standard sample exists to date.

This study utilized a 4" wide by 8" high rubber sample manufactured by Research Engineering of Grass Valley, California for verification of consistency throughout the testing program. This sample provided a consistent and reliable M_r value slightly higher than 800 psi. The testing system was checked for consistency periodically during testing and after any minor hardware or software modification.

It is recommended that the U. S. DOT produce a set of standard samples over a typical range of M_r expected during testing. A recommended range of standard samples would include M_r values of 2,000, 10,000 and 30,000 psi to provide a suitable range for calibration of individual devices.

Recommendations for Future Study

The following items are offered for further research:

1. Since this study investigated frost-susceptible soils for freeze-thaw effects, further investigation of the less-susceptible cohesive clays could provide a broader background of the response of subgrade soils found in the western United States.

2. Further investigation of the correlation between freeze-thaw conditioning and imbibition conditioning could provide testing agencies with simpler, more manageable conditioning regimes when investigating M_r for thaw-weakened soils.

3. Although this study determined a significant correlation of M_r results between AASHTO T 274 test procedure and the Asphalt Institute test procedure, further testing would be needed to validate the correlation for other soils, particularly the more cohesive and granular soils.

4. Investigation and development of a representative testing regime that could be used for the silty soil types.

APPENDIX A

SAMPLE PREPARATION AND TESTING PROCEDURES

Sample Preparation Using the Soil Test Kneading Compactor

1. Check hydraulic fluid level. It should be 2" to 2-1/2" inches from the top of the fluid housing.
2. Adjust the indexing stroke stud if necessary. The stud should be in the lowest position, indexing the platen approximately one revolution every five strokes.
3. Place the 4" by 8" mold on the platen and fasten down the wing nuts to securely fix the mold on the platen.
4. Place the collar on the mold and secure it firmly in place with the wing nuts.
5. Reset the counter to zero.
6. Make sure a minimum pressure of 80 p.s.i. is available to the kneading compactor from the compressed air source.
7. Dial in desired tamping rammer (footer) pressure (use Table IV-4 for representative sample construction parameters).
8. Set timer duration to .5 seconds.
9. Place a small amount of soil (approximately 100 grams) in the mold.
10. Turn on the compactor to activate tamping rammer. Be careful that the rammer does not strike the side of the mold.
11. Continue compaction while slowly adding a small (approximately 75 grams) amount of soil every two strokes, until the specimen is compacted slightly above the mold.
12. Remove mold and collar.
13. Using a striker, trim the end of the specimen flush to the top of the mold.
14. Weigh the mold and specimen.

15. Remove the specimen from the mold with a screw type extractor. It may be necessary to slightly loosen the mold screws 3/4 to 1-1/2 turns to ease extraction. Be careful not to over-loosen the screws, as this tends to fracture the specimen along the mold seams.

16. Using a vacuum membrane expander, place a thin leak-proof membrane around the specimen.

17. Place plastic end caps on the specimen and secure with rubber O-rings.

18. Place specimen in an atmosphere of no less than 75% relative humidity for a period of not less than 24 hours to allow dissipation of transient pore pressures developed during compaction and provide uniform moisture distribution.

Testing Procedures

1. Place the sample on the porous stone on the lower platen of the testing chamber. Filter paper should be used between the sample and the porous stone to protect the stone.

2. Pull the rubber membrane over the sides of the base and seal with a rubber O-ring.

3. Apply a vacuum to the base of the sample of 3 p.s.i. to flush the membrane onto the sample. This usually takes about 90 seconds. Be sure the vacuum valves from the lower platen are in the open position. This step must be performed prior to placement of chamber over the sample to assure positive flow from the specimen.

4. Place the lower LVDT ring around the sample at 2" above the bottom of the sample. Secure the LVDT ring with one or two rubber bands just tightly enough to keep the ring secured. Avoid tightening the LVDT to the point of inducing confining stresses to the sample.

5. Place the upper LVDT ring on the sample and secure similarly as the lower LVDT ring. Using calipers, adjust the upper LVDT ring to a distance of 4.00" between centers of rings. The LVDT rings used in this research have a width of 0.225", requiring a distance of 4.225" from the bottom of the lower LVDT ring to the top of the upper LVDT ring.

6. Connect the LVDT lead wire.

7. Place the upper platen on the sample using filter paper to protect the porous stone. Roll the rubber membrane over the sides of the platen and seal with rubber O-ring.

8. Place the 3/4" steel ball on top of the upper platen.

9. Check to see if the sample is aligned with the load rod and load cell. If adjustment is necessary, carefully slide the upper platen on the sample. If excessive adjustment is necessary, carefully slide the sample on the lower platen and re-vacuum the sample.

10. Place the chamber over the mounted sample.

11. Slide the cell onto the loading base and center to the load rod from the load cylinder.

12. Fasten the load cell rod to the load rod from the load cylinder. Be sure the rod fits smoothly into the receptor. If the rod inserts roughly, re-adjust the cell on the load base until the rod inserts smoothly.

13. Fasten the base of the cell to the loading base.

14. Connect the lead from the load cell.

15. Turn on air supply.

16. Begin testing sequence with developed software.

17. In the UEI directory, execute "Resil".

APPENDIX B

SAMPLE OUTPUT DATA

Resilient Modulus Test
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Sample Number: 1
Sample Description: a-4 soil(5); no imbibe; no f/t
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 115.9 pcf Sample w = 13.4 %
Number of Freeze/Thaw Cycles = 0

Date: Tuesday,10/2/1990 Time: 13: 9:45

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00010	1.00	9809.7
2	6	0.00019	2.01	10526.0
4	6	0.00047	3.99	8448.9
8	6	0.00138	8.00	5818.6
10	6	0.00191	9.99	5238.0
1	6	0.00010	1.01	9654.8
1	3	0.00012	1.01	8599.1
1	0	0.00010	0.99	9634.7
2	6	0.00022	2.00	9167.5
6	2	0.00109	6.00	5522.3
2	3	0.00022	1.99	9027.0
2	0	0.00023	2.00	8753.2
4	6	0.00054	4.01	7368.3
4	3	0.00057	4.00	6953.9
4	0	0.00060	3.98	6681.7
8	6	0.00137	7.98	5839.2
8	3	0.00152	8.02	5262.9
8	0	0.00161	8.02	4984.8
10	6	0.00182	9.98	5476.3
10	3	0.00205	10.00	4889.2
10	0	0.00216	9.99	4628.8
6	2	0.00117	6.00	5129.2
20	15	0.00573	20.06	3503.0
6	2	0.00105	5.98	5683.9

Resilient Modulus Test
~~~~~~~~~~~~~~~~~~~~~~

Sample Number: 101
Sample Description: A-4(5) Soil; 8 F/T; w = 13.5%
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 117.0 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 8

Date: Sunday, 3/3/1991 Time: 20:24:10

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00028	1.00	3523.7
2	6	0.00066	2.00	3013.5
4	6	0.00305	4.01	1314.6
8	6	0.00658	8.00	1215.8
10	6	0.00661	10.01	1513.7
6	2	0.00422	5.99	1420.5
1	6	0.00028	1.00	3542.7
1	3	0.00032	1.00	3120.3
1	0	0.00034	1.01	2897.5
2	6	0.00071	2.00	2825.9
2	3	0.00071	2.01	2801.0
2	0	0.00072	2.00	2790.4
4	6	0.00188	4.00	2122.5
4	3	0.00209	4.01	1918.7
4	0	0.00216	4.00	1852.5
8	6	0.00419	8.01	1912.6
8	3	0.00432	8.01	1852.7
8	0	0.00432	8.00	1850.3
10	6	0.00562	10.01	1782.1
10	3	0.00580	9.99	1721.3
10	0	0.00571	10.00	1750.0
6	2	0.00373	6.02	1612.4
20	15	0.00990	19.95	2015.1
6	2	0.00375	5.99	1595.3

Resilient Modulus Test

Sample Number: 100
Sample Description: A-4(5) Soil; Imbibed w no f/t
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 115.9 pcf   Sample w = 13.3 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 11/26/1990   Time: 16: 3:27

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00033	1.00	3060.6
2	6	0.00089	1.99	2230.0
4	6	0.00243	3.99	1642.9
8	6	0.00519	7.98	1538.4
10	6	0.00579	10.00	1726.0
6	2	0.00438	6.00	1367.9
1	6	0.00029	1.00	3484.1
1	3	0.00045	1.00	2237.3
1	0	0.00056	1.00	1797.1
2	6	0.00090	1.95	2164.5
2	3	0.00133	2.00	1502.7
2	0	0.00168	1.99	1187.4
4	6	0.00244	4.01	1641.3
4	3	0.00303	4.01	1324.3
4	0	0.00323	4.00	1240.2
8	6	0.00456	7.98	1751.2
8	3	0.00501	8.02	1599.5
8	0	0.00513	7.99	1557.8
10	6	0.00526	10.01	1903.5
10	3	0.00567	9.97	1758.9
10	0	0.00575	10.01	1740.8
6	2	0.00381	6.01	1577.9
20	15	0.00754	19.86	2633.3
6	2	0.00392	6.01	1531.4

Resilient Modulus Test

Sample Number: 104
Sample Description: A-4(5) Soil; w = 13.3%; 1 F/T
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 117.0 pcf   Sample w = 13.3 %
Number of Freeze/Thaw Cycles = 1

Date: Monday, 12/10/1990   Time: 20:24:20

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00014	0.99	7262.7
2	6	0.00031	2.01	6416.6
4	6	0.00117	4.01	3439.5
8	6	0.00450	8.02	1783.3
10	6	0.00581	10.00	1720.6
6	2	0.00420	6.00	1426.8
1	6	0.00018	0.99	5628.5
1	3	0.00028	1.01	3612.6
1	0	0.00038	1.00	2618.3
2	6	0.00071	1.99	2788.5
2	3	0.00108	2.00	1854.2
2	0	0.00131	2.02	1539.0
4	6	0.00215	4.01	1868.5
4	3	0.00268	4.00	1492.6
4	0	0.00296	4.01	1357.3
8	6	0.00443	8.01	1805.7
8	3	0.00486	8.02	1651.4
8	0	0.00524	7.98	1522.1
10	6	0.00562	10.02	1782.2
10	3	0.00606	9.99	1648.5
10	0	0.00606	10.01	1651.3
6	2	0.00414	5.99	1445.2
20	15	0.00954	19.96	2092.0
6	2	0.00462	6.00	1299.6

Resilient Modulus Test

Sample Number: 110
Sample Description: A-4(5) soil; Imbibed w/ no f/t
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 118.4 pcf Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 11/26/1990 Time: 12:10: 5

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00007	1.00	14425.7
2	6	0.00019	2.01	10364.2
4	6	0.00023	4.02	17334.4
8	6	0.00326	8.00	2452.0
10	6	0.00437	10.00	2290.1
6	2	0.00330	5.98	1809.8
1	6	0.00010	1.00	9541.7
1	3	0.00017	1.01	5965.1
1	0	0.00025	1.00	4086.0
2	6	0.00036	2.00	5504.3
2	3	0.00067	2.01	2986.3
2	0	0.00088	2.01	2294.4
4	6	0.00144	3.99	2768.5
4	3	0.00193	4.01	2075.1
4	0	0.00219	4.00	1830.9
8	6	0.00325	8.02	2464.2
8	3	0.00379	8.00	2113.3
8	0	0.00404	7.99	1976.3
10	6	0.00405	10.01	2471.5
10	3	0.00456	9.99	2189.9
10	0	0.00482	10.00	2073.2
6	2	0.00301	6.01	1998.4
20	15	0.00636	19.93	3134.4
6	2	0.00320	6.00	1875.7

Resilient Modulus Test

Sample Number: 111
Sample Description: A-4(5) Soil; w = 14.5%; 1 F/T
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 117.0 pcf Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 1

Date: Monday, 11/12/1990 Time: 11:11:49

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00001	0.99	77013.2
2	6	0.00008	2.01	23645.3
4	6	0.00047	4.00	8504.6
8	6	0.00208	8.01	3853.9
10	6	0.00276	10.02	3631.8
6	2	0.00218	6.00	2750.1
1	6	-0.00002	1.01	-49235.4
1	3	0.00004	1.01	26860.0
1	0	0.00010	1.00	10285.9
2	6	0.00012	1.99	16126.0
2	3	0.00025	2.01	8078.9
2	0	0.00044	2.00	4504.6
4	6	0.00086	4.09	4778.4
4	3	0.00109	4.00	3689.3
4	0	0.00149	4.00	2677.1
8	6	0.00220	8.02	3651.3
8	3	0.00262	8.00	3054.6
8	0	0.00303	7.99	2638.0
10	6	0.00269	9.99	3710.6
10	3	0.00325	10.01	3081.2
10	0	0.00372	9.98	2686.1
6	2	0.00230	6.00	2609.0
20	15	0.00422	19.96	4728.5
6	2	0.00235	6.02	2561.4

Resilient Modulus Test

Sample Number: 114
Sample Description: A-4(5) Soil; w = 14.5%; 4 F/T
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 117.6 pcf Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 4

Date: Thursday, 12/13/1990 Time: 7:12:45

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00123	1.00	813.0
2	6	0.00314	2.00	637.1
4	6	0.00601	4.01	667.1
8	6	0.00355	8.02	2262.1
10	6	0.00686	10.00	1457.3
6	2	0.00496	6.00	1209.2
1	6	0.00060	1.01	1692.6
1	3	0.00070	1.00	1422.2
1	0	0.00072	1.00	1387.2
2	6	0.00175	1.99	1132.8
2	3	0.00193	2.00	1036.3
2	0	0.00193	2.00	1039.7
4	6	0.00367	3.99	1086.8
4	3	0.00378	4.01	1062.1
4	0	0.00370	4.01	1086.1
8	6	0.00566	8.00	1413.5
8	3	0.00537	8.01	1490.7
8	0	0.00505	7.99	1580.6
10	6	0.00524	10.03	1912.1
10	3	0.00493	10.02	2030.8
10	0	0.00448	10.03	2237.1
6	2	0.00350	6.00	1715.2
20	15	0.00702	19.93	2838.4
6	2	0.00320	5.98	1868.1

Resilient Modulus Test

Sample Number: 120
Sample Description: a-4(5) soil; imbibed w/ no freeze thaw
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 116.4 pcf Sample w = 15.2 %
Number of Freeze/Thaw Cycles = 0

Date: Sunday, 11/25/1990 Time: 21:29: 9

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00061	1.00	1647.8
2	6	0.00162	2.01	1242.8
4	6	0.00336	4.00	1191.6
8	6	0.00641	8.00	1247.5
10	6	0.00721	10.01	1388.6
6	2	0.00554	6.00	1082.0
1	6	0.00035	1.00	2821.8
1	3	0.00058	1.00	1736.4
1	0	0.00059	1.00	1711.8
2	6	0.00095	1.99	2100.0
2	3	0.00163	2.00	1229.5
2	0	0.00175	1.99	1137.9
4	6	0.00283	4.00	1416.9
4	3	0.00351	3.99	1137.6
4	0	0.00392	3.99	1019.9
8	6	0.00535	8.01	1497.7
8	3	0.00589	8.00	1357.3
8	0	0.00587	7.99	1363.0
10	6	0.00566	9.99	1763.7
10	3	0.00638	9.98	1564.5
10	0	0.00642	9.9	

- DATA LOST DUE TO COMPUTER FAILURE -

Resilient Modulus Test

Sample Number: 121
Sample Description: A-4(5) Soil; w = 15.2%; 1 F/T
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 116.1 pcf Sample w = 15.2 %
Number of Freeze/Thaw Cycles = 1

Date: Wednesday, 11/14/1990 Time: 15: 6:17

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00040	1.01	2533.1
2	6	0.00135	2.00	1483.6
4	6	0.00322	4.00	1242.4
8	6	0.00517	7.99	1545.0
10	6	0.00585	10.00	1710.0
6	2	0.00431	5.99	1387.3
1	6	0.00038	0.99	2621.8
1	3	0.00034	0.96	2788.9
1	0	0.00034	1.00	2908.2
2	6	0.00117	2.00	1711.7
2	3	0.00117	2.00	1706.1
2	0	0.00116	2.01	1727.6
4	6	0.00294	4.00	1361.9
4	3	0.00297	4.00	1347.4
4	0	0.00298	4.00	1342.5
8	6	0.00501	8.00	1596.1
8	3	0.00501	7.99	1596.7
8	0	0.00503	8.01	1594.1
10	6	0.00572	9.97	1742.5
10	3	0.00574	10.00	1742.1
10	0	0.00575	10.00	1740.4
6	2	0.00432	6.01	1393.3
20	15	0.00977	19.88	2034.9
6	2	0.00400	6.00	1501.8

Resilient Modulus Test

Sample Number: 124
Sample Description: a-4(5) soil; 4 f/t; 15.2%
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 116.4 pcf Sample w = 15.3 %
Number of Freeze/Thaw Cycles = 4

Date: Saturday, 1/19/1991 Time: 12: 8: 6

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00003	1.00	28668.9
2	6	0.00011	2.00	17421.9
4	6	0.00031	3.99	13074.8
8	6	0.00161	8.01	4989.7
10	6	0.00263	10.01	3806.3
6	2	0.00165	6.00	3629.1
1	6	0.00006	1.00	17034.0
1	3	0.00007	1.00	15128.2
1	0	0.00008	1.00	13264.8
2	6	0.00019	2.00	10327.2
2	3	0.00020	1.99	9806.7
2	0	0.00022	1.99	9265.2
4	6	0.00056	4.01	7160.2
4	3	0.00074	4.01	5432.9
4	0	0.00083	4.00	4792.4
8	6	0.00178	7.99	4485.6
8	3	0.00205	8.00	3904.7
8	0	0.00227	8.01	3525.6
10	6	0.00259	10.03	3875.8
10	3	0.00292	9.99	3424.1
10	0	0.00326	9.99	3064.1
6	2	0.00183	6.00	3282.1
20	15	0.00587	19.99	3405.1
6	2	0.00200	6.01	3005.2

Resilient Modulus Test

Sample Number: 129
Sample Description: A-4(5) Soil; w=13.4%; 4 F/T
GammaDMax = 118.7 pcf Optimum w = 14.5 %
SampleGamma = 117.7 pcf Sample w = 13.4%
Number of Freeze/Thaw Cycles = 4

Date: Friday, 10/26/1990 Time: 19:47:53

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00045	1.00	2236.1
2	6	0.00142	1.98	1398.3
4	6	0.00283	4.01	1416.3
8	6	0.00554	8.03	1448.7
10	6	0.00630	9.98	1583.5
6	2	0.00420	6.01	1431.5
1	6	0.00026	1.01	3929.0
1	3	0.00030	0.98	3295.7
1	0	0.00047	1.04	2192.1
2	6	0.00081	2.15	2658.0
2	3	0.00102	2.03	1988.5
2	0	0.00122	2.03	1668.4
4	6	0.00251	4.02	1604.3
4	3	0.00278	4.21	1515.9
4	0	0.00280	4.00	1427.5
8	6	0.00505	8.06	1594.7
8	3	0.00538	8.02	1490.3
8	0	0.00562	8.03	1427.6
10	6	0.00573	10.03	1750.6
10	3	0.00583	9.88	1694.4
10	0	0.00611	10.00	1636.2
6	2	0.00369	5.96	1614.4
20	15	0.00943	19.95	2116.7
6	2	0.00319	6.00	1883.5

Resilient Modulus Test

Sample Number: 131
Sample Description: A-4(5) Soil; w = 14.4%; 1 F/T Cycle
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 118.0 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 1

Date: Friday, 1/25/1991 Time: 10: 5:32

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00032	1.00	3078.3
2	6	0.00097	2.00	2074.7
4	6	0.00315	4.00	1269.0
8	6	0.00621	8.01	1290.3
10	6	0.00681	9.98	1464.5
6	2	0.00486	6.01	1236.3
1	6	0.00036	1.00	2788.0
1	3	0.00044	0.99	2230.3
1	0	0.00048	0.98	2052.0
2	6	0.00109	2.01	1843.3
2	3	0.00133	2.00	1505.3
2	0	0.00142	2.00	1416.2
4	6	0.00301	4.01	1331.7
4	3	0.00325	4.00	1229.5
4	0	0.00326	4.00	1227.2
8	6	0.00542	8.00	1475.7
8	3	0.00548	8.00	1460.2
8	0	0.00537	8.02	1492.1
10	6	0.00617	9.99	1618.4
10	3	0.00622	9.98	1602.9
10	0	0.00609	9.96	1634.9
6	2	0.00439	6.00	1366.3
20	15	0.00946	19.94	2107.8
6	2	0.00410	6.00	1462.7

Resilient Modulus Test

Sample Number: 134
Sample Description: a-4(5) Soil; w = 14.4%; 1 F/T Cycle
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 118.8 pcf   Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 1

Date: Tuesday, 1/22/1991   Time: 15:23:45

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00042	1.00	2388.0
2	6	0.00131	2.01	1531.1
4	6	0.00350	4.01	1146.8
8	6	0.00609	8.01	1315.5
10	6	0.00628	10.01	1593.8
6	2	0.00441	6.00	1360.0
1	6	0.00035	1.00	2814.2
1	3	0.00032	1.00	3075.2
1	0	0.00031	1.00	3185.4
2	6	0.00110	2.00	1823.7
2	3	0.00110	1.99	1801.9
2	0	0.00111	2.00	1805.2
4	6	0.00296	4.01	1354.7
4	3	0.00298	4.02	1349.6
4	0	0.00297	4.00	1347.4
8	6	0.00507	7.99	1576.2
8	3	0.00506	8.01	1581.7
8	0	0.00504	8.00	1587.7
10	6	0.00573	9.97	1740.5
10	3	0.00566	10.00	1767.8
10	0	0.00559	10.02	1793.7
6	2	0.00406	5.98	1471.3
20	15	0.00904	20.01	2213.2
6	2	0.00358	6.02	1681.0

Resilient Modulus Test

Sample Number: 136
Sample Description: A-4(5) Soil; w=13.4%; 2 F/T
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 118.4 pcf   Sample w = 13.4 %
Number of Freeze/Thaw Cycles = 2

Date: Monday, 2/18/1991   Time: 12:23:58

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00029	1.01	3484.4
2	6	0.00092	2.01	2179.5
4	6	0.00263	4.00	1521.5
8	6	0.00448	7.99	1783.1
10	6	0.00516	10.00	1939.4
6	2	0.00342	6.01	1757.3
1	6	0.00023	1.01	4451.3
1	3	0.00021	1.01	4761.8
1	0	0.00020	0.99	5085.3
2	6	0.00060	2.00	3349.9
2	3	0.00059	2.00	3417.4
2	0	0.00058	2.01	3482.6
4	6	0.00189	3.99	2113.3
4	3	0.00191	4.00	2098.1
4	0	0.00190	3.99	2106.4
8	6	0.00405	8.00	1975.7
8	3	0.00408	8.01	1961.6
8	0	0.00408	8.00	1962.4
10	6	0.00486	10.01	2059.9
10	3	0.00489	10.03	2051.9
10	0	0.00489	9.97	2040.5
6	2	0.00336	6.02	1790.7
20	15	0.00768	19.90	2589.7
6	2	0.00282	6.00	2127.1

Resilient Modulus Test

Sample Number: 138
Sample Description: retest A-4(5); No F/T or Imbibition
GammaDMax = 117.7 pcf　　Optimum w = 14.4 %
SampleGamma = 119.3 pcf　　Sample w = 13.4 %
Number of Freeze/Thaw Cycles = 0

Date: Sunday, 2/10/1991　　Time: 9:31:49

Dev	Confine	epsilon	sigma	ResilMod
1	6	-0.00000	1.00	-362937.0
2	6	0.00005	2.00	43183.1
4	6	0.00034	4.00	11771.1
8	6	0.00126	8.02	6348.6
10	6	0.00173	9.99	5763.6
6	2	0.00106	6.02	5650.4
1	6	0.00001	1.00	182379.4
1	3	0.00000	1.00	822187.5
1	0	0.00000	0.99	362178.0
2	6	0.00012	2.00	16876.0
2	3	0.00013	2.00	15957.1
2	0	0.00013	2.00	15887.4
4	6	0.00054	4.00	7354.6
4	3	0.00055	4.00	7281.5
4	0	0.00054	4.00	7393.1
8	6	0.00142	8.02	5635.2
8	3	0.00144	8.00	5570.8
8	0	0.00145	7.99	5497.2
10	6	0.00179	10.04	5597.1
10	3	0.00183	9.99	5455.4
10	0	0.00187	10.04	5377.2
6	2	0.00117	6.01	5136.2
20	15	0.00327	20.01	6126.4
6	2	0.00110	6.02	5490.7

Resilient Modulus Test

Sample Number: 141
Sample Description: A-4(5) Soil; 4 F/t; w = 15.2%
GammaDMax = 117.7 pcf　　Optimum w = 14.4 %
SampleGamma = 117.1 pcf　　Sample w = 15.2 %
Number of Freeze/Thaw Cycles = 4

Date: Sunday, 3/3/1991　　Time: 13:24:13

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00052	1.00	1935.5
2	6	0.00168	2.01	1192.7
4	6	0.00369	3.99	1081.5
8	6	0.00569	7.99	1404.9
10	6	0.00540	10.00	1853.0
6	2	0.00383	6.00	1566.4
1	6	0.00021	1.01	4886.2
1	3	0.00029	1.00	3463.9
1	0	0.00031	1.00	3221.8
2	6	0.00067	2.01	3001.1
2	3	0.00087	1.99	2304.5
2	0	0.00094	2.00	2129.7
4	6	0.00214	4.00	1865.1
4	3	0.00242	3.99	1653.3
4	0	0.00245	4.01	1635.2
8	6	0.00451	7.99	1771.2
8	3	0.00467	8.01	1713.5
8	0	0.00464	8.00	1723.2
10	6	0.00535	10.00	1870.5
10	3	0.00528	9.98	1890.3
10	0	0.00511	10.02	1960.6
6	2	0.00349	5.98	1713.3
20	15	0.00883	19.74	2235.0
6	2	0.00250	6.00	2395.1

Resilient Modulus Test

Sample Number: 146
Sample Description: A-4(5) soil; w=14.4%; No F/T; Imbibed
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 117.1 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 0

Date: Friday, 2/22/1991 Time: 13:19:29

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00007	1.00	14019.0
2	6	0.00029	2.00	6885.1
4	6	0.00125	3.99	3188.5
8	6	0.00386	8.00	2072.2
10	6	0.00494	10.00	2023.3
6	2	0.00389	6.01	1544.2
1	6	0.00016	0.99	6148.5
1	3	0.00031	1.01	3256.9
1	0	0.00040	0.99	2470.7
2	6	0.00057	2.00	3524.7
2	3	0.00095	2.00	2106.0
2	0	0.00121	1.99	1642.5
4	6	0.00243	4.00	1645.9
4	3	0.00273	4.00	1464.3
4	0	0.00308	4.00	1297.4
8	6	0.00397	7.99	2013.5
8	3	0.00449	8.00	1783.0
8	0	0.00470	8.00	1703.0
10	6	0.00456	10.01	2197.0
10	3	0.00517	10.00	1934.6
10	0	0.00539	9.99	1852.9
6	2	0.00345	6.00	1739.6
20	15	0.00621	20.01	3222.2
6	2	0.00361	6.00	1661.5

Resilient Modulus Test

Sample Number: 149
Sample Description: A-4(5) Soil; w=14.4%; No F/T; Imbibed
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 118.1 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 0

Date: Saturday, 2/23/1991 Time: 7:04:22

Dev	Confine	epsilon	sigma	ResilMod
1	6	-0.00029	1.01	-3501.1
2	6	0.00009	2.00	21073.4
4	6	0.00025	4.00	15791.8
8	6	0.00126	7.93	6294.4
10	6	0.00207	10.00	4818.9
6	2	0.00085	5.99	7085.5
1	6	0.00001	1.00	148950.4

- ABORTED -

Resilient Modulus Test

Sample Number: 10
Sample Description: A-4(5) Soil; No F/T or Imbibition
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 117.4 pcf   Sample w = 12.9 %
Number of Freeze/Thaw Cycles = 0

Date: Friday, 10/26/1990   Time: 10:41:49

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00007	1.00	15255.6
2	6	0.00018	2.00	11135.0
4	6	0.00079	4.00	5069.5
8	6	0.00255	8.01	3137.8
10	6	0.00319	9.97	3126.4
6	2	0.00196	5.99	3051.0
1	6	0.00007	0.98	13203.1
1	3	0.00007	1.00	15101.0
1	0	0.00006	0.98	15608.9
2	6	0.00018	2.00	11392.0
2	3	0.00017	2.00	11673.3
2	0	0.00017	2.01	11565.0
4	6	0.00087	4.01	4618.5
4	3	0.00085	4.01	4703.5
4	0	0.00083	3.99	4804.3
8	6	0.00238	7.99	3357.0
8	3	0.00240	8.04	3349.9
8	0	0.00239	7.98	3336.0
10	6	0.00294	10.02	3405.1
10	3	0.00298	10.00	3357.3
10	0	0.00300	10.00	3339.0
6	2	0.00190	6.01	3164.7
20	15	0.00599	20.04	3348.5
6	2	0.00173	6.00	3475.5

Resilient Modulus Test

Sample Number: 1000
Sample Description: a-4(5) soil; no imbibe; no f/t
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 115.9 pcf   Sample w = 13.3 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 11/26/1990   Time: 21:56:20

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00004	1.02	25882.5
2	6	0.00007	2.01	29194.7
4	6	0.00014	3.99	27605.2
8	6	0.00039	7.99	20731.8
10	6	0.00053	10.00	19007.6
6	2	0.00033	6.00	18355.4
1	6	0.00002	1.00	46780.4
1	3	0.00004	0.99	23617.0
1	0	0.00002	1.00	61579.3
2	6	0.00007	2.02	30018.0
2	3	0.00006	2.00	30867.0
2	0	0.00007	1.99	29264.7
4	6	0.00016	4.00	24854.0
4	3	0.00019	3.99	21555.9
4	0	0.00017	4.01	23031.8
8	6	0.00040	7.97	19796.9
8	3	0.00042	8.01	19109.0
8	0	0.00045	7.99	17943.0
10	6	0.00056	10.01	17770.9
10	3	0.00060	9.99	16607.7
10	0	0.00063	10.00	15891.7
6	2	0.00035	5.99	16956.0
20	15	0.00113	19.98	17722.3
6	2	0.00035	6.01	17278.4

Resilient Modulus Test

Sample Number: 102
Sample Description: A-4(5) Soil; w = 13.3%; 1 F/T
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 116.5 pcf Sample w = 13.3 %
Number of Freeze/Thaw Cycles = 1

Date: Tuesday, 12/11/1990 Time: 12:46:29

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00017	0.98	5791.2
2	6	0.00042	1.99	4806.3
4	6	0.00133	4.00	3006.5
8	6	0.00454	8.00	1762.6
10	6	0.00576	10.04	1743.5
6	2	0.00423	5.99	1414.4
1	6	0.00020	0.98	4887.5
1	3	0.00031	1.01	3246.5
1	0	0.00036	1.00	2806.9
2	6	0.00071	2.00	2818.4
2	3	0.00104	2.02	1935.3
2	0	0.00122	1.98	1626.1
4	6	0.00212	4.01	1890.9
4	3	0.00271	3.99	1475.5
4	0	0.00298	3.99	1339.4
8	6	0.00444	7.99	1801.3
8	3	0.00491	7.99	1627.6
8	0	0.00513	7.98	1554.9
10	6	0.00537	10.03	1868.1
10	3	0.00570	9.98	1753.0
10	0	0.00577	9.99	1731.1
6	2	0.00380	6.00	1576.3
20	15	0.00903	20.01	2214.9
6	2	0.00439	6.00	1364.9

Resilient Modulus Test

Sample Number: 108
Sample Description: a-4(5); 1 f/t; 13.3%
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 117.0 pcf Sample w = 13.3 %
Number of Freeze/Thaw Cycles = 1

Date: Friday, 1/18/1991 Time: 13:40:45

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00014	1.00	7394.5
2	6	0.00029	2.00	6853.6
4	6	0.00075	3.99	5342.4
8	6	0.00278	8.00	2876.9
10	6	0.00411	10.00	2431.2
6	2	0.00267	6.02	2256.2
1	6	0.00014	1.00	7198.0
1	3	0.00013	1.00	7851.5
1	0	0.00012	1.00	7995.9
2	6	0.00049	2.00	4126.7
2	3	0.00047	1.99	4217.4
2	0	0.00046	1.99	4293.3
4	6	0.00154	4.00	2599.1
4	3	0.00152	4.00	2638.7
4	0	0.00153	4.00	2621.0
8	6	0.00332	8.02	2414.2
8	3	0.00334	8.00	2397.3
8	0	0.00336	8.02	2387.1
10	6	0.00417	10.00	2398.1
10	3	0.00425	10.01	2355.7
10	0	0.00428	10.00	2339.3
6	2	0.00287	6.01	2090.9
20	15	0.00809	20.04	2478.3
6	2	0.00274	6.01	2193.0

Resilient Modulus Test

Sample Number: 1100
Sample Description: A-4(5) soil; No F/T or Imbibition
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 117.5 pcf   Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 0

Date: Saturday, 11/10/1990   Time: 12:24:54

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00001	1.00	116853.5
2	6	0.00018	2.01	11373.5
4	6	0.00096	4.00	4185.7
8	6	0.00406	8.00	1968.4
10	6	0.00484	9.98	2061.2
6	2	0.00318	6.00	1886.5
1	6	0.00012	0.99	8496.0
1	3	0.00010	1.00	10153.7
1	0	0.00010	1.00	10291.9
2	6	0.00046	2.00	4337.5
2	3	0.00045	1.99	4395.5
2	0	0.00045	2.01	4448.6
4	6	0.00172	4.00	2329.0
4	3	0.00173	4.01	2317.9
4	0	0.00174	3.99	2291.4
8	6	0.00373	7.99	2143.1
8	3	0.00375	8.01	2134.2
8	0	0.00377	8.00	2120.8
10	6	0.00454	10.00	2200.7
10	3	0.00459	9.98	2174.0
10	0	0.00461	10.01	2169.5
6	2	0.00314	6.00	1909.4
20	15	0.00828	20.00	2415.2
6	2	0.00284	6.01	2116.9

Resilient Modulus Test

Sample Number: 112
Sample Description: A-4(5) Soil; w=14.4%; 8 F/T
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 117.4 pcf   Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 8

Date: Sunday, 11/18/1990   Time: 21: 2: 4

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00086	1.00	1168.0
2	6	0.00219	2.02	923.4
4	6	0.00434	4.01	922.6
8	6	0.00666	8.01	1203.5
10	6	0.00840	9.99	1189.7
6	2	0.00650	6.00	923.7
1	6	0.00086	0.99	1159.8
1	3	0.00075	1.00	1333.4
1	0	0.00071	1.00	1404.8
2	6	0.00241	2.01	835.4
2	3	0.00241	2.00	829.9
2	0	0.00235	2.00	847.9
4	6	0.00475	4.00	842.7
4	3	0.00475	3.99	840.0
4	0	0.00476	4.00	840.9
8	6	0.00743	8.00	1077.6
8	3	0.00744	8.01	1077.2
8	0	0.00742	7.99	1076.1
10	6	0.00786	9.99	1270.7
10	3	0.00335	10.00	2985.2
10	0	0.00317	10.02	3156.4
6	2	0.00150	5.99	3983.7
20	15	0.00846	19.91	2352.5
6	2	0.00367	6.01	1637.2

Resilient Modulus Test

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Sample Number: 12
Sample Description: A-4(5) soil; No imbibition or F/T
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 118.4 pcf   Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 0

Date: Tuesday, 10/9/1990   Time: 14:27:17

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00003	1.00	32853.1
2	6	0.00009	2.03	23278.4
4	6	0.00024	4.00	16868.9
8	6	0.00073	7.99	10888.3
10	6	0.00098	10.00	10196.8
6	2	0.00052	6.00	11550.7
1	6	0.00004	1.00	26094.5
1	3	0.00003	1.00	28840.5
1	0	0.00004	1.00	26905.6
2	6	0.00008	1.98	23970.7
2	3	0.00008	1.98	24544.0
2	0	0.00008	2.02	24512.6
4	6	0.00021	3.25	15597.1
4	3	0.00025	4.00	15844.0
4	0	0.00025	3.99	16130.3
8	6	0.00080	8.53	10673.9
8	3	0.00074	8.00	10740.9
8	0	0.00075	8.01	10742.9
10	6	0.00097	10.02	10276.9
10	3	0.00099	10.03	10087.0
10	0	0.00099	9.99	10103.1
6	2	0.00052	5.70	10867.9
20	15	0.00190	19.97	10525.8
6	2	0.00053	6.00	11361.5

Resilient Modulus Test

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Sample Number: 1200
Sample Description: a-4(5) soil; no imbibe or f/t
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 116.1 pcf   Sample w = 15.2 %
Number of Freeze/Thaw Cycles = 0

Date: Tuesday, 11/27/1990   Time: 11:30:28

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00009	1.01	10717.7
2	6	0.00035	2.00	5789.2
4	6	0.00187	3.99	2128.2
8	6	0.00502	7.99	1592.0
10	6	0.00628	10.01	1594.0
6	2	0.00497	5.99	1204.6
1	6	0.00021	1.00	4712.3
1	3	0.00041	1.01	2434.8
1	0	0.00044	1.00	2288.6
2	6	0.00071	1.99	2811.6
2	3	0.00130	1.98	1521.2
2	0	0.00148	1.99	1349.5
4	6	0.00238	4.01	1683.3
4	3	0.00336	4.00	1191.6
4	0	0.00367	4.00	1091.1
8	6	0.00504	8.00	1586.8
8	3	0.00591	7.99	1352.4
8	0	0.00621	8.01	1289.7
10	6	0.00521	10.01	1921.7
10	3	0.00570	10.00	1754.5
10	0	0.00580	9.99	1721.2
6	2	0.00387	5.99	1548.8
20	15	0.00708	19.93	2814.7
6	2	0.00413	6.00	1452.8

Resilient Modulus Test

Sample Number: 122
Sample Description: A-4(5) Soil; w = 15.2%; 2 F/T
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 116.3 pcf Sample w = 15.2 %
Number of Freeze/Thaw Cycles = 2

Date: Monday, 11/19/1990 Time: 14:51: 5

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00072	1.01	1403.0
2	6	0.00130	2.00	1543.8
4	6	0.00449	3.99	888.5
8	6	0.00709	7.99	1126.9
10	6	0.00343	9.99	2917.2
6	2	0.00125	5.99	4770.6
1	6	0.00041	1.01	2489.8
1	3	0.00044	0.99	2249.6
1	0	0.00044	1.00	2262.2
2	6	0.00154	1.99	1293.4
2	3	0.00159	2.00	1261.9
2	0	0.00160	2.01	1257.3
4	6	0.00186	3.99	2152.6
4	3	0.00171	3.99	2328.3
4	0	0.00169	4.00	2367.0
8	6	0.00201	8.00	3980.9
8	3	0.00201	8.00	3985.8
8	0	0.00286	8.00	2802.3
10	6	0.00563	9.99	1775.2
10	3	0.00538	9.97	1853.1
10	0	0.00518	10.01	1930.1
6	2	0.00390	5.99	1536.0
20	15	0.00704	19.91	2829.8
6	2	0.00344	6.01	1749.4

Resilient Modulus Test

Sample Number: 128
Sample Description: a-4(5) soil; 15.3%; 116.6 #/ft3
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 116.3 pcf Sample w = 15.2 %
Number of Freeze/Thaw Cycles = 4

Date: Saturday, 1/19/1991 Time: 15:14:53

Dev	Confine	epsilon	sigma	ResilMod
1	6	-0.00004	0.99	-26419.4
2	6	-0.00003	2.00	-58577.2
4	6	-0.00004	4.01	-113228.5
8	6	0.00028	8.01	28162.7
10	6	0.00054	10.01	18498.6
6	2	0.00024	6.01	25479.4
1	6	-0.00003	0.99	-38793.9
1	3	-0.00004	1.01	-22594.3
1	0	-0.00005	1.00	-21906.8
2	6	-0.00003	1.99	-66536.4
2	3	-0.00004	2.00	-56396.3
2	0	-0.00004	2.01	-50662.7
4	6	0.00005	3.98	74598.9
4	3	0.00006	4.00	71554.2

- ABORTED -

Resilient Modulus Test

Sample Number: 130
Sample Description: a-4(5) Soil; w=14.4%; 1 F/T Cycle
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 118.2 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 1

Date: Tuesday, 2/5/1991 Time: 9:32:21

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00014	1.01	7232.1
2	6	0.00034	2.00	5925.7
4	6	0.00112	4.01	3597.0
8	6	0.00442	8.01	1810.6
10	6	0.00561	9.98	1779.3
6	2	0.00412	5.98	1453.9
1	6	0.00027	0.99	3684.6
1	3	0.00036	1.00	2783.3
1	0	0.00044	1.01	2300.1
2	6	0.00078	2.01	2585.1
2	3	0.00106	2.00	1885.3
2	0	0.00124	1.99	1599.4
4	6	0.00224	3.99	1778.8
4	3	0.00270	3.98	1472.8
4	0	0.00291	4.00	1374.8
8	6	0.00452	8.01	1772.1
8	3	0.00490	8.02	1637.3
8	0	0.00504	7.99	1585.7
10	6	0.00542	10.00	1844.3
10	3	0.00581	10.02	1724.8
10	0	0.00595	10.01	1682.7
6	2	0.00412	6.02	1462.6
20	15	0.00758	19.94	2630.0
6	2	0.00412	6.00	1456.0

Resilient Modulus Test

Sample Number: 133
Sample Description: A-4(5) Soil; w = 14.4%; 1 F/T cycle
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 118.9 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 1

Date: Tuesday, 1/22/1991 Time: 20:52:39

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00025	1.00	4018.9
2	6	0.00061	2.00	3255.1
4	6	0.00300	4.00	1333.4
8	6	0.00561	8.00	1427.5
10	6	0.00512	10.01	1956.6
6	2	0.00329	5.99	1821.5
1	6	0.00024	1.00	4163.1
1	3	0.00031	1.00	3183.2
1	0	0.00036	0.99	2756.7
2	6	0.00089	2.01	2265.5
2	3	0.00112	2.01	1798.0
2	0	0.00119	2.00	1682.9
4	6	0.00252	4.00	1588.0
4	3	0.00280	4.00	1429.2
4	0	0.00290	4.00	1382.6
8	6	0.00467	8.01	1714.0
8	3	0.00473	8.02	1696.8
8	0	0.00475	7.99	1682.5
10	6	0.00556	10.01	1801.4
10	3	0.00580	9.99	1721.9
10	0	0.00591	10.00	1691.1
6	2	0.00413	6.02	1457.4
20	15	0.00883	19.97	2262.0
6	2	0.00453	5.99	1321.4

Resilient Modulus Test

Sample Number: 135
Sample Description: A-4(5) Soil; w=13.4%; Imbibed w/ no F/t
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 119.3 pcf Sample w = 13.4%
Number of Freeze/Thaw Cycles = 0

Date: Saturday, 2/9/1991 Time: 9:45:36

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00000	0.99	1626157.3
2	6	0.00004	2.01	46936.6
4	6	0.00030	4.01	13560.2
8	6	0.00117	8.00	6833.3
10	6	0.00170	10.01	5881.9
6	2	0.00107	5.99	5624.5
1	6	0.00004	1.00	26273.6
1	3	0.00004	1.01	26628.7
1	0	0.00004	1.00	25303.5
2	6	0.00017	1.99	11553.7
2	3	0.00017	1.99	11423.5
2	0	0.00018	2.00	11159.9
4	6	0.00060	4.00	6709.0
4	3	0.00060	4.00	6680.8
4	0	0.00060	4.01	6631.3
8	6	0.00142	8.02	5629.9
8	3	0.00144	8.00	5567.7
8	0	0.00145	8.01	5536.8
10	6	0.00179	10.01	5600.9
10	3	0.00185	10.01	5423.3
10	0	0.00187	10.01	5346.1
6	2	0.00122	6.00	4910.6
20	15	0.00347	19.99	5763.6
6	2	0.00108	5.99	5526.4

Resilient Modulus Test

Sample Number: 137
Sample Description: a-4(5) soil; imbibed; no f/t
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 119.4 pcf Sample w = 13.4 %
Number of Freeze/Thaw Cycles = 0

Date: Wednesday, 2/6/1991 Time: 18:33:55

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00007	1.01	13960.5
2	6	0.00019	2.00	10571.3
4	6	0.00082	4.00	4868.3
8	6	0.00304	8.01	2637.6
10	6	0.00404	10.01	2479.8
6	2	0.00264	6.00	2270.1
1	6	0.00014	1.00	7102.1
1	3	0.00013	1.00	7901.7
1	0	0.00013	0.99	7757.7
2	6	0.00038	2.01	5227.1
2	3	0.00038	2.00	5227.8
2	0	0.00039	2.00	5177.2
4	6	0.00156	4.01	2566.0
4	3	0.00157	4.01	2550.8
4	0	0.00154	4.01	2594.5
8	6	0.00143	7.99	5592.5
8	3	0.00147	8.02	5468.7
8	0	0.00144	8.02	5577.1
10	6	0.00177	10.03	5679.4
10	3	0.00178	10.01	5632.3
10	0	0.00182	10.01	5510.9
6	2	0.00117	6.00	5134.0
20	15	0.00323	19.96	6171.2
6	2	0.00103	6.00	5825.0

Resilient Modulus Test
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Sample Number: 140
Sample Description: A-4(5) Soil; w=15.2%; No F/T or Imbibition
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 117.3 pcf Sample w = 15.2 %
Number of Freeze/Thaw Cycles = 0

Date: Saturday, 2/23/1991 Time: 19:42:49

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00001	1.00	121636.9
2	6	0.00001	2.00	226056.5
4	6	0.00081	4.00	4920.3
8	6	0.00235	7.99	3396.7
10	6	0.00276	10.01	3624.2
6	2	0.00196	5.99	3057.2
1	6	0.00006	1.00	15911.6
1	3	0.00011	1.00	8805.6
1	0	0.00013	1.01	7931.5
2	6	0.00026	2.00	7744.7
2	3	0.00039	2.01	5182.9
2	0	0.00043	1.96	4578.5
4	6	0.00090	4.00	4420.0
4	3	0.00117	3.99	3404.0
4	0	0.00124	4.01	3229.5
8	6	0.00207	8.01	3875.3
8	3	0.00228	8.02	3518.2
8	0	0.00231	8.01	3460.7
10	6	0.00245	9.99	4078.3
10	3	0.00262	9.99	3807.6
10	0	0.00263	10.00	3802.2
6	2	0.00167	6.01	3610.6
20	15	0.00263	19.96	7577.7
6	2	0.00155	6.01	3883.0

Resilient Modulus Test
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Sample Number: 147
Sample Description: A-4(5) Soil; w=14.4%; No F/T or Imbibition
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 118.3 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 0

Date: Saturday, 2/23/1991 Time: 11:48: 5

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00012	1.00	8446.3
2	6	0.00026	2.00	7554.8
4	6	0.00091	4.01	4404.7
8	6	0.00400	8.01	1999.5
10	6	0.00519	10.01	1928.1
6	2	0.00399	5.99	1502.6
1	6	0.00018	1.00	5587.9
1	3	0.00027	0.98	3565.4
1	0	0.00033	1.00	2983.2
2	6	0.00051	1.99	3908.6
2	3	0.00080	2.01	2519.6
2	0	0.00100	2.01	2001.6
4	6	0.00171	4.00	2342.2
4	3	0.00231	4.01	1732.6
4	0	0.00261	4.00	1532.4
8	6	0.00396	8.02	2024.3
8	3	0.00456	8.01	1753.9
8	0	0.00479	7.98	1664.6
10	6	0.00471	9.99	2120.8
10	3	0.00527	9.99	1895.0
10	0	0.00543	10.01	1843.8
6	2	0.00341	6.01	1762.9
20	15	0.00773	19.88	2573.3
6	2	0.00320	6.00	1873.7

Resilient Modulus Test

Sample Number: 154
Sample Description: a-4(5) soil; w= 14.4%; 2 f/t
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 118.0 pcf   Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 2

Date: Wednesday, 3/16/1991   Time: 10:38:56

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00018	1.00	5531.4
2	6	0.00054	2.00	3674.8
4	6	0.00199	4.00	2010.3
8	6	0.00446	7.99	1790.7
10	6	0.00539	10.00	1855.1
6	2	0.00386	6.01	1557.8
1	6	0.00031	1.00	3277.0
1	3	0.00029	1.00	3445.3
1	0	0.00028	1.02	3625.2
2	6	0.00092	2.01	2182.0
2	3	0.00094	2.01	2143.2
2	0	0.00092	1.99	2166.4
4	6	0.00268	4.00	1492.5
4	3	0.00271	4.03	1488.4
4	0	0.00272	4.01	1472.3
8	6	0.00510	8.00	1568.2
8	3	0.00510	8.00	1567.2
8	0	0.00513	7.99	1557.5
10	6	0.00591	10.01	1692.4
10	3	0.00596	10.01	1679.4
10	0	0.00594	10.03	1688.1
6	2	0.00443	5.99	1352.2
20	15	0.00926	20.01	2161.6
6	2	0.00407	6.00	1473.5

Resilient Modulus Test

Sample Number: 3
Sample Description: a-4(5) soil; no imbibe; no f/t
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 115.9 pcf   Sample w = 13.3 %
Number of Freeze/Thaw Cycles = 0

Date: Wednesday, 10/10/90   Time: 14: 4:52

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00003	1.00	32701.4
2	6	0.00007	2.01	27149.6
4	6	0.00016	3.99	25719.0
8	6	0.00041	7.99	19664.2
10	6	0.00061	10.00	16410.7
6	2	0.00045	6.00	13223.7
1	6	0.00003	0.99	31289.4
1	3	0.00004	1.00	23503.4
1	0	0.00004	1.00	28339.8
2	6	0.00006	2.00	31144.0
2	3	0.00008	2.00	25129.6
2	0	0.00009	1.99	21695.9
4	6	0.00018	3.98	21695.0
4	3	0.00023	3.98	17669.0
4	0	0.00025	3.99	15947.1
8	6	0.00051	8.01	15638.8
8	3	0.00064	8.00	12495.2
8	0	0.00073	8.02	10987.0
10	6	0.00075	9.99	13337.9
10	3	0.00090	10.00	11097.4
10	0	0.00105	10.00	9559.5
6	2	0.00054	6.01	11187.4
20	15	0.00214	19.89	9272.1
6	2	0.00053	6.01	11335.9

Resilient Modulus Test
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Sample Number: 200
Sample Description: a-6(2) soil; 2 F/T; + .9%
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 114.5 pcf Sample w = 15.4 %
Number of Freeze/Thaw Cycles = 2

Date: Saturday, 8/17/1991 Time: 15:41:25

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00015	1.01	6576.9
2	6	0.00066	2.00	3012.4
4	6	0.00225	4.00	1782.2
8	6	0.00451	7.98	1769.3
10	6	0.00512	10.00	1955.1
6	2	0.00341	6.00	1758.2
1	6	0.00009	1.00	10906.3
1	3	0.00015	0.99	6759.3
1	0	0.00018	1.00	5484.9
2	6	0.00040	1.99	4955.9
2	3	0.00057	2.01	3530.9
2	0	0.00070	2.00	2865.7
4	6	0.00146	4.00	2742.2
4	3	0.00179	3.98	2221.4
4	0	0.00200	4.00	1993.4
8	6	0.00373	8.00	2147.3
8	3	0.00399	8.00	2004.6
8	0	0.00404	8.03	1987.8
10	6	0.00442	10.01	2265.8
10	3	0.00479	10.01	2091.7
10	0	0.00495	10.00	2022.2
6	2	0.00282	6.00	2125.5
20	15	0.01069	19.91	1862.0
6	2	0.00204	6.00	2935.7

Resilient Modulus Test
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Sample Number: 202
Sample Description: A-6(2) soil; w = 14.5%; 2 F/T
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 113.4 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 2

Date: Wednesday, 8/21/1991 Time: 3:54:23

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00012	0.99	7969.9
2	6	0.00065	2.00	3060.1
4	6	0.00219	3.99	1825.6
8	6	0.00434	8.01	1846.4
10	6	0.00480	9.99	2079.0
6	2	0.00328	6.01	1831.7
1	6	0.00011	0.99	8754.5
1	3	0.00016	0.97	6211.6
1	0	0.00023	1.00	4406.5
2	6	0.00034	2.01	5909.6
2	3	0.00051	2.00	3907.8
2	0	0.00070	1.99	2834.5
4	6	0.00111	4.00	3592.5
4	3	0.00160	4.00	2498.8
4	0	0.00195	4.00	2054.1
8	6	0.00306	8.01	2620.4
8	3	0.00366	7.99	2181.1
8	0	0.00385	8.00	2077.2
10	6	0.00371	10.00	2694.2
10	3	0.00423	9.97	2357.1
10	0	0.00436	9.98	2290.2
6	2	0.00225	5.99	2658.1
20	15	0.01166	19.63	1683.3
6	2	0.00144	6.00	4164.1

Resilient Modulus Test

Sample Number: 203
Sample Description: A-6(2) Soil; 8 F/T; w = 14.5%
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 115.9 pcf Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 8

Date: Tuesday, 8/27/1991 Time: 23:11:53

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00050	0.99	1973.5
2	6	0.00141	2.01	1425.9
4	6	0.00312	4.01	1284.9
8	6	0.00488	8.01	1642.1
10	6	0.00528	10.00	1894.2
6	2	0.00371	5.98	1612.0
1	6	0.00018	1.01	5762.0
1	3	0.00027	1.06	3995.7
1	0	0.00031	0.99	3204.8
2	6	0.00059	1.98	3367.5
2	3	0.00079	2.00	2539.1
2	0	0.00064	1.54	2383.1
4	6	0.00197	4.00	2034.0
4	3	0.00228	4.00	1755.8
4	0	0.00252	4.01	1591.7
8	6	0.00422	7.99	1893.1
8	3	0.00435	8.01	1841.3
8	0	0.00464	8.00	1723.5
10	6	0.00497	10.01	2014.7
10	3	0.00512	10.00	1953.8
10	0	0.00517	10.00	1935.6
6	2	0.00327	6.00	1836.7
20	15	0.00842	20.04	2380.4
6	2	0.00275	6.01	2185.3

Resilient Modulus Test

Sample Number: 204
Sample Description: A-6(2) Soil; Non-Imbibed
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 117.0 pcf Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 8/5/1991 Time: 21:35:39

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00000	0.99	808147.6
2	6	0.00000	2.01	941472.0
4	6	0.00010	4.01	40354.8
8	6	0.00048	7.81	16320.7
10	6	0.00041	7.81	19158.4
6	2	0.00039	6.01	15314.3
1	6	0.00000	0.99	217040.1
1	3	0.00001	1.01	143944.9
1	0	0.00000	1.01	366314.4
2	6	0.00000	1.99	1301665.3
2	3	0.00000	1.99	933664.6
2	0	0.00001	1.99	151735.5
4	6	0.00008	4.02	51015.2
4	3	0.00011	4.00	36592.4
4	0	0.00015	3.99	26985.7
8	6	0.00034	7.81	22865.5
8	3	0.00053	7.96	15058.7
8	0	0.00082	8.04	9801.5
10	6	0.00039	7.76	19888.1
10	3	0.00053	7.91	15053.0
10	0	0.00077	7.68	9930.4
6	2	0.00031	6.01	19189.1
20	15	0.00035	7.31	20837.2
6	2	0.00030	6.00	19863.8

Resilient Modulus Test

Sample Number: 205
Sample Description: A-6(2) Soil; w = 14.5%; 4 F/T
GammaDMax = 112.0 pcf   Optimum w = 14.5 %
SampleGamma = 115.8 pcf   Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 4

Date: Tuesday, 8/20/1991   Time: 19: 3:24

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00016	1.21	7510.3
2	6	0.00041	1.99	4910.7
4	6	0.00157	4.00	2541.0
8	6	0.00264	8.01	3028.4
10	6	0.00261	10.00	3826.9
6	2	0.00205	5.99	2930.2
1	6	0.00007	0.99	13316.7
1	3	0.00018	1.00	5426.6
1	0	0.00029	1.01	3433.2
2	6	0.00085	2.01	2357.6
2	3	0.00074	2.00	2702.6
2	0	0.00090	1.99	2221.7
4	6	0.00114	3.99	3505.5
4	3	0.00147	4.00	2718.1
4	0	0.00168	4.00	2376.7
8	6	0.00211	8.02	3803.1
8	3	0.00231	8.01	3471.9
8	0	0.00415	8.01	1930.8
10	6	0.00403	10.00	2479.6
10	3	0.00469	10.01	2131.7
10	0	0.00484	9.98	2062.6
6	2	0.00283	6.01	2121.6
20	15	0.00978	19.87	2031.1
6	2	0.00257	5.99	2334.6

Resilient Modulus Test

Sample Number: 206
Sample Description: A-6(2) Soil; w = 15.4%; 4 F/T cycles
GammaDMax = 112.0 pcf   Optimum w = 14.5 %
SampleGamma = 113.4 pcf   Sample w = 15.5 %
Number of Freeze/Thaw Cycles = 4

Date: Tuesday, 8/20/1991   Time: 22: 1: 2

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00041	1.01	2462.7
2	6	0.00132	2.00	1517.9
4	6	0.00358	4.00	1116.7
8	6	0.00496	8.01	1615.7
10	6	0.00566	9.98	1763.7
6	2	0.00377	5.98	1586.1
1	6	0.00018	1.02	5667.3
1	3	0.00021	0.97	4579.1
1	0	0.00030	1.07	3566.6
2	6	0.00054	1.99	3647.9
2	3	0.00096	2.43	2517.1
2	0	0.00088	1.99	2258.5
4	6	0.00178	4.01	2258.4
4	3	0.00210	4.00	1902.1
4	0	0.00251	4.00	1598.2
8	6	0.00406	8.01	1974.6
8	3	0.00438	8.00	1826.2
8	0	0.00477	7.99	1674.1
10	6	0.00483	9.98	2063.9
10	3	0.00490	10.00	2042.5
10	0	0.00515	10.02	1943.1
6	2	0.00305	6.02	1975.9
20	15	0.00736	19.97	2713.6
6	2	0.00219	6.00	2746.7

Resilient Modulus Test
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Sample Number: 207
Sample Description: A-6(2) Soil; w=13.5%; 4 F/T
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 116.9 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 4

Date: Monday, 9/2/1991 Time: 18:48:15

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00020	0.67	3363.9
2	6	0.00095	2.00	2114.2
4	6	0.00267	3.99	1498.1
8	6	0.00488	8.00	1638.1
10	6	0.00571	10.00	1751.8
6	2	0.00419	6.01	1436.6
1	6	0.00024	1.05	4343.1
1	3	0.00031	1.00	3178.8
1	0	0.00040	1.00	2491.2
2	6	0.00061	1.99	3241.1
2	3	0.00091	1.99	2197.7
2	0	0.00117	2.01	1713.3
4	6	0.00215	4.01	1866.8
4	3	0.00288	4.39	1526.2
4	0	0.00294	4.00	1360.8
8	6	0.00450	7.99	1773.2
8	3	0.00504	8.00	1588.9
8	0	0.00504	7.79	1543.6
10	6	0.00501	10.00	1995.7
10	3	0.00514	10.00	1945.1
10	0	0.00554	10.00	1805.7
6	2	0.00325	6.01	1848.3
20	15	0.00778	20.07	2579.9
6	2	0.00307	5.97	1944.7

Resilient Modulus Test
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Sample Number: 208
Sample Description: A-6(2) Soil; w=13.5%; 8 F/T
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 116.3 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 8

Date: Friday, 11/15/1991 Time: 13:47:43

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00035	0.74	2117.1
2	6	0.00136	1.92	1411.8
4	6	0.00284	4.01	1410.5
8	6	0.00562	8.07	1436.1
10	6	0.00634	9.98	1573.7
6	2	0.00424	6.04	1424.9
1	6	0.00025	0.98	3925.0
1	3	0.00030	0.99	3285.7
1	0	0.00060	1.31	2183.5
2	6	0.00056	1.48	2645.6
2	3	0.00100	1.98	1985.5
2	0	0.00134	2.23	1660.5
4	6	0.00260	4.12	1583.8
4	3	0.00281	4.20	1496.9
4	0	0.00287	4.00	1396.5
8	6	0.00516	8.16	1581.1
8	3	0.00545	8.02	1471.3
8	0	0.00559	7.99	1427.6
10	6	0.00574	9.99	1740.6
10	3	0.00591	9.98	1689.4
10	0	0.00613	10.03	1637.3
6	2	0.00377	5.98	1585.9
20	15	0.00947	19.97	2108.7
6	2	0.00307	6.00	1955.7

Resilient Modulus Test

Sample Number: 210
Sample Description: A-6(2) Soil; NO F/T or Imbibition
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 116.8 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 0

Date: Wednesday, 8/21/1991 Time: 15:14:26

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00000	1.00	233227.8
2	6	0.00003	1.99	58802.0
4	6	0.00009	4.01	45433.5
8	6	0.00026	8.01	30667.6
10	6	0.00038	9.99	26159.0
6	2	0.00021	6.01	28161.8
1	6	0.00000	1.00	235008.4
1	3	0.00001	1.00	149441.9
1	0	0.00002	1.01	50380.5
2	6	0.00002	2.00	91032.6
2	3	0.00002	1.58	68099.9
2	0	0.00002	1.99	81402.0
4	6	0.00009	4.01	42978.3
4	3	0.00010	4.00	42021.2
4	0	0.00010	3.99	39284.8
8	6	0.00031	7.99	26026.2
8	3	0.00031	8.01	25429.1
8	0	0.00033	7.99	24379.7
10	6	0.00044	10.02	22934.1
10	3	0.00045	10.01	22037.9
10	0	0.00048	9.98	20910.9
6	2	0.00022	6.00	26917.9
20	15	0.00106	20.03	18830.5
6	2	0.00022	5.99	27373.2

Resilient Modulus Test

Sample Number: 211
Sample Description: a-6(2) soil; no F/T; w = 13.5%; Imbibed
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 115.9 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 0

Date: Sunday, 8/25/1991 Time: 15:23:49

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00002	0.99	46467.5
2	6	0.00008	2.02	26711.1
4	6	0.00120	4.02	3341.1
8	6	0.00329	7.99	2431.7
10	6	0.00348	9.99	2871.4
6	2	0.00278	6.00	2157.2
1	6	0.00002	1.02	46893.4
1	3	0.00009	1.17	12984.3
1	0	0.00013	1.01	7855.3
2	6	0.00019	2.00	10409.1
2	3	0.00043	2.00	4656.6
2	0	0.00061	2.01	3314.9
4	6	0.00104	4.01	3860.7
4	3	0.00142	4.00	2820.5
4	0	0.00174	4.02	2312.2
8	6	0.00283	7.99	2825.6
8	3	0.00302	7.99	2645.4
8	0	0.00316	7.98	2524.6
10	6	0.00307	10.02	3269.1
10	3	0.00314	10.01	3185.0
10	0	0.00322	10.01	3110.0
6	2	0.00203	6.00	2957.7
20	15	0.00368	20.01	5444.8
6	2	0.00223	6.21	2790.4

Resilient Modulus Test

Sample Number: 212
Sample Description: a-6(2) Soil; No F/T; Imbibed
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 116.8 pcf Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 0

Date: Tuesday, 8/27/1991 Time: 20:13:32

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00008	1.01	12242.4
2	6	0.00022	2.01	9345.2
4	6	0.00079	3.96	4983.2
8	6	0.00263	8.02	3045.5
10	6	0.00348	10.00	2875.8
6	2	0.00232	6.02	2593.8
1	6	0.00007	0.98	14403.6
1	3	0.00004	0.69	16485.0
1	0	0.00011	1.01	9132.4
2	6	0.00021	2.24	10898.5
2	3	0.00027	1.98	7404.2
2	0	0.00038	1.99	5284.7
4	6	0.00084	4.02	4781.5
4	3	0.00113	4.00	3551.4
4	0	0.00129	4.00	3099.9
8	6	0.00254	8.00	3143.7
8	3	0.00294	8.01	2728.4
8	0	0.00316	7.99	2528.5
10	6	0.00324	9.99	3085.0
10	3	0.00362	10.02	2765.5
10	0	0.00374	10.00	2670.3
6	2	0.00188	5.99	3193.1
20	15	0.00773	19.89	2575.2
6	2	0.00125	5.99	4805.5

Resilient Modulus Test

Sample Number: 213
Sample Description: A-6(2) Soil; No F/T; w = 15.4%; Imbibed
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 115.5 pcf Sample w = 15.4 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 9/2/1991 Time: 15:53:15

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00011	0.99	9054.0
2	6	0.00023	1.99	8728.5
4	6	0.00099	4.00	4042.9
8	6	0.00370	7.99	2157.7
10	6	0.00435	10.02	2302.0
6	2	0.00305	6.02	1975.1
1	6	0.00008	1.01	12495.1
1	3	0.00011	1.00	8789.4
1	0	0.00015	1.01	6746.7
2	6	0.00031	2.00	6487.8
2	3	0.00044	2.01	4586.1
2	0	0.00042	1.59	3777.3
4	6	0.00116	3.92	3368.7
4	3	0.00156	4.00	2570.2
4	0	0.00186	3.99	2152.5
8	6	0.00409	7.99	1954.4
8	3	0.00347	8.00	2308.4
8	0	0.00367	8.02	2185.2
10	6	0.00373	10.00	2680.3
10	3	0.00411	9.98	2429.6
10	0	0.00436	9.99	2290.3
6	2	0.00249	5.99	2405.3
20	15	0.00683	19.95	2921.9
6	2	0.00220	6.00	2727.1

Resilient Modulus Test

Sample Number: 214
Sample Description: A-6(2) Soil; 2 F/T; w = 13.5%
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 116.7 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 2

Date: Tuesday, 9/3/1991 Time: 9:47:40

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00011	0.75	6974.4
2	6	0.00045	2.01	4478.2
4	6	0.00139	4.00	2873.3
8	6	0.00335	8.00	2386.4

SAMPLE FAILED DUE TO LOST CONTACT WITH SPECIMEN -
SAMPLE WAS RE-COMPACTED AND CONDITIONED AND TESTED.
(SEE SAMPLE # 305)

Resilient Modulus Test

Sample Number: 215
Sample Description: A-6(2) Soil; 1 F/T; w = 15.4%
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 115.0 pcf Sample w = 15.4 %
Number of Freeze/Thaw Cycles = 1

Date: Tuesday, 9/10/1991 Time: 21: 5:46

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00017	1.01	6103.1
2	6	0.00045	2.03	4560.2
4	6	0.00127	4.01	3147.2
8	6	0.00349	8.00	2290.5
10	6	0.00416	10.02	2407.3
6	2	0.00284	6.00	2113.6
1	6	0.00009	1.01	10930.9
1	3	0.00013	0.99	7816.6
1	0	0.00018	0.99	5470.0
2	6	0.00029	2.00	6979.9
2	3	0.00037	1.80	4894.4
2	0	0.00055	2.01	3682.4
4	6	0.00106	4.00	3767.9
4	3	0.00138	4.00	2895.8
4	0	0.00171	4.01	2345.3
8	6	0.00303	7.99	2641.6
8	3	0.00339	8.02	2363.8
8	0	0.00389	8.00	2058.0
10	6	0.00379	10.02	2643.2
10	3	0.00423	10.02	2372.7
10	0	0.00452	9.99	2209.0
6	2	0.00230	6.00	2612.9
20	15	0.00763	20.05	2628.4
6	2	0.00170	6.01	3534.9

Resilient Modulus Test

Sample Number: 216
Sample Description: A-6(2) Soil; 1 F/T; w= 14.5%
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 116.8 pcf Sample w = 14.5 %
Number of Freeze/Thaw Cycles = 1

Date: Monday, 9/9/1991 Time: 11:53:13

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00005	1.00	19254.9
2	6	0.00012	2.00	16214.1
4	6	0.00072	4.00	5544.2
8	6	0.00225	8.00	3551.3
10	6	0.00291	9.99	3437.8
6	2	0.00198	5.98	3025.3
1	6	0.00010	1.02	10440.8
1	3	0.00012	1.00	8243.0
1	0	0.00014	0.91	6344.2
2	6	0.00027	2.02	7462.8
2	3	0.00034	2.00	5810.9
2	0	0.00032	1.56	4898.6
4	6	0.00083	4.01	4806.4
4	3	0.00111	4.13	3716.1
4	0	0.00123	3.99	3236.7
8	6	0.00220	7.82	3557.3
8	3	0.00259	7.76	2994.1
8	0	0.00291	7.97	2737.2
10	6	0.00285	9.98	3498.6
10	3	0.00327	10.00	3054.7
10	0	0.00350	9.99	2856.7
6	2	0.00187	5.98	3193.9
20	15	0.00544	20.01	3678.5
6	2	0.00141	5.78	4095.4

Resilient Modulus Test

Sample Number: 217
Sample Description: A-6(2) Soil; 1 F/T
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 116.0 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 1

Date: Sunday, 10/13/1991 Time: 18:39:41

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00021	1.77	8557.0
2	6	0.00027	1.99	7382.4
4	6	0.00089	3.95	4455.4
8	6	0.00261	8.16	3128.9
10	6	0.00330	9.99	3024.4
6	2	0.00224	6.00	2673.4
1	6	0.00010	0.87	8686.2
1	3	0.00014	0.96	7068.5
1	0	0.00018	0.97	5313.5
2	6	0.00043	2.37	5544.1
2	3	0.00040	1.96	4951.7
2	0	0.00051	2.01	3913.8
4	6	0.00109	4.40	4017.5
4	3	0.00119	3.89	3274.7
4	0	0.00145	4.05	2801.3
8	6	0.00252	7.99	3175.4
8	3	0.00294	8.31	2823.0
8	0	0.00324	8.04	2482.3
10	6	0.00314	10.02	3186.5
10	3	0.00350	10.02	2861.9
10	0	0.00385	9.99	2594.2
6	2	0.00215	5.87	2727.4
20	15	0.00529	19.97	3775.9
6	2	0.00212	6.03	2842.0

Resilient Modulus Test

Sample Number: 305
Sample Description: A-6(2) Soil; w=13.5%; 2 F/T; retest and resample
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 114.5 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 2

Date: Wednesday, 10/16/1991 Time: 19:26:26

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00030	1.20	3944.1
2	6	0.00060	1.96	3273.2
4	6	0.00172	3.99	2325.6
8	6	0.00423	8.01	1893.5
10	6	0.00522	10.03	1920.0
6	2	0.00384	5.99	1558.9
1	6	0.00021	0.97	4546.7
1	3	0.00028	0.93	3339.4
1	0	0.00082	1.77	2164.3
2	6	0.00082	2.40	2928.7
2	3	0.00081	1.90	2348.4
2	0	0.00102	2.00	1966.0
4	6	0.00196	4.34	2209.5
4	3	0.00219	3.90	1776.8
4	0	0.00262	4.21	1605.6
8	6	0.00404	8.02	1984.5
8	3	0.00450	8.00	1778.6
8	0	0.00495	8.00	1613.9
10	6	0.00490	10.00	2040.2
10	3	0.00540	10.00	1849.8
10	0	0.00593	9.98	1682.2
6	2	0.00358	6.03	1683.5
20	15	0.00760	19.86	2614.8
6	2	0.00343	6.00	1749.0

Resilient Modulus Test

Sample Number: 302
Sample Description: A-7-6(14) Soil; 1 F/T
GammaDMax = 101.0 pcf Optimum w = 21.4 %
SampleGamma = 99.8 pcf Sample w = 23.5 %
Number of Freeze/Thaw Cycles = 2

Date: Tuesday, 10/15/1991 Time: 19:25:19

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00033	1.11	3340.0
2	6	0.00119	2.01	1688.2
4	6	0.00435	4.37	1005.1
8	6	0.00700	7.99	1141.6
10	6	0.00644	9.91	1538.9
6	2	0.00376	5.98	1589.2
1	6	0.00018	1.23	6827.3
1	3	0.00014	0.88	6425.6
1	0	0.00009	0.81	8894.8
2	6	0.00038	1.63	4333.3
2	3	0.00058	2.04	3527.4
2	0	0.00043	1.66	3821.1
4	6	0.00219	4.14	1895.3
4	3	0.00239	4.28	1790.9
4	0	0.00226	3.99	1761.9
8	6	0.00452	7.99	1769.9
8	3	0.00446	7.97	1789.2
8	0	0.00485	7.89	1628.0
10	6	0.00523	10.03	1919.5
10	3	0.00549	9.98	1817.6
10	0	0.00572	10.17	1778.8
6	2	0.00342	5.99	1749.6
20	15	0.00830	16.48	1985.9
6	2	0.00288	5.81	2013.4

Resilient Modulus Test

Sample Number: 301
Sample Description: A-7-6(14) Soil; No F/T; Imbibed
GammaDMax = 101.0 pcf   Optimum w = 22.4 %
SampleGamma = 99.5 pcf   Sample w = 23.5 %
Number of Freeze/Thaw Cycles = 0

Date: Sunday, 10/13/1991   Time: 15:20:46

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00007	1.20	18135.1
2	6	0.00020	1.68	8331.4
4	6	0.00318	4.19	1316.3
8	6	0.00739	8.00	1082.7
10	6	0.00769	10.13	1318.0
6	2	0.00370	5.79	1564.4
1	6	0.00015	1.00	6912.0
1	3	0.00013	0.98	7750.5
1	0	0.00013	1.00	7886.4
2	6	0.00047	2.01	4272.3
2	3	0.00049	1.99	4051.8
2	0	0.00059	2.15	3627.2
4	6	0.00203	4.00	1966.5
4	3	0.00217	4.03	1862.2
4	0	0.00212	4.01	1895.9
8	6	0.00509	8.00	1572.1
8	3	0.00538	8.00	1487.1
8	0	0.00546	8.00	1466.2
10	6	0.00681	9.94	1458.7
10	3	0.00697	10.21	1463.5
10	0	0.00690	9.89	1432.8
6	2	0.00450	5.99	1330.9
20	15	0.01119	19.18	1714.7
6	2	0.00329	5.99	1822.6

Resilient Modulus Test

Sample Number: 303
Sample Description: A-4(5) Soil; 2 f/t; w = 14.4%
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 116.7 pcf   Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 2

Date: Wednesday, 10/23/1991   Time: 15: 0:53

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00015	0.98	6523.3
2	6	0.00040	2.02	5110.5
4	6	0.00121	3.99	3281.7
8	6	0.00352	8.00	2276.2
10	6	0.00452	9.94	2199.5
6	2	0.00341	6.02	1765.8
1	6	0.00047	1.50	3208.6
1	3	0.00031	0.91	2890.7
1	0	0.00039	0.89	2275.1
2	6	0.00071	2.06	2887.7
2	3	0.00109	2.20	2025.0
2	0	0.00117	1.92	1639.6
4	6	0.00183	4.03	2202.0
4	3	0.00233	4.28	1836.8
4	0	0.00258	3.99	1547.6
8	6	0.00362	8.01	2210.9
8	3	0.00397	7.99	2010.6
8	0	0.00428	7.99	1868.1
10	6	0.00421	9.96	2364.4
10	3	0.00482	10.04	2085.3
10	0	0.00528	9.99	1892.5
6	2	0.00356	6.10	1714.3
20	15	0.00467	17.88	3825.4
6	2	0.00328	6.01	1832.0

Resilient Modulus Test
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Sample Number: 304
Sample Description: A-2-6(1) Soil; 2 F/T
GammaDMax = 125.0 pcf   Optimum w = 11.0 %
SampleGamma = 125.6 pcf   Sample w = 11.0 %
Number of Freeze/Thaw Cycles = 2

Date: Tuesday, 10/15/1991   Time: 10:49:19

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00010	0.57	6007.2
2	6	0.00039	2.01	5132.8
4	6	0.00113	4.09	3615.7
8	6	0.00244	7.91	3239.3
10	6	0.00283	10.02	3537.0
6	2	0.00191	5.88	3076.9
1	6	0.00012	1.01	8434.5
1	3	0.00016	0.98	6132.8
1	0	0.00018	0.87	4953.3
2	6	0.00029	2.00	6893.2
2	3	0.00038	2.01	5243.6
2	0	0.00050	2.01	4016.3
4	6	0.00074	3.66	4930.5
4	3	0.00106	3.99	3764.2
4	0	0.00135	4.38	3254.1
8	6	0.00216	8.01	3708.9
8	3	0.00248	8.08	3256.3
8	0	0.00258	8.04	3117.3
10	6	0.00260	10.00	3849.5
10	3	0.00293	10.27	3512.2
10	0	0.00296	10.00	3375.5
6	2	0.00166	6.34	3827.6
20	15	0.00828	19.51	2354.8
6	2	0.00069	5.99	8706.7

Resilient Modulus Test
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Sample Number: 305
Sample Description: A-6(2) Soil; w=13.5%; 2 F/T; retest and resample
GammaDMax = 112.0 pcf   Optimum w = 14.5 %
SampleGamma = 114.5 pcf   Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 2

Date: Wednesday, 10/16/1991   Time: 19:26:26

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00030	1.20	3944.1
2	6	0.00060	1.96	3273.2
4	6	0.00172	3.99	2325.6
8	6	0.00423	8.01	1893.5
10	6	0.00522	10.03	1920.0
6	2	0.00384	5.99	1558.9
1	6	0.00021	0.97	4546.7
1	3	0.00028	0.93	3339.4
1	0	0.00082	1.77	2164.3
2	6	0.00082	2.40	2928.7
2	3	0.00081	1.90	2348.4
2	0	0.00102	2.00	1966.0
4	6	0.00196	4.34	2209.5
4	3	0.00219	3.90	1776.8
4	0	0.00262	4.21	1605.6
8	6	0.00404	8.02	1984.5
8	3	0.00450	8.00	1778.6
8	0	0.00495	8.00	1613.9
10	6	0.00490	10.00	2040.2
10	3	0.00540	10.00	1849.8
10	0	0.00593	9.98	1682.2
6	2	0.00358	6.03	1683.5
20	15	0.00760	19.86	2614.8
6	2	0.00343	6.00	1749.0

Resilient Modulus Test
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Sample Number: 306
Sample Description: A-4(5) Soil; w = 14.4%; 1 F/T
GammaDMax = 117.7 pcf   Optimum w = 14.4 %
SampleGamma = 116.7 pcf   Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 1

Date: Friday, 10/18/1991   Time: 20:29:37

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00014	1.00	7318.8
2	6	0.00032	1.95	6185.3
4	6	0.00093	4.01	4319.5
8	6	0.00261	8.01	3067.7
10	6	0.00353	10.02	2837.7
6	2	0.00278	5.88	2112.7
1	6	0.00018	0.99	5559.3
1	3	0.00041	1.41	3437.5
1	0	0.00034	0.98	2909.7
2	6	0.00046	2.01	4369.5
2	3	0.00067	2.00	2971.6
2	0	0.00093	2.04	2198.7
4	6	0.00124	4.12	3335.3
4	3	0.00157	3.91	2495.5
4	0	0.00218	4.42	2027.3
8	6	0.00268	7.98	2975.7
8	3	0.00323	8.00	2474.4
8	0	0.00360	7.99	2216.2
10	6	0.00337	10.01	2970.4
10	3	0.00406	10.00	2462.6
10	0	0.00456	10.16	2227.5
6	2	0.00277	5.97	2153.5
20	15	0.00412	19.87	4823.5
6	2	0.00277	6.00	2164.5

Resilient Modulus Test
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Sample Number: 307
Sample Description: A-7-6(14) Soil; No F/T or Imbibition
GammaDMax = 101.0 pcf   Optimum w = 22.4 %
SampleGamma = 99.5 pcf   Sample w = 23.5 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 10/7/1991   Time: 13:43:48

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00070	1.21	1728.1
2	6	0.00210	1.61	767.9
4	6	0.00566	3.99	704.8
8	6	0.00711	8.01	1127.5
10	6	0.00209	10.08	4828.7

SAMPLE LOST CONTACT WITH LOAD CELL; RETEST WITH NEW SAMPLE. (SAMPLE # 315)

Resilient Modulus Test

Sample Number: 308
Sample Description: A-2-6(1) Soil; 1 F/T
GammaDMax = 125.0 pcf Optimum w = 11.0 %
SampleGamma = 125.3 pcf Sample w = 11.0 %
Number of Freeze/Thaw Cycles = 1

Date: Monday, 10/21/1991 Time: 14: 7:48

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00010	0.99	10059.8
2	6	0.00023	1.99	8629.8
4	6	0.00060	4.00	6707.4
8	6	0.00094	8.00	8469.9
10	6	0.00127	10.01	7852.1
6	2	0.00097	5.85	6019.8
1	6	0.00010	1.64	16593.8
1	3	0.00007	0.98	13149.1
1	0	0.00011	1.02	9502.4
2	6	0.00014	2.01	14766.9
2	3	0.00017	1.98	11485.2
2	0	0.00030	2.00	6648.3
4	6	0.00036	4.02	11135.1
4	3	0.00048	3.79	7938.3
4	0	0.00065	4.01	6193.7
8	6	0.00098	8.01	8146.5
8	3	0.00116	7.99	6890.6
8	0	0.00127	7.98	6292.0
10	6	0.00114	9.99	8767.0
10	3	0.00139	9.99	7193.4
10	0	0.00146	9.98	6835.7
6	2	0.00074	5.96	8073.7
20	15	0.00585	18.20	3108.8
6	2	0.00043	6.06	13984.6

Resilient Modulus Test

Sample Number: 309
Sample Description: A-2-6(1) Soil; No F/T or Imbibition
GammaDMax = 125.0 pcf Optimum w = 11.0 %
SampleGamma = 125.5 pcf Sample w = 11.0 %
Number of Freeze/Thaw Cycles = 0

Date: Thursday, 10/10/1991 Time: 8:59: 0

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00001	0.64	47613.1
2	6	0.00004	2.00	45156.1
4	6	0.00010	3.65	37959.3
8	6	0.00036	8.00	21913.7
10	6	0.00051	9.96	19456.7
6	2	0.00035	6.05	17144.4
1	6	0.00001	0.98	74641.4
1	3	0.00003	0.99	37549.2
1	0	0.00003	1.04	32875.7
2	6	0.00005	1.92	40585.0
2	3	0.00005	2.03	38451.7
2	0	0.00010	2.64	25160.1
4	6	0.00073	4.00	5497.4
4	3	0.00037	3.99	10665.8
4	0	0.00039	3.59	9174.7
8	6	0.00095	8.38	8778.8
8	3	0.00115	8.00	6942.1
8	0	0.00142	7.99	5620.8
10	6	0.00125	10.15	8126.7
10	3	0.00155	9.99	6422.5
10	0	0.00188	9.99	5307.8
6	2	0.00087	6.00	6913.9
20	15	0.00283	20.23	7143.3
6	2	0.00074	6.00	8053.0

Resilient Modulus Test

Sample Number: 311
Sample Description: A-7-6(14) Soil; 2 F/T
GammaDMax = 101.0 pcf Optimum w = 22.4 %
SampleGamma = 99.6 pcf Sample w = 23.5 %
Number of Freeze/Thaw Cycles = 2

Date: Tuesday, 10/22/1991 Time: 20:30:48

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00047	1.07	2292.9
2	6	0.00200	1.88	936.8
4	6	0.00518	4.43	855.5
8	6	0.00178	8.03	4499.0
10	6	0.00000	9.99	999212829.5
6	2	0.00320	5.98	1866.7
1	6	0.00011	0.98	9223.1
1	3	0.00012	0.99	8517.4
1	0	0.00020	1.32	6638.6
2	6	0.00035	1.67	4822.4
2	3	0.00051	1.99	3916.6
2	0	0.00045	1.79	4030.2
4	6	0.00192	4.22	2199.6
4	3	0.00183	3.73	2036.5
4	0	0.00199	4.01	2015.0
8	6	0.00418	7.97	1909.7
8	3	0.00465	8.03	1726.4
8	0	0.00487	8.05	1651.5
10	6	0.00495	10.00	2020.0
10	3	0.00453	10.02	2210.4

DATA LOST DUE TO EXCESSIVE PLASTIC DEFORMATION;
LOAD PISTON BEYOND LIMITS OF EXTENSION.

Resilient Modulus Test

Sample Number: 312
Sample Description: A-2-6(1) Soil; No F/T; Imbibed
GammaDMax = 125.0 pcf Optimum w = 11.0 %
SampleGamma = 125.7 pcf Sample w = 11.0 %
Number of Freeze/Thaw Cycles = 0

Date: Saturday, 10/19/1991 Time: 10:36:33

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00015	1.57	10177.8
2	6	0.00023	2.00	8743.7
4	6	0.00069	4.05	5872.7
8	6	0.00193	8.01	4144.6
10	6	0.00244	10.02	4113.4
6	2	0.00161	5.85	3623.2
1	6	0.00008	0.91	10863.1
1	3	0.00009	0.74	7819.1
1	0	0.00015	1.00	6622.6
2	6	0.00028	2.30	8198.5
2	3	0.00031	1.96	6275.2
2	0	0.00033	1.73	5235.8
4	6	0.00066	4.00	6049.3
4	3	0.00091	4.18	4614.5
4	0	0.00102	4.04	3957.1
8	6	0.00171	8.05	4703.8
8	3	0.00203	8.02	3960.0
8	0	0.00217	7.98	3672.8
10	6	0.00221	10.01	4525.8
10	3	0.00249	9.92	3981.6
10	0	0.00259	10.00	3854.9
6	2	0.00128	5.88	4597.6
20	15	0.00395	18.82	4763.1
6	2	0.00131	6.11	4650.0

Resilient Modulus Test

Sample Number: 313
Sample Description: A-2-6(1) Soil; 4 F/T
GammaDMax = 125.0 pcf Optimum w = 11.0 %
SampleGamma = 125.6 pcf Sample w = 11.0 %
Number of Freeze/Thaw Cycles = 4

Date: Wednesday, 11/13/1991 Time: 21:20:53

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00031	1.00	3249.7
2	6	0.00072	2.03	2818.1
4	6	0.00172	4.17	2417.5
8	6	0.00327	8.00	2448.9
10	6	0.00356	10.00	2809.0
6	2	0.00206	6.01	2912.3
1	6	0.00016	1.00	6406.0
1	3	0.00010	0.64	6493.9
1	0	0.00016	0.99	6158.7
2	6	0.00040	1.99	4995.6
2	3	0.00036	1.83	5121.7
2	0	0.00042	2.02	4803.0
4	6	0.00120	4.03	3354.3
4	3	0.00120	3.99	3333.4
4	0	0.00114	3.79	3320.9
8	6	0.00285	8.01	2815.9
8	3	0.00287	7.98	2779.6
8	0	0.00287	8.00	2788.7
10	6	0.00342	10.02	2926.9
10	3	0.00338	10.02	2967.9
10	0	0.00334	9.99	2987.8
6	2	0.00203	6.16	3032.1
20	15	0.00608	20.15	3312.5
6	2	0.00090	6.03	6715.3

Resilient Modulus Test

Sample Number: 314
Sample Description: A-4(5) Soil; w = 14.4%; 4 F/T Cycles
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 116.3 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 4

Date: Friday, 11/15/1991 Time: 20:59: 3

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00050	0.94	1878.7
2	6	0.00121	1.79	1473.9
4	6	0.00329	4.11	1248.0
8	6	0.00588	8.03	1365.4
10	6	0.00642	10.24	1594.5
6	2	0.00505	6.03	1193.3
1	6	0.00065	1.47	2257.2
1	3	0.00051	1.00	1953.8
1	0	0.00093	1.22	1313.1
2	6	0.00136	2.26	1668.5
2	3	0.00146	2.00	1370.3
2	0	0.00146	2.02	1383.5
4	6	0.00289	3.99	1379.5
4	3	0.00348	3.85	1108.3
4	0	0.00359	3.89	1084.3
8	6	0.00513	7.97	1553.6
8	3	0.00527	8.00	1519.3
8	0	0.00517	7.97	1541.6
10	6	0.00542	10.11	1866.2
10	3	0.00571	9.98	1749.6
10	0	0.00616	10.03	1628.6
6	2	0.00394	5.99	1520.1
20	15	0.00722	19.93	2759.2
6	2	0.00402	6.01	1492.9

Resilient Modulus Test

Sample Number: 315
Sample Description: A-7-6(14) Soil; No F/T or Imbibition
GammaDMax = 101.0 pcf Optimum w = 22.4 %
SampleGamma = 99.8 pcf Sample w = 23.5 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 10/28/1991 Time: 14:15:26

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00022	0.99	4383.5
2	6	0.00090	2.05	2282.7
4	6	0.00441	4.05	918.6
8	6	0.00698	7.99	1145.7
10	6	0.00673	9.80	1455.6
6	2	0.00418	5.96	1428.1
1	6	0.00013	1.02	7751.8
1	3	0.00014	1.01	7188.9
1	0	0.00022	1.15	5136.2
2	6	0.00053	1.88	3564.2
2	3	0.00068	2.03	2969.4
2	0	0.00066	1.94	2933.6
4	6	0.00226	4.01	1777.5
4	3	0.00255	4.08	1599.9
4	0	0.00269	3.83	1421.4
8	6	0.00522	7.87	1507.9
8	3	0.00571	8.03	1407.6
8	0	0.00596	8.02	1344.2
10	6	0.00645	10.27	1593.0
10	3	0.00647	10.11	1562.2
10	0	0.00685	9.98	1457.2
6	2	0.00431	5.99	1391.2
20	15	0.00789	13.78	1746.5
6	2	0.00406	6.00	1479.9

Resilient Modulus Test

Sample Number: 317
Sample Description: A-4(5) Soil; No F/T or Imbibition
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 116.5 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 0

Date: Thursday, 11/14/1991 Time: 10:40:38

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00007	0.98	15023.4
2	6	0.00029	2.02	7045.3
4	6	0.00025	3.99	5298.7
8	6	0.00192	8.01	4163.5
10	6	0.00249	10.00	4015.4
6	2	0.00167	6.30	3774.6
1	6	0.00007	1.01	14328.9
1	3	0.00009	1.00	11432.4
1	0	0.00013	0.85	6504.3
2	6	0.00020	1.88	9258.4
2	3	0.00051	2.05	4057.3
2	0	0.00051	2.01	3958.4
4	6	0.00053	4.02	7523.7
4	3	0.00069	4.01	5838.3
4	0	0.00087	4.10	4723.6
8	6	0.00162	8.00	4952.6
8	3	0.00177	7.96	4504.3
8	0	0.00185	7.99	4323.9
10	6	0.00205	9.94	4837.8
10	3	0.00227	10.05	4420.1
10	0	0.00242	10.01	4133.0
6	2	0.00147	6.01	4097.7
20	15	0.00307	20.02	6528.2
6	2	0.00150	6.00	4002.1

Resilient Modulus Test

Sample Number: 000
Sample Description: Rubber Specimen
GammaDMax = 12.0 pcf   Optimum w = 10.0 %
SampleGamma = 12.0 pcf   Sample w = 10.0 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 3/4/1991   Time: 16:14:24

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00107	1.00	929.8
2	6	0.00224	2.01	896.4
4	6	0.00485	4.00	824.4
8	6	0.00994	8.03	808.1
10	6	0.01243	10.03	806.6
6	2	0.00740	6.00	810.3
1	6	0.00099	0.99	998.2
1	3	0.00106	0.99	941.5
1	0	0.00116	1.01	868.8
2	6	0.00226	1.99	883.9
2	3	0.00233	2.01	862.6
2	0	0.00248	2.00	805.5
4	6	0.00480	4.00	833.1
4	3	0.00487	4.01	822.9
4	0	0.00507	4.01	790.4

- END OF TEST -

Resilient Modulus Test

Sample Number: 316
Sample Description: A-7-6(14) Soil; No F/T or Imbibition
GammaDMax = 101.0 pcf   Optimum w = 22.4 %
SampleGamma = 100.7 pcf   Sample w = 21.0 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 11/25/1991   Time: 21:51:18

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00000	1.63	445929.2
2	6	-0.00000	1.96	-1608006.6
4	6	0.00000	3.75	3069275.0
8	6	0.00002	8.00	524526.9
10	6	0.00001	9.98	1556827.5
6	2	0.00001	5.98	891393.4
1	6	0.00001	0.50	63520.2
1	3	0.00000	0.66	215216.1
1	0	-0.00000	0.96	-448503.9
2	6	0.00001	2.01	329369.8
2	3	-0.00000	1.95	-708808.6
2	0	0.00000	1.99	466794.8
4	6	0.00000	4.00	2183250.9
4	3	-0.00001	3.78	-728359.9
4	0	-0.00000	4.01	-1458484.4
8	6	0.00001	7.77	636549.1
8	3	0.00001	8.00	1007691.2
8	0	-0.00001	8.42	-1149629.4
10	6	-0.00000	9.98	-3271639.5
10	3	0.00001	10.01	1366959.5
10	0	-0.00001	9.98	-1817497.6
6	2	-0.00000	6.02	-3947162.9
20	15	0.00013	19.95	149578.2
6	2	0.00000	6.03	1410454.6

Resilient Modulus Test
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Sample Number: 318
Sample Description: A-7-6(14) Soil; w = 21%; Imbibed W/ no F/T
GammaDMax = 101.0 pcf   Optimum w = 22.4 %
SampleGamma = 101.0 pcf   Sample w = 21.0 %
Number of Freeze/Thaw Cycles = 0

Date: Monday, 11/18/1991   Time: 20:56:40

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00002	1.00	57224.7
2	6	0.00006	2.28	37951.6
4	6	0.00021	3.70	17268.8
8	6	0.00219	8.00	3648.7
10	6	0.00330	10.02	3034.6
6	2	0.00174	6.02	3455.8
1	6	0.00000	1.00	410783.2
1	3	0.00001	0.99	95879.1
1	0	0.00000	1.13	619481.6
2	6	0.00003	1.97	71669.4
2	3	0.00004	2.06	52018.7
2	0	0.00001	1.94	167131.2
4	6	0.00062	4.00	6445.5
4	3	0.00064	3.73	5870.5
4	0	0.00070	4.00	5679.3
8	6	0.00273	7.98	2923.5
8	3	0.00290	8.06	2779.5
8	0	0.00287	7.97	2779.8
10	6	0.00315	9.97	3167.1
10	3	0.00312	10.01	3210.3
10	0	0.00308	10.00	3248.9
6	2	0.00193	6.01	3117.1
20	15	0.00754	19.98	2650.7
6	2	0.00142	6.08	4283.6

Resilient Modulus Test
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Sample Number: 319
Sample Description: A-7-6(14) Soil; w = 21%; 1 F/T
GammaDMax = 101.0 pcf   Optimum w = 22.4 %
SampleGamma = 100.7 pcf   Sample w = 21.0 %
Number of Freeze/Thaw Cycles = 1

Date: Tuesday, 11/26/1991   Time: 21:13:36

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00007	1.00	13502.0
2	6	0.00020	2.01	10265.8
4	6	0.00067	3.72	5568.6
8	6	0.00257	7.81	3038.4
10	6	0.00376	9.97	2649.9
6	2	0.00202	6.00	2973.1
1	6	0.00007	1.03	14771.0
1	3	0.00007	0.99	15215.2
1	0	0.00007	0.98	14859.0
2	6	0.00018	1.95	10993.0
2	3	0.00021	2.19	10451.5
2	0	0.00026	2.42	9385.1
4	6	0.00092	4.30	4673.7
4	3	0.00086	4.01	4677.5
4	0	0.00087	4.00	4589.6
8	6	0.00303	7.98	2632.6
8	3	0.00319	8.08	2530.4
8	0	0.00320	8.00	2501.3
10	6	0.00405	9.95	2460.2
10	3	0.00401	9.80	2443.2
10	0	0.00392	9.99	2549.7
6	2	0.00221	6.04	2727.0
20	15	0.00859	19.92	2317.9
6	2	0.00166	6.01	3617.3

Resilient Modulus Test

Sample Number: 320
Sample Description: A-7-6(14) Soil; 2 f/t; w = 21%
GammaDMax = 101.0 pcf Optimum w = 22.4 %
SampleGamma = 100.9 pcf Sample w = 21.0 %
Number of Freeze/Thaw Cycles = 2

Date: Friday, 11/29/1991 Time: 15:34: 3

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00010	1.08	10891.7
2	6	0.00031	2.04	6496.6
4	6	0.00135	3.99	2959.1
8	6	0.00374	8.01	2144.7
10	6	0.00513	9.96	1943.2
6	2	0.00283	6.03	2130.0
1	6	0.00001	0.99	129379.0
1	3	0.00000	0.72	2368432.0
1	0	0.00000	0.99	270258.9
2	6	0.00010	2.02	20572.4
2	3	0.00018	2.34	13262.5
2	0	0.00011	1.99	17749.4
4	6	0.00114	4.00	3491.5
4	3	0.00122	4.02	3277.7
4	0	0.00121	4.00	3317.3
8	6	0.00406	7.94	1955.4
8	3	0.00427	8.00	1873.0
8	0	0.00419	7.98	1903.5
10	6	0.00423	9.99	2365.2
10	3	0.00333	9.95	2992.1
10	0	0.00282	9.95	3535.1
6	2	0.00198	5.91	2985.9
20	15	0.00196	19.25	9806.2
6	2	0.00126	6.05	4811.2

Resilient Modulus Test

Sample Number: 321
Sample Description: A-6(2) Soil; w = 13.5%; Imbibed 96 hours
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 114.7 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 0

Date: Saturday, 11/30/1991 Time: 14: 5:26

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00039	1.02	2640.7
2	6	0.00104	1.95	1861.7
4	6	0.00292	3.98	1362.4
8	6	0.00555	8.02	1445.7
10	6	0.00604	10.00	1655.5
6	2	0.00370	6.01	1621.7
1	6	0.00011	1.03	9125.4
1	3	0.00015	0.98	6441.4
1	0	0.00027	0.99	3656.5
2	6	0.00039	2.00	5125.5
2	3	0.00059	2.04	3462.1
2	0	0.00095	1.97	2074.5
4	6	0.00148	3.96	2679.3
4	3	0.00192	3.95	2061.4
4	0	0.00257	4.07	1584.2
8	6	0.00378	8.01	2118.3
8	3	0.00446	8.10	1817.0
8	0	0.00532	8.05	1513.0
10	6	0.00478	9.96	2084.7
10	3	0.00565	9.98	1768.1
10	0	0.00590	10.02	1698.7
6	2	0.00334	5.96	1785.3
20	15	0.00861	19.82	2303.5
6	2	0.00349	6.01	1720.6

Resilient Modulus Test

Sample Number: 323
Sample Description: A-6(2) Soil; w = 13.5%; 48 Hour Imbibition
GammaDMax = 112.0 pcf Optimum w = 14.5 %
SampleGamma = 114.3 pcf Sample w = 13.5 %
Number of Freeze/Thaw Cycles = 0

Date: Wednesday, 11/27/1991 Time: 14:32:46

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00017	1.00	5920.7
2	6	0.00048	1.70	3572.2
4	6	0.00212	4.00	1888.2
8	6	0.00473	7.99	1689.6
10	6	0.00558	10.00	1793.4
6	2	0.00476	6.00	1260.7
1	6	0.00026	1.01	3912.6
1	3	0.00022	0.64	2847.1
1	0	0.00058	1.02	1763.1
2	6	0.00061	2.03	3296.5
2	3	0.00093	2.01	2169.9
2	0	0.00141	2.01	1425.3
4	6	0.00165	3.99	2417.6
4	3	0.00222	4.01	1806.4
4	0	0.00286	4.01	1400.7
8	6	0.00397	8.01	2017.4
8	3	0.00477	8.02	1681.7
8	0	0.00523	8.00	1529.8
10	6	0.00467	10.04	2150.5
10	3	0.00544	9.94	1827.5
10	0	0.00611	9.98	1633.6
6	2	0.00308	5.99	1944.5
20	15	0.00733	19.94	2718.3
6	2	0.00346	5.98	1730.0

Resilient Modulus Test

Sample Number: 324
Sample Description: A-4(5) Soil; w = 14.4%; 48 hour imbibition
GammaDMax = 117.7 pcf Optimum w = 14.4 %
SampleGamma = 117.5 pcf Sample w = 14.4 %
Number of Freeze/Thaw Cycles = 0

Date: Friday, 11/29/1991 Time: 20:55:40

Dev	Confine	epsilon	sigma	ResilMod
1	6	0.00021	1.02	4920.2
2	6	0.00058	2.02	3468.6
4	6	0.00167	4.00	2400.6
8	6	0.00413	7.95	1926.3
10	6	0.00510	9.95	1949.6
6	2	0.00422	6.01	1424.6
1	6	0.00047	1.37	2913.8
1	3	0.00064	1.46	2270.1
1	0	0.00049	0.97	1974.0
2	6	0.00074	1.98	2668.4
2	3	0.00102	2.02	1987.6
2	0	0.00119	2.03	1711.8
4	6	0.00202	4.00	1984.0
4	3	0.00244	4.01	1640.0
4	0	0.00254	3.99	1571.4
8	6	0.00410	8.02	1954.0
8	3	0.00447	8.01	1791.9
8	0	0.00455	7.99	1756.2
10	6	0.00491	9.97	2027.9
10	3	0.00542	10.00	1845.9
10	0	0.00576	9.99	1735.0
6	2	0.00411	5.96	1449.5
20	15	0.00671	19.88	2961.5
6	2	0.00398	5.99	1504.1

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