PREDICTING RESILIENT MODULUS OF HIGHWAY SUBGRADE SOILS IN OHIO

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Pavement structural responses (stresses, strains, and displacements) are mainly influenced by the subgrade soil. When repetitive traffic wheel loads are applied to the road surface, the pavement system deforms. A large percentage of this deformation is accumulated by the subgrade. The deformation of the in-service multi-layer pavement system by traffic wheel loads is composed of two parts: plastic deformation (permanent deformation) or rupture and elastic deformation referred to as recoverable or resilient deformation. The resilient modulus is therefore considered a required input for determining the stresses, strain, and deflections in a pavement system.

In order to achieve a proper characterization of a subgrade soil, its dynamic behavior must be measured using representative samples obtained from the site where the pavement system is to be constructed. The samples should be tested under conditions expected to occur during the service of the pavement system. Although field tests can be used to determine dynamic behavior of soils, most engineers prefer laboratory tests. This is because field tests have limitations, such as constraints associated with relatively small loading magnitudes, accessibility to a construction site where a pavement structure already exists, and weather conditions. Laboratory tests, on the other hand, are less constrained since they are under more controlled conditions. Most researchers agree that laboratory testing is more appropriate for design purposes and that field tests are more appropriate for the evaluation of pavement structures [20]. Many types of laboratory tests have been developed to determine the dynamic behavior of a wide variety of materials. One common test is the repeated load triaxial compression test, usually called the resilient modulus test.

1.2 RESILIENT BEHAVIOR

The resilient modulus, E_r, is a dynamic response parameter defined by the ratio of the axial deviator stress (σ_d) to the recoverable axial strain (ε_r). Deviator stress is the difference between the axial and confining stress. This parameter is determined from laboratory dynamic (or repeated) triaxial loading tests. The axial stress (σ_1) is applied to the top of the soil sample simultaneously with a confining stress or chamber pressure (σ_3). The recoverable axial strain (ε_r) is measured in the testing process. The resilient modulus is calculated from Equation 1.1.

$$M_r = \frac{\sigma_d}{\epsilon_r} \tag{1.1}$$

Where: M_r = resilient modulus

σ_d = repeated deviator stress (σ_1 - σ_3)

ε_a = recoverable axial strain

Figure 1.1 illustrates a typical pattern of soil deformation, under repeated load applications and the a sustained confining pressure observed by previous researchers [35]. First, there is a small volumetric compression of the specimen when the confining pressure is applied. Next, with the deviator stress applied and sustained, an immediate axial deformation occurs and is increased. Finally, rebound occurs when the axial load is removed. Elastic axial deformation is recovered. For most soils, the rebound or resilient deformation per load cycle remains constant for about 100 cycles of loading.

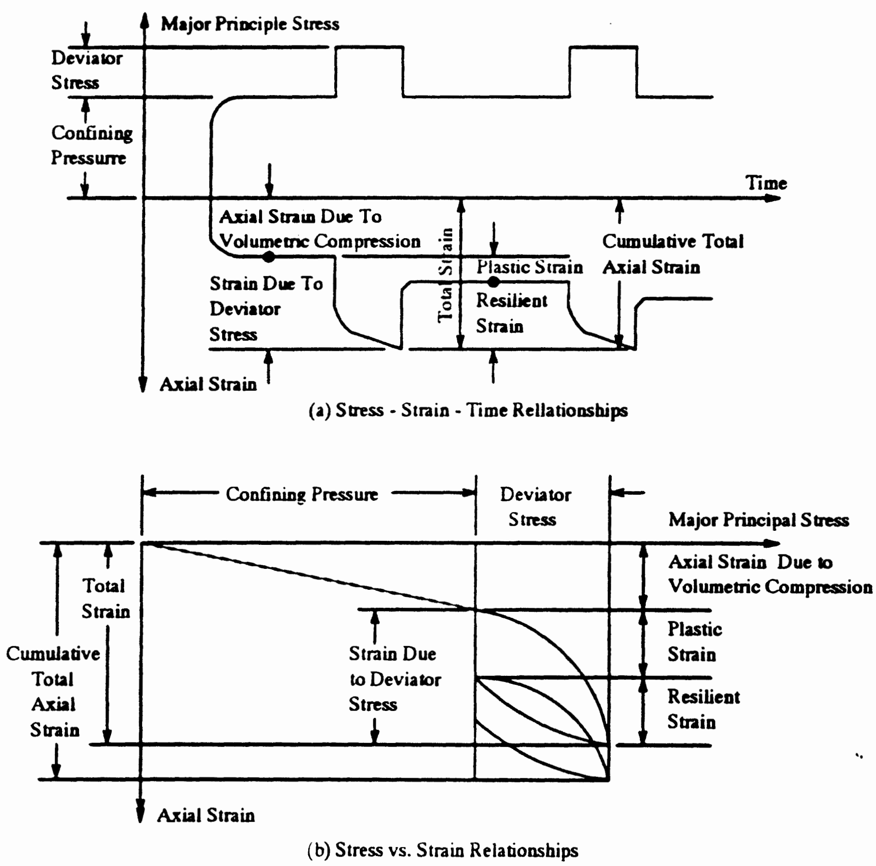


Figure 1.1 Pattern of Soil Deformation Under Repeated Loading and a Sustained Confining Stress (after [3,22]).

The axial deviator stress is defined as the applied axial load (P) and the cross-sectional area of the sample (A) Equation 1.2.

$$\sigma_d = \frac{P}{A} \tag{1.2}$$

The axial strain is defined as the relation between the axial deformation (Δ) and the specimen length (L_s) as:

$$\epsilon_a = \frac{\Delta}{L_s} \tag{1.3}$$

Thus, the resilient modulus (M_r), which is an estimate of the dynamic Young's modulus, is defined as the ratio of the applied repetitive axial deviator stress to the recoverable or induced elastic axial strain:

$$M_r = \frac{\sigma_d}{\epsilon_a} \tag{1.4}$$

The resilient modulus of any soil is a function of the state of stress. As the applied stress is varied, the strain in the soil may vary. Coarse grained materials generally exhibit a decrease in strain at higher stress levels, and fine grained soils generally exhibit an increase in strain at higher stress levels. This behavior explains why granular materials are sometimes referred to as "stress hardening" materials while fine grained soils are referred to as "stress softening" materials. with "stress softening", an increase in strain causes the resilient modulus value to decrease when greater stresses are applied. This trend is clearly visible on graphs of the resilient modulus versus the applied deviator stress for fine grained soils.

In addition, the behavior of soil due to repeated loading depends on factors other than applied stress. Some other factors that have been recognized to affect the resilient modulus include moisture content, grain size distribution, dry density, and method of compaction [22].

1.3 OBJECTIVES

The general objective of this study is to evaluate the resilient properties of fine-grain soils using SHRP Type 2 testing procedure and to identify and quantify the soil properties that control the resilient characteristics of soils. In this study, ten subgrade samples taken from five counties in Ohio were tested. The standard test SHRP P-46 Type 2 [28] was utilized to establish general ranges of resilient behavior for certain soil groups in Ohio. Some basic soil index property tests (CBR, group index, atterberg, etc) were conducted. A prediction method currently being used by the Ohio Department of Transportation was evaluated through comparisons to the results obtained from the laboratory tests. Furthermore, a statistical analysis was conducted to evaluate correlations between basic soil index properties and the resilient modulus. Finally, mathematical models were established to predict the resilient modulus from the major factors that affect resilient behavior of subgrade soils.

1.4 OUTLINE OF THESIS

Chapter 2 of this thesis reviews historically developments in made resilient modulus testing of highway subgrade soils. It also covers mathematical models and various testing methods applicable to resilient modulus. Chapter 3 presents information on field sampling, testing facility, the procedures used to obtain basic index properties, and resilient modulus of soils. Testing results are also given in this chapter. Chapter 4 makes comparisons between the test results and prediction methods. Finally summary and conclusions are made, and recommendations for further research are presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORICAL DEVELOPMENT

Repeated load tests on subgrade soils were first proposed when data from the Washington Association of State Highway Officials (WASHO) and the American Association of State Highway Officials (AASHO) Road Tests showed significantly greater deflections than the values calculated from static load applications. Researchers began in the middle 1950's to characterize behavior of soils under repeated load and to determine the factors that affect the resilient modulus [25].

Comparisons between statically tested modulus values (E_s) and those obtained from repeated load tests (E_r) revealed significant differences between moduli. At any given stress level, the modulus determined from conventional static load testing was found to be 1.5 to 2 times greater than the modulus from a repeated load test. A general trend of increased moduli (E_s and E_r) was found to occur when water content was kept constant and dry density was increased. For a given dry density, modulus values were found to decrease as the water content was increased [4].

In 1958, Seed and McNeill [24] made one of the earliest attempts to duplicate the stress state history by considering the actual variation in vertical stress in a soil element at a depth of 27 in. below the pavement surface at the Stockton Test Track Figure 2.1. Owing to the limitations of their test equipment, they did not use the actual form of the vertical stress that was observed but choose to use a square wave in their laboratory investigations. Seed and McNeill also applied a repeated confining pressure to the specimens in their program to assess the consequences of changes in both the vertical and horizontal stress state on the permanent deformation characteristics of subgrade soils. Beyond this initial effort, however, only a few researches have cycled both the vertical and horizontal stresses in repeated load triaxial tests.

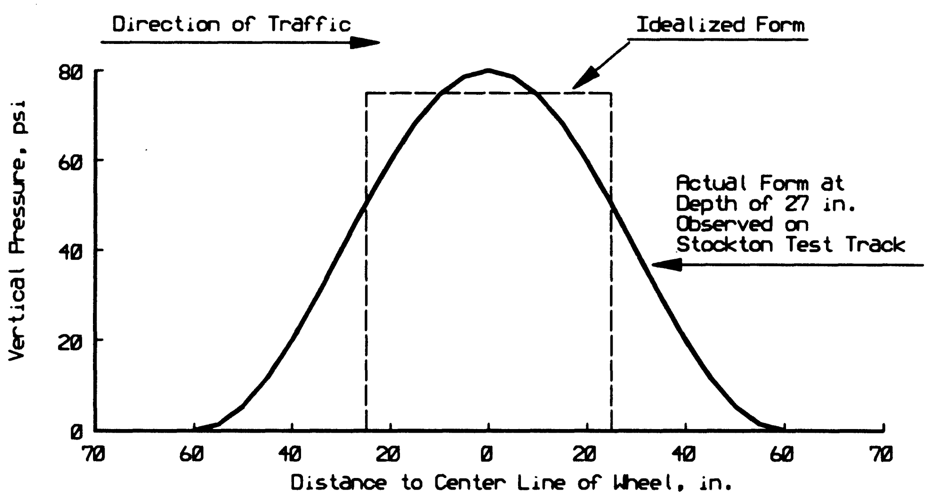


Figure 2.1 Changes in Stress on Soil Element Due to Moving Load, After Seed and McNeill [24]

Barksdale [7] observed that vehicle speed and depth beneath the surface of the pavement are very important in selecting the appropriate vertical compressive stress pulse time for use in repeated load testing. Using the results of a typical pavement, he established that for full-depth construction with 5 to 12 inches of asphaltic concrete and with vehicle speeds of 50 to 60 mph, pulse times of 0.03 to 0.05 seconds are appropriate.

Terrel, Awad, and Foss [29] observed that since asphalt mixes are viscoelastic materials, a computed value of modulus will be dependent upon the rest period between individual stress pulses, and that the viscoelastic response must be included as a parameter in the material properties. Based on their test results, they concluded that:

1. There is no significant difference in the magnitude of the total or the resilient stress between the triangular or the sinusoidal stress pulse.
2. An equivalent square pulse can be replaced by applying (a) the same stress for a duration of 33 percent of the equivalent sinusoidal, or (b) 66 percent of the stress with the same duration as the equivalent sinusoidal.
3. A square vertical stress pulse and a resting time between the individual pulses of about 0.7 to 2 seconds are reasonable approximation of the actual conditions within a pavement layer.

2.2 TEST METHODS

The resilient moduli of subgrade materials is measured in a repeated load triaxial compression test, known as the resilient modulus test. The equipment used in this type of test is similar to that used in common triaxial compression test. During the test, specimens are subjected to testing sequences that consist of the application of different repeated axial deviator stress (σ_d) under different confining pressures (σ_3). Also during the test, the recoverable induced axial strain (ε_a) is determined by measuring the resilient deformations of the sample across a known gauge length.

Earlier suggested methods for determining the resilient modulus were the complex modulus test, flexural bending test, and the resonant column method. In 1970, the procedures for cyclic triaxial tests were included by the United States Army Corps of Engineers in their Laboratory Soils Testing Engineering Manual [13]. The American Society of Testing and Materials (ASTM) presented an instrumented triaxial cell for cyclic loading of clays as a guideline for experimental work [10]. The Transportation Research Board (TRR) also revealed an apparatus and results from a preliminary study on repeated load testing [11].

The American Association of State Highway and Transportation officials (AASHTO) established a standard testing method [5] as the official laboratory test for determination of resilient modulus of subgrade soils in 1982. A recommended apparatus, a variety of compaction procedures, and a detailed testing procedure are given in the procedure. The American Society of Testing and Materials (ASTM) proposed a standard testing method similar to the AASHTO procedure [6]. The Strategic Highway Research Program (SHRP) specified one conditioning stage testing sequence SHRP P-46 Type 1 for cohesive soils and another Type 2 for cohesionless soils [28]. There are several testing methods recognized for determining the resilient modulus of subgrade soils such as Florida testing sequence[16], Illinois testing sequence[14], Washington testing sequence

[17] and New York method testing sequence[27].

AASHTO T-274 specifies two types of testing sequence for cohesive soils and cohesionless soils. For cohesive soils, the critical state (maximum principal stress ratio) occurs at a 10 psi deviator stress under zero confining pressure. For cohesionless soils, the stress states are largely varied. The stress state appears to be out of perspective. In this case, the critical state occurs at a 10 psi deviator stress under a confining stress of 1 psi. In general, the critical states for both types of materials are severe, particularly for the cohesionless material that has to undergo higher values of principal stress ratio.

The ASTM (draft) testing sequence specifies 200 applications at deviator stresses of 1, 2, 5, and 10 psi and at confining pressure of 6, 3 and 1 psi. This meets the practical sense that a few stress states are used. In addition, the fact that the lowest confining pressure specified is not 0 psi prevents to some degree, the failure of samples having reduced cohesive properties.

The Florida testing sequence [16] specifies the same stresses state used in conditioning the sample. However, it requires a maximum of 10,000 applications at each of the deviator stress.

The Illinois testing sequence, as described by Dhamrait [14] specifies that deviator stresses of 2, 4, 6, 8, 10, 14, and 18 psi are applied only 10 times at atmospheric pressure. This specification is practical in the sense that a few stress states are applied and repeated. however, since one confining pressure is used, the test cannot represent conditions that exist in lower pavement layers. Such an omission limits the sequence to testing of materials that have cohesive properties capable of withstanding high values of principal stress ratios.

The Washington testing sequence [17] specifies 200 applications at deviator stresses of 1, 2, 4, 6, 8, 10, and 12 psi. These deviator stresses are applied at different confining pressures (e.g., 1, 2, 4, and 6 psi). While this method avoids subjecting the test material to very high values of principal stress ratios, the process is still somewhat protracted and cumbersome.

The New York method testing sequence [27] specifies that , for cohesive soils, 200 applications at deviator stresses of 6, 3, and 0 psi are applied under different confining pressures of 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 psi.

Finally, SHRP Protocol P-46 [28] testing sequence specifies that, for cohesive soils, 100 applications of 2, 4, 6, 8, and 10 psi deviator stress should be applied under confining stresses of 6, 4, and 2, psi. This testing sequence appears to be adequate, since stress states are within normal ranges of stresses observed in actual pavements; it is also more efficient because it requires a fewer stress applications.

SHRP P-46 testing sequence [28] for granular materials specifies applications of a substantial variety of stress states, with the critical state occurring when a 30 psi deviator stress is applied to a sample subjected to a 10 psi confining pressure. This testing sequence appears to be more appropriate for granular base and subbase materials than for subgrade and non-granular subbase layers.

2.3 MATHEMATICAL MODELS

There are several models to characterize the resilient response of pavement materials. For cohesionless materials exhibiting stress-hardening behavior, the resilient modulus tests have demonstrated the significant effect of confining pressure on test results [20]. The resilient modulus for cohesionless materials is often expressed by the following equations:

1. Modulus dependent on confining pressure:

$$M_r = K_1 \sigma_3^{K_2} \tag{2.1}$$

2. Modulus dependent on bulk stress:

$$M_r = K_1 \theta^{K_2} \tag{2.2}$$

3. Modulus dependent on mean normal stresses:

$$M_r = K_1 (\sigma_o)^{K_2} \tag{2.3}$$

where: K_1 and K_2 = experimental regression constants determined from a set of test results.

σ_3 = total confining pressure.

θ = bulk stress, or sum of principal stress, $\sigma_1 + \sigma_2 + \sigma_3$.

σ_o = mean total normal stress, $\theta/3$.

Typical test results [19] are shown in Figure 2.2. The results illustrate these relationships for cohesionless materials. The constants K_1 and K_2 are derived from a set of test results by rewriting Equation 2.2 as follows:

$$\log M_r = \log K_1 + K_2 \log \theta \tag{2.4}$$

The relationship between M_r and θ is a straight line on a log-log plot. K_1 is the anti-log of the y-intercept and K_2 is the slope of the line.

Unlike cohesionless materials, the deformational characteristics of cohesive materials are somewhat independent of the confining pressure [19, 23, 34, 38]. Moreover, it has been concluded that the axial deviator stress applied to the specimen during the test has the most significant effect on the moduli of cohesive materials. The resilient modulus for cohesive materials is often expressed by the equation:

$$M_r = K_1 \, \sigma_d^{K_2} \tag{2.5}$$

where: σ_3 = deviator stress

K_1 and K_2 = experimental regression constants determined from a set of test results

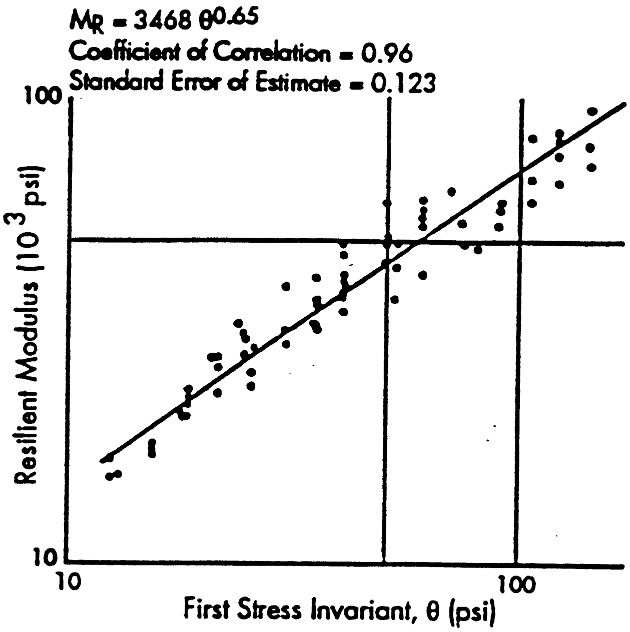


Figure 2.2 Typical Test Results of Resilient Modulus Versus Sum of Principal Stresses (Base Course Material) [19].

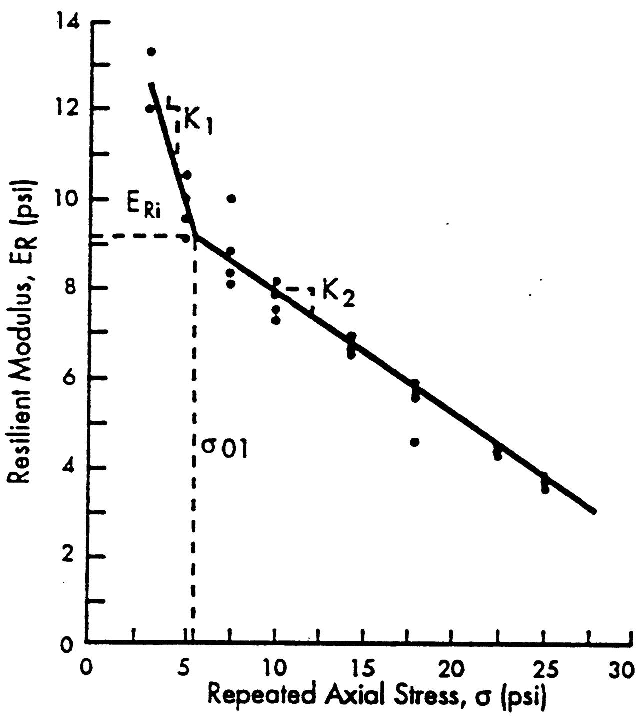


Figure 2.3 Typical Variation of Modulus Versus Deviator Stress on Cohesive Soils [31, 34].

The nonlinear stress-softening relationship between resilient moduli and applied deviator stress for cohesive soils is often characterized by a bilinear relationship in terms of a "break point" deviator stress where there is a substantial change in slope of the curve. Figure 2.3. taken from Thompson [34], shows typical test results that illustrate these relationships for cohesive materials. Linear regression analyses were conducted using the data for deviator stresses less than and greater than the "break point" deviator stress.

Thompson explained that these graphs were developed based on an extensive resilient testing program carried out at the University of Illinois [34]. He proposed the use of "M_{Ri}" (the resilient modulus at interception) as an effective indicator of a soil's resilient behavior, and added that M_{Ri} is typically associated with a repeated deviator stress of about 6 psi.

2.4 RELEVANT RESEARCH IN PREDICTING RESILIENT MODULI

The resilient response of fine-grained soils can be influenced by many factors. An extensive resilient testing study [31, 34] of 50 fine-grained soils conducted by University of Illinois summarized several major factors:

<u>Soil Properties</u>

For a given compaction condition (for example, 95% AASHTO T99 dry density and optimum or above optimum water content), E_{Ri} is significantly correlated with liquid limit, plasticity index, group index, silt content, clay content, specific gravity, and organic carbon content. Those properties that tend to contribute to low resilient modulus (low E_{Ri}) are low plasticity (LL, PI), low group index, high silt content, low clay content, low specific gravity, and high organic carbon contents. Thompson and Robnett [31] also developed regression equations for predicting E_{Ri} based on soil properties. For Illinois fine-grained soils, Thompson and LaGrow [33] have proposed using the following relation for conventional flexible pavement design purposes:

$$E_{Ri}\ (OPT) = 4.46 + 0.098\ C + 0.119\ (PI) \tag{2.6}$$

where: E_{Ri} = "Breakpoint Modulus", ksi (Figure 2.1) at AASHTO T99 optimum moisture content and 95% compaction.

C = less than 2 micron clay content (%).

PI = Plasticity index (%).

Soil Classification Effects

Analysis of variance [34] showed that the resilient behavior (E_{Ri}, K_1 response parameters) of the various groups in the soil classification systems (Unified, AASHTO, USDA) is not significantly different. Thus, placing the soil into the different classification does not place fine-grained soils into distinctive resilient behavior groups.

Several fourth-order equations derived by University of Nebraska [37] showed a strong correlation between resilient modulus and Nebraska Group Index under various deviator stresses. They concluded that the resilient moduli of soils can be reliably determined by indirect method. The mathematical form of the equation is:

$$M_r = 100[B_0 + B_1(GI) + B_2(GI^2) + B_3(GI^3) + B_4(GI^4)] \tag{2.7}$$

where: M_r = resilient modulus.

B_n = coefficient.

GI = Nebraska Group Index.

Moisture-Density Effects

A previous research [36]conducted by Bryan Wilson of Ohio University indicated that for a particular soil at a given stress level, moisture content seems to be the factor of greatest importance affecting the resilient modulus.

Degree of saturation is a factor that reflects the combined effect of density and moisture content. E_{Ri} is strongly correlated with the degree of saturation. The E_{Ri} - degree of saturation regression equations differ for 95% AASHTO T99 and 100% AASHTO T99 compaction. One hundred percent compaction provides higher E_{Ri} for a give degree of saturation.

Dingqing Li and Ermest Selig [18] of University of Massachusetts developed an equation 2.8, 2.9 to predict resilient at optimum moisture content in the absence of actual testing data. Several applications of this method showed that it is simple and versatile and also gives consistency between predicted resilient modulus resilient modulus test results.

$$M_r = R_m M_{r(opt)} \tag{2.8}$$

$$R_m = 0.96 - 0.18(w - w_{opt}) + 0.0067(w - w_{opt})^2 \qquad (2.9)$$

Compressive Strength Effects

University of Illinois data [34] indicated that E_{Ri} can be predicted using unconfined compressive strength. The regression equation is:

$$E_{Ri} = 0.86 + 0.307\ Q_u \qquad (2.10)$$

where: E_{Ri} = "Breakpoint" resilient modulus, ksi.

Q_u = Unconfined compressive strength, psi.

It is important to note that in-situ strength typically displays considerable seasonal variability. The unconfined compressive strength should be representative of the in-situ conditions.

Freeze-Thaw Effects

Studies, performed by Bergan and Fredlund [8], Bergan and Monismith [9], Culley [12], and Robnett and Thompson [21], have shown that the resilient behavior of fine-grained cohesive soils is greatly affected by cyclic freeze-thaw action. Research revealed that substantial increases in resilient deformation (reduced resilient moduli) were caused by the imposition of a small number of freeze-thaw cycles, even when no gross moisture changes were allowed [30].

CHAPTER 3

LABORATORY TESTING PROCEDURE

3.1 FIELD SAMPLING

Soil samples for this study were collected from three sites in Ohio. The first site (I-71 site) was located on the border of Madison County and Fayette County. The second site (State Route 4) was located in the area where Montgomery County and Greene County meet. The last site (I-75 site) was located in Butler County.

Field soil sampling at the first site was performed on April 21, 1993. The disturbed soil samples were extracted from desired depths by augering within the shoulder section. Six auger holes on the north bound side and eight on the south bound side. The distance between each hole was about 0.2 miles. Only four soil samples from this site are tested in this study. The soil samples from the second site were provided by Ohio Department of Transportation in May, 1993. According to their record, the same sampling method was utilized at this site. Samples were obtained from two auger holes, one (MN2 and MN4 at Station 23.77 with different depths) in Montgomery County and one (GN2 and GS5 at station 0.00 with different depths) in Greene County. The soil samples from the third site were obtained in July, 1993. The soils were obtained from desired depths in an excavated area next to I-71 in Butler County. Samples were taken from two locations (BN3 and BS2).

The soil samples from all three sites were cohesive material, containing mostly clay with some varying amounts of fine gravel, fine sand and silt. The samples were placed in plastic bags and transported to the CGER Research Laboratory, Ohio University. The natural moisture contents of the soils from the first site were determined to range from 9.7 to 21.0%, with a mean of 17%. The natural moisture content of the soils from the second site was found to vary from 10 to 12%. However, this might not indicate the true value of the natural moisture content, since the soil samples had been retained inside the bags for a relatively long period of time. The natural moisture contents of the soils from the third site shown on boring data supplied by ODOT were 10 and 11%. Once the natural moisture content was determined, the soil samples were subjected to the Standard Proctor Tests (AASHTO T-99) and the resilient modulus test (SHRP Protocol P46 type 2). The selected soils to be tested are listed in Table 3.1.

Table 3.1 Locations of Soil Samples for Resilient Modulus Testing.

Sample I. D.	County	Location
NB4	Fayette	I-71 North Bound
NB6	Madison	I-71 North Bound
SB3	Madison	I-71 South Bound
SB4	Fayette	I-71 South Bound
MN2	Montgomery	State Route 4 North Bound
MN4	Montgomery	State Route 4 North Bound
GN2	Greene	State Route 4 North Bound
GS5	Greene	State Route 4 South Bound
BN3	Butler	I-75 South Bound
BS2	Butler	I-75 North Bound

3.2 INDEX PROPERTIES OF THE SOIL SAMPLES

The representative soil samples from the three sites were selected for index property and resilient modulus tests. Standard tests were performed to obtain the index properties of the soils for classification purposes and also to form a data base for developing a correlation of the basic properties to the resilient modulus properties. The test procedures used are listed in Table 3.2 and the results are presented in Table 3.3

Each soil was classified according to the common soil classification systems: The Unified Soil Classification System (USCS), and the American Association of State Highway and Transportation Officials (AASHTO) soil classification system. These classification systems are based on grain size distribution and the Atterberg limits of the soils. The classification results of the selected soils are shown in Table 3.3.

Table 3.2 AASHTO Specifications for Various Index Properties Tests

Test type	Specifications	
	AASHTO	ASTM
Atterberg Limits:		
Liquid Limit (LL)	T89	D423
Plastic Limit (PL)	T90	D424
California Bering Ratio (CBR)	T193	D1883
Grain Size Analysis:		
Hydrometer Analysis	T88	D422
Mechanical Sieve Analysis	T88	D1140
Specific Gravity of Solids	T100	C854
Standard Proctor Test:		
Maximum Dry Density	T99	D698
Optimum Moisture Content	T99	D698

Table 3.3 Standard Laboratory Test Results

Sample I.D.	Soil Classification		Group Index (GI)	Passing #200 Sieve (%)	Silt Content (%)	Clay Content (%)	Atterberg Limits		G_s of Solids	Proctor Tests		CBR Value	
	USCS	AASHTO					LL	PI		Max.Dry Density (lb/ft^3)	Opt. M.C. (%)	Unsoaked %	Soaked %
NB4	CL	A-7-6	14	70.5	40.0	30.5	40.4	21.4	2.74	111.2	15.7	9.41	6.80
NB6	CL	A-6	8	71.3	44.0	27.3	31.1	13.4	2.72	114.4	15.5	4.71	4.07
SB3	CL	A-6	8	72.5	45.7	26.8	30.0	13.6	2.70	116.1	15.1	5.24	4.10
SB4	CL	A-6	8	73.2	43.5	29.7	31.7	13.8	2.72	115.5	14.9	4.06	3.58
MN2	CL	A-6	5	65.9	40.3	25.6	27.4	10.7	2.69	117.7	13.9	5.97	2.52
MN4	CL	A-6	13	75.8	36.1	39.7	37.6	18.0	2.76	116.4	14.5	6.64	3.31
GN2	CL	A-4	4	53.4	38.4	15.0	24.3	9.1	2.68	119.2	12.9	1.02	0.67
GS5	CL	A-6	10	95.1	42.1	53.0	35.6	14.8	2.75	111.5	17.4	9.49	7.29
BN3	CL	A-6	10	73.9	41.8	32.1	33.4	15.2	2.73	115.8	15.2	8.36	6.91
BS2	CL	A-4	3	65.2	47.9	17.3	24.9	8.6	2.67	121.5	13.2	3.89	2.34

3.3 LABORATORY SPECIMEN PREPARATION

The first important step in preparing the laboratory specimens for resilient modulus tests is to obtain specimens that are representative of field conditions. Since all the soil samples from the field were disturbed, AASHTO test methods Designation T 146-86 [2] and T 87-86 [3], were followed for the preparation of all soil samples used in this study. The moisture content and dry density of the test specimens were required by the Ohio Department of Transportation. This requirement met the condition that the subgrade in a pavement system be placed at the optimum moisture content determined from the Standard Proctor test in accordance with AASHTO T99 or ASTM D698 test methods. In addition, the moisture content of the subgrade in the pavement systems is varied about the optimum moisture content. Therefore, each soil sample was tested at three different moisture contents (2% below optimum, optimum, 2% above optimum), and the fourth test was conducted to duplicate the test at optimum moisture content. Table A.1 in Appendix A shows the actual moisture content and dry density of the specimens tested. Any deviation from the Standard Proctor optimum moisture content and dry density was due to difficulty in reproducing the exact moisture content and dry density in the compacted specimens.

After measuring the initial moisture content, the soil sample was air-dried and pulverized to pass the No. 4 sieve. Moisture content tests were conducted on randomly selected samples to determine the moisture content after the air drying condition. Once the desired moisture content and the air dried conditions of the soil sample had been determined, the proper amount of water was added into the soil sample to prepare the test soil specimen. about 12 kg of dried soil mass was placed into a 60-rpm soil mixer for each specimen, and then a known volume of water was added. The mixing process continued until a relatively homogeneous material, free of lumps, was achieved.

The CGER Research Laboratory is equipped to test soil specimens of diameters 2.8, 4, and 6 inches. Specimens of 6 inch in diameter were used in this study. This size was chosen because the larger size specimen simulate the in-situ soil mass more realistically. Soil was compacted in a 6 inch split compaction mold with 0.030 inch thick rubber membrane mounted on a bottom platen. A vacuum line was connected to the fittings on the outside wall of the mold, so that the air between the rubber membrane and mold could be extracted out, and the membrane could be stretched tightly over the inner surface of the mold. The soil was compacted in a total of 6 equal-thickness layers inside the mold. Each layer was tamped with 75 blows using a 24.5 N standard rammer. The numbers of blows per layer was computed based on the compaction energy per unit volume applied in the standard proctor compaction test (AASHTO T99). The specimen length must be at least two times the diameter (12 inches), as required by SHRP. After compaction the upper platen was placed at the top of the specimen, and two rubber O-rings were used to tie the membrane on the upper platen. The specimen was then carefully removed from the split mold. The weight and height of the specimen were measured and recorded. These measurements were used for the determination of the wet and dry densities of the specimens and also used during the resilience testing.

3.4 DESCRIPTION OF TEST SYSTEM

The resilient modulus test system utilized in this study was state-of-the-art equipment which featured a large triaxial chamber, an elector-servo controlled actuator, and a computerized load command generation and data acquisition unit. Figure 3.1 illustrates the overall set-up of the resilient modulus test system. The equipment and test control system was developed by Structural Behavior Engineering Laboratories Inc. (SBEL), and are compatible with the current AASHTO specifications T-274 "Resilient Modulus of Subgrade Soils" and SHRP Protocol P-46 "Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils." The system consists of the following seven (7) items, as shown in Figure 3.1. Table 3.4 summarizes basic specifications for some of the system components described below.

1. Triaxial pressure chamber (Model HX-100) - A stainless steel construction with 150 psi acrylic plastic cell wall. This unit is larger than the standard size to accept up to a 6 inch diameter specimen and includes all necessary ports, valves, fittings, hoses and specimen platens. Figure 3.2 shows the detailed assembly of a this triaxial pressure chamber whit a test soil specimen placed inside.

2. Computerized signal generator/data acquisition unit - This system, includes an IBM compatible PC and a servo control system, provides suitable excitation voltage, conditioning, and recording of all the sensors attached to the triaxial cell. User-friendly, menu driven software is installed on the PC to control the test, acquire data, and produce test results. A summary

report and graphical plots of the test results are automatically saved on the computer hard drive at the end of each test.

3. Hydraulic pump - The manually operated hydraulic pump (MTS Model 510.10B) supplies approximately 800 psi constant hydraulic pressure to the actuator piston for loading.

4. Loading actuator - The compact closed-loop servo electro-hydraulic controlled actuator is mounted atop the triaxial cell. The actuator piston has a stroke of 2.5 inches and capacity for generating cycles of haversine shaped or other types (triangular, sawtooth, square, and random) of stress pulses by receiving signals from the computer driven servo control system.

5. Load cell - This strain gage based electric load cell has a capacity of 1,400 lbs. and is located under the base platen.

6. Linear Variable Differential Transformers (LVDTs) - Three LVDTs (by Schaevitz) are attached externally to the actuator piston, at the top of the triaxial chamber. Two miniature, high resolution LVDTs are clamped co-axially to the piston rod. LVDT linearity range is ± 0.25 inch (250 mil), and they can be clamped along the side of the test specimen through the use of special ring clamps. One larger, coarser resolution LVDT, with a range of ± 1.0 inch, is located above the actuator piston.

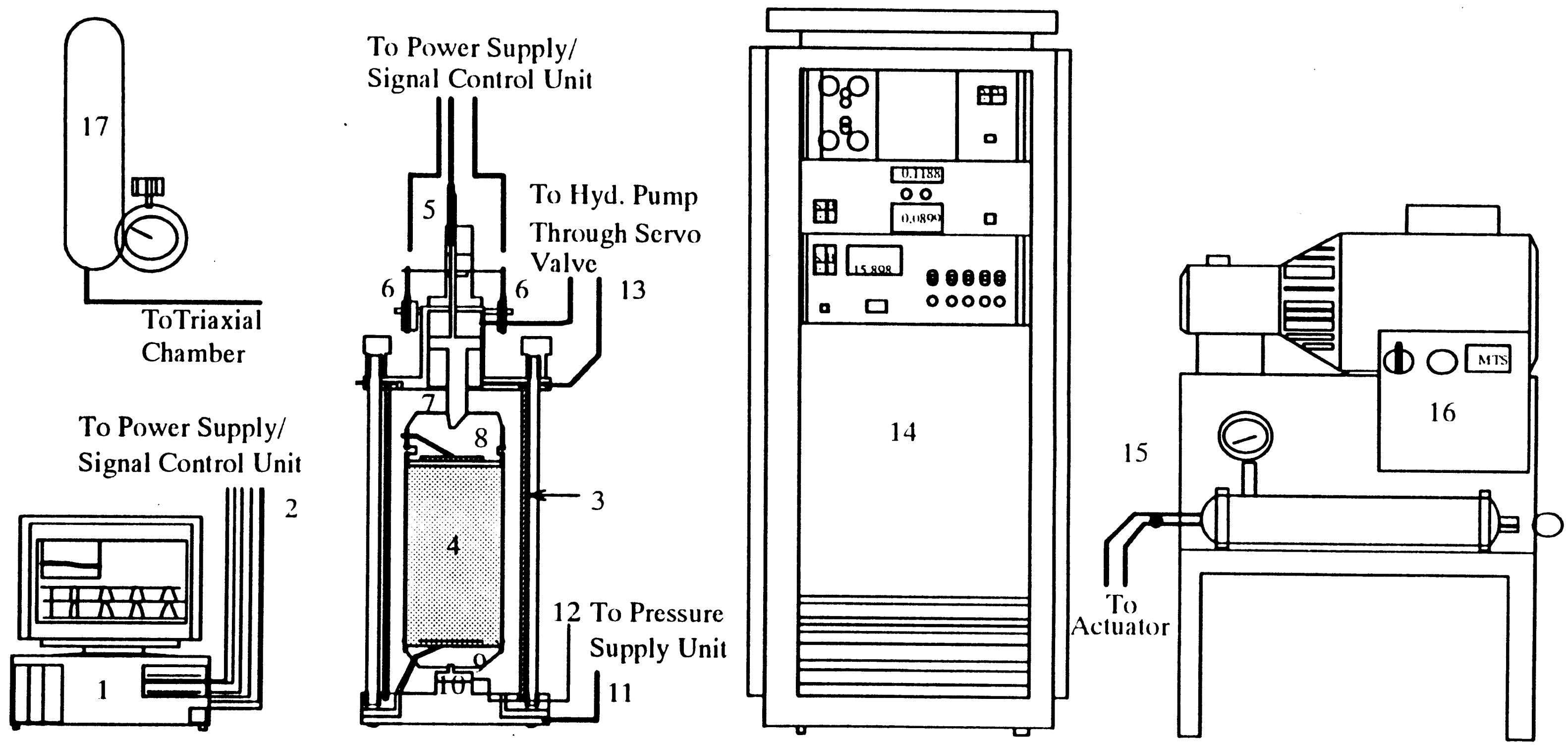
7. Chamber lateral pressure application unit - This unit has a manually controlled set-up to be utilized as a pressurized air source. It consists of a pressure line/valve, 40 psi pressure regulator, and a quick

connect/disconnect type hookup to the triaxial chamber.

Table 3.4 Basic Information on Resilient Modulus Test Sensors

	Load Cell	Miniature LVDTs	System LVDT
Range	0-1,400 lbs.	±250 mil	±1,000 mil
Calibration Factor	140 lbs/V	25 mil/V	500 mil/V *
Accuracy	±1.0% F.S.	±1.0% F.S.	±1.0% F.S.
Other Information	Temp.Range = 0-150^{o}F Excitation Voltage=10V	Linearity = ±25% F.S. Useful for Resilient Modulus Tests	Linearity = ±25% F.S. Useful for Conventional Triaxial Tests

Note: Only 50% of the full range is being used.



1 - IBM PC
2 - Interface Ribbon Cable
3 - Trixial Chamber
4 - Test Specimen in Rubber Membrane
5 - System LVDT
6 - Mineature LVDTs
7 - Actuator Piston
8 - Top End Platen
9 - Bottom End Platen
10 - Load Cell
11 - Pressure Air Inlet
12 - Cable for Load Cell
13 - Hydraulic Hose Attachments
14 - Power Supply/Signal ConditioningUnit for Servo Valve, Load Cell,and LVDTs
15 - Hydraulic Hose Attachments
16 - Hydraulic Pump
17 - Air Pressure Source

Figure 3.1 Sketch of the Resilient Modulus Test System at Ohio University

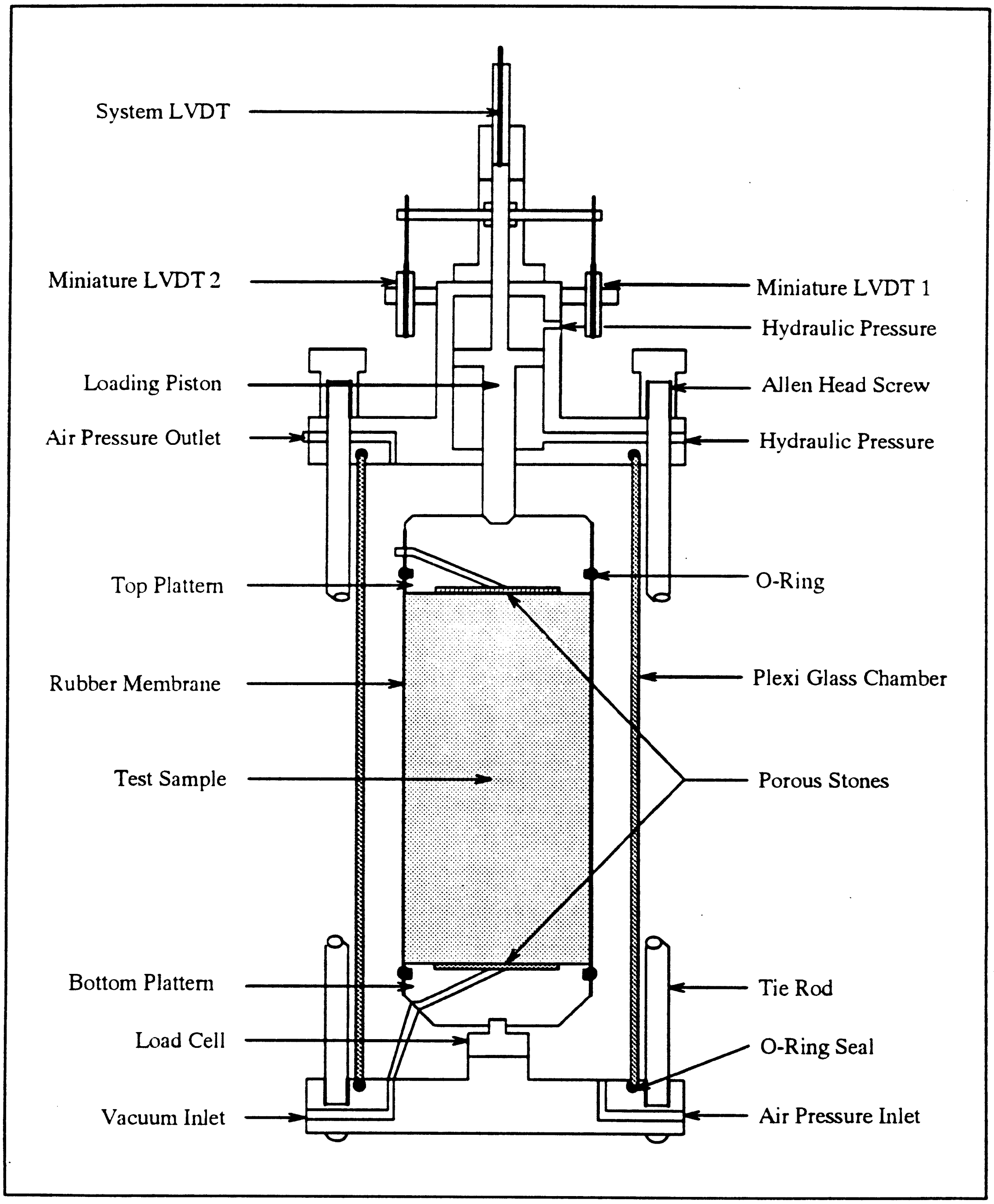


Figure 3.2 Configuration Detail of the Triaxial Cell

3.5 TESTING PROCEDURE

According to the SHRP testing procedures, laboratory compacted specimens should be tested within 24 hours of preparation. A prepared specimen, compacted inside a rubber membrane was sealed between the top and bottom platens, and was tested in the triaxial chamber in the following steps.

1. The specimen was placed on the top of the bottom end platen of the triaxial chamber.
2. The bottom drainage line was connected to the fitting on the bottom platen.
3. The cover platen with the loading assembly was placed on the pressure chamber surrounding the test specimen. The chamber tie rods were firmly tightened.
4. The two hydraulic lines were connected to the actuator and cables to the load cell and three LVDTs.
5. The gain factor for the servo actuator was reset to the manual operating mode. The actuator piston was lowered down to apply a seating pressure of 0.5 to 1.0 psi to the specimen. This was to ensure a full contact of the piston with the specimen.
6. After resetting all the sensor outputs, the servo actuator was placed in a computer control mode.
7. The drainage valves leading to the specimen were opened, and a confining pressure of 6 psi was applied to the test specimen.

At the beginning of the test, the specimen was conditioned by applying 200 repetitions of a deviator stress of 4 psi. This application is to eliminate the effects of the interval between compaction and loading and to minimize the effects of initially imperfect contact between the end platens and the test specimen. At the end of the initial conditioning, the actual test is performed. The recovered deformation reading readings from all the sensors are not recorded until the last five cycles of each loading application sequence. The average of the last five recoverable strains was used as recoverable axial strain to calculate the resilient modulus. In any of the loading sequence, the load applied has a wave form of a pulse, which is defined by a 0.1 second loading period and a 0.9 second period of no load. Figure 3.3 illustrates such a wave form.The specimen testing is performed following the loading sequence shown in Table 3.5.

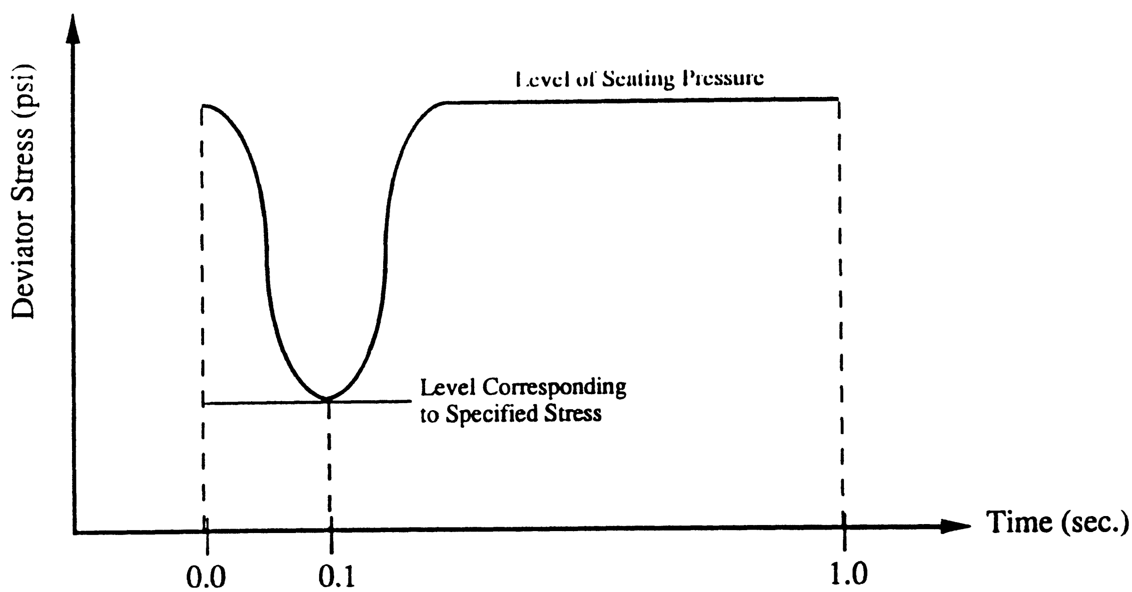


Figure 3.6 Stress Ware Form of a Typical Load Cycle

The test is controlled by the software with a closed - loop control algorithm. The algorithm specifically applied is the Proportional - Integral - Derivative (PID). The PID algorithm uses the equation 3.1 to determine the output value.

$$F(t) = K_p e(t) + K_i \int e(t)\,dt + K d\frac{de}{dt} \tag{3.1}$$

where: K_p = Proportional gain

K_i = Integral gain

K_d = Derivative gain

F(t) = Control signal

e(t) = Error signal

T = Sampling time

The Proportional gain (K_p) provides proportional response to the difference between the feedback and the correction.

The Integral gain (K_i) is multiplied by the integral of the error. Thus, as long as the error in non zero, the controller output will continue to change. This effect helps to reduce the difference between the desired operating point after load changes occur.

The Derivative gain (K_d) is multiplied by the derivative of the error. This improves the controller action, but may lead to problems in environments where noise is present.

During the test, only the system gains P.I.D need be adjusted manually. These adjustment provide the optimum setting between actuator piston and specimen, and allow the feedback to stabilize as quickly as possible.

Table 3.5 SHRP Testing Sequences for Cohesive Type Soils

Sequence No.	Confining Pressure σ_3 (psi)	Deviator Stress σ_d (psi)	Number of Load Applications
1	6	2	100
2	6	4	100
3	6	6	100
4	6	8	100
5	6	10	100
6	4	2	100
7	4	4	100
8	4	6	100
9	4	8	100
10	4	10	100
11	2	2	100
12	2	4	100
13	2	6	100
14	2	8	100
15	2	10	100

3.6 TESTING RESULTS

The results of each test generated by the computer software SERVO in a tabular form, a variation plot of resilient modulus vs. deviator stress, and a logarithmic plot of resilient modulus vs. deviator stress for cohesive type soils. The tabular form results and plots for the all soil samples are contained in Appendix A. A typical set of test result is presented in Table 3.6 and Figures 3.3 and 3.4 for soil sample NB4. The regression equation is obtained by a applying a linear curve fitting through the data points on a log-log scale. The equation for this curve is:

$$\text{Log}\,(M_r) = \text{Log}\,a + b * \text{Log}\,(\sigma_d), \quad \text{or} \quad M_r = a * (\sigma_d)^b \qquad (3.2)$$

where: M_r = Resilient modulus.

σ_d = Deviator stress.

a, b = Coefficients.

Table 3.6 Results of Resilient Modulus Test for Soil Sample NB4 at Moisture Content 0.4% Above optimum

* Ohio University *

Resilient Modulus Test for material type 2

Data File UC-10.DAT Date: 05/09/92

Soil Sample Silty Clay
Location Ohio Univ.
Sample No. NB4-2
Specific Gravity 2.74

SOIL SPECIMEN WEIGHT:
Initial Wt. of Container +Wet Soil-gms 13949.0
Final Wt of Container +Wet Soil-gms 2380.0
Weight Wet Soil Used 11569.0

Compaction Method Std. Proctor
Water Content After Mr Testing % 16.1
Vertical Spacing Between LVDT Clamps(inch) 0.00

SOIL SPECIMEN MEASUREMENTS:
Diameter Top 6.00
Middle 6.00
Bottom 6.00
Average 6.00
Membrane Thickness 0.0300
Net Diameter (inch) 5.94
Ht Specimen+Cap+Base 13.75
Ht Cap+Base 1.00
Initial Length,Lo(inch) 12.75
Inside Diameter of Mold 6.00

SOIL SPECIMEN VOLUME:
Initial Area Ao (inch²) 27.71
Volume Ao*Lo (inch3) 353.32
Wet Density (pcf) 124.76
Compaction water Content % 15.70
% Stauration 73.46
Dry Density (pcf) 107.33

LOAD ID:
SHRP P46 Soil type 2
Number of cycles per sequence 100
Load time 0.10 Cycle time 1.00 sec
Seating Load (lbs) 0.5
Waveform Type Havesine
Comments:
TESTING AT 15.7% OPTIMUM MISTURE CONTENT

A Chamber Press. σ3 psi	B Nominal σd psi	C Mean Deviator Load lbs	D Standard Deviation of Load lbs	E Applied Deviator Stress psi	F Mean Recov Df LVDT #1 inch	G Mean Recov Df LVDT #2 inch	H Mean Recov. Def. inch	I Std. Dev. of Recov. Def. inch	J Mean of Resilient Strain in/in	K Mean of Mr psi	L Std Dev of Mr psi	M θ (σd+3σ3) psi
6.0	2.0	65.59	1.35	2.367	0.003485	0.003711	0.003598	0.000200	0.000282	8402	383	20.367
6.0	4.0	120.59	1.83	4.351	0.007422	0.007654	0.007538	0.000256	0.000591	7364	157	22.351
6.0	6.0	170.97	0.62	6.169	0.012469	0.012207	0.012338	0.000126	0.000968	6376	45	24.169
6.0	8.0	216.49	0.60	7.812	0.017426	0.017389	0.017407	0.000137	0.001365	5722	43	25.812
6.0	10.0	266.33	0.81	9.611	0.023865	0.023846	0.023856	0.000242	0.001871	5137	64	27.611
4.0	2.0	64.94	1.48	2.343	0.003113	0.003607	0.003360	0.000137	0.000264	8899	250	14.343
4.0	4.0	120.45	0.16	4.347	0.007703	0.007697	0.007684	0.000143	0.000603	7214	124	16.347
4.0	6.0	170.56	0.62	6.155	0.012231	0.012012	0.012122	0.000158	0.000951	6474	69	18.155
4.0	8.0	218.31	0.30	7.878	0.016986	0.017133	0.017059	0.000139	0.001338	5888	51	19.878
4.0	10.0	267.35	1.15	9.648	0.023389	0.023236	0.023312	0.000236	0.001828	5277	74	21.648
2.0	2.0	64.74	1.03	2.336	0.002979	0.003473	0.003210	0.000119	0.000252	9285	283	8.336
2.0	4.0	119.36	1.41	4.307	0.007562	0.007819	0.007690	0.000193	0.000603	7143	107	10.307
2.0	6.0	170.21	0.50	6.142	0.012396	0.012183	0.012289	0.000160	0.000964	6373	65	12.142
2.0	8.0	218.31	0.80	7.878	0.017084	0.017200	0.017142	0.000192	0.001344	5860	69	13.878
2.0	10.0	267.32	0.17	9.646	0.023578	0.023370	0.023474	0.000296	0.001841	5240	67	15.646

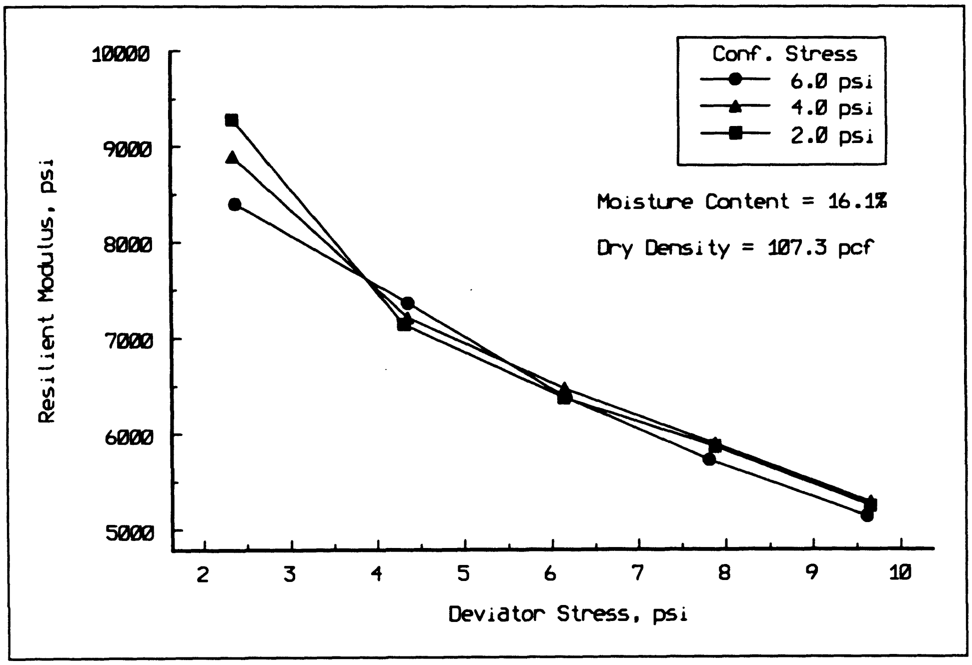


Figure 3.4 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB4 at Moisture Content 0.4% Above Optimum.

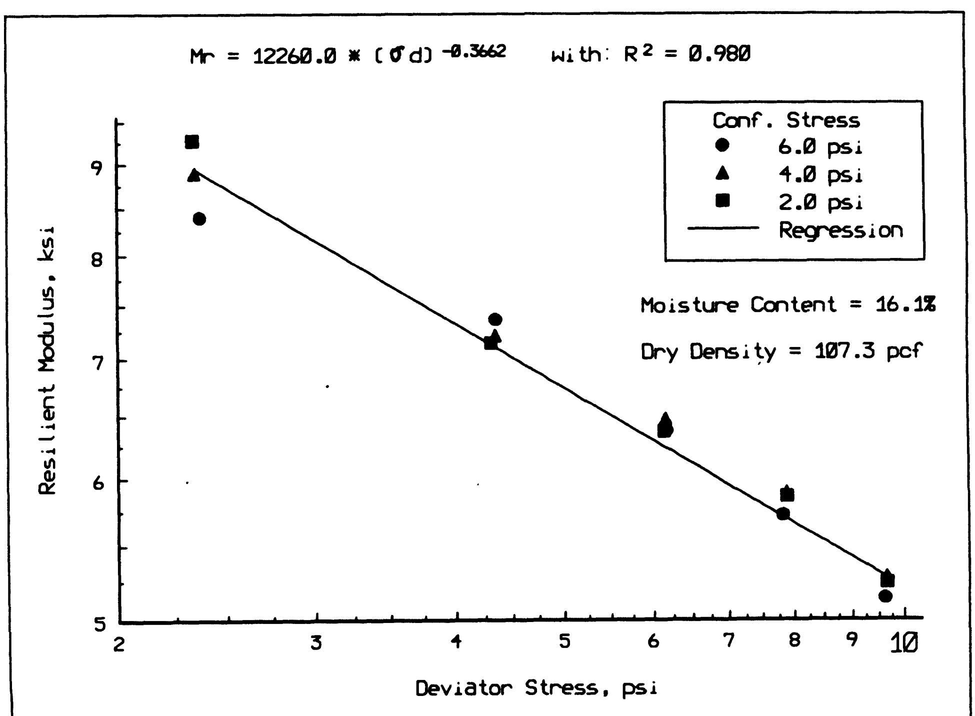


Figure 3.5 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB4 at Moisture Content 0.4% Above Optimum.

CHAPTER 4

EVALUATION AND MODELING OF RESULTS

4.1 EVALUATION OF RESULTS

The primary objectives of this study were to evaluate the resilient modulus measured and compare them to those determined by the ODOT's method, correlate the results of resilient response to standard index properties, and obtain equations which accurately predict the resilient modulus. The resilient modulus data determined for a deviator stress of 6.0 psi and at moisture contents of 2.0% below optimum, optimum, and 2.0% above optimum were included in the evaluation and statistical analyses. The resilient modulus for a deviator stress of 6.0 psi is a representative modulus that has been incorporated into design procedures [15, 20, 32]. However, due to the difficulty in reproducing the exact desired moisture content in the compacted specimens, the moisture contents of resilient modulus specimen resulted in some variations.

A relationship between resilient modulus and specimen moisture content was developed to obtain a resilient modulus value at a desired moisture content. Figure 4.1 shows a typical example of this relationship for Soil MN4. Similar plots of the moisture content vs. resilient modulus for all the test specimens are shown in Appendix B. A smooth curve was fitted through the data points, and a regression equation were obtained by using second degree polynomial regression analysis. The resilient modulus at the optimum moisture content can be easily calculated by substituting the value of the optimum content value into the regression equation shown in Figure 4.1.

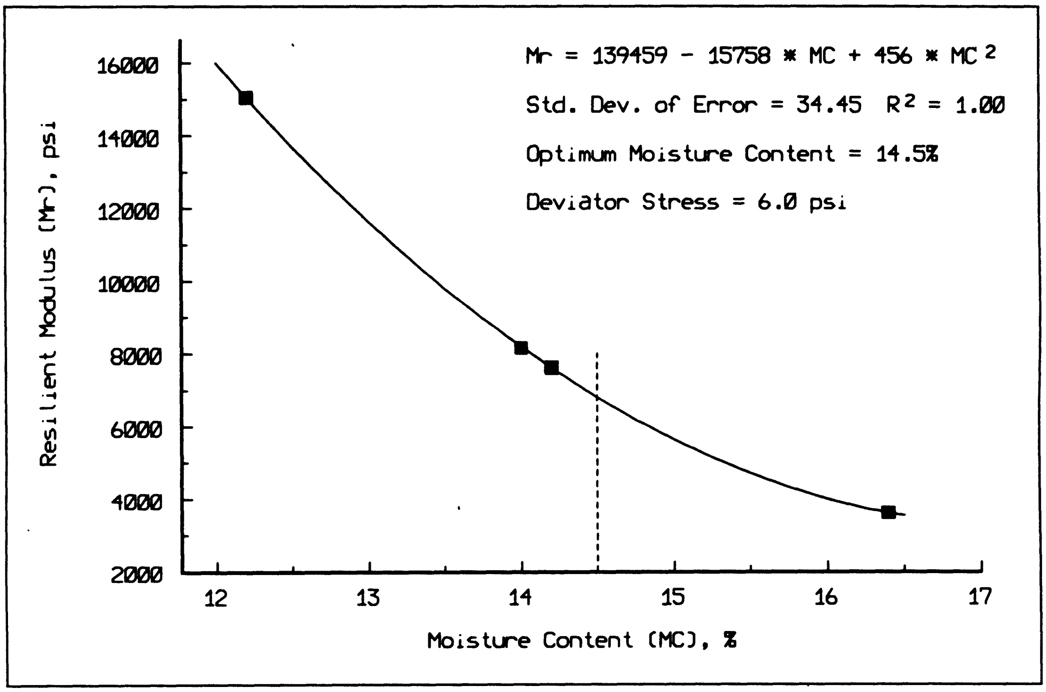


Figure 4.1 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample MN4

4.2 COMPARISON OF RESULTS

To validate the resilient modulus results obtained from the laboratory tests, the results were compared with the ODOT prediction procedure. The ODOT prediction procedure includes the following steps:

1. Determine Group Index (GI) from Atterberg Limits and Grain-Size Analysis.
2. Determine the California Bearing Ratio (CBR) from Group Index value.
3. Calculate M_r using Equation 4.1.

$$M_r = 1200 * CBR \tag{4.1}$$

Table 4.1 shows the results obtained by laboratory tests and by the ODOT prediction procedure. If the measured values were identical or similar to predicted values, the regression plot showing the predicted measured M_r on the Y axis versus Mr on the X axis would have a slope of 1 and a correlation coefficient R of 1. However, from the results shown in Table 4.1 and Figure 4.2, we can clearly identify that only two laboratory test results were close to the predicted results. The plot shows a correlation coefficient of -0.737 and a slope of -0.799.

Table 4.1 The Results of Measured M_r and Predicted M_r

Sample I. D.	Lab Measured M_r (ksi)	Predicted M_r (ksi)
NB4	6.844	6.00
NB6	4.550	7.20
SB3	3.260	7.20
SB4	4.426	7.20
MN2	3.835	8.40
MN4	6.794	6.00
GN2	4.452	9.60
GS5	3.971	7.20
BN3	5.370	7.20
BS2	2.460	10.80

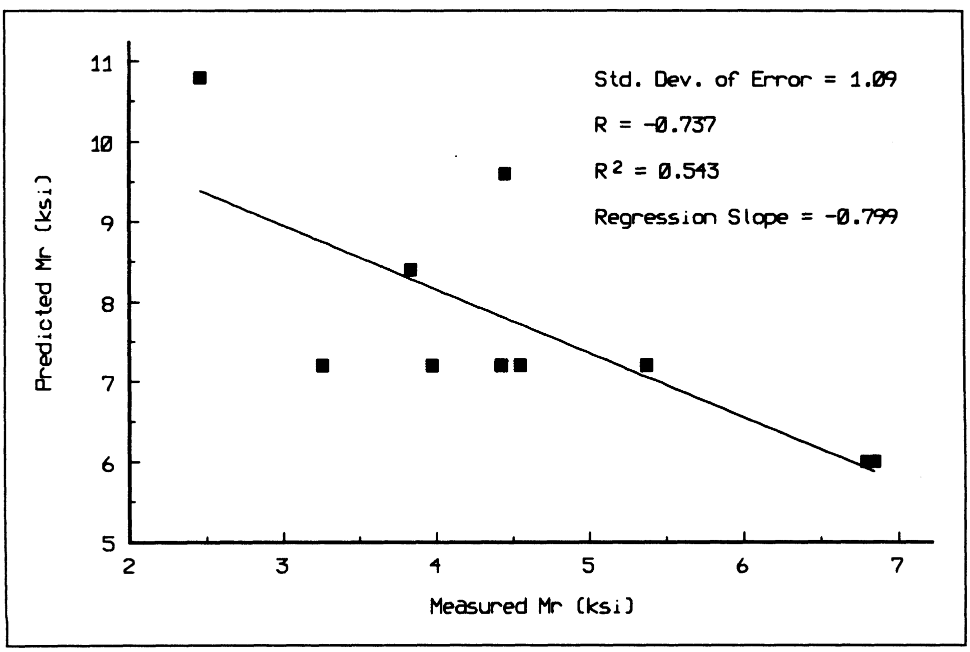


Figure 4.2 Regression Plot of Predicted M_r Versus Measured M_r

4.3 STATISTICAL DATA ANALYSIS

The parameters obtained from the resilient modulus tests and the index property tests were analyzed using STATGRAPHICS (Statistical Graphics System) computer software to evaluate the data for any correlation. STATGRAPHICS is a unique software package integrating a wide variety of statistical functions. These functions provide many modeling techniques that relate a dependent variable to one or more independent variables. However, only the Data Management and Regression Analysis capabilities were used in this study. The Data Management section facilitates the creation, storage, and manipulation of the data stored in the variables. Regression Analysis provides a variety of multivariate modeling procedures. In its common usage, it expresses the dependent variable as a function of the independent variables based on the strength of the relationships among them. The Regression Analysis section contains six procedures, which are summarized in Table 4.2.

The Stepwise Variable Selection procedure was utilized in this study. It allows either a forward or backward selection procedure to control the entry of variables into the model. The variables are entered or removed with the primary aim of obtaining a model with a small set of significant variables. The forward procedure starts with no variable in the model and then introduces one at a time based on the importance or significance of the new variable to the model. The program at this stage checks to see if the previously selected variables are significant; any insignificant variables are discarded at that point.

The backward procedure begins with a model containing all the variables. It then removes them one at a time, based on their insignificance to the model. In the backward selection, the program allows the re-entry of a variable into the model if it is later found to add significance to the fit. This procedure is summarized in the flow diagram of Figure 4.3. The backward procedure was used in this analysis. Tabulated output of the Regression Analysis, showing the constant, coefficients and the statistical parameters of the model, is given. The statistical parameters essentially explain the significance of a variable to the model. Table 4.3 gives a simple description and explains the importance of the statistical parameters to the study.

The parameters obtained from the resilient modulus tests and the index property tests listed in Table 4.5 were used to form the data base for the statistical correlation analysis. Based on the goal of obtaining means to predict the design resilient modulus for a given soil using simpler test methods, the resilient modulus values ($M_{r)}$ at 6 psi deviator stress and the optimum moisture content were to be treated as the dependent variable Y , and the basic soil index properties as independent variables X_1, X_2, ... X_n, respectively. The independent variables (LL, PI, Silt C., Clay C., GI, G_s, Unsoaked, and Soaked) are described and summarized in Table 4.4.

Table 4.2 Summary of Various Procedures in the Regression Analysis Section of STATGRAPHICS.

Procedure	Number of Variables	Data Type	Description
Simple Regression	2	Numbers	Performs an ordinary least squares regression using one independent variable. Estimates linear or selected nonlinear models.
Interactive outlier Rejection	2	Numbers	Allows user to selectively exclude outlier points from a simple linear regression plot.
Multiple Regression	2 or more	Numbers	Performs ordinary linear least squares regression using several independent variables.
Stepwise Variable Selection	2 or more	Numbers	Performs backward or forward stepwise multiple regression.
Ridge Regression	2 or more	Numbers	Performs a ridge regression on standardized variables and plots results.
Nonlinear Regression	2 or more	Numbers	Produces least squares estimates of parameters in a nonlinear regression model.

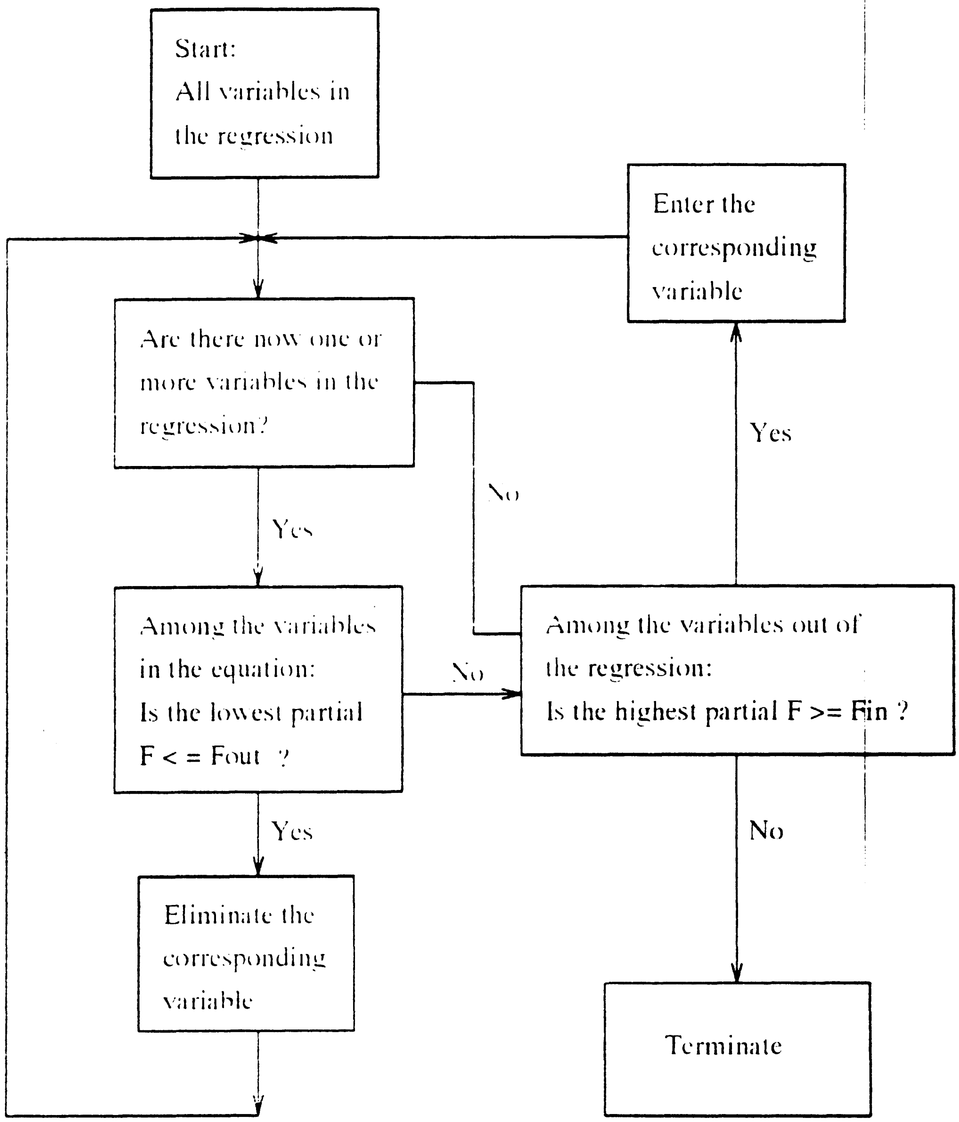


Figure 4.3 Flow Diagram of Backward Stepwise Regression Procedure

Table 4.3 Simple Definition and Description of Statistical Parameters.

Parameter	Definition and Description
R - squared	Coefficient of Determination. Indicates the percentage of variation explained by the model.
Adjusted R - Squared	Adjusted Coefficient of Determination. Decrease if insignificant variables are in the model. The Adjusted R - squared depicts or give the level of correlation of the model. A value of 1.0 indicates the best and highest correlation.
Standard Error of Estimation	Square root of the mean squared error. Measures the unexplained variability in the dependent variable.
t - value	It is calculated by dividing the coefficient of determination by the Standard Error of Estimation
Significance Level	It explains the t - value for each coefficient, and gives the probability that a larger absolute t - value would occur if there were no marginal contribution from that variable. A significance Level of 0.0 for a variable indicates the model is highly dependent on that variable.

Table 4.4 Description of Variables for STATGRAPHICS Analysis.

Variables	Description
M_r	The measured resilient modulus at 6 psi deviator stress.
M_r*	The predicted resilient modulus using STATGRAPHICS.
LL	The liquid limit of a soil sample obtained from Atterberg Limits tests.
PI	The plastic index of a soil sample obtained from the Atterberg Limits tests; PI = LL - PL.
Silt C	The silt content of a soil sample obtained from grain size analysis.
Clay C	The clay content of a soil sample obtained from grain size analysis.
GI	The group index obtained from AASHTO Soil Classification.
G_s	Specific gravity of solid.
Unsoaked	Unsoaked CBR value obtained from California Bering Ratio Tests.
Soaked	Soaked CBR value obtained from California Bearing Ratio Tests.

Simple regression analysis was conducted to obtain a relation between resilient modulus and soil properties. The purpose of the analyses was to establish a series of equations which could be used to predict resilient modulus by using a single soil property. In table 4.6 lines 1 through 5 summarize the simple regression coefficient data. Only those correlations significant at $\alpha = 0.05$ are shown.

The backward stepwise regression analysis was then used to establish a relationship between resilient modulus and soil properties obtained from more than one basic property test. The analysis started with two test data on two properties, Atterberg limits and grain-size analysis. The first procedure began with a model containing four independent variables (LL, PI, silt content, and clay content) and then proceeded with one eliminated at a time depending on whether the variable's partial F value was less than the given constant F_{out}. The sixth equation in Table 4.6 is the "best" equation containing Atterberg limits and grain-size analysis test data. The analyses was further continued by introducing one soil property at a time until all possible combinations were analyzed. In each combination of procedures, only the variables at significant level 0.05 were kept in the equation. The output data from STATGRAPHICS are contained in Appendix B. Table 4.6 lists regression equation coefficients. Their mathematical model is given by Equation 4.2.

$$M_r^* = a + b_1 X_1 + b_2 X_2 + \cdots + b_n X_n \tag{4.2}$$

Where:

M_r^* = predicted resilient modulus (ksi).

a = intercept (ksi).

b_1, b_2, ... b_n = regression coefficients.

X_1, X_2, ... X_n = independent variables.

Table 4.5 Measured Resilient Modulus and Basic Index Property Data for Statistical Analysis

Sample I. D.	Resilient Modulus* (ksi)	Atterberg Limits		Grain-Size Analysis		Group Index (GI)	Specific Gravity (G_s)	CBR	
		LL (%)	PI (%)	Silt Content (%)	Clay Content (%)			Unsoaked (%)	Soaked (%)
NB	6.844	40.4	21.4	40.0	30.5	14	2.74	9.41	6.80
NB	4.550	31.1	13.4	44.0	27.3	8	2.72	4.71	4.07
SB3	3.260	30.0	13.6	45.7	26.8	8	2.70	5.24	4.10
SB4	4.426	31.7	13.8	43.5	29.7	8	2.72	4.06	3.58
MN2	3.835	27.4	10.7	40.3	25.6	5	2.69	5.97	2.52
MN4	6.794	37.6	18.0	36.1	39.7	13	2.76	6.64	3.31
GN2	4.452	24.3	9.1	38.4	15.0	4	2.68	1.02	0.67
GS5	3.971	35.6	14.8	42.1	53.0	10	2.75	9.49	7.29
BN3	5.370	33.4	15.2	41.8	32.1	10	2.73	8.36	6.91
BS2	2.460	24.9	8.6	47.9	17.3	3	2.67	3.89	2.34

Note: * Resilient Modulus at Optimum Moisture Content Relative to AASHTO T-99;

Table 4.6 Summary of Regression Equations Including Soil Properties

Equation Number	Intercept a (ksi)	Regression Coefficient b								Correlation Coefficient R	Standard Error of Estimate
		LL	PI	Silt (%)	Clay (%)	GI	Gs	CBR Value			
								Unsoaked	Soaked		
1	-2.022	0.209*								0.785*	0.926
2	0.436		0.300*							0.832*	0.828
3	17.545			-0.308**						-0.764*	0.964
4	1.903					0.324*				0.834*	0.823
5	-89.01						34.46**			0.740**	1.004
6	7.378	0.248*		-0.209*	-0.062*					0.981*	0.335
7	4.428	0.587**	-0.801**	-0.184*	-0.129*	0.513**				0.996*	0.214
8	-86.459	0.127**		-0.166*	-0.101*		35.716*			0.996*	0.172
9	-143.213			-0.161*	-0.136*		58.087*	0.143*		0.997*	0.136
10	-90.406	0.281**	-0.215**	-0.193*	-0.131*		37.058*		0.099*	0.999*	0.064
11	-158.639			-0.143*	-0.121*		63.637*			0.984*	0.311

Note: * indicates significance at $\alpha = 0.01$; ** indicates significance at $\alpha = 0.05$.
Regression equation of the form: $M_r^* = a + b_1X_1 + b_2X_2 + ... + b_nX_n$ where M_r^* is in ksi and at optimum moisture content.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 SUMMARY

An investigation was conducted to determine the resilient modulus of subgrade soil samples obtained from five highway project site in Ohio and to develop a mathematical model for predicting the resilient modulus on the basis of basic soil property data. The study included a review of previous research on resilient modulus. Based on the study of the average daily traffic (ADT) on prevalent soils, priority soils were selected for laboratory testing. Standard laboratory tests were conducted to determine the index properties of each soil. From the grain-size distribution analyses, it was deduced that all the selected soil samples were fine-grained. Test specimens for repeated load tests were prepared at various water contents by a kneading compaction method in accordance with SHRP Protocol P46 test procedure. Four specimens of each soil sample were tested to establish a comprehensive resilience modulus behavior.

Resilient modulus results for each test series are shown in Appendix A. The regression plot of resilient modulus versus deviator stresses gives an equation which can be used to calculate the resilient modulus value at various deviator stresses.

A polynomial regression plot of resilient modulus versus moisture content was developed for each soil sample. The resilient modulus at 6 psi deviator stress was used in this study because this particular value is commonly used in pavement design procedures. The resilient modulus value at a desired moisture content can be easily calculated using the regression equation. The resilient modulus results from the laboratory tests were also compared to the ODOT prediction procedure.

Several regression analyses were made to find a reliable, indirect method of determining resilient modulus without complicated triaxial testing equipment. A total number of eleven equations are given by computer software STATGRAPHICS. These equations can be utilized to predict resilient modulus using either a single soil property value or data on several soil properties.

5.2 CONCLUSIONS

The following conclusions are made from this research:

1. Increasing in deviator stress decreases the resilient modulus of fine-grain soils.
2. Increasing in moisture content decreases the resilient modulus of fine-grain soils.
3. A simple prediction method adapted by the Ohio DOT, which is based on CBR values tends to over predict the actual resilient modulus.
4. It is possible to reliably determine the resilient modulus of soil through indirect methods
5. Low plasticity (LL, PI), high silt content, low clay content, low group index (GI), and low specific gravity (G_s) tend to lower the resilient modulus.

6. Unsoaked California bearing ratio (CBR) and soaked CBR (the value normally used in pavement design) indicate insignificant correlation with resilient modulus (M_r).

5.2 RECOMMENDATIONS

The following recommendations are based on the outcome of the laboratory tests and correlation procedure:

1. Extreme caution is required during laboratory determination of the index properties of soil samples since regression equations are highly dependent on their value.
2. The soils tested in this study are mostly A-6 and A-4 types from the AASHTO classification system. The testing of other soil types may develop an extensive range of resilient modulus prediction model for Ohio soils.
3. The laboratory M_r results were lower than the results predicted using ODOT prediction method. Past research [21, 22] has shown that sample age is an important factor affecting the M_r results. The older the sample is at the time of testing, the higher the resilient modulus becomes. however the effect diminishes its significance two days after compaction. In order to obtain reliable and stable results, two day curing in an environment chamber is recommended.
4. Instead of 6 inch specimen, using 2.8 inch specimen would reduce

specimen preparation time and required soil volume.

5. While performing the test, the gain factor (D, P and I values) in the computer software should not be changed frequently. Changing the gain factors during the test introduces some error in the test results.

6. Additional testing is required to establish a large data base for statistical analysis, which may improve the correlation coefficient.

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APPENDIX A

Table A.1 Actual Moisture Content and Dry Density of Tested Specimens

Test No.	Sample I.D.	Moisture Content	Dry Density
1	NB4	14.0%	106.7 pcf
2		16.1%	107.8 pcf
3		18.9%	107.0 pcf
1	NB6	13.0%	108.7 pcf
2		15.5%	114.4 pcf
3		16.4%	113.7 pcf
4		16.9%	111.8 pcf
1	SB3	13.9%	116.2 pcf
2		14.8%	115.9 pcf
3		15.4%	117.4 pcf
4		17.1%	114.3 pcf
1	SB4	14.0%	103.9 pcf
2		14.7%	114.4 pcf
3		16.2%	114.4 pcf
4		16.8%	114.2 pcf
1	MN2	11.3%	113.2 pcf
2		12.9%	116.6 pcf
3		14.4%	116.6 pcf
4		15.8%	115.6 pcf

Table A.1 Continued

Test No.	Sample I.D.	Moisture Content	Dry Density
1	MN4	12.2%	107.5 pcf
2		14.0%	113.1 pcf
3		14.2%	114.4 pcf
4		16.4%	112.0 pcf
1	GN2	10.9%	117.1 pcf
2		12.5%	117.8 pcf
3		12.9%	118.1 pcf
4		13.1%	118.3 pcf
1	GS5	15.5%	106.8 pcf
2		17.7%	114.2 pcf
3		18.5%	114.0 pcf
4		19.5%	112.0 pcf
1	BN3	12.6%	107.8 pcf
2		14.3%	119.3 pcf
3		15.6%	121.4 pcf
4		17.3%	110.6 pcf
1	BS2	11.3%	106.5 pcf
2		12.8%	120.9 pcf
3		13.4%	121.6 pcf
4		15.0%	118.2 pcf

Table A.2 Results of Resilient Modulus Test for Soil Sample NB4 at Moisture Content 1.7% Below Optimum

* Ohio University * Date: 5/9/92

Resilient Modulus Test for Material Type 2

Data File	UC-9.DAT
Soil sample	Silty Clay
Sample No.	NB4-1
Specific gravity	2.74

Load ID: SHRP P46 Soil type 2
Number of cycle time=1.0 sec
Time: Load=0.1 Cycle=1.0sec
Seating load = 0.5 lb.
Waverform type: Havesine

Specimen Measurements:

	Top:	6.00
Diameter	Middle:	6.00
	Bottom:	6.00
	Average:	6.00
Membrane Thickness:		0.03
Net Diameter:		5.94
Ht Specimen + Cap + Base:		13.56
Ht Cap + Base:		1.00
Initial Length, Lo (inch):		12.56
Inside Diameter of Mold:		6.00

Soil Specimen Weight:

Initial wt. of container+wet so	13461.00
Final wt. of container wet soi	2380.00
Weight of wet soil used:	11081.00

Soil Specimen Volume:

Initial Area Ao (inch):	27.71
Volume Ao * Lo (inch):	348.04
Wet Density (pcf):	121.18
Compaction water content %:	13.70
Water content after Mr testing	14.00
Dry density (pcf):	106.66

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.416	0.002414	0.000192	12590	484	20.416
6.0	4.0	4.710	0.006265	0.000499	9492	650	22.710
6.0	6.0	6.891	0.010385	0.000827	8432	981	24.891
6.0	8.0	8.906	0.012732	0.001013	8791	169	26.906
6.0	10.0	10.880	0.016561	0.001321	8248	89	28.405
4.0	2.0	2.405	0.002591	0.000206	11665	210	14.405
4.0	4.0	4.655	0.006168	0.000491	9491	321	16.655
4.0	6.0	6.842	0.010236	0.000815	8466	825	18.842
4.0	8.0	8.867	0.013483	0.001073	8263	73	20.867
4.0	10.0	10.997	0.017142	0.001364	8060	76	22.997
2.0	2.0	2.399	0.002460	0.000196	12262	340	8.399
2.0	4.0	4.723	0.006491	0.000517	9148	273	10.723
2.0	6.0	6.799	0.010287	0.000819	8305	166	12.799
2.0	8.0	8.914	0.013489	0.001074	8303	126	14.914
2.0	10.0	10.944	0.016494	0.001349	8113	95	16.944

Table A.3 Results of Resilient Modulus Test for Soil Sample NB4 at Moisture Content 0.4% Above Optimum

* Ohio University * Date: 5/9/92

Resilient Modulus Test for Material Type 2

Data File	UC-10.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	NB4-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.74		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	13949.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11569.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	353.30
Ht Specimen + Cap + Base:	13.75	Wet Density (pcf):	124.63
Ht Cap + Base:	1.00	Compaction water content %:	15.70
Initial Length, Lo (inch):	12.75	Water content after Mr testing	16.10
Inside Diameter of Mold:	6.00	Dry density (pcf):	107.83

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.367	0.003598	0.000282	8402	383	20.367
6.0	4.0	4.351	0.007538	0.000591	7364	157	22.351
6.0	6.0	6.169	0.012338	0.000968	6376	45	24.169
6.0	8.0	7.812	0.017407	0.001365	5722	43	25.812
6.0	10.0	9.611	0.023856	0.001971	5137	64	27.611
4.0	2.0	2.343	0.003360	0.000264	8899	250	14.343
4.0	4.0	4.347	0.007684	0.000603	7214	124	16.347
4.0	6.0	6.155	0.012122	0.000951	6474	69	18.155
4.0	8.0	7.878	0.017059	0.001338	5888	51	19.878
4.0	10.0	9.648	0.023312	0.001828	5277	74	21.648
2.0	2.0	2.336	0.003210	0.000252	9285	283	8.336
2.0	4.0	4.307	0.007690	0.000603	7143	107	10.307
2.0	6.0	6.142	0.012289	0.000964	6373	65	12.142
2.0	8.0	7.878	0.017142	0.001344	5860	69	13.878
2.0	10.0	9.646	0.023474	0.001941	5240	67	15.646

Table A.4 Results of Resilient Modulus Test for Soil Sample NB4 at Moisture Content 3.2% Above Optimum

* Ohio University * Date: 5/9/92

Resilient Modulus Test for Material Type 2

Data File	UC-11.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	NB4-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.74		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14133.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11753.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	351.64
Ht Specimen + Cap + Base:	13.69	Wet Density (pcf):	127.21
Ht Cap + Base:	1.00	Compaction water content %:	17.70
Initial Length, Lo (inch):	12.69	Water content after Mr testing	18.90
Inside Diameter of Mold:	6.00	Dry density (pcf):	108.21

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.050	0.003378	0.000266	7701	149	20.050
6.0	4.0	3.947	0.009766	0.000770	5128	29	21.947
6.0	6.0	5.437	0.017630	0.001390	3913	4	23.437
6.0	8.0	6.715	0.026013	0.002050	3275	8	24.715
6.0	10.0	7.900	0.033691	0.002655	2975	75	25.900
4.0	2.0	2.089	0.003436	0.000271	7716	33	14.089
4.0	4.0	3.942	0.009714	0.000766	5149	11	15.942
4.0	6.0	5.489	0.017105	0.001348	4071	10	17.489
4.0	8.0	6.845	0.025974	0.002047	3344	10	18.845
4.0	10.0	7.970	0.035175	0.002772	2875	129	19.970
2.0	2.0	2.072	0.003064	0.000241	8582	27	8.072
2.0	4.0	3.910	0.009851	0.000776	5036	14	9091.000
2.0	6.0	5.434	0.018109	0.001427	3808	15	11.434
2.0	8.0	5.901	0.026770	0.002110	3223	11	12.801
2.0	10.0	8.027	0.035974	0.002835	2831	95	14.027

Table A.5 Results of Resilient Modulus Test for Soil Sample NB6 at Moisture Content 2.5% Below Optimum

* Ohio University * Date: 5/6/92

Resilient Modulus Test for Material Type 2

Data File	UC-2.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	NB6-1		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.72		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	13541.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11161.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	344.71
Ht Specimen + Cap + Base:	13.44	Wet Density (pcf):	123.23
Ht Cap + Base:	1.00	Compaction water content %:	13.50
Initial Length, Lo (inch):	12.44	Water content after Mr testing	13.00
Inside Diameter of Mold:	6.00	Dry density (pcf):	108.69

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.339	0.002646	0.000213	10999	220	20.399
6.0	4.0	4.662	0.005890	0.000473	9867	441	22.662
6.0	6.0	6.606	0.008939	0.000719	9195	112	24.606
6.0	8.0	8.545	0.012448	0.001001	8540	43	26.545
6.0	10.0	10.395	0.016251	0.001306	7959	114	28.395
4.0	2.0	2.335	0.002725	0.000219	10662	243	14.335
4.0	4.0	4.569	0.005798	0.000466	9802	98	16.569
4.0	6.0	6.559	0.008966	0.000721	9101	70	18.559
4.0	8.0	8.498	0.012766	0.001026	8282	119	20.498
4.0	10.0	10.378	0.016193	0.001302	7975	149	22.378
2.0	2.0	2.315	0.002637	0.000212	10930	318	8.315
2.0	4.0	4.564	0.006100	0.000490	9308	105	10.564
2.0	6.0	6.504	0.009302	0.000748	8698	50	12.504
2.0	8.0	8.485	0.013010	0.001046	8114	63	14.485
2.0	10.0	10.384	0.016803	0.001351	7688	48	16.384

Table A.6 Results of Resilient Modulus Test for Soil Sample NB6 at 15.5% Optimum Moisture Content

* Ohio University * Date: 5/14/92

Resilient Modulus Test for Material Type 2

Data File	UC-20.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	NB6-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.72		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14275.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11895.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	356.90
Ht Specimen + Cap + Base:	13.88	Wet Density (pcf):	132.16
Ht Cap + Base:	1.00	Compaction water content %:	15.50
Initial Length, Lo (inch):	12.88	Water content after Mr testing	15.50
Inside Diameter of Mold:	6.00	Dry density (pcf):	114.43

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.247	0.004062	0.000328	6851	165	20.247
6.0	4.0	4.224	0.009625	0.000778	5431	23	22.224
6.0	6.0	5.329	0.016623	0.001343	4339	11	23.829
6.0	8.0	7.479	0.024637	0.001991	3757	19	25.479
6.0	10.0	9.132	0.032928	0.002661	3432	44	27.132
4.0	2.0	2.300	0.003812	0.000308	7470	119	14.300
4.0	4.0	4.134	0.008826	0.000713	5805	246	16.134
4.0	6.0	6.068	0.014932	0.001207	5029	47	18.068
4.0	8.0	7.872	0.022598	0.001826	4311	32	19.872
4.0	10.0	9.442	0.031488	0.002544	3711	28	21.442
2.0	2.0	2.283	0.003479	0.000281	8123	132	8.283
2.0	4.0	4.217	0.009055	0.000732	5764	63	10.217
2.0	6.0	6.086	0.014731	0.001190	5112	17	12.086
2.0	8.0	7.896	0.022513	0.001819	4341	45	13.896
2.0	10.0	9.326	0.031384	0.002536	3677	33	15.326

Table A.7 Results of Resilient Modulus Test for Soil Sample NB6 at Moisture Content 0.9% Above Optimum

* Ohio University * Date: 5/6/92

Resilient Modulus Test for Material Type 2

Data File	UC-4.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	NB6-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.72		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14255.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11875.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	344.71
Ht Specimen + Cap + Base:	13.44	Wet Density (pcf):	131.12
Ht Cap + Base:	1.00	Compaction water content %:	15.50
Initial Length, Lo (inch):	12.44	Water content after Mr testing	16.40
Inside Diameter of Mold:	6.00	Dry density (pcf):	113.66

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	1.897	0.004218	0.000339	5596	119	19.897
6.0	4.0	3.597	0.010794	0.000868	4144	16	21.597
6.0	6.0	4.952	0.018787	0.001510	3279	14	22.952
6.0	8.0	6.236	0.027521	0.002213	2818	10	24.236
6.0	10.0	7.394	0.036707	0.002951	2506	7	25.394
4.0	2.0	1.887	0.004132	0.000332	5683	143	13.887
4.0	4.0	3.519	0.011185	0.000899	3913	18	15.519
4.0	6.0	4.869	0.019324	0.001554	3134	17	16.869
4.0	8.0	6.211	0.028024	0.002253	2757	14	18.211
4.0	10.0	7.477	0.037085	0.002981	2508	5	19.477
2.0	2.0	1.890	0.004218	0.000339	5574	132	7.890
2.0	4.0	3.479	0.011487	0.000923	3768	13	9.479
2.0	6.0	4.849	0.019742	0.001587	3055	6	10.849
2.0	8.0	6.209	0.028320	0.002277	2727	4	12.209
2.0	10.0	7.461	0.037430	0.003010	2479	4	13.461

Table A.8 Results of Resilient Modulus Test for Soil Sample NB6 at Moisture Content 1.4% Above Optimum

* Ohio University * Date: 5/8/92

Resilient Modulus Test for Material Type 2

Data File	UC-7.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	NB6-4		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.72		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14506.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12126.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	351.64
Ht Specimen + Cap + Base:	13.69	Wet Density (pcf):	131.41
Ht Cap + Base:	1.00	Compaction water content %:	17.50
Initial Length, Lo (inch):	12.69	Water content after Mr testing	16.90
Inside Diameter of Mold:	6.00	Dry density (pcf):	111.23

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	1.351	0.003394	0.000268	5050	31	19.351
6.0	4.0	2.936	0.011780	0.000929	3162	20	20.936
6.0	6.0	4.105	0.021005	0.001656	2479	3	22.105
6.0	8.0	5.348	0.029776	0.002347	2279	6	23.348
6.0	10.0	6.654	0.037573	0.002961	2247	3	24.654
4.0	2.0	1.406	0.002496	0.000197	7150	173	13.406
4.0	4.0	3.359	0.011716	0.000924	3637	15	15.359
4.0	6.0	4.736	0.020682	0.001630	2906	7	16.736
4.0	8.0	5.968	0.029846	0.002352	2537	2	17.968
4.0	10.0	7.043	0.038605	0.003042	2315	3	19.043
2.0	2.0	1.468	0.002707	0.000213	6882	126	7.468
2.0	4.0	3.578	0.012964	0.001022	3502	4	9.578
2.0	6.0	4.914	0.022455	0.001770	2777	7	10.914
2.0	8.0	6.216	0.032364	0.002551	2437	2	12.216
2.0	10.0	7.252	0.041553	0.003274	2215	3	13.252

Table A.9 Results of Resilient Modulus Test for Soil Sample SB3 at Moisture Content 1.2% Below Optimum

* Ohio University * Date: 5/11/92

Resilient Modulus Test for Material Type 2

Data File	UC-16.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	SB3-1		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.70		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14300.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11920.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	343.05
Ht Specimen + Cap + Base:	13.38	Wet Density (pcf):	132.44
Ht Cap + Base:	1.00	Compaction water content %:	13.10
Initial Length, Lo (inch):	12.38	Water content after Mr testing	13.90
Inside Diameter of Mold:	6.00	Dry density (pcf):	117.10

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.257	0.002881	0.000233	9700	267	20.257
6.0	4.0	4.305	0.008167	0.000660	6523	30	22.305
6.0	6.0	6.044	0.014514	0.001173	5153	28	24.044
6.0	8.0	7.672	0.022192	0.001793	4278	22	25.672
6.0	10.0	9.249	0.030298	0.002448	3778	24	27.249
4.0	2.0	2.263	0.002100	0.000170	13344	255	14.263
4.0	4.0	4.112	0.007666	0.000619	6638	30	16.112
4.0	6.0	5.871	0.014508	0.001172	5008	23	17.871
4.0	8.0	7.708	0.022882	0.001849	4168	9	19.708
4.0	10.0	9.294	0.031317	0.002531	3672	9	21.294
2.0	2.0	2.232	0.002255	0.000182	12251	100	8.232
2.0	4.0	4.085	0.007666	0.000619	6595	43	10.085
2.0	6.0	5.886	0.015289	0.001236	4764	20	11.886
2.0	8.0	7.627	0.023193	0.001874	4070	20	13.627
2.0	10.0	9.289	0.031516	0.002547	3647	12	15.289

Table A.10 Results of Resilient Modulus Test for Soil Sample SB3 at Moisture Content 0.3% Below Optimum

* Ohio University * Date: 5/8/92

Resilient Modulus Test for Material Type 2

Data File	UC-8.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	SB3-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.70		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14571.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12191.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	348.04
Ht Specimen + Cap + Base:	13.56	Wet Density (pcf):	133.42
Ht Cap + Base:	1.00	Compaction water content %:	15.10
Initial Length, Lo (inch):	12.56	Water content after Mr testing	14.80
Inside Diameter of Mold:	6.00	Dry density (pcf):	115.92

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.013	0.003897	0.000310	6489	56	20.013
6.0	4.0	3.761	0.010867	0.000865	4348	39	21.761
6.0	6.0	5.127	0.018869	0.001502	3414	24	23.127
6.0	8.0	6.501	0.027087	0.002156	3015	3	24.501
6.0	10.0	7.974	0.034607	0.002754	2895	13	25.974
4.0	2.0	2.086	0.003687	0.000293	7110	154	14.086
4.0	4.0	3.835	0.010596	0.000843	4547	38	15.835
4.0	6.0	5.404	0.018918	0.001506	3588	18	17.404
4.0	8.0	6.876	0.027414	0.002182	3151	7	18.876
4.0	10.0	8.217	0.035464	0.002823	2911	4	20.217
2.0	2.0	2.088	0.003470	0.000276	7561	66	8.088
2.0	4.0	3.848	0.010657	0.000848	4537	27	9.848
2.0	6.0	5.422	0.019019	0.001514	3582	6	11.422
2.0	8.0	6.944	0.027805	0.002213	3138	7	12.944
2.0	10.0	8.339	0.036084	0.002873	2903	3	14.339

Table A.11 Results of Resilient Modulus Test for Soil Sample SB3 at Moisture Content 0.3% Above Optimum

* Ohio University * Date: 5/11/92

Resilient Modulus Test for Material Type 2

Data File	UC-17.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	SB3-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.70		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14604.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12224.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	344.71
Ht Specimen + Cap + Base:	13.44	Wet Density (pcf):	135.14
Ht Cap + Base:	1.00	Compaction water content %:	15.10
Initial Length, Lo (inch):	12.44	Water content after Mr testing	15.40
Inside Diameter of Mold:	6.00	Dry density (pcf):	117.41

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.047	0.004523	0.000363	5632	127	20.047
6.0	4.0	3.783	0.012030	0.000967	3911	36	21.783
6.0	6.0	5.162	0.021375	0.001719	3003	17	23.162
6.0	8.0	6.636	0.030435	0.002447	2712	18	24.636
6.0	10.0	8.157	0.038974	0.003134	2603	14	26.157
4.0	2.0	2.142	0.004709	0.000378	5666	205	14.142
4.0	4.0	3.830	0.011530	0.000927	4133	96	15.830
4.0	6.0	5.448	0.020428	0.001642	3317	34	17.448
4.0	8.0	6.996	0.030316	0.002438	2870	34	18.996
4.0	10.0	8.433	0.040036	0.003219	2620	24	20.433
2.0	2.0	2.110	0.004492	0.000361	5847	135	8.110
2.0	4.0	3.854	0.011301	0.000909	4242	20	9.854
2.0	6.0	5.465	0.020242	0.001627	3358	17	11.465
2.0	8.0	7.061	0.028959	0.002299	3071	9	13.061
2.0	10.0	8.535	0.037326	0.003001	2844	6	14.535

Table A.12 Results of Resilient Modulus Test for Soil Sample SB3 at Moisture Content 2.0% Above Optimum

* Ohio University * Date: 5/11/92

Resilient Modulus Test for Material Type 2

Data File	UC-18.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	SB3-4		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.70		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	14431.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	12051.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	343.05
Ht Specimen + Cap + Base:	13.38	Wet Density (pcf):	133.90
Ht Cap + Base:	1.00	Compaction water content %:	17.10
Initial Length, Lo (inch):	12.38	Water content after Mr testing	17.10
Inside Diameter of Mold:	6.00	Dry density (pcf):	114.34

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	1.992	0.005997	0.000485	4111	40	19.992
6.0	4.0	3.566	0.014523	0.001174	3038	24	21.566
6.0	6.0	4.976	0.025095	0.002028	2454	12	22.976
6.0	8.0	6.263	0.036823	0.002975	2105	13	24.263
6.0	10.0	7.769	0.046402	0.003750	2072	10	25.769
4.0	2.0	2.029	0.005109	0.000413	4915	20	14.029
4.0	4.0	3.652	0.013431	0.001085	3365	37	15.652
4.0	6.0	5.153	0.023029	0.001861	2769	9	17.153
4.0	8.0	6.615	0.033038	0.002669	2478	7	18.615
4.0	10.0	8.004	0.042184	0.003409	2348	11	20.004
2.0	2.0	2.023	0.004742	0.000383	5280	102	8.023
2.0	4.0	3.725	0.012741	0.001030	3618	22	9.725
2.0	6.0	5.186	0.022552	0.001822	2846	14	11.186
2.0	8.0	6.651	0.032825	0.002653	2507	13	12.651
2.0	10.0	8.000	0.042444	0.003431	2332	7	14.000

Table A.13 Results of Resilient Modulus Test for Soil Sample SB4 at Moisture Content 0.9% Below Optimum

* Ohio University * Date: 5/18/92

Resilient Modulus Test for Material Type 2

Data File	UC-21.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	SB4-1		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.72		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	14188.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	11808.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	344.71
Ht Specimen + Cap + Base:	13.44	Wet Density (pcf):	130.54
Ht Cap + Base:	1.00	Compaction water content %:	12.90
Initial Length, Lo (inch):	12.44	Water content after Mr testing	14.00
Inside Diameter of Mold:	6.00	Dry density (pcf):	115.63

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.461	0.002643	0.000213	11581	135	20.461
6.0	4.0	4.618	0.005844	0.000470	9829	149	22.618
6.0	6.0	6.827	0.009467	0.000761	8969	30	24.827
6.0	8.0	8.827	0.013977	0.001124	7855	54	26.827
6.0	10.0	10.694	0.018613	0.001497	7146	26	28.694
4.0	2.0	2.461	0.002332	0.000187	13132	355	14.461
4.0	4.0	4.587	0.006006	0.000483	9499	20	16.587
4.0	6.0	6.623	0.009576	0.000770	8602	54	18.623
4.0	8.0	8.498	0.013138	0.001056	8047	132	20.498
4.0	10.0	10.485	0.018179	0.001462	7173	8	22.485
2.0	2.0	2.454	0.002231	0.000179	13700	469	8.454
2.0	4.0	4.570	0.005954	0.000478	9552	276	10.570
2.0	6.0	6.578	0.009732	0.000782	8407	70	12.578
2.0	8.0	8.564	0.013879	0.001116	7675	116	14.564
2.0	10.0	10.472	0.018542	0.001491	7024	93	16.472

Table A.14 Results of Resilient Modulus Test for Soil Sample SB4 at Moisture Content 0.2% Below Optimum

* Ohio University * Date: 5/10/92

Resilient Modulus Test for Material Type 2

Data File	UC-12.DAT
Soil sample	Silty Clay
Sample No.	SB4-2
Specific gravity	2.72

Load ID: SHRP P46 Soil type 2
Number of cycle time=1.0 sec
Time: Load=0.1 Cycle=1.0sec
Seating load = 0.5 lb.
Waverform type: Havesine

Specimen Measurements:

Diameter	Top:	6.00
	Middle:	6.00
	Bottom:	6.00
	Average:	6.00
Membrane Thickness:		0.03
Net Diameter:		5.94
Ht Specimen + Cap + Base:		13.75
Ht Cap + Base:		1.00
Initial Length, Lo (inch):		12.75
Inside Diameter of Mold:		6.00

Soil Specimen Weight:

Initial wt. of container+wet so	14568.00
Final wt. of container wet soi	2380.00
Weight of wet soil used:	12188.00

Soil Specimen Volume:

Initial Area Ao (inch):	27.71
Volume Ao * Lo (inch):	353.30
Wet Density (pcf):	131.44
Compaction water content %:	14.90
Water content after Mr testing	14.70
Dry density (pcf):	114.39

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.245	0.003580	0.000281	7996	135	20.245
6.0	4.0	4.179	0.008374	0.000657	6363	149	22.179
6.0	6.0	6.058	0.014575	0.001143	5301	30	24.058
6.0	8.0	7.709	0.022531	0.001767	4362	54	25.709
6.0	10.0	9.304	0.030994	0.002431	3827	26	27.304
4.0	2.0	2.215	0.003619	0.000284	7804	355	14.215
4.0	4.0	4.125	0.009335	0.000732	5636	20	16.125
4.0	6.0	5.870	0.016422	0.001288	4558	54	17.870
4.0	8.0	7.657	0.024063	0.001887	4058	132	19.657
4.0	10.0	9.318	0.032843	0.002575	3618	8	21.318
2.0	2.0	2.208	0.003491	0.000274	8065	469	8.208
2.0	4.0	4.033	0.009616	0.000754	5348	276	10.033
2.0	6.0	5.779	0.016562	0.001299	4449	70	11.779
2.0	8.0	7.592	0.023895	0.001874	4051	116	13.592
2.0	10.0	9.230	0.031723	0.002488	3710	93	15.230

Table A.15 Results of Resilient Modulus Test for Soil Sample SB4 at Moisture Content 1.3% Above Optimum

* Ohio University * Date: 5/13/92

Resilient Modulus Test for Material Type 2

Data File	UC-19.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	SB4-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.72		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14656.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12276.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	322.27
Ht Specimen + Cap + Base:	12.63	Wet Density (pcf):	133.70
Ht Cap + Base:	1.00	Compaction water content %:	16.90
Initial Length, Lo (inch):	11.63	Water content after Mr testing	16.20
Inside Diameter of Mold:	6.00	Dry density (pcf):	114.37

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.017	0.005240	0.000415	4860	97	20.017
6.0	4.0	3.743	0.013821	0.001095	3419	19	21.743
6.0	6.0	5.143	0.024103	0.001909	2694	17	23.143
6.0	8.0	6.674	0.033350	0.002641	2527	11	24.674
6.0	10.0	8.282	0.042667	0.003379	2451	6	26.282
4.0	2.0	2.115	0.005130	0.000406	5206	54	14.115
4.0	4.0	3.867	0.013098	0.001038	3727	32	15.867
4.0	6.0	5.508	0.021881	0.001733	3178	26	17.508
4.0	8.0	7.139	0.032043	0.002538	2813	20	19.139
4.0	10.0	8.630	0.041397	0.003279	2632	16	20.630
2.0	2.0	2.157	0.004782	0.000379	5697	125	8.157
2.0	4.0	3.891	0.012704	0.001005	3870	104	9.891
2.0	6.0	5.521	0.021838	0.001730	3192	20	11.521
2.0	8.0	7.129	0.032510	0.002575	2769	21	13.129
2.0	10.0	8.633	0.042822	0.003392	2545	16	14.633

Table A.16 Results of Resilient Modulus Test for Soil Sample SB4 at Moisture Content 1.9% Above Optimum

* Ohio University * Date: 5/18/92

Resilient Modulus Test for Material Type 2

Data File	UC-23.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	SB4-4		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.72		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14394.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12014.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	343.05
Ht Specimen + Cap + Base:	13.38	Wet Density (pcf):	133.48
Ht Cap + Base:	1.00	Compaction water content %:	16.90
Initial Length, Lo (inch):	12.38	Water content after Mr testing	16.80
Inside Diameter of Mold:	6.00	Dry density (pcf):	114.19

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.029	0.006161	0.000498	4075	37	20.029
6.0	4.0	3.632	0.016393	0.001244	2920	31	21.632
6.0	6.0	5.099	0.026590	0.002149	2373	9	23.099
6.0	8.0	6.669	0.035928	0.002903	2297	26	24.669
6.0	10.0	8.293	0.044431	0.003590	2310	21	26.293
4.0	2.0	2.168	0.005087	0.000411	5277	101	14.168
4.0	4.0	3.886	0.012674	0.001024	3796	63	15.886
4.0	6.0	5.602	0.022122	0.001787	3134	31	17.602
4.0	8.0	7.135	0.031046	0.002509	2844	10	19.135
4.0	10.0	8.582	0.040292	0.003256	2636	13	20.582
2.0	2.0	2.130	0.004810	0.000389	5481	40	8.130
2.0	4.0	3.882	0.012100	0.000978	3970	56	9.882
2.0	6.0	5.549	0.021170	0.001711	3244	33	11.549
2.0	8.0	7.250	0.030887	0.002496	2905	10	13.250
2.0	10.0	8.713	0.039859	0.003221	2705	9	14.713

Table A.17 Results of Resilient Modulus Test for Soil Sample MN2 at Moisture Content 2.6% Below Optimum

* Ohio University * Date: 5/28/92

Resilient Modulus Test for Material Type 2

Data File	UC2-1.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	MN2-1		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.69		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	14126.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	11746.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	353.30
Ht Specimen + Cap + Base:	13.75	Wet Density (pcf):	126.67
Ht Cap + Base:	1.00	Compaction water content %:	11.90
Initial Length, Lo (inch):	12.75	Water content after Mr testing	11.30
Inside Diameter of Mold:	6.00	Dry density (pcf):	113.20

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.653	0.002716	0.000213	12477	586	20.653
6.0	4.0	4.905	0.005582	0.000437	11216	370	22.905
6.0	6.0	7.162	0.008640	0.000677	10576	290	25.162
6.0	8.0	9.189	0.012195	0.000956	9607	62	27.189
6.0	10.0	11.246	0.016144	0.001266	8882	62	29.246
4.0	2.0	2.574	0.002695	0.000211	12180	89	14.574
4.0	4.0	4.876	0.005667	0.000443	11006	654	16.876
4.0	6.0	6.748	0.008762	0.000686	9837	448	18.748
4.0	8.0	9.174	0.012204	0.000957	9586	157	21.174
4.0	10.0	11.303	0.013199	0.001270	8897	49	23.303
2.0	2.0	2.511	0.002640	0.000206	12204	940	8.511
2.0	4.0	5.020	0.006042	0.000474	10593	122	11.020
2.0	6.0	7.130	0.009238	0.000724	9842	137	13.130
2.0	8.0	9.146	0.012814	0.001005	9101	137	15.146
2.0	10.0	11.300	0.016940	0.001328	8506	111	17.300

Table A.18 Results of Resilient Modulus Test for Soil Sample MN2 at Moisture Content 1.0% Below Optimum

* Ohio University * Date: 5/28/92

Resilient Modulus Test for Material Type 2

Data File	UC2-2.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	MN2-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.69		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14284.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11904.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	341.39
Ht Specimen + Cap + Base:	13.32	Wet Density (pcf):	132.80
Ht Cap + Base:	1.00	Compaction water content %:	13.90
Initial Length, Lo (inch):	12.32	Water content after Mr testing	12.90
Inside Diameter of Mold:	6.00	Dry density (pcf):	116.59

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.357	0.003879	0.000315	7491	172	20.357
6.0	4.0	4.305	0.008383	0.000680	6334	203	22.305
6.0	6.0	6.010	0.014029	0.001138	5282	112	24.010
6.0	8.0	7.778	0.021585	0.001751	4442	66	25.778
6.0	10.0	9.563	0.028656	0.002325	4113	61	27.563
4.0	2.0	2.362	0.003867	0.000314	7533	198	14.362
4.0	4.0	4.243	0.008563	0.000694	6111	173	16.243
4.0	6.0	6.075	0.013660	0.001108	5483	122	18.075
4.0	8.0	7.968	0.021429	0.001739	4583	53	19.968
4.0	10.0	9.744	0.029846	0.002421	4024	70	21.744
2.0	2.0	2.343	0.004147	0.000336	6969	211	8.343
2.0	4.0	4.200	0.009082	0.000736	5709	250	10.200
2.0	6.0	6.013	0.014713	0.001194	5038	77	12.013
2.0	8.0	8.134	0.021225	0.001722	4724	46	14.134
2.0	10.0	9.917	0.028687	0.002327	4261	37	15.917

Table A.19 Results of Resilient Modulus Test for Soil Sample MN2 at Moisture Content 0.5% Above Optimum

* Ohio University * Date: 5/30/92

Resilient Modulus Test for Material Type 2

Data File	UC2-3.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	MN2-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.69		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	14755.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	12375.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	354.97
Ht Specimen + Cap + Base:	13.81	Wet Density (pcf):	132.80
Ht Cap + Base:	1.00	Compaction water content %:	13.90
Initial Length, Lo (inch):	12.81	Water content after Mr testing	14.40
Inside Diameter of Mold:	6.00	Dry density (pcf):	116.59

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.245	0.003879	0.000356	6309	36	20.245
6.0	4.0	4.113	0.000038	0.000809	5086	62	22.113
6.0	6.0	5.769	0.000134	0.001461	3948	33	23.769
6.0	8.0	7.472	0.000198	0.002182	3424	40	25.472
6.0	10.0	8.609	0.000238	0.002925	2943	14	26.609
4.0	2.0	2.246	0.000130	0.000372	6041	46	14.246
4.0	4.0	4.188	0.000460	0.000878	4769	56	16.188
4.0	6.0	5.996	0.000179	0.001442	4157	18	17.996
4.0	8.0	7.357	0.000116	0.002169	3392	34	19.357
4.0	10.0	8.503	0.000181	0.002988	2846	10	20.503
2.0	2.0	2.228	0.000098	0.000364	6121	56	8.228
2.0	4.0	4.122	0.000092	0.000874	4718	61	10.122
2.0	6.0	5.962	0.000065	0.001464	4072	23	11.962
2.0	8.0	7.264	0.000264	0.002225	3264	30	13.264
2.0	10.0	8.425	0.000165	0.003053	2760	16	14.425

Table A.20 Results of Resilient Modulus Test for Soil Sample MN2 at Moisture Content 1.9% Above Optimum

* Ohio University * Date: 5/30/92

Resilient Modulus Test for Material Type 2

Data File	UC2-4.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	MN2-4		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.69		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14624.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12244.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	348.04
Ht Specimen + Cap + Base:	13.56	Wet Density (pcf):	134.00
Ht Cap + Base:	1.00	Compaction water content %:	15.90
Initial Length, Lo (inch):	12.56	Water content after Mr testing	15.80
Inside Diameter of Mold:	6.00	Dry density (pcf):	115.62

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.239	0.005667	0.000451	4964	77	20.239
6.0	4.0	4.047	0.013351	0.001063	3808	54	22.047
6.0	6.0	5.589	0.023843	0.001898	2945	12	23.589
6.0	8.0	7.277	0.032367	0.000567	12825	28	25.277
6.0	10.0	9.017	0.039072	0.003110	2899	11	27.017
4.0	2.0	2.318	0.004730	0.000376	6163	233	14.318
4.0	4.0	4.250	0.011118	0.000885	4803	43	16.250
4.0	6.0	6.068	0.018933	0.001507	4027	42	18.068
4.0	8.0	7.851	0.028229	0.002247	3494	32	19.851
4.0	10.0	9.339	0.037970	0.003022	3090	26	21.339
2.0	2.0	2.309	0.004465	0.000355	6498	83	8.309
2.0	4.0	4.250	0.011111	0.000884	4806	54	10.250
2.0	6.0	6.116	0.018912	0.001505	4063	37	12.116
2.0	8.0	7.960	0.028571	0.002274	3500	25	13.960
2.0	10.0	9.554	0.038800	0.003089	3093	17	15.554

Table A.21 Results of Resilient Modulus Test for Soil Sample MN4 at Moisture Content 2.3% Below Optimum

* Ohio University * Date: 6/3/92

Resilient Modulus Test for Material Type 2

Data File	UC2-4.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time = 1.0 sec
Sample No.	MN4-1		Load time=0.1, Cycle time=1.0
Specific gravity	2.76		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	13708.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11328.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	356.90
Ht Specimen + Cap + Base:	13.88	Wet Density (pcf):	130.98
Ht Cap + Base:	1.00	Compaction water content %:	12.50
Initial Length, Lo (inch):	12.88	Water content after Mr testing	12.20
Inside Diameter of Mold:	6.00	Dry density (pcf):	107.53

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.551	0.000057	0.000133	19164	649	20.551
6.0	4.0	4.935	0.000121	0.000292	16923	436	22.935
6.0	6.0	7.408	0.000046	0.000563	13148	100	25.408
6.0	8.0	9.487	0.000040	0.000799	11877	38	27.487
6.0	10.0	11.559	0.000035	0.000974	11863	38	29.559
4.0	2.0	2.701	0.000054	0.000115	23569	859	14.701
4.0	4.0	5.263	0.000034	0.000359	14656	104	17.263
4.0	6.0	7.320	0.000048	0.000557	13137	124	19.320
4.0	8.0	9.484	0.000201	0.000755	12555	273	21.484
4.0	10.0	11.527	0.000014	0.000949	12146	43	23.527
2.0	2.0	2.706	0.000052	0.000111	24472	913	8.706
2.0	4.0	5.259	0.000061	0.000357	14735	159	11.259
2.0	6.0	7.310	0.000145	0.000552	13235	281	13.310
2.0	8.0	9.471	0.000091	0.000762	12437	126	15.471
2.0	10.0	11.484	0.000161	0.000961	11953	207	17.484

Table A.22 Results of Resilient Modulus Test for Soil Sample MN4 at Moisture Content 0.5% Below Optimum

* Ohio University * Date: 6/3/92

Resilient Modulus Test for Material Type 2

Data File	UC2-5.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	MN4-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.76		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	13917.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11537.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	339.45
Ht Specimen + Cap + Base:	13.25	Wet Density (pcf):	129.49
Ht Cap + Base:	1.00	Compaction water content %:	14.50
Initial Length, Lo (inch):	12.25	Water content after Mr testing	14.00
Inside Diameter of Mold:	6.00	Dry density (pcf):	113.09

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.605	0.003244	0.000265	9840	190	20.605
6.0	4.0	4.823	0.006378	0.000521	9264	116	22.823
6.0	6.0	6.876	0.010672	0.000871	7896	189	24.876
6.0	8.0	8.827	0.015039	0.001228	7191	70	26.827
6.0	10.0	10.784	0.019720	0.001610	6699	53	28.784
4.0	2.0	2.596	0.003088	0.000252	10299	111	14.596
4.0	4.0	4.792	0.006583	0.000537	8921	184	16.792
4.0	6.0	6.842	0.010843	0.000885	7731	129	18.842
4.0	8.0	8.826	0.014868	0.001214	7273	124	20.826
4.0	10.0	10.848	0.019086	0.001558	6963	79	22.848
2.0	2.0	2.574	0.002988	0.000244	10555	52	8.574
2.0	4.0	4.782	0.006671	0.000545	8782	115	10.782
2.0	6.0	6.839	0.010916	0.000891	7676	101	12.839
2.0	8.0	8.807	0.014612	0.001193	7384	123	14.807
2.0	10.0	10.790	0.019208	0.001568	6882	93	16.790

Table A.23 Results of Resilient Modulus Test for Soil Sample MN4 at Moisture Content 0.3% Above Optimum

* Ohio University * Date: 6/3/92

Resilient Modulus Test for Material Type 2

Data File	UC2-6.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	MN4-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.76		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	13349.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	10969.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	348.04
Ht Specimen + Cap + Base:	13.56	Wet Density (pcf):	130.99
Ht Cap + Base:	1.00	Compaction water content %:	14.50
Initial Length, Lo (inch):	12.56	Water content after Mr testing	14.20
Inside Diameter of Mold:	6.00	Dry density (pcf):	114.41

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.584	0.000057	0.000287	9010	193	20.584
6.0	4.0	4.784	0.000121	0.000608	7869	196	22.784
6.0	6.0	6.818	0.000046	0.000986	6916	80	24.818
6.0	8.0	8.646	0.000040	0.001317	6567	69	26.646
6.0	10.0	10.620	0.000035	0.001702	6241	54	28.620
4.0	2.0	2.579	0.000054	0.000222	11624	373	14.579
4.0	4.0	4.750	0.000034	0.000579	8198	179	16.750
4.0	6.0	6.773	0.000048	0.000971	6973	71	18.773
4.0	8.0	8.646	0.000201	0.001259	6865	59	20.646
4.0	10.0	10.632	0.000014	0.001655	6425	104	22.632
2.0	2.0	2.578	0.000052	0.000216	11951	115	8.578
2.0	4.0	4.713	0.000061	0.000579	8139	123	10.713
2.0	6.0	6.728	0.000145	0.000980	6863	71	12.728
2.0	8.0	8.652	0.000091	0.001260	6864	111	14.652
2.0	10.0	10.681	0.000161	0.001662	6425	92	16.681

Table A.24 Results of Resilient Modulus Test for Soil Sample MN4 at Moisture Content 1.9% Above Optimum

* Ohio University * Date: 6/3/92

Resilient Modulus Test for Material Type 2

Data File	UC2-8.DAT
Soil sample	Silty Clay
Sample No.	MN4-4
Specific gravity	2.76

Load ID: SHRP P46 Soil type 2
Number of cycle time=1.0 sec
Time: Load=0.1 Cycle=1.0sec
Seating load = 0.5 lb.
Waverform type: Havesine

Specimen Measurements:

Diameter Top:	6.00
Middle:	6.00
Bottom:	6.00
Average:	6.00
Membrane Thickness:	0.03
Net Diameter:	5.94
Ht Specimen + Cap + Base:	13.63
Ht Cap + Base:	1.00
Initial Length, Lo (inch):	12.63
Inside Diameter of Mold:	6.00

Soil Specimen Weight:

Initial wt. of container+wet so	14359.00
Final wt. of container wet soi	2380.00
Weight of wet soil used:	11979.00

Soil Specimen Volume:

Initial Area Ao (inch):	27.71
Volume Ao * Lo (inch):	349.98
Wet Density (pcf):	134.46
Compaction water content %:	16.50
Water content after Mr testing	16.40
Dry density (pcf):	111.98

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.294	0.003885	0.000308	7457	132	20.294
6.0	4.0	4.165	0.010968	0.000869	4795	66	22.165
6.0	6.0	5.718	0.020013	0.001585	3607	38	23.718
6.0	8.0	7.246	0.031299	0.002479	2923	42	25.246
6.0	10.0	8.808	0.042175	0.003340	2637	30	26.808
4.0	2.0	2.346	0.004498	0.000428	5486	93	14.346
4.0	4.0	4.173	0.010858	0.000860	4852	64	16.173
4.0	6.0	5.929	0.019104	0.001513	3918	23	17.929
4.0	8.0	7.573	0.029880	0.002367	3200	35	19.573
4.0	10.0	8.957	0.042267	0.003348	2675	24	20.957
2.0	2.0	2.336	0.004501	0.000356	6554	181	8.336
2.0	4.0	4.147	0.010995	0.000871	4762	82	10.147
2.0	6.0	5.891	0.019763	0.001566	3763	33	11.891
2.0	8.0	7.600	0.030502	0.002416	3146	16	13.600
2.0	10.0	9.030	0.042474	0.003364	2684	16	15.030

Table A.25 Results of Resilient Modulus Test for Soil Sample GN2 at Moisture Content 2.0% Below Optimum

* Ohio University * Date: 6/9/95

Resilient Modulus Test for Material Type 2

Data File	UC2-13.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	GN2-1		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.68		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14005.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11625.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	341.11
Ht Specimen + Cap + Base:	13.31	Wet Density (pcf):	129.81
Ht Cap + Base:	1.00	Compaction water content %:	10.90
Initial Length, Lo (inch):	12.31	Water content after Mr testing	10.90
Inside Diameter of Mold:	6.00	Dry density (pcf):	117.05

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.676	0.002972	0.000241	11094	309	20.676
6.0	4.0	4.911	0.005927	0.000481	10220	383	22.911
6.0	6.0	6.833	0.008719	0.000708	9655	228	24.833
6.0	8.0	8.857	0.012408	0.001008	8791	187	26.857
6.0	10.0	10.946	0.016034	0.001302	8408	133	28.946
4.0	2.0	2.578	0.002856	0.000232	11116	229	14.578
4.0	4.0	4.758	0.006284	0.000510	9325	85	16.758
4.0	6.0	6.673	0.009409	0.000763	8744	348	18.673
4.0	8.0	8.720	0.013199	0.001072	8136	123	20.720
4.0	10.0	10.819	0.016727	0.001358	7965	138	22.819
2.0	2.0	2.556	0.003040	0.000247	10356	208	8.556
2.0	4.0	4.909	0.006763	0.000549	8938	92	10.909
2.0	6.0	7.097	0.010425	0.000846	8384	98	13.097
2.0	8.0	9.160	0.013809	0.001121	8168	63	15.160
2.0	10.0	11.435	0.018698	0.001519	7530	77	17.435

Table A.26 Results of Resilient Modulus Test for Soil Sample GN2 at Moisture Content 0.4% Below Optimum

* Ohio University * Date: 6/4/92

Resilient Modulus Test for Material Type 2

Data File	UC2-12.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	GN2-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.68		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	14415.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	12035.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	344.71
Ht Specimen + Cap + Base:	13.44	Wet Density (pcf):	133.04
Ht Cap + Base:	1.00	Compaction water content %:	12.90
Initial Length, Lo (inch):	12.44	Water content after Mr testing	12.50
Inside Diameter of Mold:	6.00	Dry density (pcf):	117.84

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.235	0.002972	0.000355	6289	151	20.235
6.0	4.0	4.145	0.005927	0.000857	4837	100	22.145
6.0	6.0	2.959	0.008719	0.000731	4047	86	20.959
6.0	8.0	7.868	0.012408	0.001967	4000	46	25.868
6.0	10.0	9.873	0.016034	0.002483	3976	45	27.873
4.0	2.0	2.282	0.002856	0.000329	6940	101	14.282
4.0	4.0	4.222	0.006284	0.000801	5268	40	16.222
4.0	6.0	6.139	0.009409	0.001296	4738	61	18.139
4.0	8.0	8.139	0.013199	0.001841	4420	40	20.139
4.0	10.0	10.081	0.016727	0.002310	4365	62	22.081
2.0	2.0	2.311	0.003040	0.000331	6978	33	8.311
2.0	4.0	4.221	0.006763	0.000802	5261	67	10.221
2.0	6.0	6.150	0.010425	0.001316	4672	47	12.150
2.0	8.0	8.197	0.013809	0.001843	4448	45	14.197
2.0	10.0	10.076	0.018698	0.002390	4216	43	16.076

Table A.27 Results of Resilient Modulus Test for Soil Sample GN2 at 12.9% Optimum Moisture Content

* Ohio University * Date: 6/4/92

Resilient Modulus Test for Material Type 2

Data File	UC2-11.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	GN2-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.68		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:			**Soil Specimen Weight:**	
	Top:	6.00	Initial wt. of container+wet so	14082.00
Diameter	Middle:	6.00	Final wt. of container wet soi	2380.00
	Bottom:	6.00	Weight of wet soil used:	11702.00
	Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:		0.03	Initial Area Ao (inch):	27.71
Net Diameter:		5.94	Volume Ao * Lo (inch):	334.18
Ht Specimen + Cap + Base:		13.06	Wet Density (pcf):	133.38
Ht Cap + Base:		1.00	Compaction water content %:	12.90
Initial Length, Lo (inch):		12.06	Water content after Mr testing	12.90
Inside Diameter of Mold:		6.00	Dry density (pcf):	118.14

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.300	0.004617	0.000383	6012	113	20.300
6.0	4.0	4.279	0.010361	0.000859	4982	38	22.279
6.0	6.0	6.081	0.018097	0.001500	4053	29	24.081
6.0	8.0	8.038	0.025015	0.002073	3877	44	26.038
6.0	10.0	10.021	0.031467	0.002608	3842	37	28.021
4.0	2.0	2.337	0.004324	0.000358	6521	62	14.337
4.0	4.0	4.305	0.009943	0.000824	5223	28	16.305
4.0	6.0	6.305	0.016211	0.001344	4692	53	18.305
4.0	8.0	8.332	0.022995	0.001906	4371	35	20.332
4.0	10.0	10.206	0.030017	0.002488	4102	45	22.206
2.0	2.0	2.319	0.004279	0.000355	6540	113	8.319
2.0	4.0	4.292	0.010184	0.000844	5084	27	10.292
2.0	6.0	6.278	0.016562	0.001373	4573	48	12.278
2.0	8.0	8.319	0.023297	0.001931	4308	52	14.319
2.0	10.0	10.231	0.030450	0.002524	4053	36	16.231

Table A.28 Results of Resilient Modulus Test for Soil Sample GN2 at Moisture Content 0.2% Above Optimum

* Ohio University * Date: 6/9/95

Resilient Modulus Test for Material Type 2

Data File	UC2-14.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	GN2-4		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.68		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	14554.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	12174.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	341.11
Ht Specimen + Cap + Base:	13.31	Wet Density (pcf):	135.94
Ht Cap + Base:	1.00	Compaction water content %:	14.90
Initial Length, Lo (inch):	12.31	Water content after Mr testing	13.10
Inside Diameter of Mold:	6.00	Dry density (pcf):	118.31

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.250	0.005151	0.000418	5378	89	20.250
6.0	4.0	4.168	0.011978	0.000973	4285	43	22.168
6.0	6.0	5.883	0.020374	0.001654	3556	27	23.883
6.0	8.0	7.873	0.027170	0.002207	3568	9	25.873
6.0	10.0	9.893	0.032529	0.002642	3745	26	27.893
4.0	2.0	2.311	0.004684	0.000380	6081	182	14.311
4.0	4.0	4.273	0.011026	0.000895	4772	57	16.273
4.0	6.0	6.283	0.017728	0.001439	4365	58	18.283
4.0	8.0	8.269	0.024976	0.002028	4077	50	20.269
4.0	10.0	10.116	0.031796	0.002582	3918	26	22.116
2.0	2.0	2.304	0.004663	0.000378	6089	187	8.304
2.0	4.0	4.293	0.010815	0.000878	4888	31	10.293
2.0	6.0	6.298	0.017508	0.001422	4430	50	12.298
2.0	8.0	8.305	0.024356	0.001978	4198	43	14.305
2.0	10.0	10.189	0.031113	0.002526	4033	50	16.189

Table A.29 Results of Resilient Modulus Test for Soil Sample GS5 at Moisture Content 1.9% Below Optimum

* Ohio University * Date: 6/12/92

Resilient Modulus Test for Material Type 2

Data File	UC2-15.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	GS5-1		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.75		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	13915.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	11535.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	356.90
Ht Specimen + Cap + Base:	13.88	Wet Density (pcf):	123.19
Ht Cap + Base:	1.00	Compaction water content %:	15.40
Initial Length, Lo (inch):	12.88	Water content after Mr testing	15.50
Inside Diameter of Mold:	6.00	Dry density (pcf):	106.75

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.494	0.003830	0.000297	8390	205	20.494
6.0	4.0	4.713	0.007742	0.000601	7842	231	22.713
6.0	6.0	6.765	0.012790	0.000993	6811	64	24.765
6.0	8.0	8.804	0.018616	0.001445	6091	140	26.804
6.0	10.0	10.829	0.024899	0.001934	5600	19	28.829
4.0	2.0	2.482	0.003717	0.000289	8601	229	14.482
4.0	4.0	4.631	0.007785	0.000604	7665	222	16.631
4.0	6.0	6.633	0.013034	0.001012	6553	62	18.633
4.0	8.0	8.708	0.019574	0.001518	5736	75	20.708
4.0	10.0	10.795	0.025998	0.002019	5346	50	22.795
2.0	2.0	2.568	0.004041	0.000318	8085	147	8.568
2.0	4.0	4.629	0.008475	0.000658	7034	100	10.629
2.0	6.0	6.605	0.013812	0.001073	6158	109	12.605
2.0	8.0	8.715	0.020697	0.001607	5422	41	14.715
2.0	10.0	10.786	0.027396	0.002128	5069	59	16.786

Table A.30 Results of Resilient Modulus Test for Soil Sample GS5 at Moisture Content 0.3% Above Optimum

* Ohio University * Date: 6/12/92

Resilient Modulus Test for Material Type 2

Data File	UC2-16.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	GS5-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.75		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	14365.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	11985.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	349.98
Ht Specimen + Cap + Base:	13.63	Wet Density (pcf):	130.53
Ht Cap + Base:	1.00	Compaction water content %:	17.40
Initial Length, Lo (inch):	12.63	Water content after Mr testing	17.70
Inside Diameter of Mold:	6.00	Dry density (pcf):	111.18

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.325	0.004871	0.000386	6028	87	20.325
6.0	4.0	4.328	0.011545	0.000914	4734	84	22.328
6.0	6.0	6.051	0.020041	0.001587	3812	39	24.051
6.0	8.0	7.678	0.031390	0.002486	3088	23	25.678
6.0	10.0	9.264	0.042896	0.003397	2727	12	27.264
4.0	2.0	2.361	0.004645	0.000368	6420	153	14.361
4.0	4.0	4.200	0.011182	0.000886	4742	44	16.200
4.0	6.0	5.909	0.021649	0.001715	3446	37	17.909
4.0	8.0	7.615	0.033850	0.002681	2840	16	19.615
4.0	10.0	9.157	0.045325	0.003590	2551	11	21.157
2.0	2.0	2.330	0.004749	0.000376	6196	112	8.330
2.0	4.0	4.150	0.011554	0.000915	4536	61	10.150
2.0	6.0	5.841	0.022662	0.001795	3254	13	11.841
2.0	8.0	7.503	0.035156	0.002785	2694	24	13.503
2.0	10.0	9.042	0.046906	0.003715	2434	10	15.042

Table A.31 Results of Resilient Modulus Test for Soil Sample GS5 at Moisture Content 1.1% Above Optimum

* Ohio University * Date: 6/12/92

Resilient Modulus Test for Material Type 2

Data File	UC2-17.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	GS5-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.75		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14429.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12049.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	343.05
Ht Specimen + Cap + Base:	13.38	Wet Density (pcf):	133.87
Ht Cap + Base:	1.00	Compaction water content %:	17.40
Initial Length, Lo (inch):	12.38	Water content after Mr testing	18.50
Inside Diameter of Mold:	6.00	Dry density (pcf):	114.03

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.219	0.005685	0.000459	4831	91	20.219
6.0	4.0	4.086	0.014310	0.001156	3534	5	22.086
6.0	6.0	5.716	0.026297	0.002125	2690	9	23.716
6.0	8.0	7.203	0.038815	0.003137	2296	12	25.203
6.0	10.0	8.522	0.051550	0.004165	2046	6	26.522
4.0	2.0	2.276	0.005096	0.000412	5526	51	14.276
4.0	4.0	4.009	0.013959	0.001128	3554	5	16.009
4.0	6.0	5.550	0.027554	0.002226	2493	17	17.550
4.0	8.0	6.986	0.042072	0.003400	2055	9	18.986
4.0	10.0	8.338	0.054691	0.004419	1887	8	20.338
2.0	2.0	2.245	0.005304	0.000429	5238	62	8.245
2.0	4.0	3.915	0.014847	0.001200	3263	24	9.915
2.0	6.0	5.402	0.029086	0.002351	2298	8	11.402
2.0	8.0	6.838	0.044022	0.003558	1922	12	12.838
2.0	10.0	9.251	0.056561	0.005125	1805	9	15.251

Table A.32 Results of Resilient Modulus Test for Soil Sample GS5 at Moisture Content 2.1% Above Optimum

* Ohio University * Date: 6/12/92

Resilient Modulus Test for Material Type 2

Data File	UC2-18.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	GS5-4		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.75		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14785.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12405.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	353.30
Ht Specimen + Cap + Base:	13.75	Wet Density (pcf):	133.73
Ht Cap + Base:	1.00	Compaction water content %:	19.40
Initial Length, Lo (inch):	12.75	Water content after Mr testing	19.50
Inside Diameter of Mold:	6.00	Dry density (pcf):	112.04

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	1.892	0.008127	0.000637	2968	28	19.892
6.0	4.0	3.404	0.023251	0.001823	1867	8	21.404
6.0	6.0	4.767	0.037762	0.002961	1610	9	22.767
6.0	8.0	6.103	0.052292	0.004101	1488	6	24.103
6.0	10.0	7.431	0.006549	0.005135	1447	4	25.431
4.0	2.0	2.091	0.006778	0.000532	3933	44	14.091
4.0	4.0	3.503	0.021005	0.001648	2126	16	15.503
4.0	6.0	4.808	0.038803	0.003043	1580	7	16.808
4.0	8.0	6.145	0.054474	0.004273	1438	5	18.145
4.0	10.0	7.441	0.066888	0.005248	1418	5	19.441
2.0	2.0	2.082	0.006934	0.000544	3829	34	8.082
2.0	4.0	3.473	0.020993	0.001646	2110	31	9.473
2.0	6.0	4.755	0.038928	0.003054	1557	10	10.755
2.0	8.0	6.108	0.054883	0.004304	1419	4	12.108
2.0	10.0	7.440	0.067813	0.005318	1399	6	13.440

Table A.33 Results of Resilient Modulus Test for Soil Sample BN3 at Moisture Content 2.6% Below Optimum

* Ohio University * Date: 11/30/92

Resilient Modulus Test for Material Type 2

Data File	BP3-2.DAT
Soil sample	Silty Clay
Sample No.	BN3-1
Specific gravity	2.73

Load ID: SHRP P46 Soil type 2
Number of cycle time=1.0 sec
Time: Load=0.1 Cycle=1.0sec
Seating load = 0.5 lb.
Waverform type: Havesine

Specimen Measurements:

Diameter Top:	6.00
Diameter Middle:	6.00
Diameter Bottom:	6.00
Diameter Average:	6.00
Membrane Thickness:	0.03
Net Diameter:	5.94
Ht Specimen + Cap + Base:	16.50
Ht Cap + Base:	4.00
Initial Length, Lo (inch):	12.50
Inside Diameter of Mold:	6.00

Soil Specimen Weight:

Initial wt. of container+wet so	13478.00
Final wt. of container wet soi	2380.00
Weight of wet soil used:	11098.00

Soil Specimen Volume:

Initial Area Ao (inch):	27.71
Volume Ao * Lo (inch):	346.38
Wet Density (pcf):	122.07
Compaction water content %:	13.20
Water content after Mr testing	12.60
Dry density (pcf):	107.84

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	1.933	0.001233	0.000098	19708	1490	19.933
6.0	4.0	4.675	0.005786	0.000463	10106	354	22.675
6.0	6.0	6.570	0.009207	0.000736	8921	123	24.570
6.0	8.0	8.626	0.012881	0.001030	8371	54	26.626
6.0	10.0	10.416	0.016568	0.001325	7859	40	28.416
4.0	2.0	2.334	0.002148	0.000172	13583	368	14.334
4.0	4.0	4.617	0.005679	0.000454	10164	182	16.617
4.0	6.0	6.505	0.009476	0.000758	8582	71	18.505
4.0	8.0	8.438	0.012714	0.001017	8296	29	20.438
4.0	10.0	10.242	0.016135	0.001291	7936	77	22.242
2.0	2.0	2.266	0.001572	0.000126	18025	392	8.266
2.0	4.0	4.594	0.005701	0.000456	10076	133	10.594
2.0	6.0	6.522	0.009943	0.000795	8200	68	12.522
2.0	8.0	8.390	0.013116	0.001049	7995	14	14.390
2.0	10.0	10.253	0.016617	0.001329	7713	51	16.253

Table A.34 Results of Resilient Modulus Test for Soil Sample BN3 at Moisture Content 0.9% Below Optimum

* Ohio University * Date: 11/30/92

Resilient Modulus Test for Material Type 2

Data File	BP3-3.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	BN3-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.73		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14808.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12428.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	344.71
Ht Specimen + Cap + Base:	16.44	Wet Density (pcf):	137.39
Ht Cap + Base:	4.00	Compaction water content %:	15.20
Initial Length, Lo (inch):	12.44	Water content after Mr testing	14.30
Inside Diameter of Mold:	6.00	Dry density (pcf):	119.26

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.163	0.002853	0.000229	9437	306	20.163
6.0	4.0	4.446	0.006744	0.000542	8200	53	22.446
6.0	6.0	6.245	0.010263	0.000825	7568	38	24.245
6.0	8.0	7.881	0.015332	0.001233	6394	38	25.881
6.0	10.0	9.420	0.020724	0.001666	5653	41	27.420
4.0	2.0	2.203	0.001956	0.000157	14020	476	14.203
4.0	4.0	4.427	0.006705	0.000539	8212	44	16.427
4.0	6.0	6.253	0.010251	0.000824	7588	51	18.253
4.0	8.0	7.857	0.015109	0.001215	6468	49	19.857
4.0	10.0	9.466	0.020523	0.001650	5737	18	21.466
2.0	2.0	2.110	0.001938	0.000156	13550	302	8.110
2.0	4.0	4.292	0.007263	0.000584	7351	64	10.292
2.0	6.0	6.250	0.011331	0.000911	6860	25	12.250
2.0	8.0	7.873	0.016064	0.001292	6096	38	13.873
2.0	10.0	9.458	0.021146	0.001700	5563	30	15.458

Table A.35 Results of Resilient Modulus Test for Soil Sample BN3 at Moisture Content 0.4 % Above Optimum

* Ohio University * Date: 12/1/92

Resilient Modulus Test for Material Type 2

Data File	BP3-5.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	BN3-3		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.73		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Top:	6.00	Initial wt. of container+wet so	14840.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Bottom:	6.00	Weight of wet soil used:	12460.00
Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	339.45
Ht Specimen + Cap + Base:	16.25	Wet Density (pcf):	139.35
Ht Cap + Base:	4.00	Compaction water content %:	15.20
Initial Length, Lo (inch):	12.25	Water content after Mr testing	15.60
Inside Diameter of Mold:	6.00	Dry density (pcf):	121.40

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.257	0.003781	0.000309	7313	83	20.257
6.0	4.0	4.170	0.008032	0.000653	6382	416	22.170
6.0	6.0	5.841	0.014871	0.001214	4812	15	23.841
6.0	8.0	7.400	0.023700	0.001935	3825	21	25.400
6.0	10.0	8.918	0.034433	0.002811	3173	19	26.918
4.0	2.0	2.325	0.003888	0.000316	7351	445	14.325
4.0	4.0	4.232	0.008792	0.000718	5898	106	16.232
4.0	6.0	5.859	0.015533	0.001268	4621	59	17.859
4.0	8.0	7.530	0.024124	0.001969	3824	18	19.530
4.0	10.0	8.972	0.034097	0.002784	3223	27	20.972
2.0	2.0	2.331	0.004028	0.000328	7102	328	8.331
2.0	4.0	4.187	0.009006	0.000734	5703	239	10.187
2.0	6.0	5.818	0.015814	0.001290	4509	93	11.818
2.0	8.0	7.559	0.024356	0.001988	3802	20	13.559
2.0	10.0	9.059	0.034448	0.002812	3222	46	15.059

Table A.36 Results of Resilient Modulus Test for Soil Sample BN3 at Moisture Content 2.1% Above Optimum

* Ohio University * Date: 12/1/92

Resilient Modulus Test for Material Type 2

Data File	BP3-6.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	BN3-4		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.73		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14162.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	11782.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	346.38
Ht Specimen + Cap + Base:	16.50	Wet Density (pcf):	129.60
Ht Cap + Base:	4.00	Compaction water content %:	17.20
Initial Length, Lo (inch):	12.50	Water content after Mr testing	17.30
Inside Diameter of Mold:	6.00	Dry density (pcf):	110.58

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.004	0.004828	0.000386	5190	49	20.004
6.0	4.0	3.743	0.012476	0.000998	3751	10	21.743
6.0	6.0	5.014	0.022552	0.001804	2779	9	23.014
6.0	8.0	6.347	0.032516	0.002601	2440	11	24.347
6.0	10.0	7.726	0.042651	0.003413	2264	16	25.726
4.0	2.0	2.121	0.004276	0.000342	6203	58	14.121
4.0	4.0	3.836	0.011191	0.000895	4286	88	15.836
4.0	6.0	5.259	0.020349	0.001628	3231	33	17.259
4.0	8.0	6.675	0.031238	0.002499	2671	23	18.675
4.0	10.0	7.889	0.042032	0.003363	2346	19	19.889
2.0	2.0	2.133	0.004285	0.000343	6222	39	8.133
2.0	4.0	3.782	0.011539	0.000923	4097	42	9.782
2.0	6.0	5.232	0.020490	0.001639	3192	52	11.232
2.0	8.0	6.694	0.030219	0.002498	2680	18	12.694
2.0	10.0	7.962	0.041943	0.003355	2373	15	13.962

Table A.37 Results of Resilient Modulus Test for Soil Sample BS2 at Moisture Content 1.9% Below Optimum

* Ohio University * Date: 12/6/92

Resilient Modulus Test for Material Type 2

Data File	BP2-1.DAT
Soil sample	Silty Clay
Sample No.	BS2-1
Specific gravity	2.67

Load ID: SHRP P46 Soil type 2
Number of cycle time=1.0 sec
Time: Load=0.1 Cycle=1.0sec
Seating load = 0.5 lb.
Waverform type: Havesine

Specimen Measurements:

Diameter Top:	6.00
Diameter Middle:	6.00
Diameter Bottom:	6.00
Diameter Average:	6.00
Membrane Thickness:	0.03
Net Diameter:	5.94
Ht Specimen + Cap + Base:	16.50
Ht Cap + Base:	4.00
Initial Length, Lo (inch):	12.50
Inside Diameter of Mold:	6.00

Soil Specimen Weight:

Initial wt. of container+wet so	13145.00
Final wt. of container wet soi	2380.00
Weight of wet soil used:	10765.00

Soil Specimen Volume:

Initial Area Ao (inch):	27.71
Volume Ao * Lo (inch):	346.38
Wet Density (pcf):	118.41
Compaction water content %:	11.20
Water content after Mr testing	11.30
Dry density (pcf):	106.49

Chamber Press. σ_3 (psi)	Nominal σ_d (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	θ (σ_d+3σ_3) (psi)
6.0	2.0	2.327	0.002606	0.000208	11163	31	20.327
6.0	4.0	4.437	0.006192	0.000495	8967	322	22.437
6.0	6.0	6.451	0.010287	0.000823	7838	61	24.451
6.0	8.0	8.350	0.014194	0.001134	7364	288	26.350
6.0	10.0	10.319	0.019339	0.001547	6671	98	28.319
4.0	2.0	2.390	0.002667	0.000213	11235	592	14.390
4.0	4.0	4.448	0.006329	0.000506	8797	364	16.448
4.0	6.0	6.464	0.010980	0.000878	7360	110	18.464
4.0	8.0	8.370	0.015057	0.001204	6949	81	20.370
4.0	10.0	10.278	0.019116	0.001529	6722	70	22.278
2.0	2.0	2.346	0.002606	0.000208	11271	447	8.346
2.0	4.0	4.409	0.006555	0.000524	8413	237	10.409
2.0	6.0	6.367	0.011343	0.000907	7017	90	12.367
2.0	8.0	8.270	0.015338	0.001227	6740	50	14.270
2.0	10.0	10.256	0.020270	0.001621	6326	77	16.256

Table A.38 Results of Resilient Modulus Test for Soil Sample BS2 at Moisture Content 0.4% Below Optimum

* Ohio University * Date: 12/6/92

Resilient Modulus Test for Material Type 2

Data File	BP2-2.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	BS2-2		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.67		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14445.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12065.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	336.12
Ht Specimen + Cap + Base:	16.13	Wet Density (pcf):	136.82
Ht Cap + Base:	4.00	Compaction water content %:	13.20
Initial Length, Lo (inch):	12.13	Water content after Mr testing	12.80
Inside Diameter of Mold:	6.00	Dry density (pcf):	120.86

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	1.961	0.004251	0.000351	5594	79	19.961
6.0	4.0	3.848	0.001188	0.000980	3926	23	21.848
6.0	6.0	5.499	0.021411	0.001766	3114	5	23.499
6.0	8.0	7.056	0.031619	0.002608	2706	16	25.056
6.0	10.0	8.620	0.040848	0.003369	2559	12	26.620
4.0	2.0	2.040	0.004700	0.000388	5263	35	14.040
4.0	4.0	3.775	0.012842	0.001059	3565	25	15.775
4.0	6.0	5.431	0.022586	0.001863	2915	12	17.431
4.0	8.0	7.148	0.032562	0.002685	2662	12	19.148
4.0	10.0	8.758	0.041608	0.003432	2552	20	20.758
‘2.0	2.0	1.986	0.004636	0.000385	5159	75	7.986
2.0	4.0	3.719	0.013306	0.001097	3389	10	9.719
2.0	6.0	5.347	0.023819	0.001964	2722	15	11.347
2.0	8.0	7.043	0.033685	0.002778	2535	9	13.043
2.0	10.0	8.712	0.042691	0.003521	2474	19	14.712

Table A.39 Results of Resilient Modulus Test for Soil Sample BS2 at Moisture Content 0.2% Above Optimum

* Ohio University * Date: 12/7/92

Resilient Modulus Test for Material Type 2

Data File	BP2-3.DAT
Soil sample	Silty Clay
Sample No.	BS2-3
Specific gravity	2.67

Load ID: SHRP P46 Soil type 2
Number of cycle time=1.0 sec
Time: Load=0.1 Cycle=1.0sec
Seating load = 0.5 lb.
Waverform type: Havesine

Specimen Measurements:

	Top:	6.00
Diameter	Middle:	6.00
	Bottom:	6.00
	Average:	6.00
Membrane Thickness:		0.03
Net Diameter:		5.94
Ht Specimen + Cap + Base:		16.31
Ht Cap + Base:		4.00
Initial Length, Lo (inch):		12.31
Inside Diameter of Mold:		6.00

Soil Specimen Weight:

Initial wt. of container+wet so	14705.00
Final wt. of container wet soi	2380.00
Weight of wet soil used:	12325.00

Soil Specimen Volume:

Initial Area Ao (inch):	27.71
Volume Ao * Lo (inch):	341.11
Wet Density (pcf):	137.63
Compaction water content %:	13.20
Water content after Mr testing	13.40
Dry density (pcf):	121.58

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	2.023	0.005847	0.000475	4260	23	20.023
6.0	4.0	3.796	0.014087	0.001144	3318	15	21.796
6.0	6.0	5.304	0.026141	0.002123	2498	12	23.304
6.0	8.0	6.799	0.037622	0.003056	2225	4	24.799
6.0	10.0	8.419	0.048380	0.003925	2145	3	26.419
4.0	2.0	2.039	0.005545	0.000450	4528	72	14.039
4.0	4.0	3.725	0.014557	0.001182	3151	12	15.725
4.0	6.0	5.312	0.026236	0.002131	2493	4	17.312
4.0	8.0	6.976	0.037744	0.003065	2276	5	18.976
4.0	10.0	8.571	0.049374	0.004011	2137	4	20.571
2.0	2.0	2.047	0.005762	0.000468	4376	23	8.047
2.0	4.0	3.663	0.015070	0.001224	2993	24	9.663
2.0	6.0	5.236	0.027200	0.002209	2370	6	11.236
2.0	8.0	6.876	0.039056	0.003172	2168	4	12.876
2.0	10.0	8.544	0.049698	0.004036	2117	6	14.544

Table A.40 Results of Resilient Modulus Test for Soil Sample BS2 at Moisture Content 1.8% Above Optimum

* Ohio University * Date: 12/7/92

Resilient Modulus Test for Material Type 2

Data File	BP2-4.DAT	**Load ID:**	SHRP P46 Soil type 2
Soil sample	Silty Clay		Number of cycle time=1.0 sec
Sample No.	BS2-4		Time: Load=0.1 Cycle=1.0sec
Specific gravity	2.67		Seating load = 0.5 lb.
			Waverform type: Havesine

Specimen Measurements:		**Soil Specimen Weight:**	
Diameter Top:	6.00	Initial wt. of container+wet so	14640.00
Diameter Middle:	6.00	Final wt. of container wet soi	2380.00
Diameter Bottom:	6.00	Weight of wet soil used:	12260.00
Diameter Average:	6.00	**Soil Specimen Volume:**	
Membrane Thickness:	0.03	Initial Area Ao (inch):	27.71
Net Diameter:	5.94	Volume Ao * Lo (inch):	343.05
Ht Specimen + Cap + Base:	16.38	Wet Density (pcf):	136.22
Ht Cap + Base:	4.00	Compaction water content %:	15.20
Initial Length, Lo (inch):	12.38	Water content after Mr testing	15.00
Inside Diameter of Mold:	6.00	Dry density (pcf):	118.24

Chamber Press. o3 (psi)	Nominal od (psi)	Applied Deviator Stress(psi)	Mean Recov. Def. (inch)	Mean Resilient Strain (in/in	Mean of Mr (psi)	Std Dev of Mr (psi)	0 (od+3o3) (psi)
6.0	2.0	1.911	0.006522	0.000527	3626	32	19.911
6.0	4.0	3.520	0.016711	0.001350	2607	7	21.520
6.0	6.0	4.681	0.027179	0.002197	2131	14	22.681
6.0	8.0	6.489	0.036621	0.002959	2193	8	24.489
6.0	10.0	8.023	0.046249	0.003737	2147	11	26.023
4.0	2.0	1.998	0.005658	0.000457	4371	55	13.998
4.0	4.0	3.731	0.014716	0.001189	3138	5	15.731
4.0	6.0	5.391	0.025061	0.002025	2662	3	17.391
4.0	8.0	6.963	0.035825	0.002895	2405	3	18.963
4.0	10.0	9.255	0.045084	0.004084	2266	12	21.255
2.0	2.0	1.998	0.005527	0.000447	4474	48	7.998
2.0	4.0	3.713	0.014679	0.001186	3130	8	9.713
2.0	6.0	5.371	0.025623	0.002071	2594	14	11.371
2.0	8.0	6.912	0.035843	0.002897	2386	16	12.912
2.0	10.0	8.232	0.045667	0.003690	2231	14	14.232

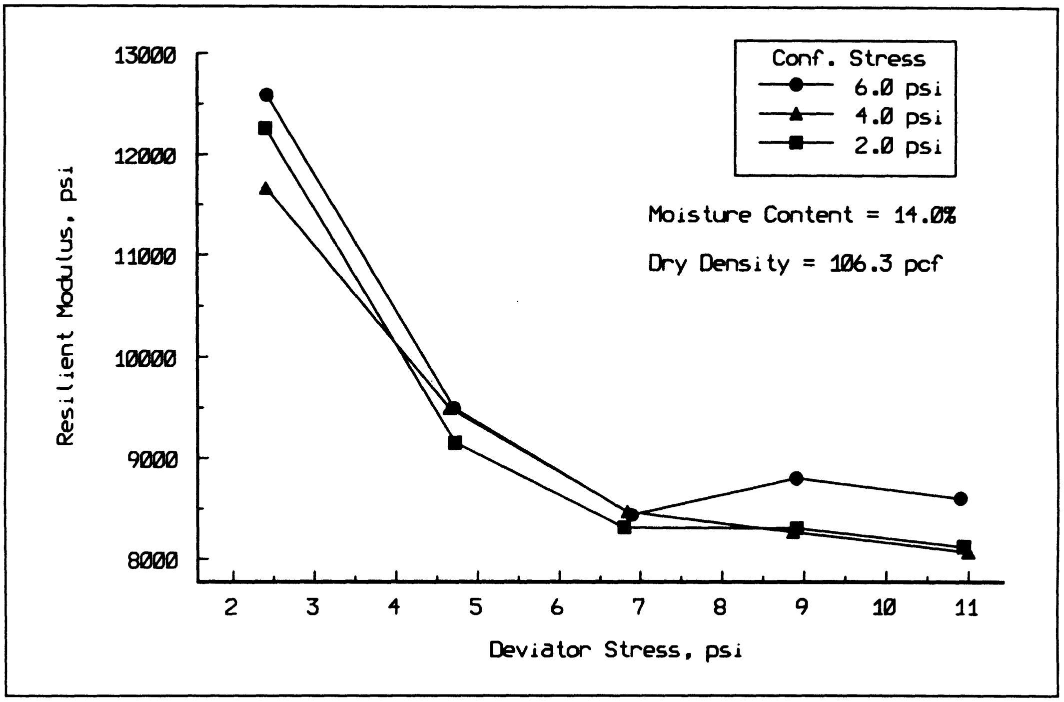

Figure A.1 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample NB4 at Moisture Content 1.7% Below Optimum

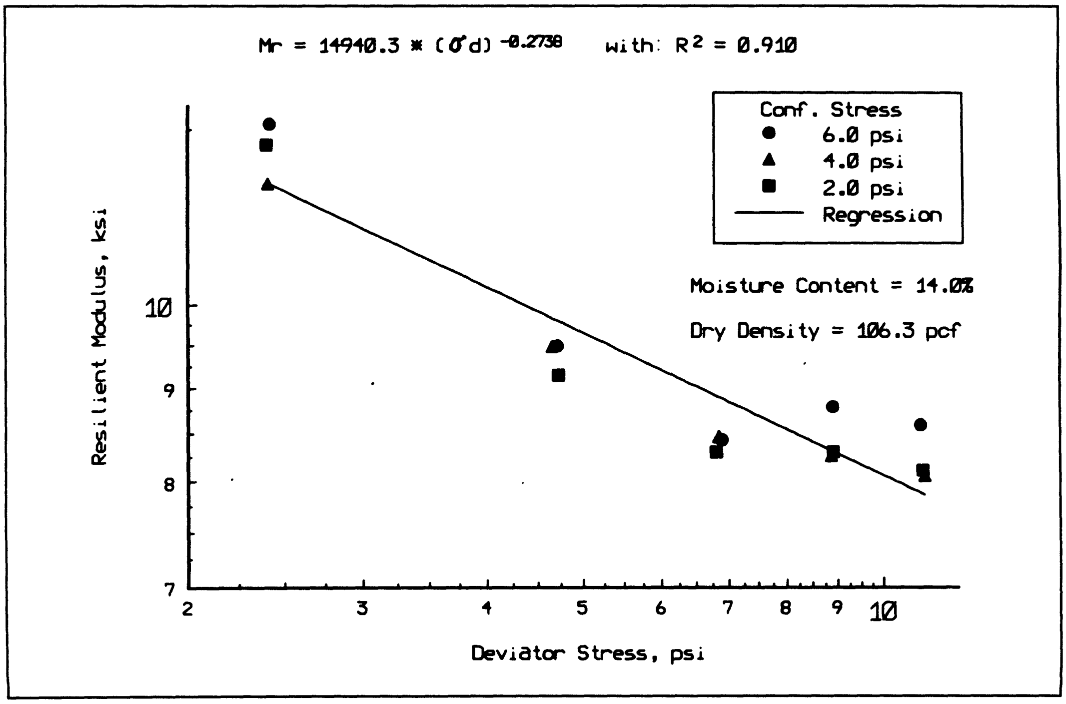

Figure A.2 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB4 at Moisture Content 1.7% Below Optimum

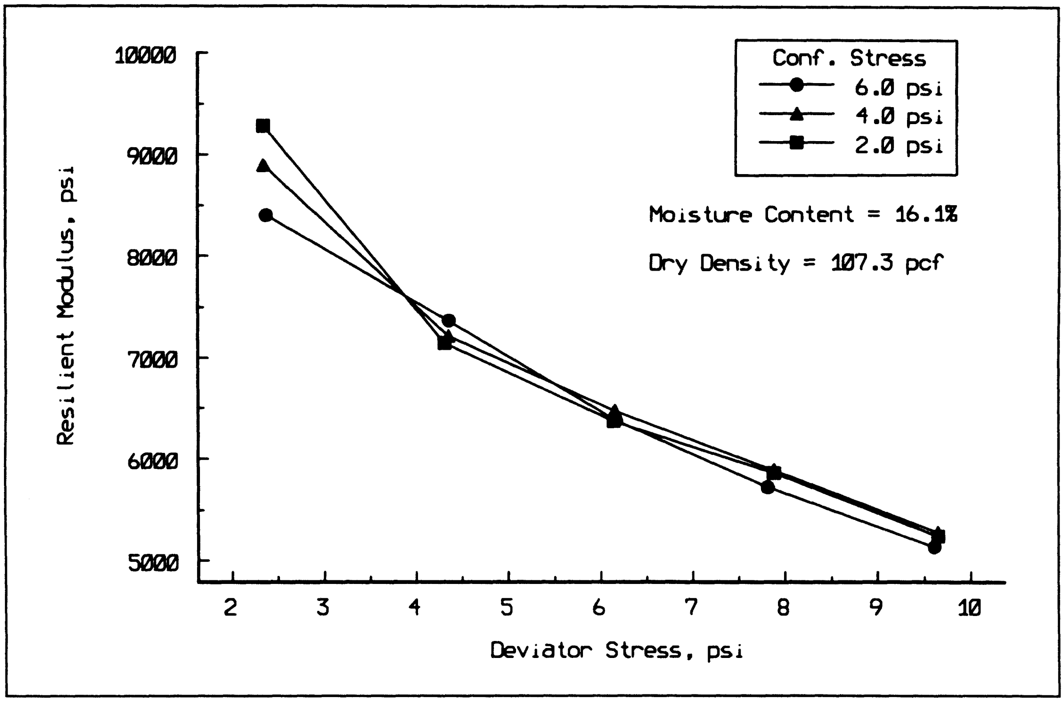

Figure A.3 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample NB4 at Moisture Content 0.4% Above Optimum

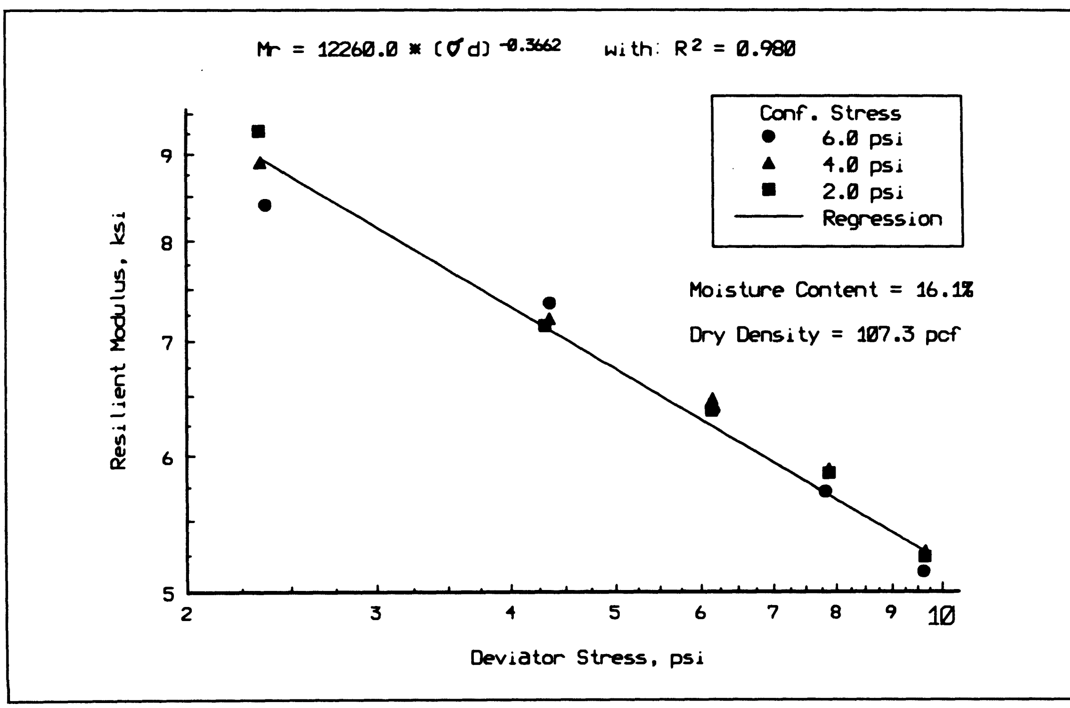

Figure A.4 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB4 at Moisture Content 0.4% Above Optimum

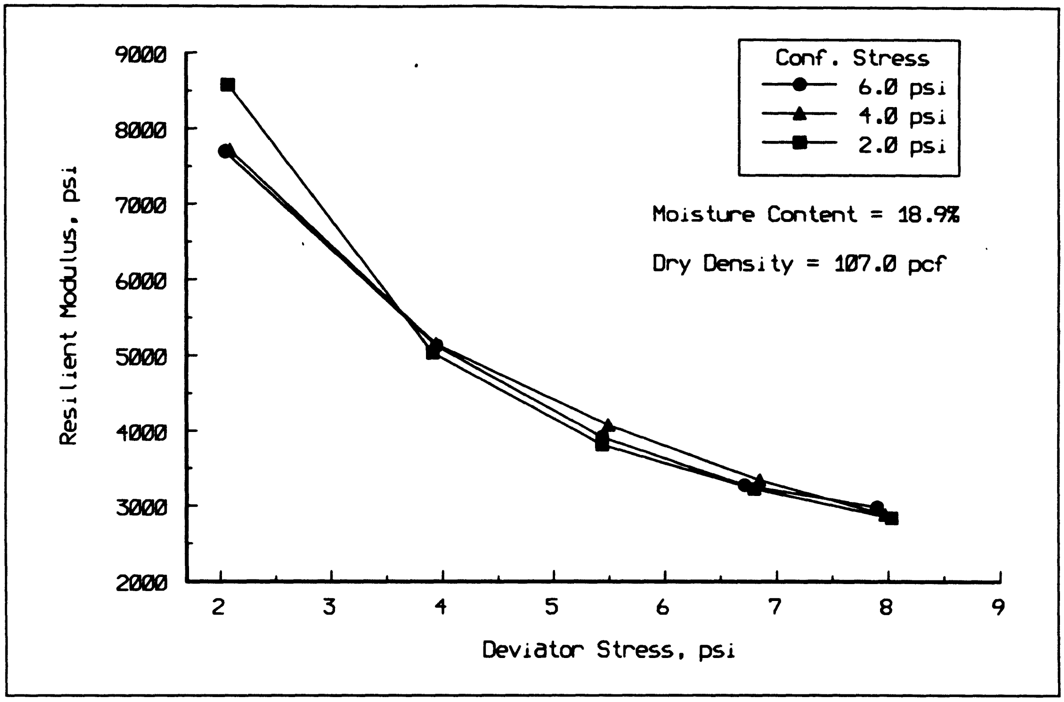

Figure A.5 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample NB4 at Moisture Content 3.2% Above Optimum

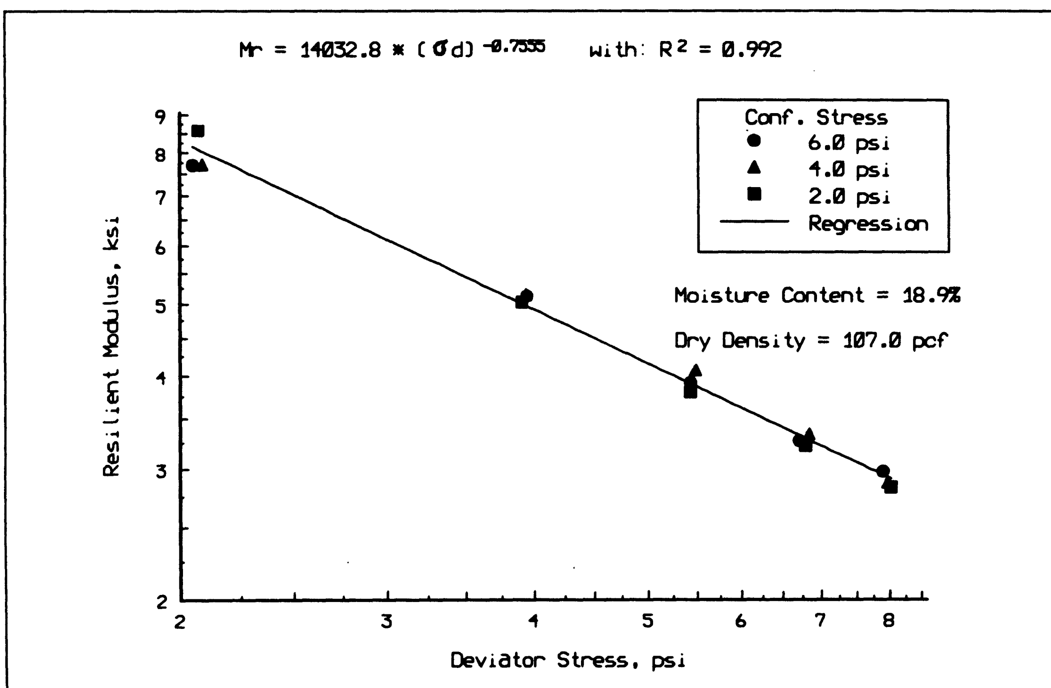

Figure A.6 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB4 at Moisture Content 3.2% Above Optimum

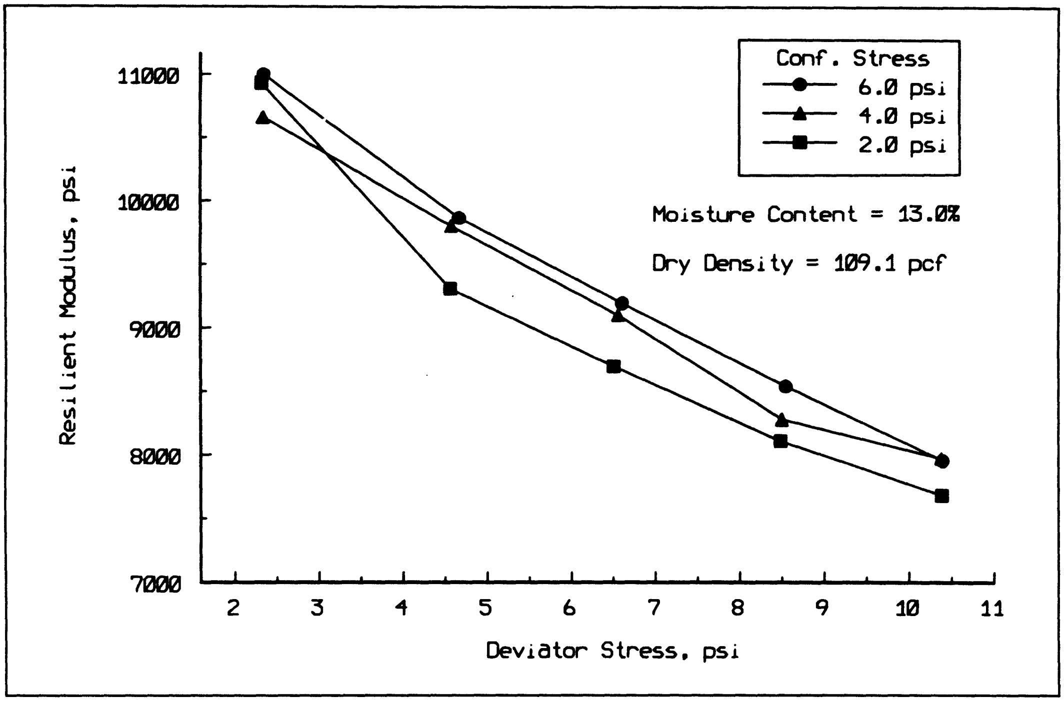

Figure A.7 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample NB6 at Moisture Content 2.5% Below Optimum

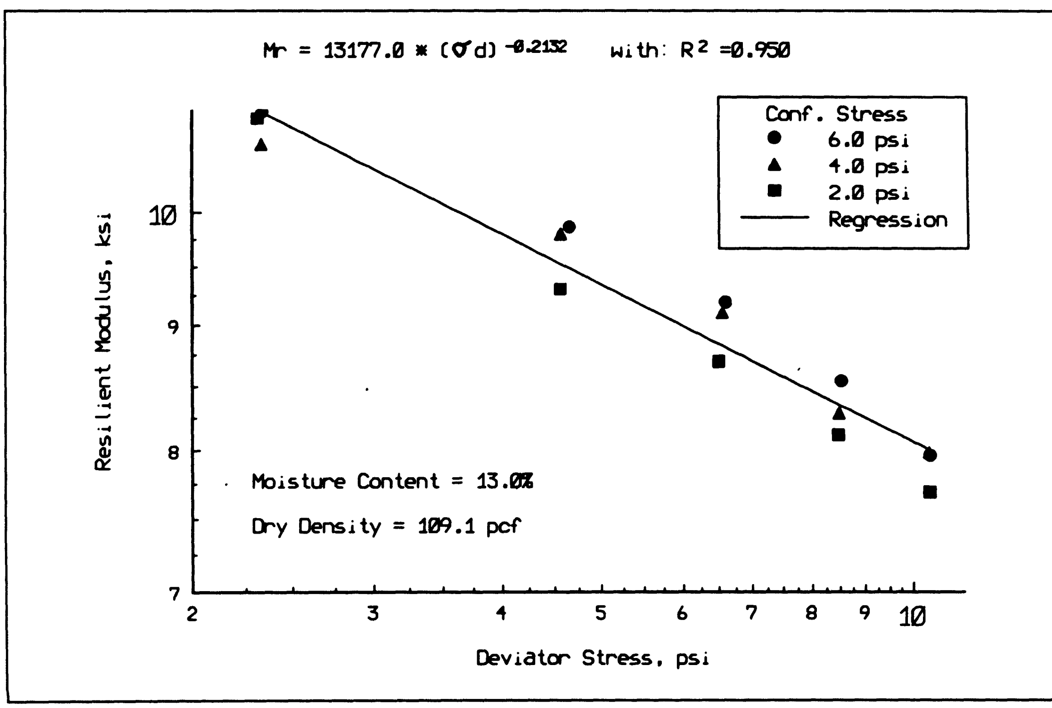

Figure A.8 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB6 at Moisture Content 2.5% Below Optimum

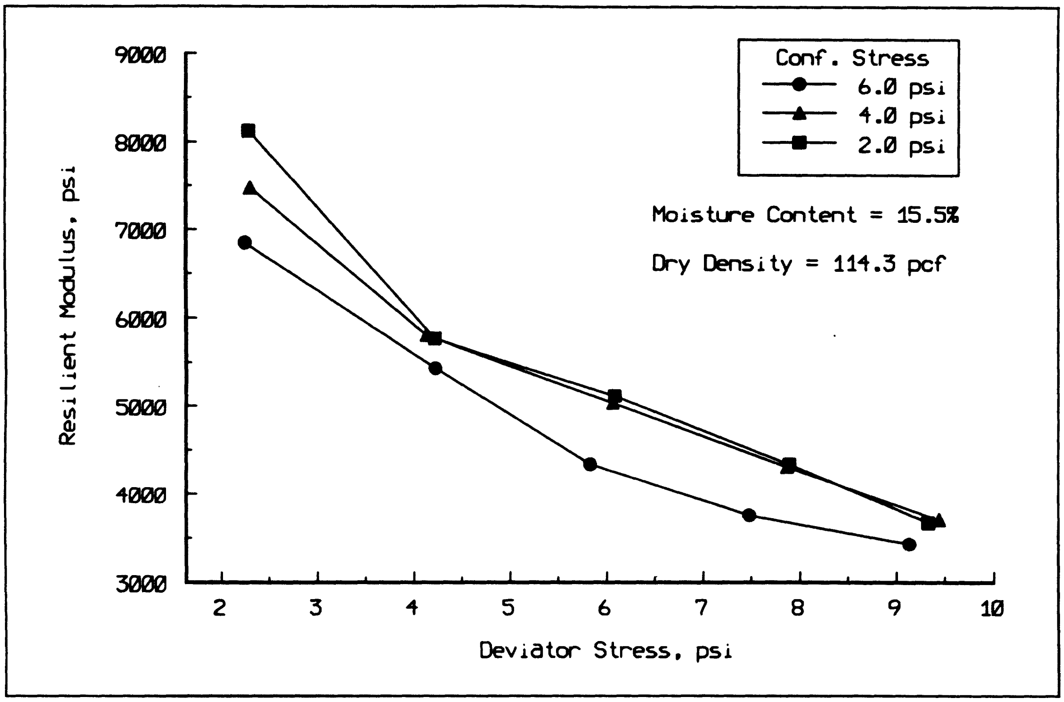

Figure A.9 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample NB6 at 15.5% Optimum Moisture Content

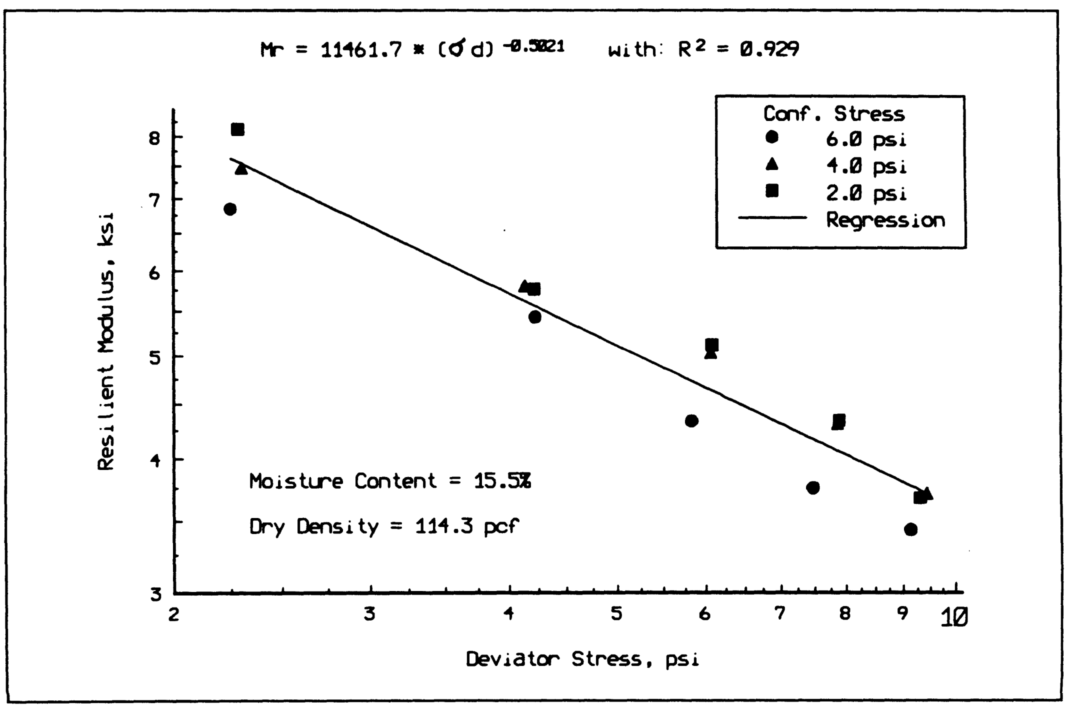

Figure A.10 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB6 at 15.5% Optimum Moisture Content

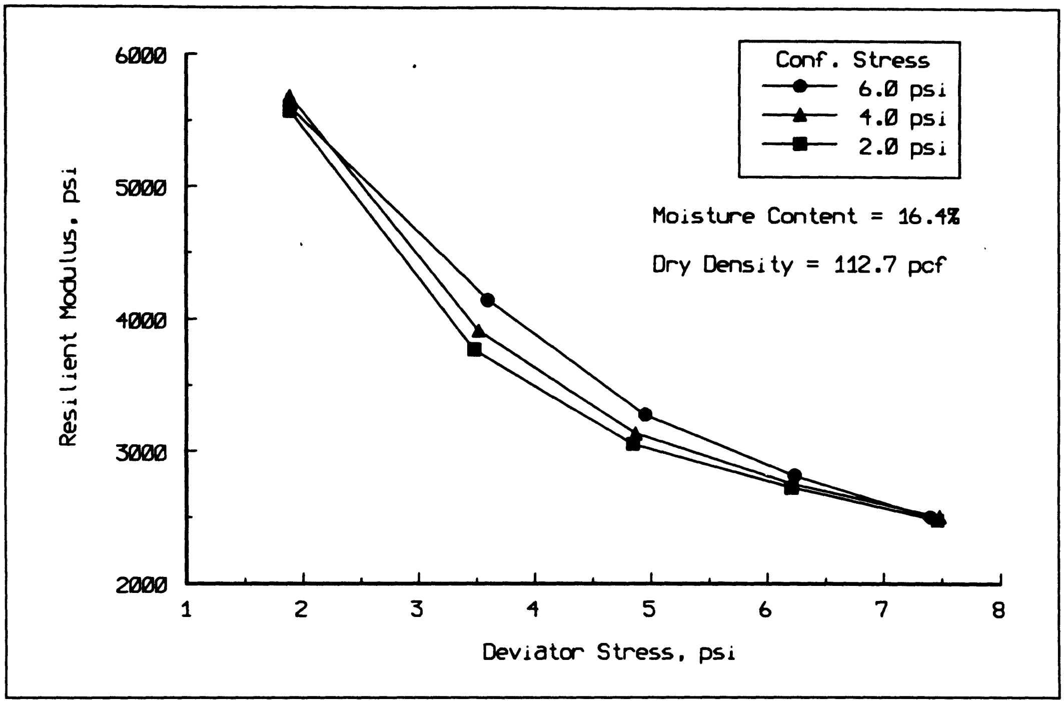

Figure A.11 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample NB6 at Moisture Content 0.9% Above Optimum

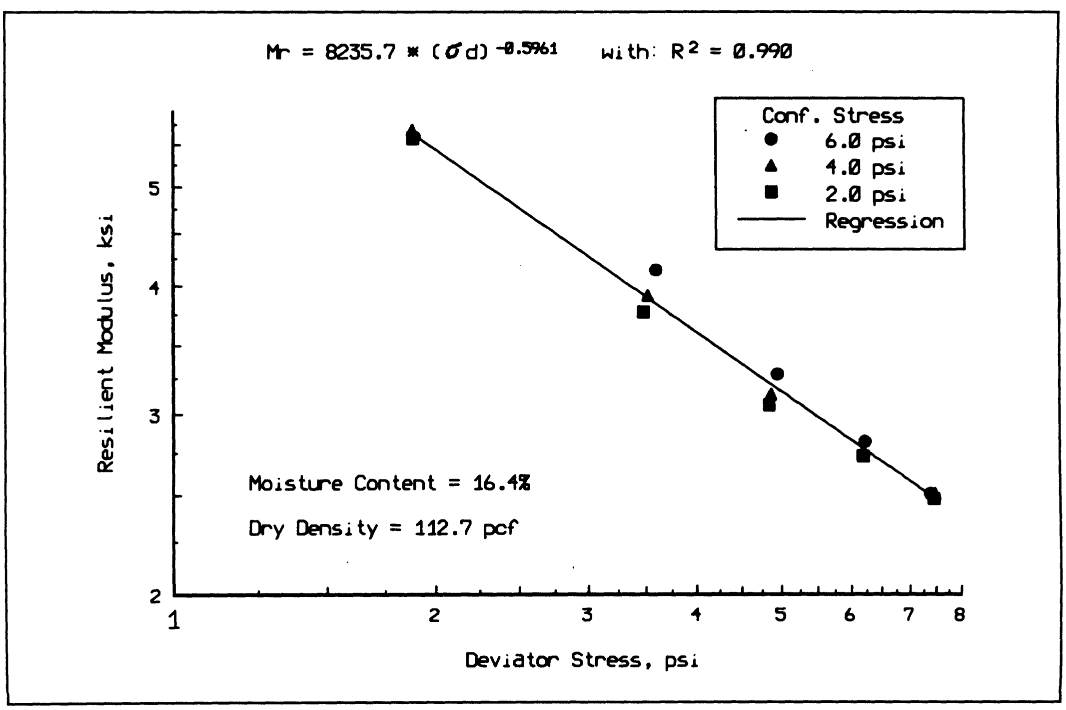

Figure A.12 Logarithmic Plot of Resilient Modulus Versus Deviator Stressfor Soil Sample NB6 at Moisture Content 0.9% Above Optimum

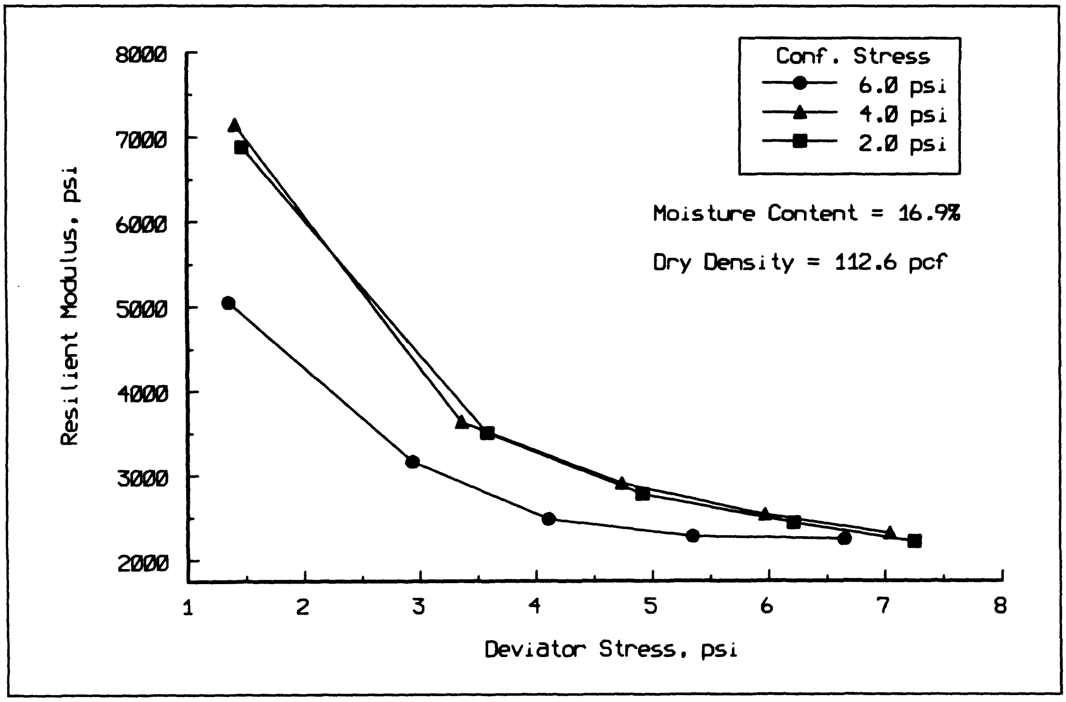

Figure A.13 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB6 at Moisture Content 1.4% Above Optimum

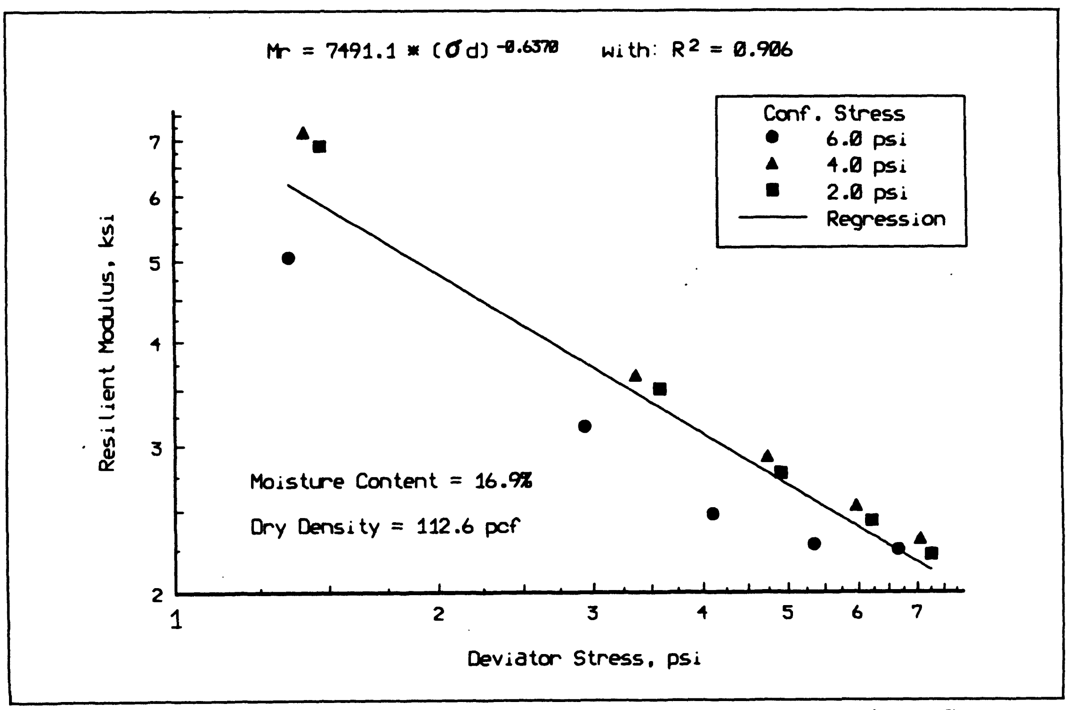

Figure A.14 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample NB6 at Moisture Content 1.4% Above Optimum

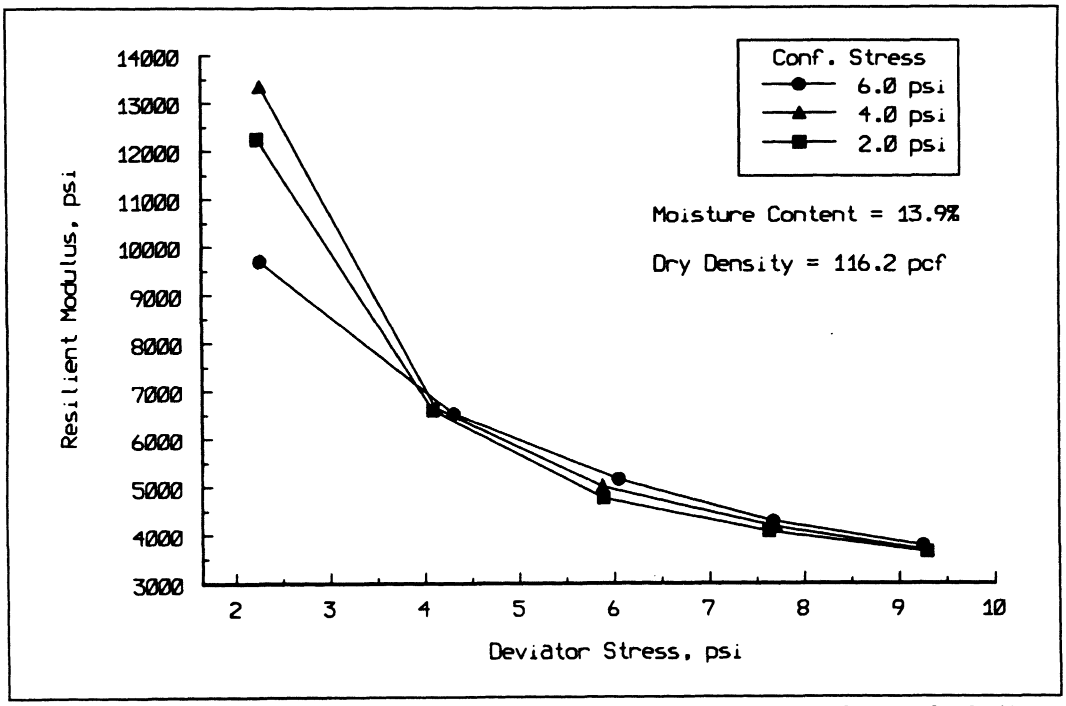

Figure A.15 Variation of Resilient Modulus Versus Deviator Stress forSoil Sample SB3 at Moisture Content 1.2% Below Optimum

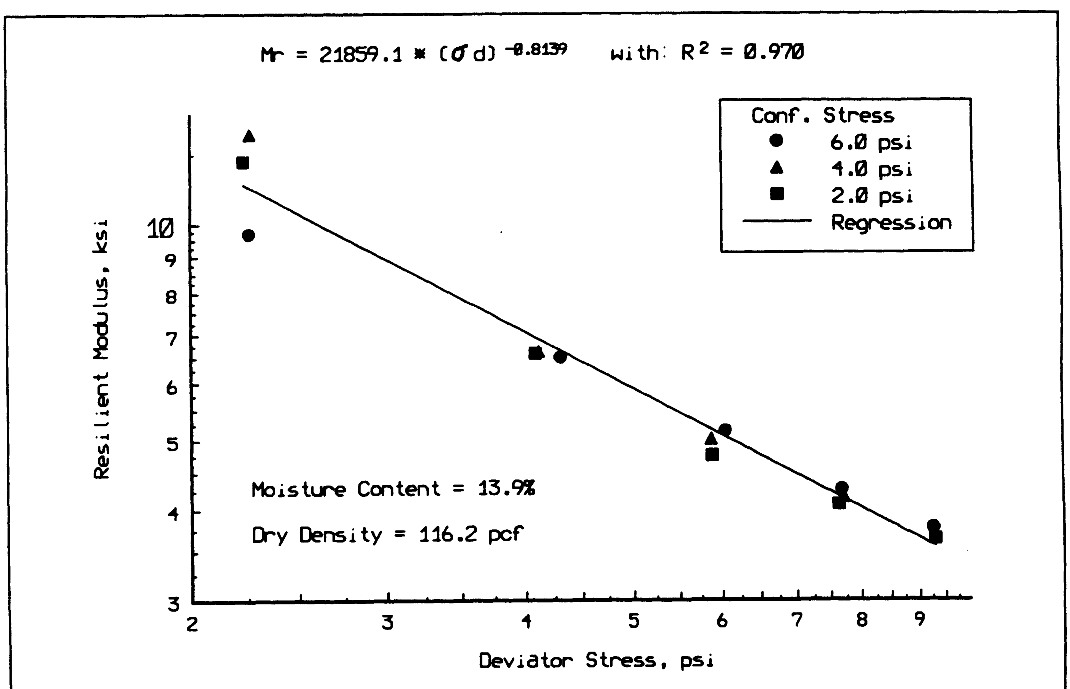

Figure A.16 Logarithmic Plot of Resilient Modulus Versus Deviator Stressfor Soil Sample SB3 at Moisture Content 1.2% Below Optimum

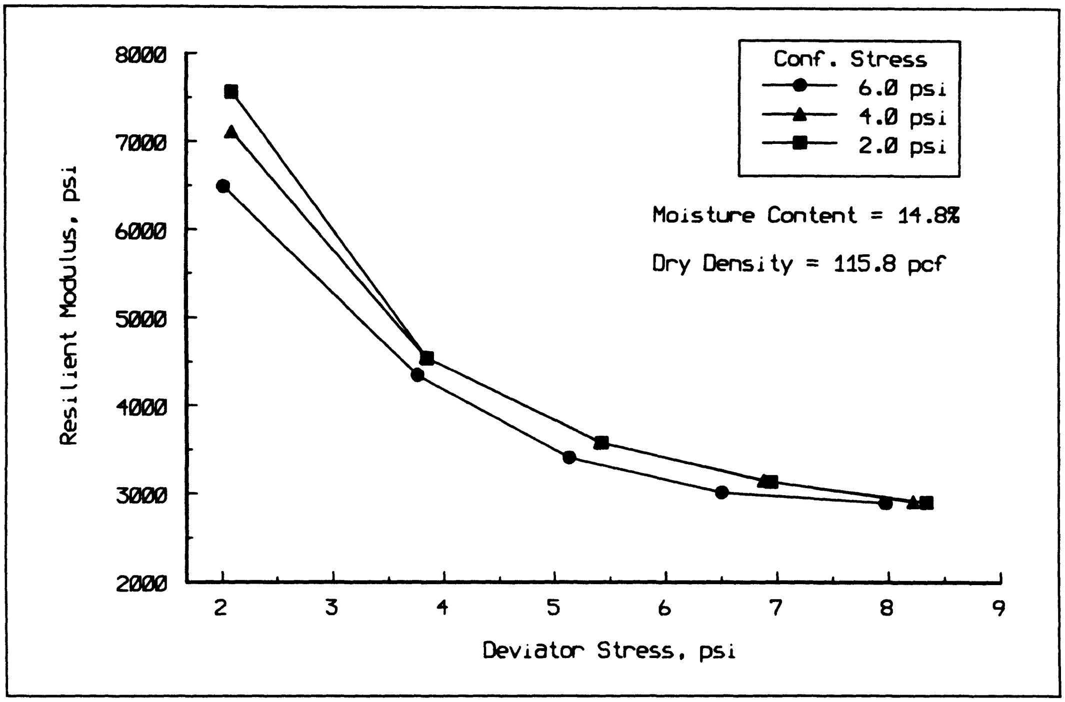

Figure A.17 Variation of Resilient Modulus Versus Deviator Stress forSoil Sample SB3 at Moisture Content 0.3% Below Optimum

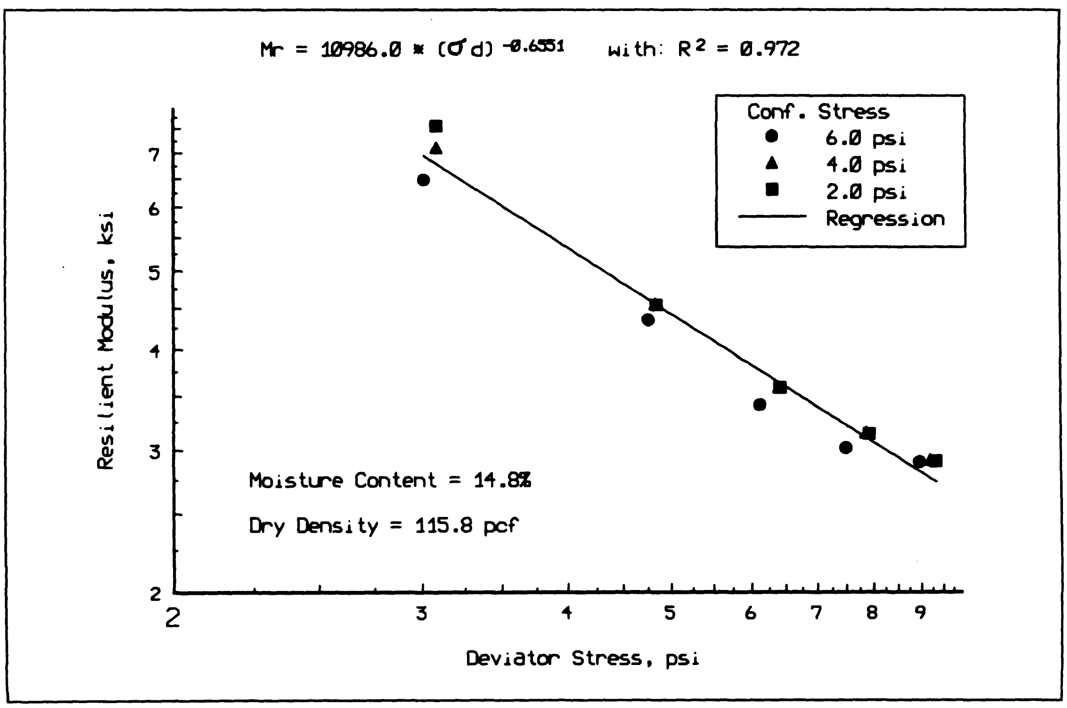

Figure A.18 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample SB3 at Moisture Content 0.3% Below Optimum

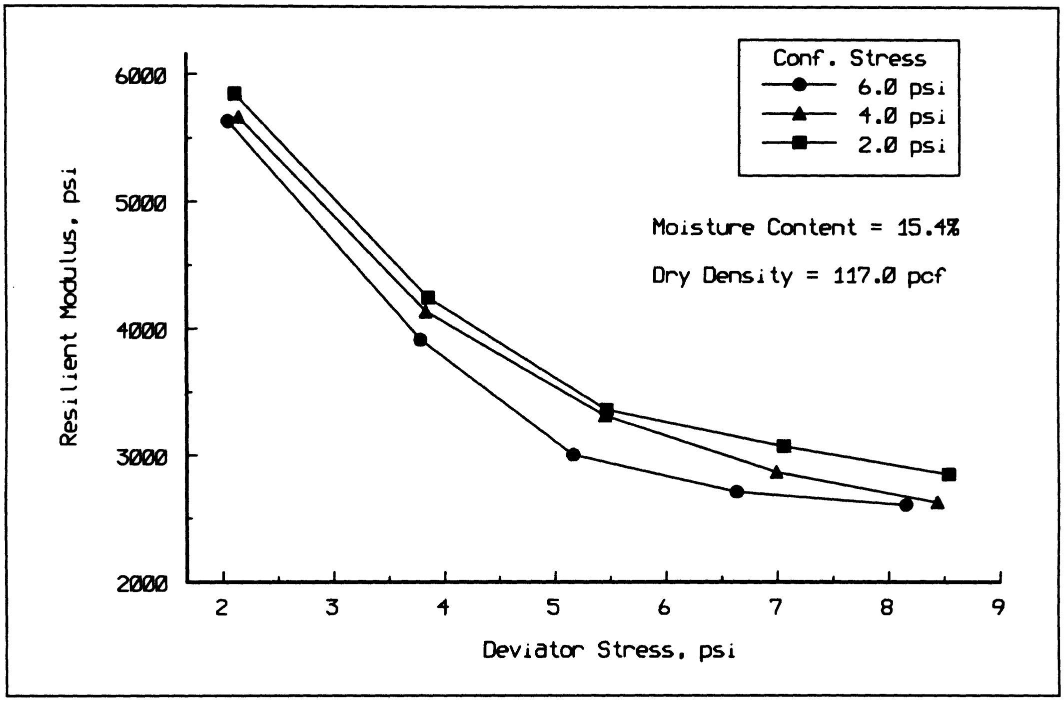

Figure A.19 Variation of Resilient Modulus Versus Deviator Stress forSoil Sample SB3 at Moisture Content 0.3% Above Optimum

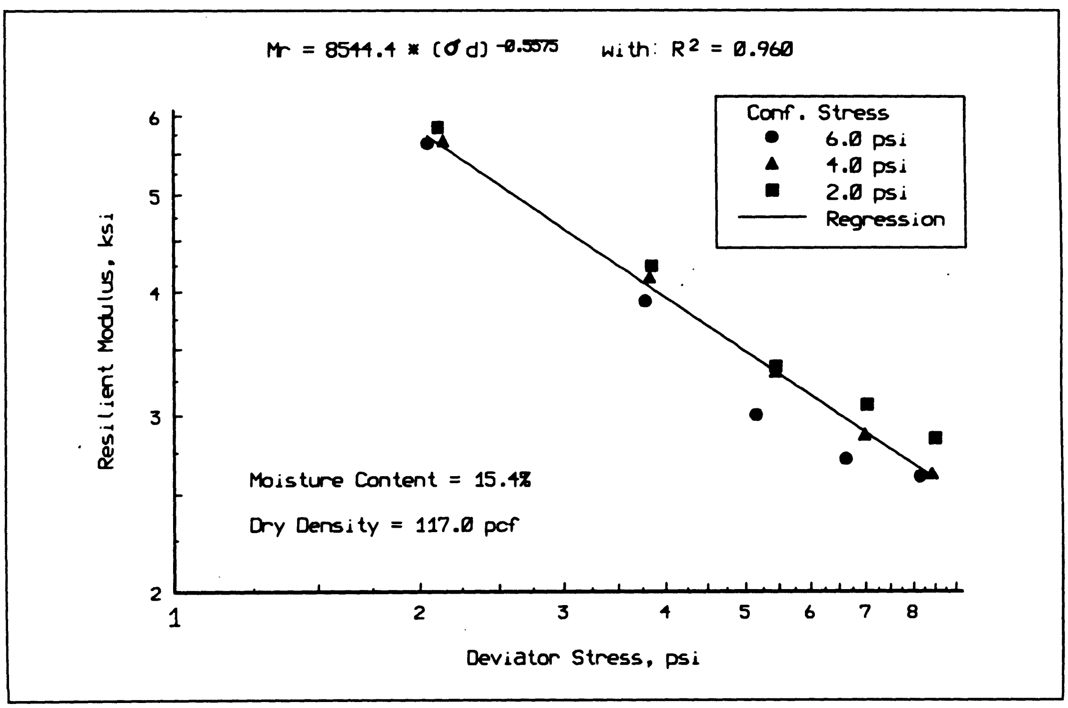

Figure A.20 Logarithmic Plot of Resilient Modulus Versus Deviator Stressfor Soil Sample SB3 at Moisture Content 0.3% Above Optimum

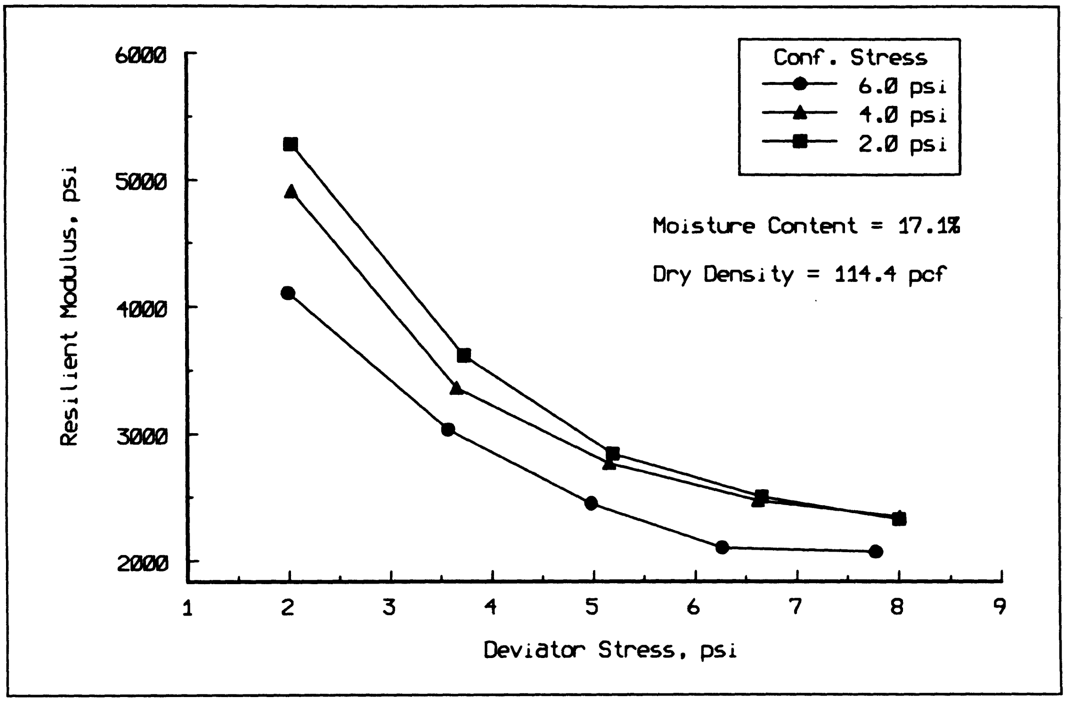

Figure A.21 Variation of Resilient Modulus Versus Deviator Stress forSoil Sample SB3 at Moisture Content 2.0% Above Optimum

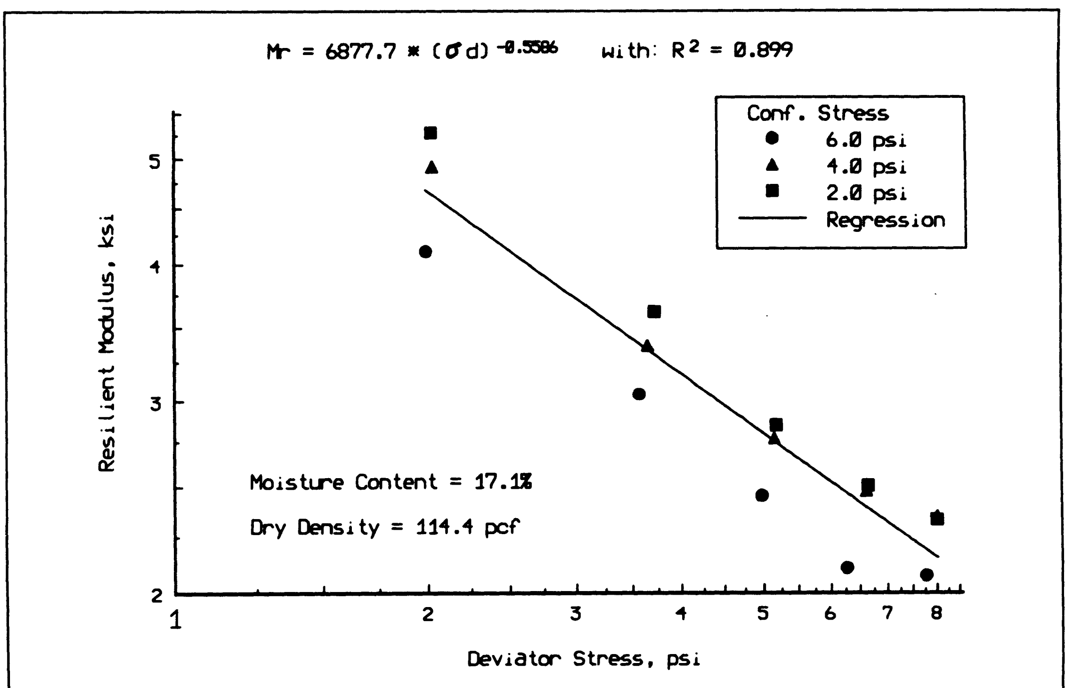

Figure A.22 Logarithmic Plot of Resilient Modulus Versus Deviator Stressfor Soil Sample SB3 at Moisture Content 2.0% Above Optimum

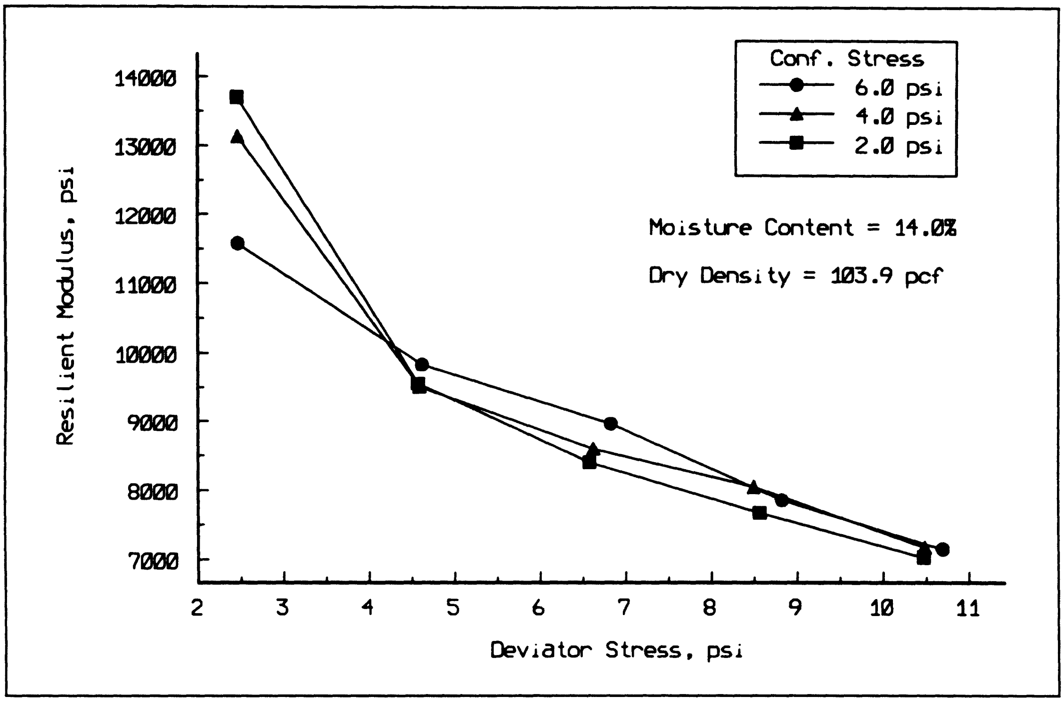

Figure A.23 Variation of Resilient Modulus Versus Deviator Stress forSoil Sample SB4 at Moisture Content 0.9% Below Optimum

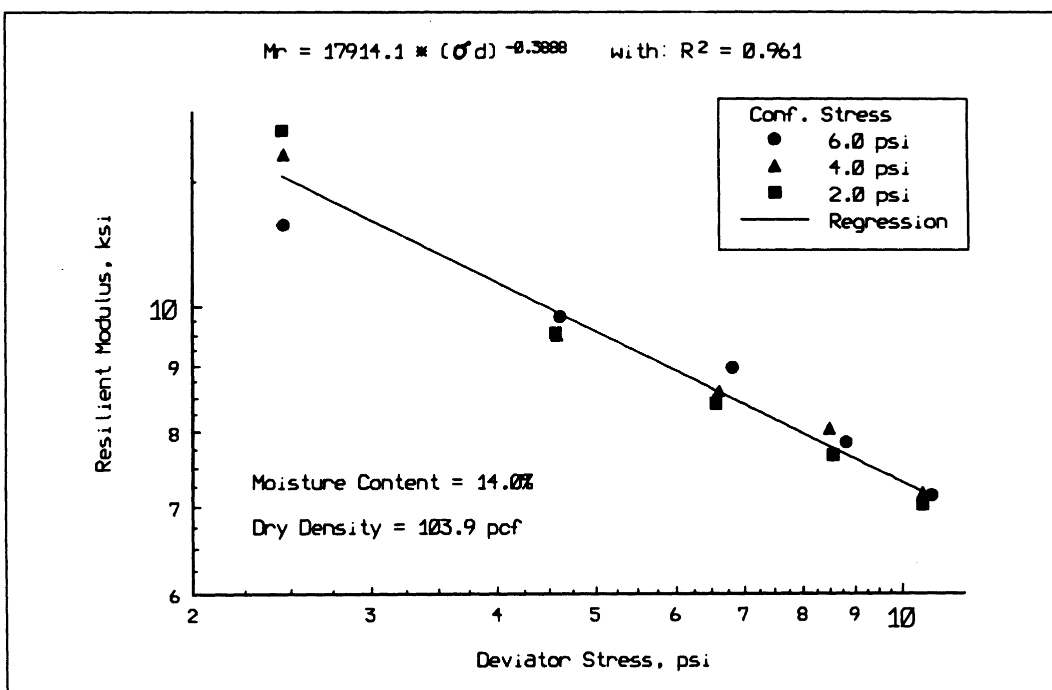

Figure A.24 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample SB4 at Moisture Content 0.9% Below Optimum

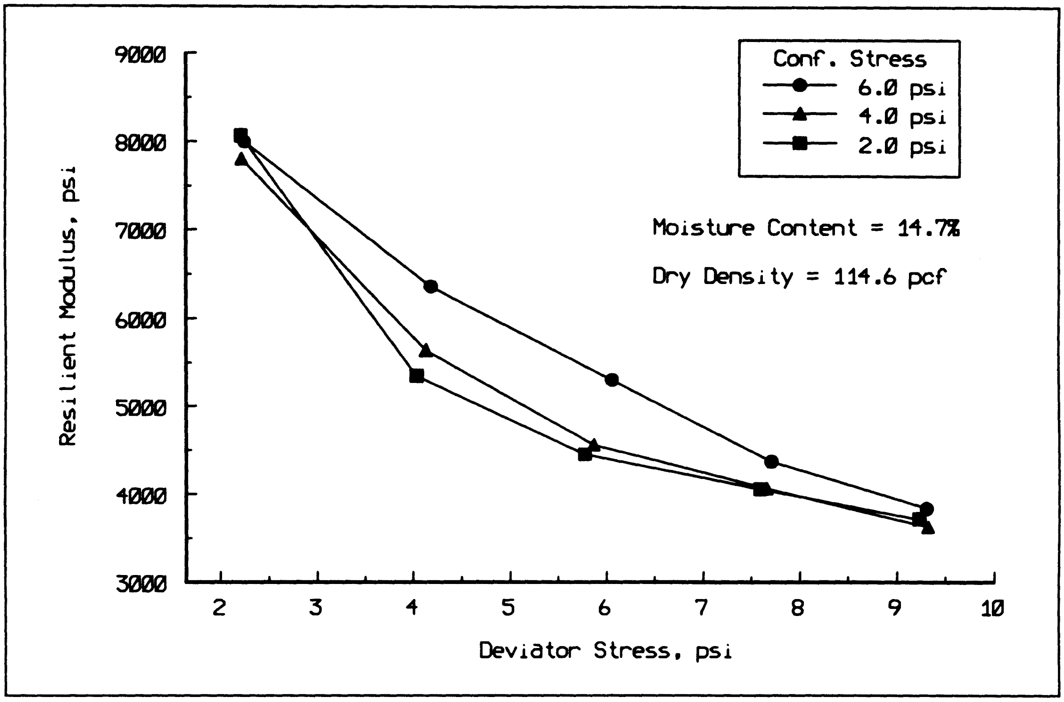

Figure A.25 Variation of Resilient Modulus Versus Deviator Stress forSoil Sample SB4 at Moisture Content 0.2% Below Optimum

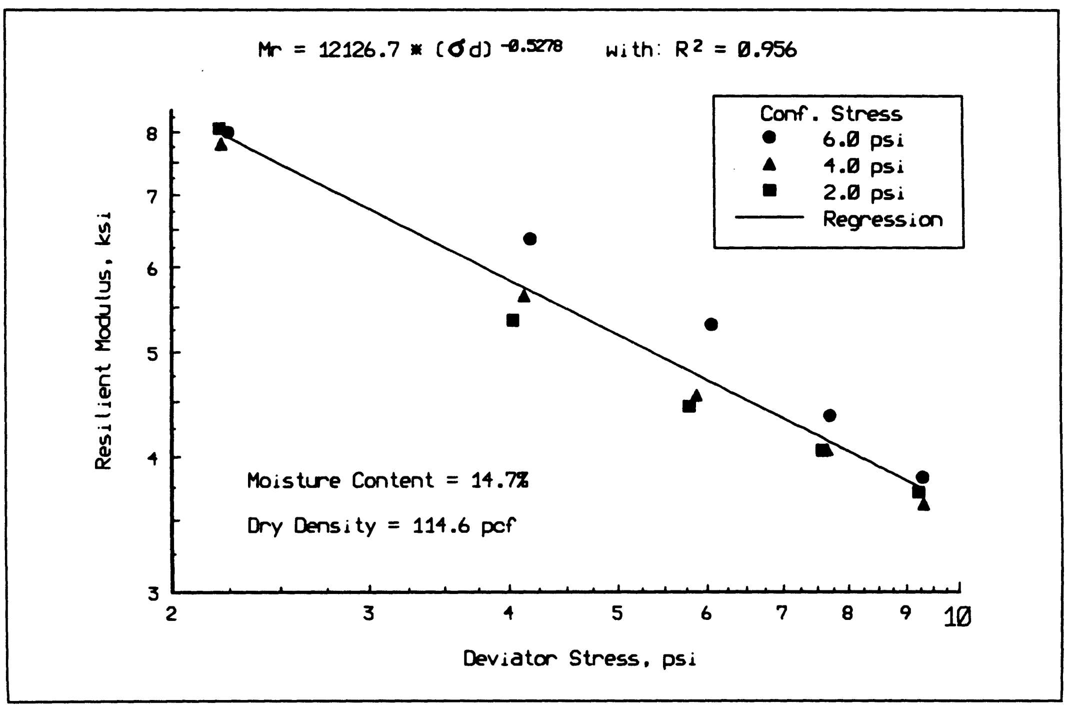

Figure A.26 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample SB4 at Moisture Content 0.2 Below Optimum

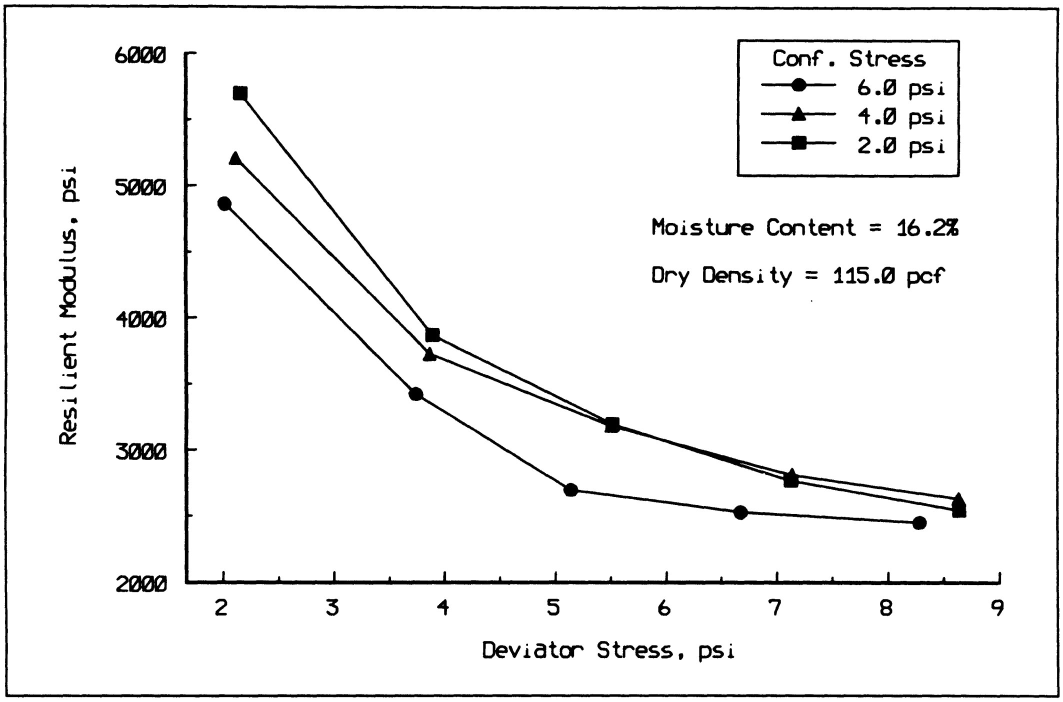

Figure A.27 Variation of Resilient Modulus Versus Deviator Stress forSoil Sample SB4 at Moisture Content 1.3% Above Optimum

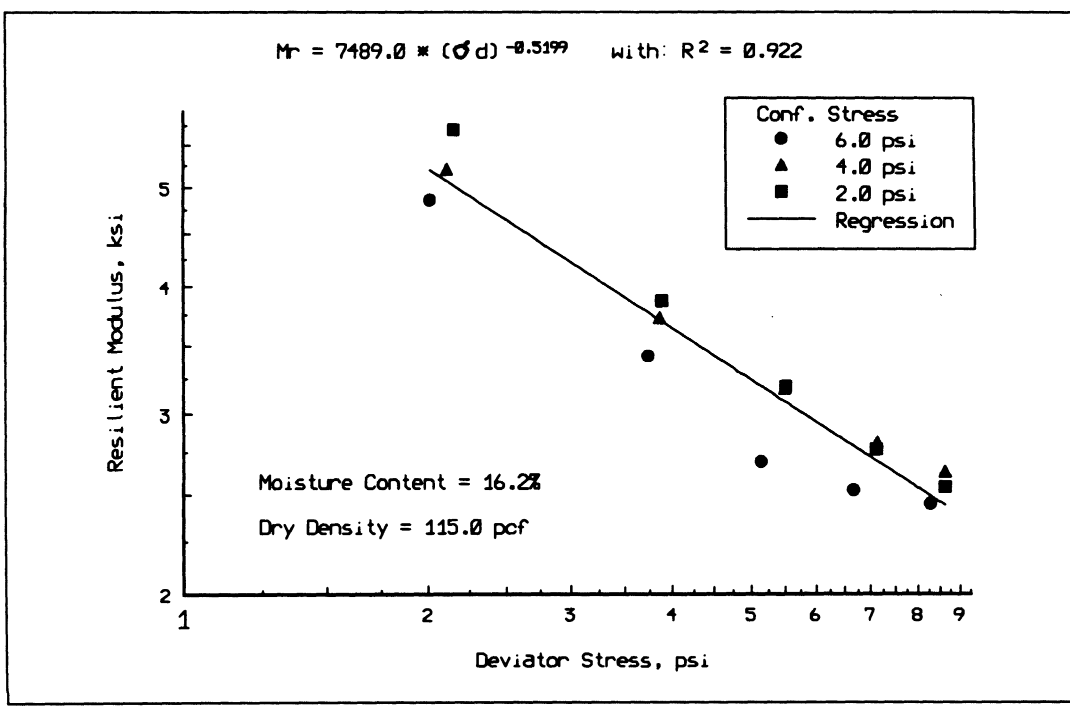

Figure A.28 Logarithmic Plot of Resilient Modulus Versus Deviator Stressfor Soil Sample SB4 at Moisture Content 1.3% Above Optimum

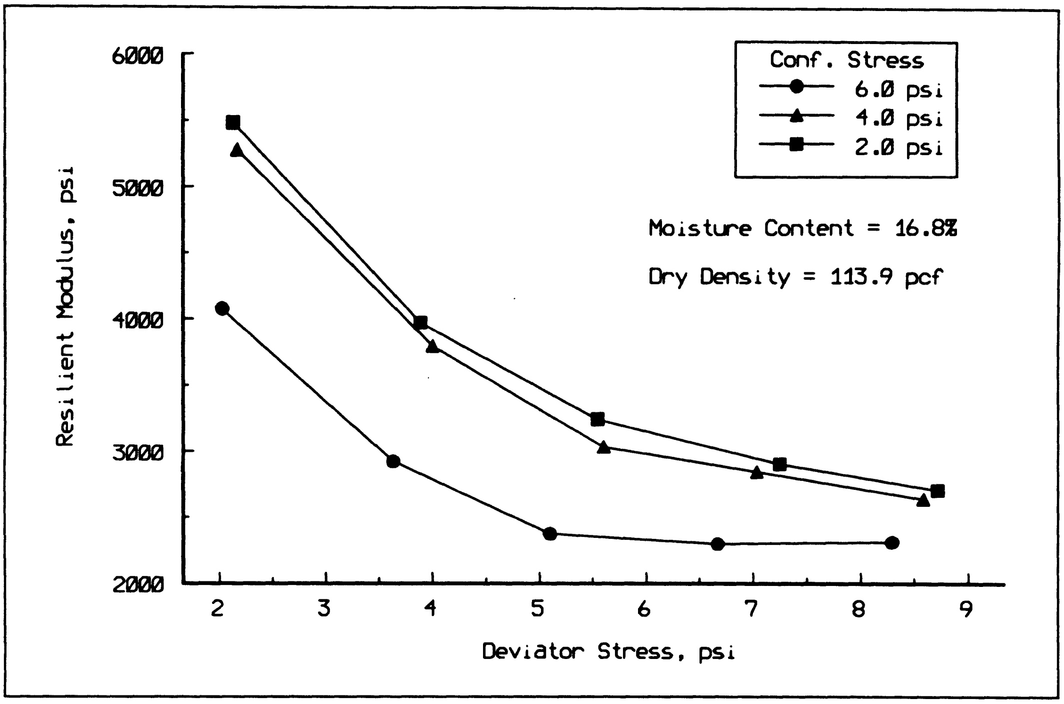

Figure A.29 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample SB4 at Moisture Content 1.9% Above Optimum

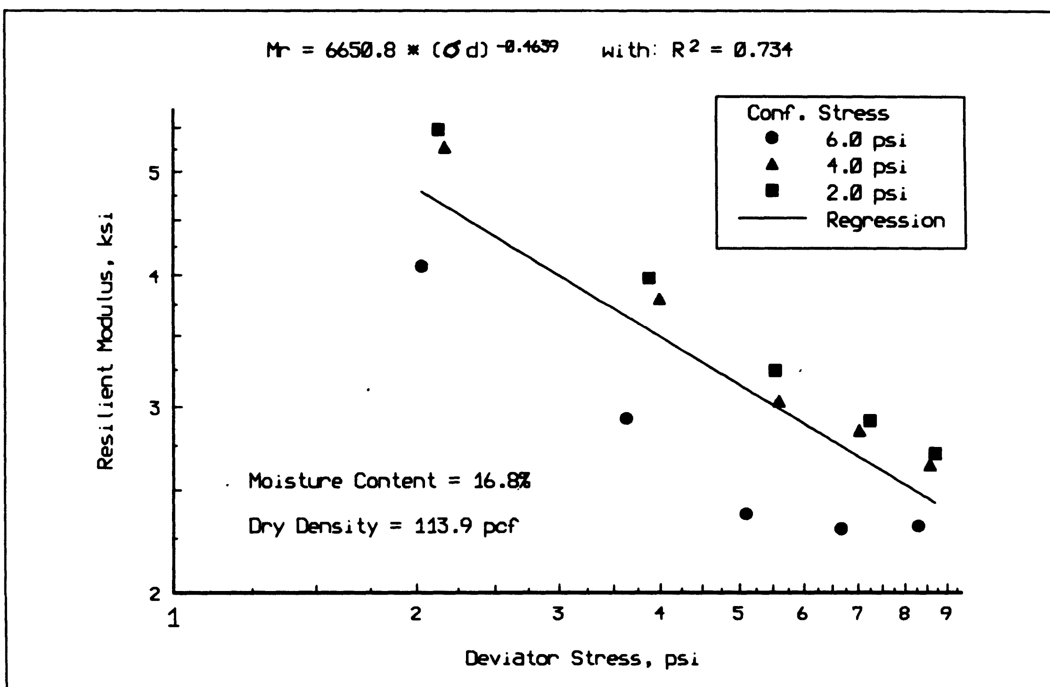

Figure A.30 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample SB4 at Moisture Content 1.9% Above Optimum

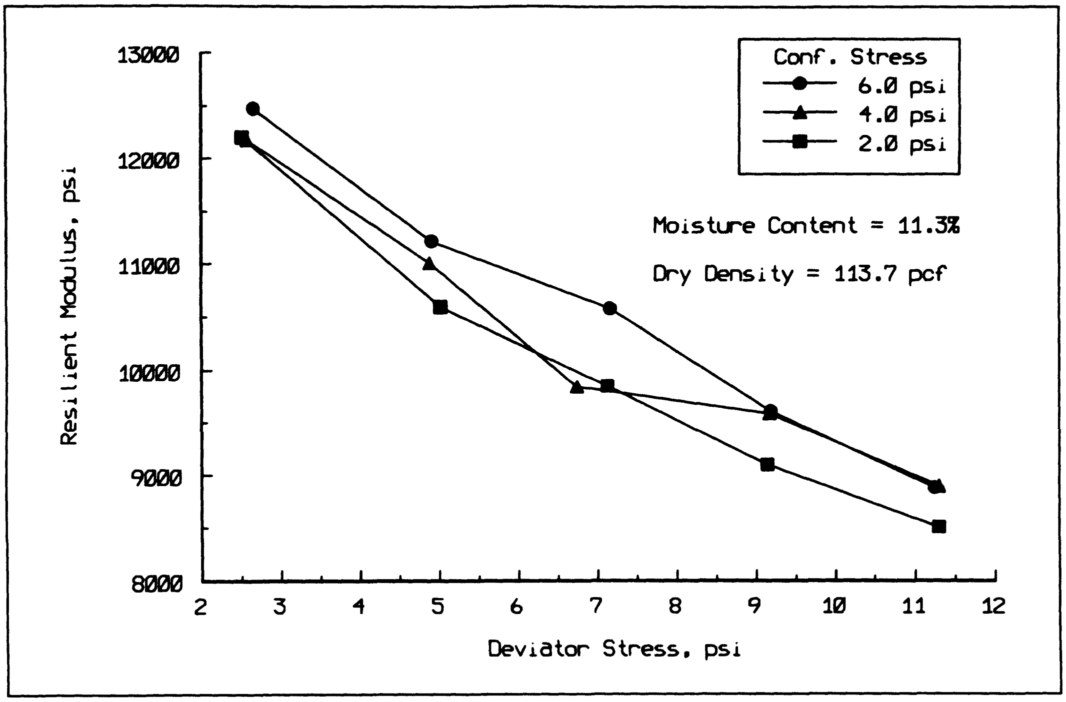

Figure A.31 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN2 at Moisture Content 2.6% Below Optimum

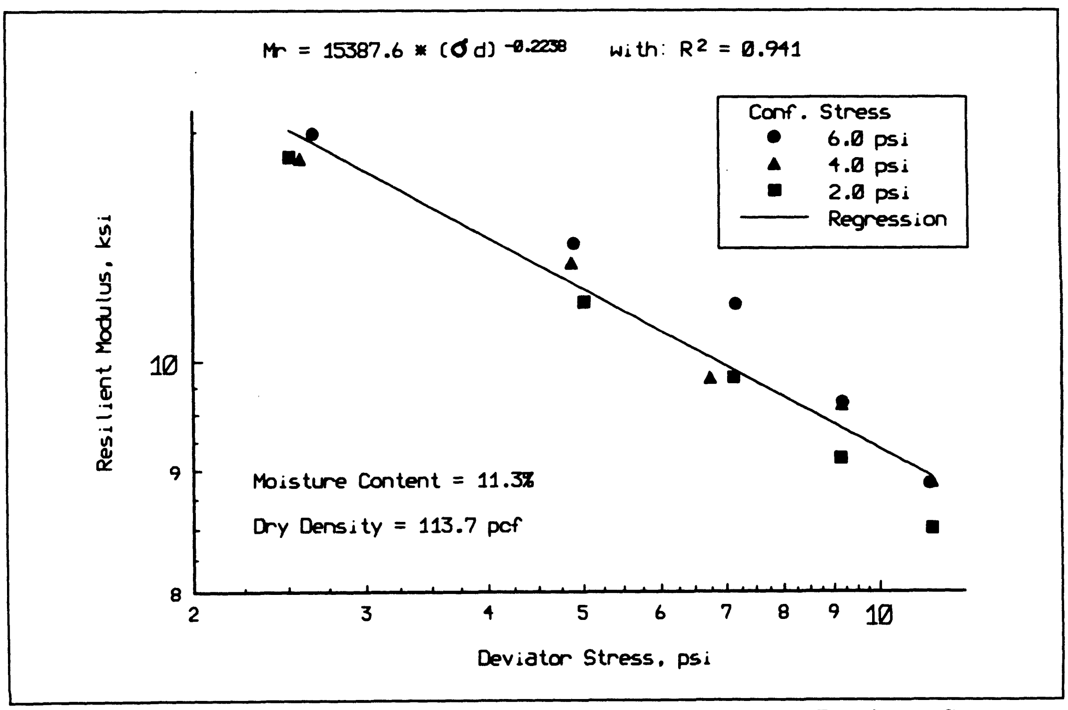

Figure A.32 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN2 at Moisture Content 2.6% Below Optimum

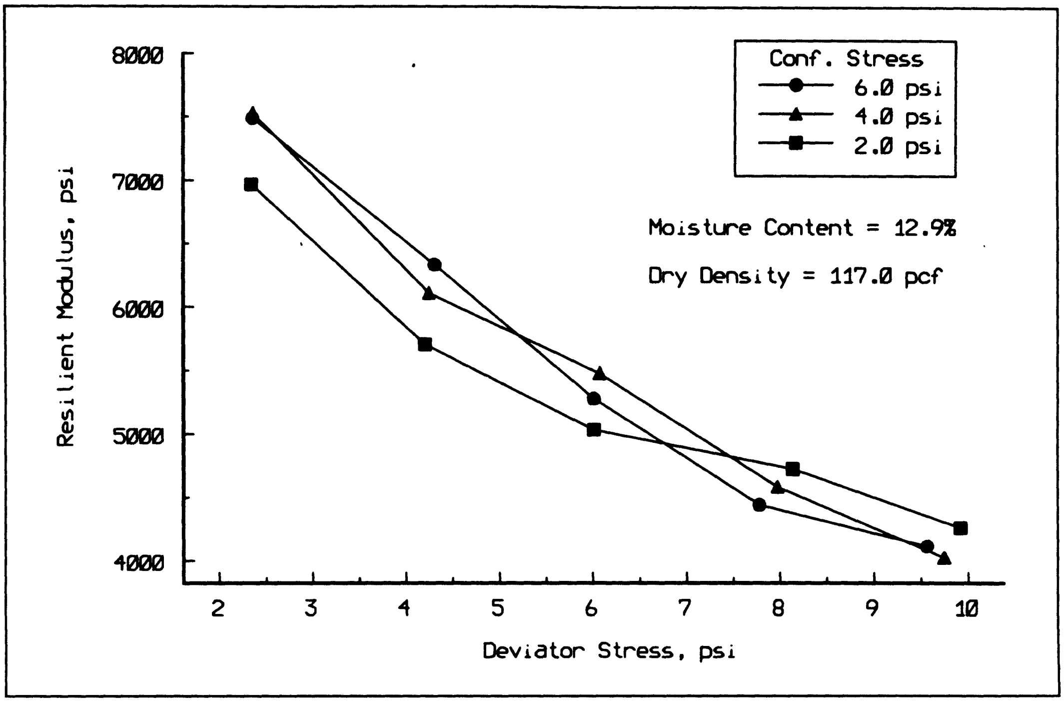

Figure A.33 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample MN2 at Moisture Content 1.0% Below Optimum

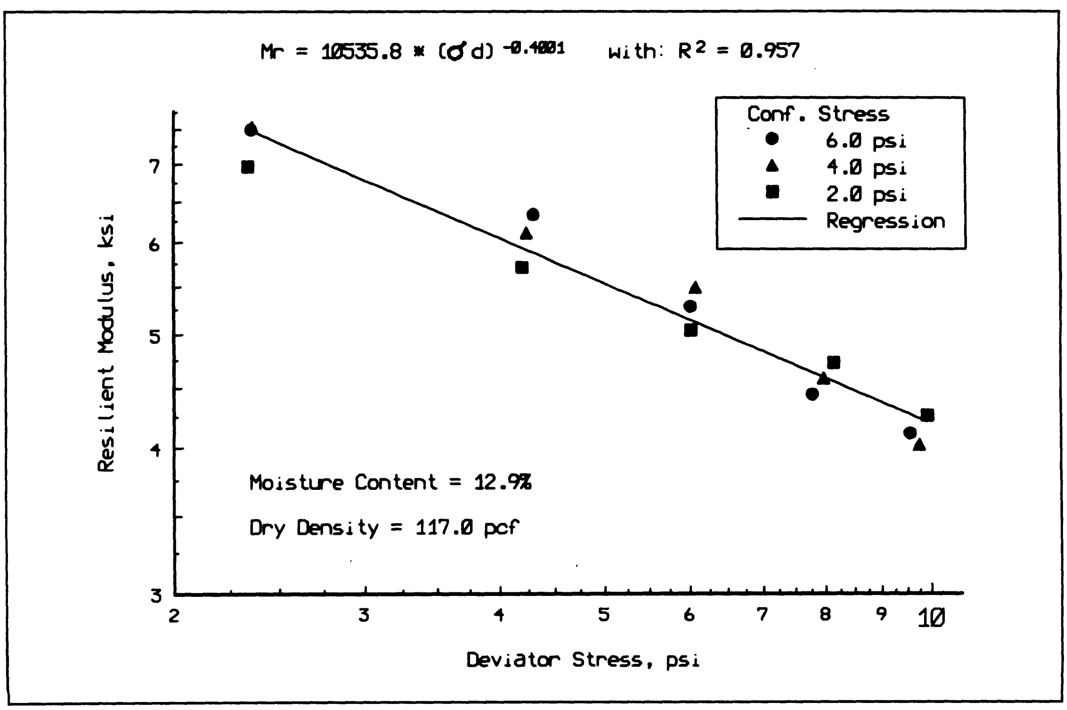

Figure A.34 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN2 at Moisture Content 1.0% Below Optimum

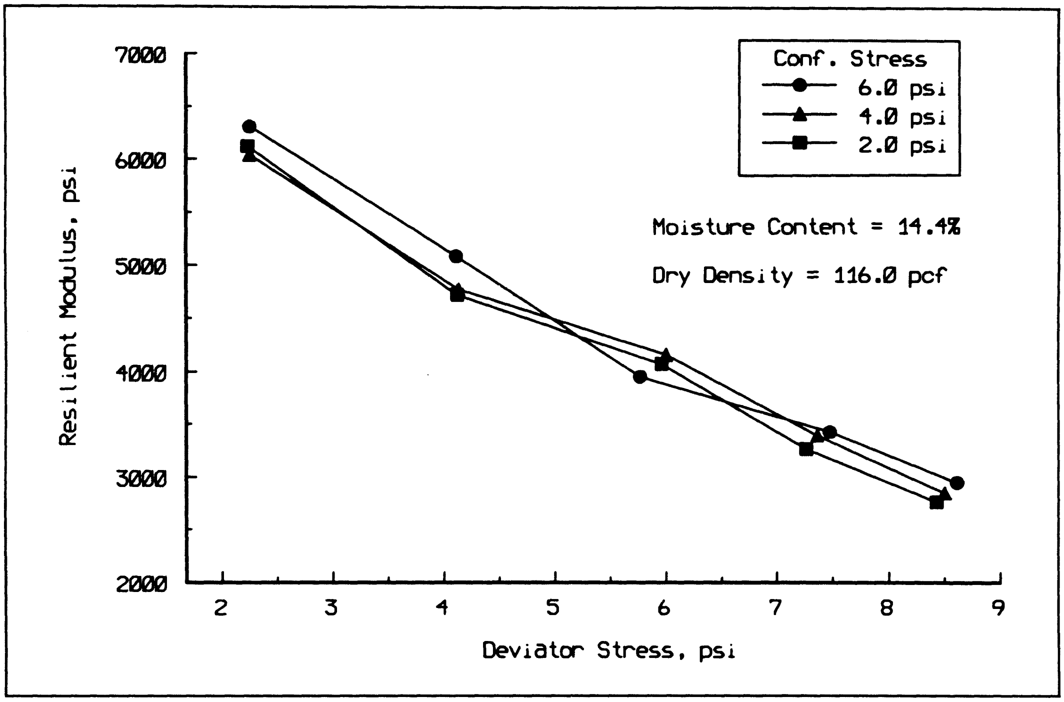

Figure A.35 Variation Plot of Resilient Modulus Versus Deviator Stress forSoil Sample NB4 at Moisture Content 0.5% Above Optimum

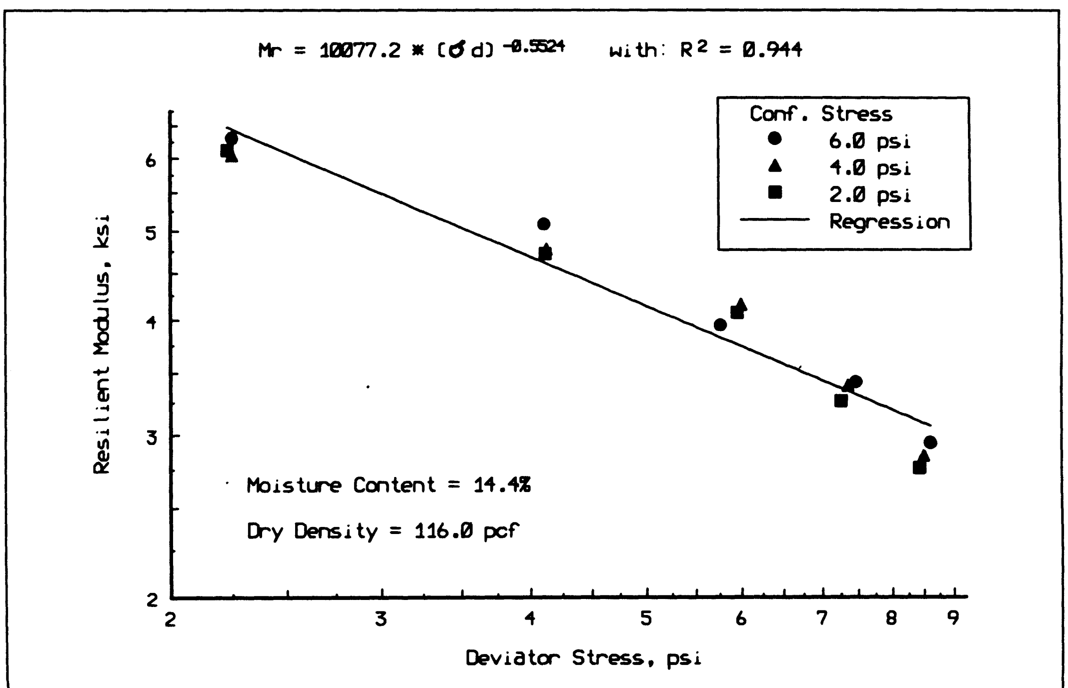

Figure A.36 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN2 at Moisture Content 0.5% Above Optimum

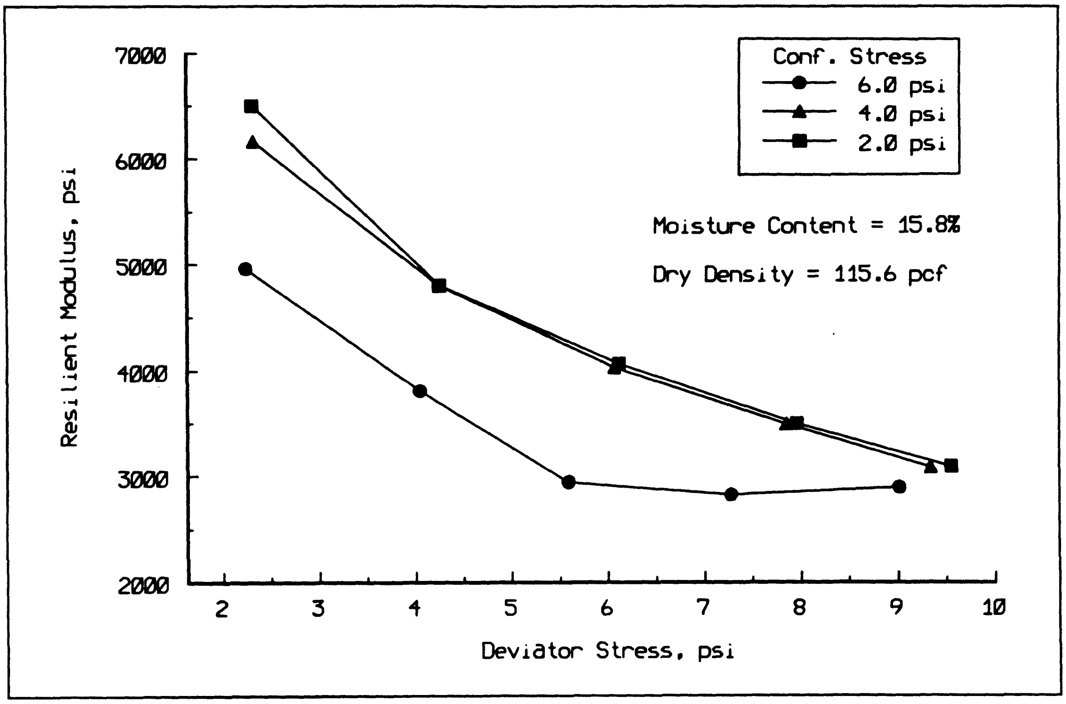

Figure A.37 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN2 at Moisture Content 1.9% Above Optimum

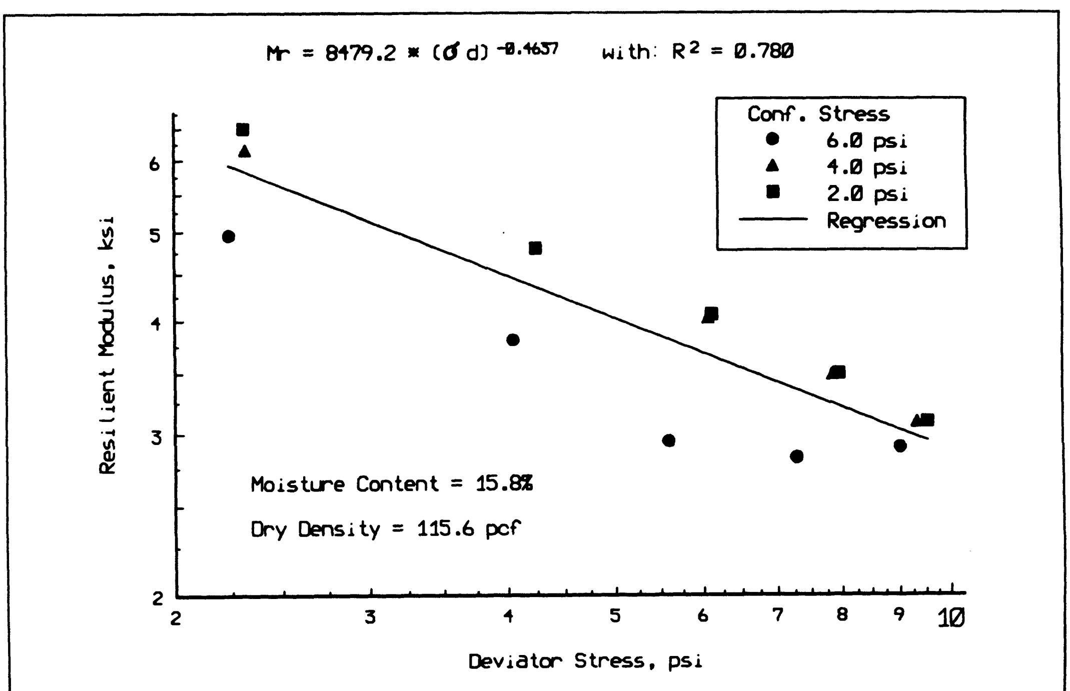

Figure A.38 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN2 at Moisture Content 1.9% Above Optimum

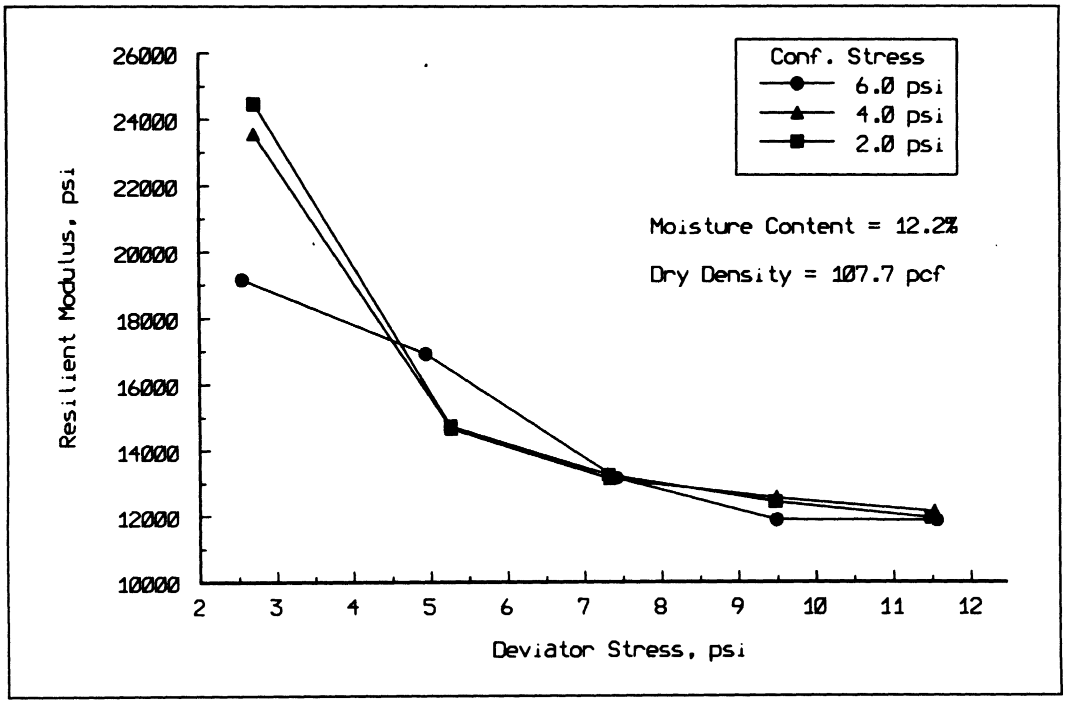

Figure A.39 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN4 at Moisture Content 2.3% Below Optimum

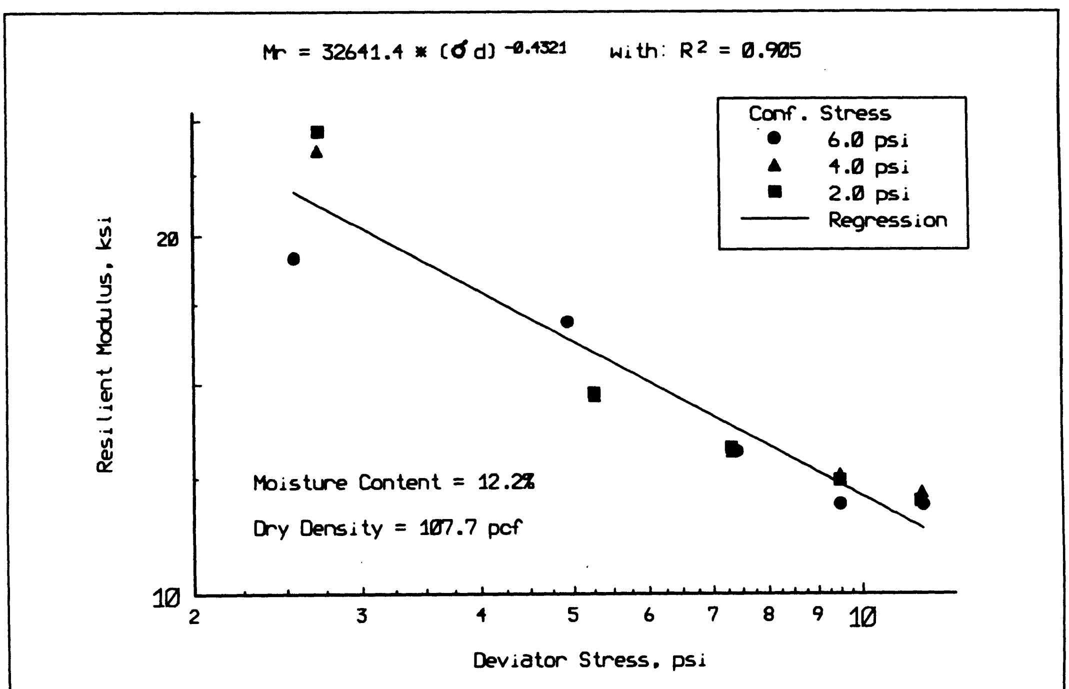

Figure A.40 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN4 at Moisture Content 2.3% Below Optimum

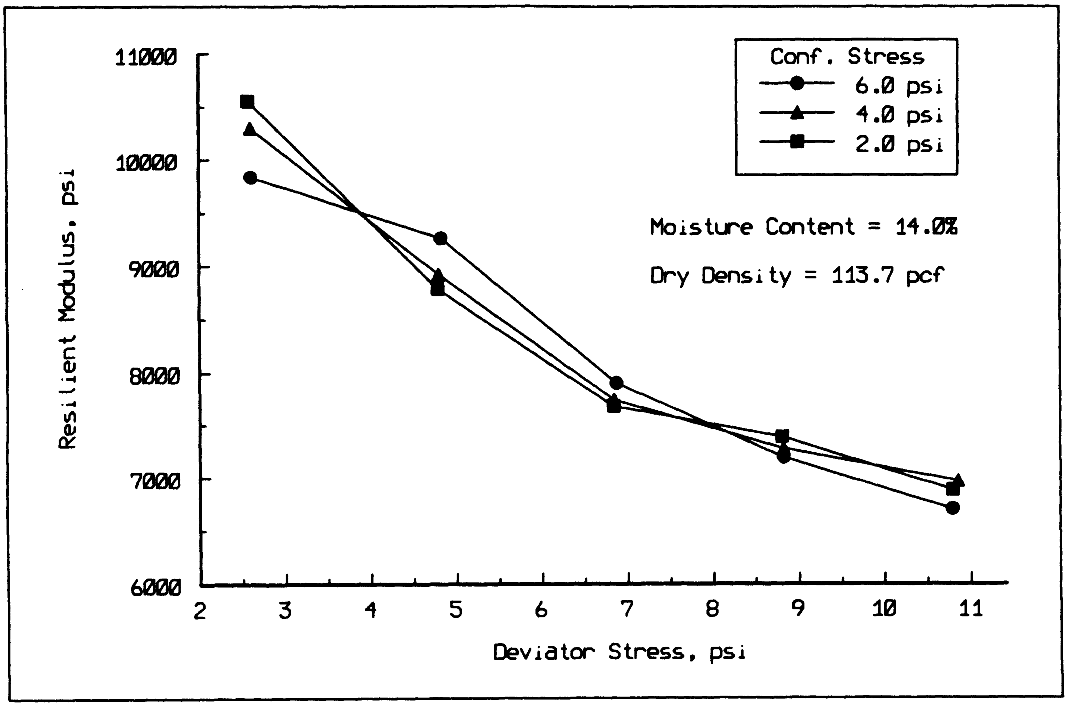

Figure A.41 Variation Plot of Resilient Modulus versus Deviator Stress for Soil Sample MN4 at Moisture Content 0.5% Below Optimum

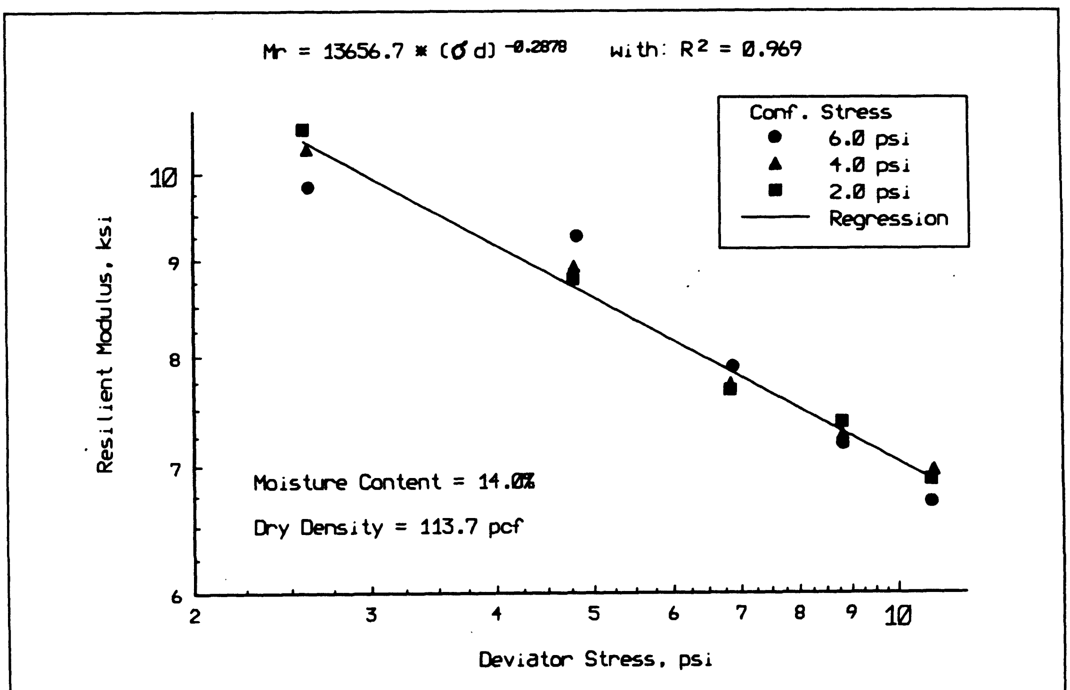

Figure A.42 Logarithmic Plot of Resilient Modulus Versus Deviator Stressfor Soil Sample MN4 at Moisture Content 0.5% Below Optimum

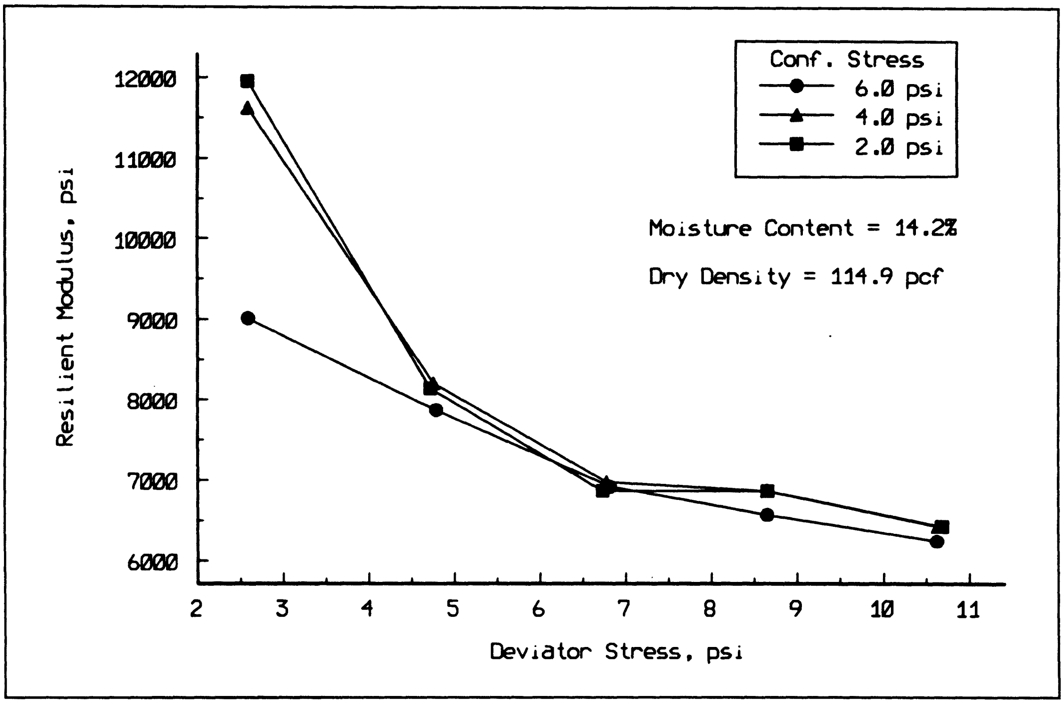

Figure A.43 Variation Plot of Resilient Modulus Versus Deviator Stress forSoil Sample MN4 at Moisture Content 0.3% Above Optimum

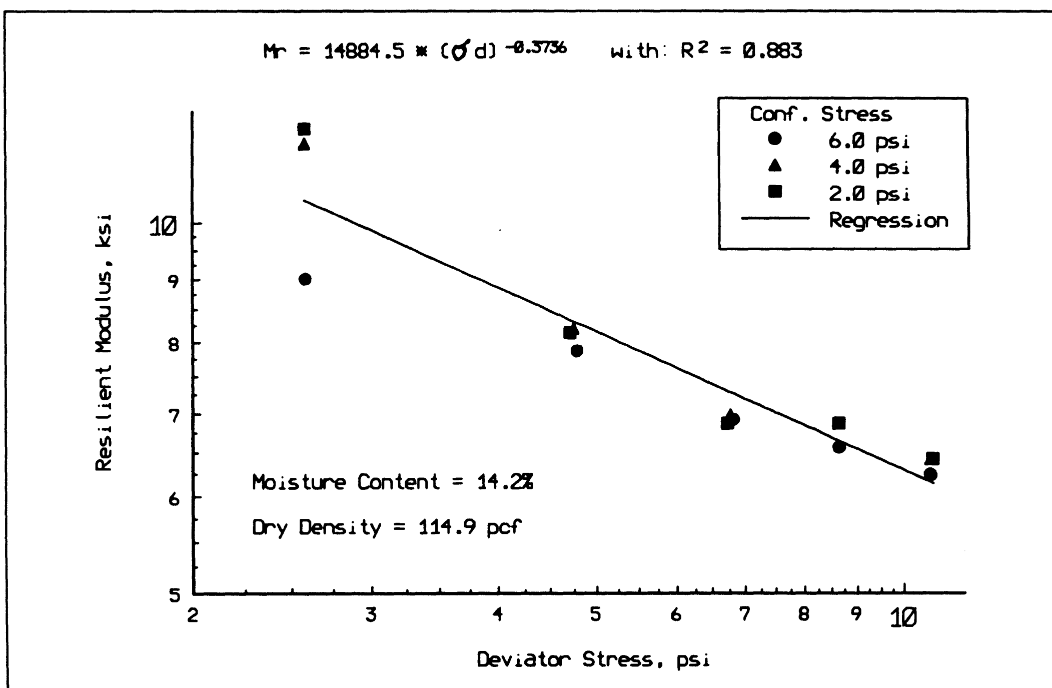

Figure A.44 Logarithmic Plot of Resilient Modulus Versus Deviator Stressfor Soil Sample MN4 at Moisture Content 0.3% Above Optimum

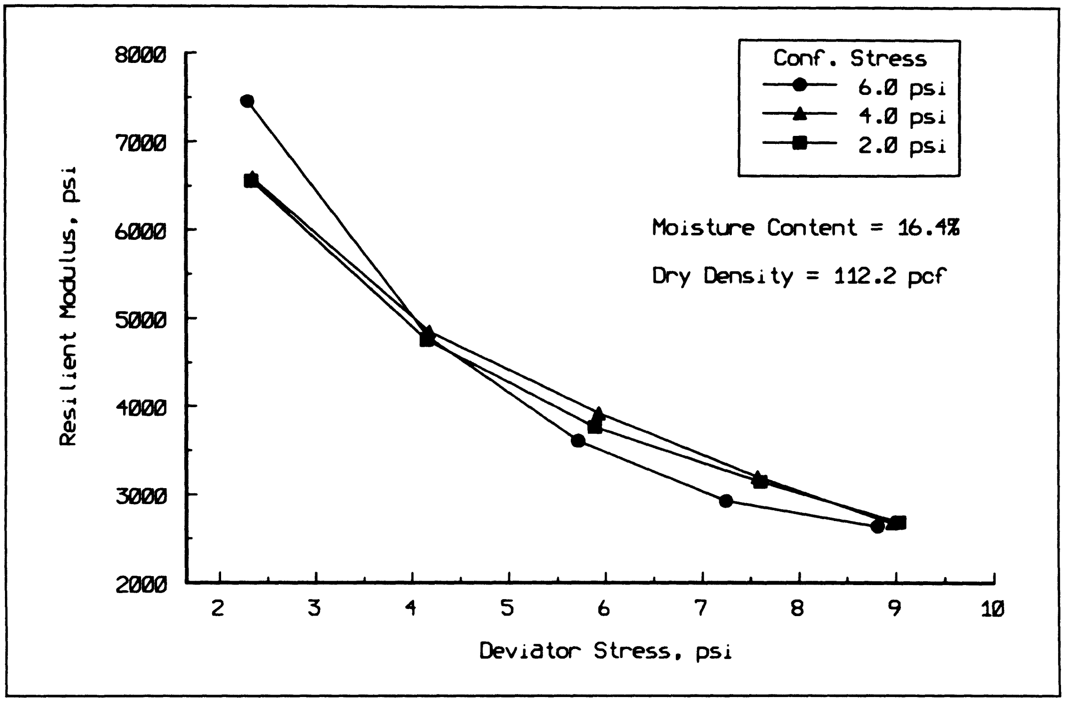

Figure A.45 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN4 at Moisture Content 1.9% Above Optimum

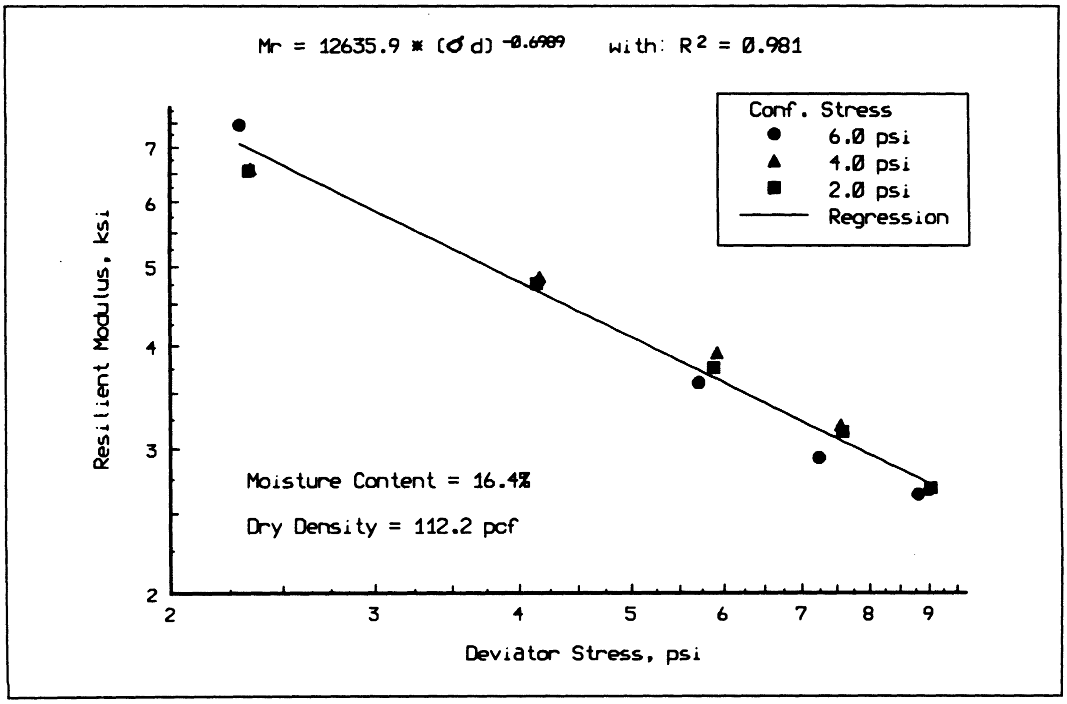

Figure A.46 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample MN4 at Moisture Content 1.9% Above Optimum

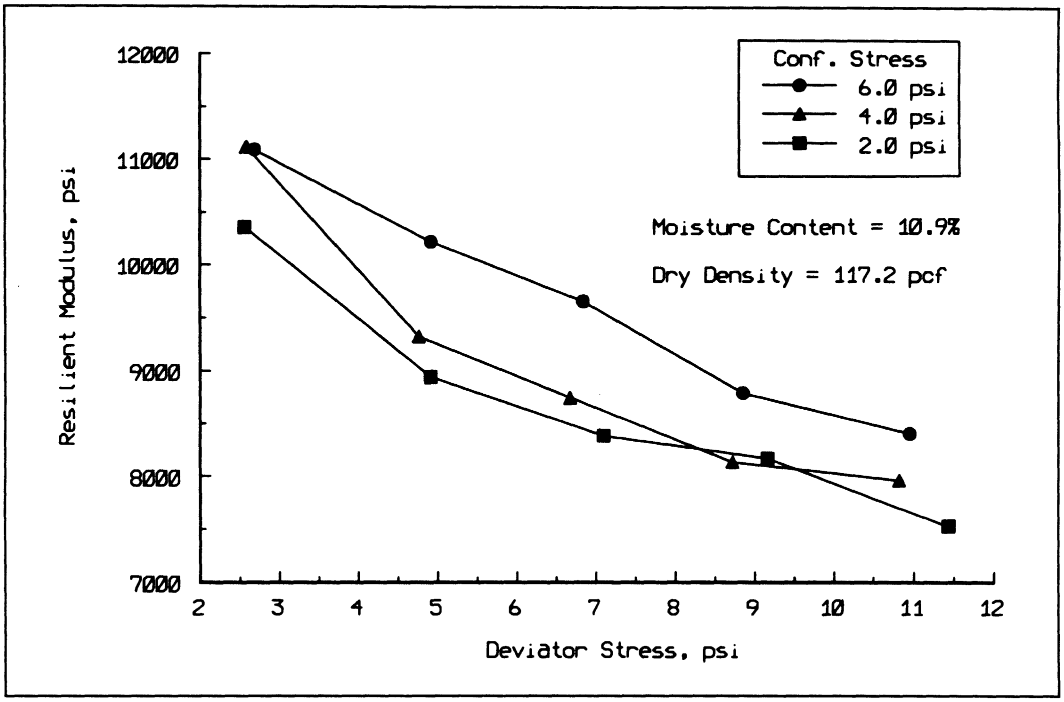

Figure A.47 Variation Plot of Resilient Modulus Versus Deviator Stress forSoil Sample GN2 at Moisture Content 2.0% Below Optimum

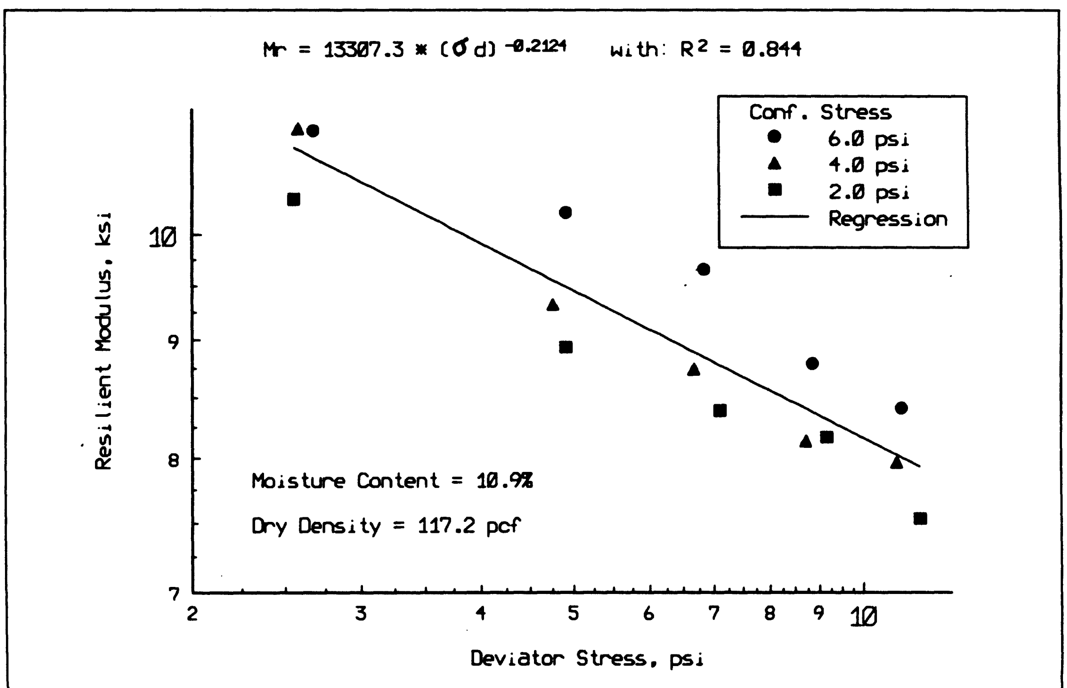

Figure A.48 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GN2 at Moisture Content 2.0% Below Optimum

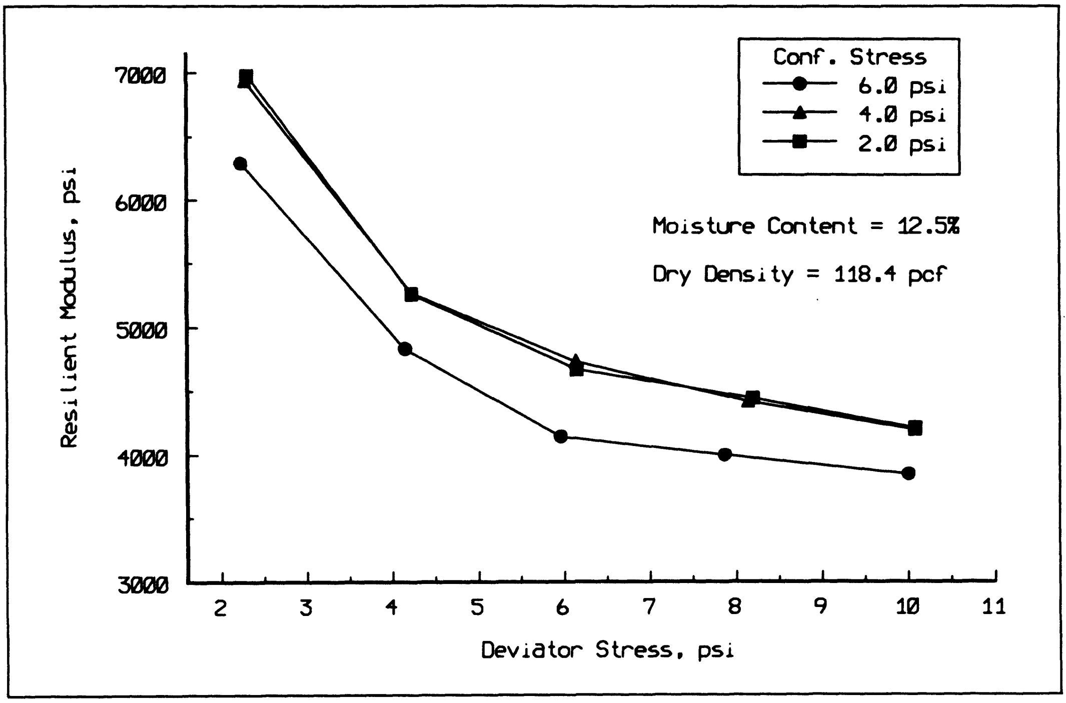

Figure A.49 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GN2 at Moisture Content 0.4% Below Optimum

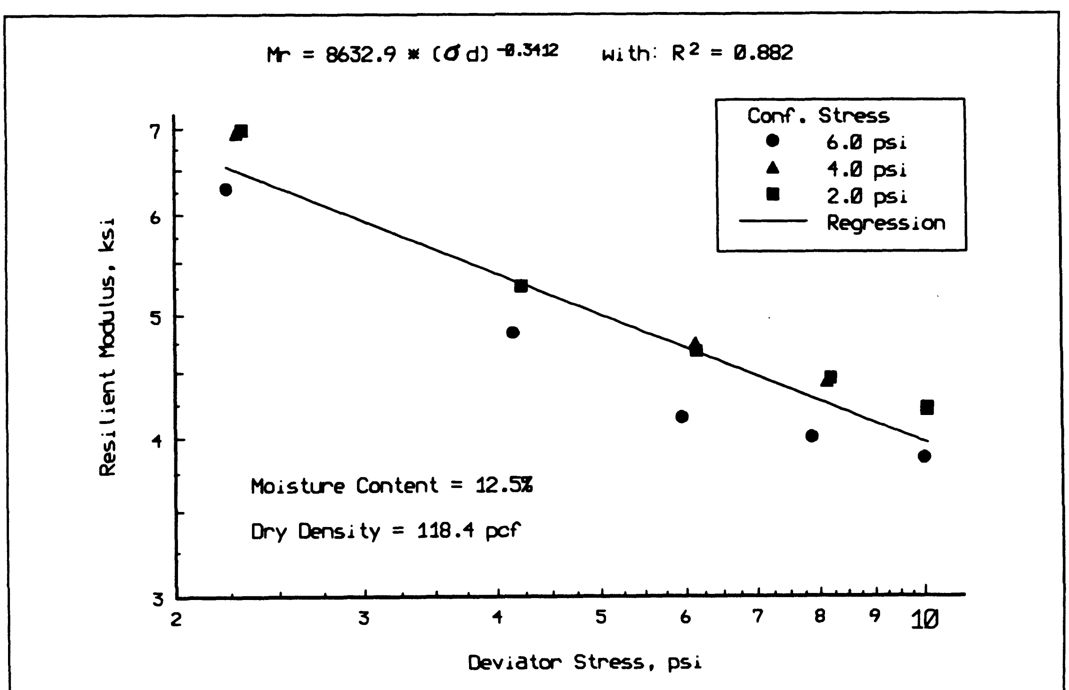

Figure A.50 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GN2 at Moisture Content 0.4% Below Optimum

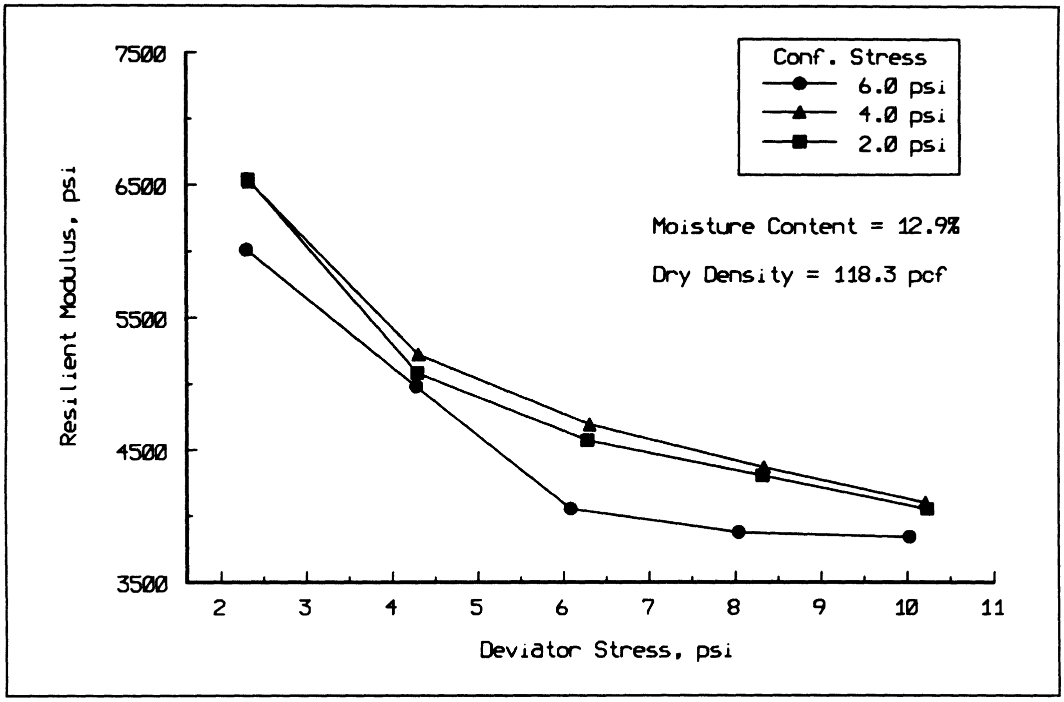

Figure A.51 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GN2 at 12.9% Optimum Moisture Content

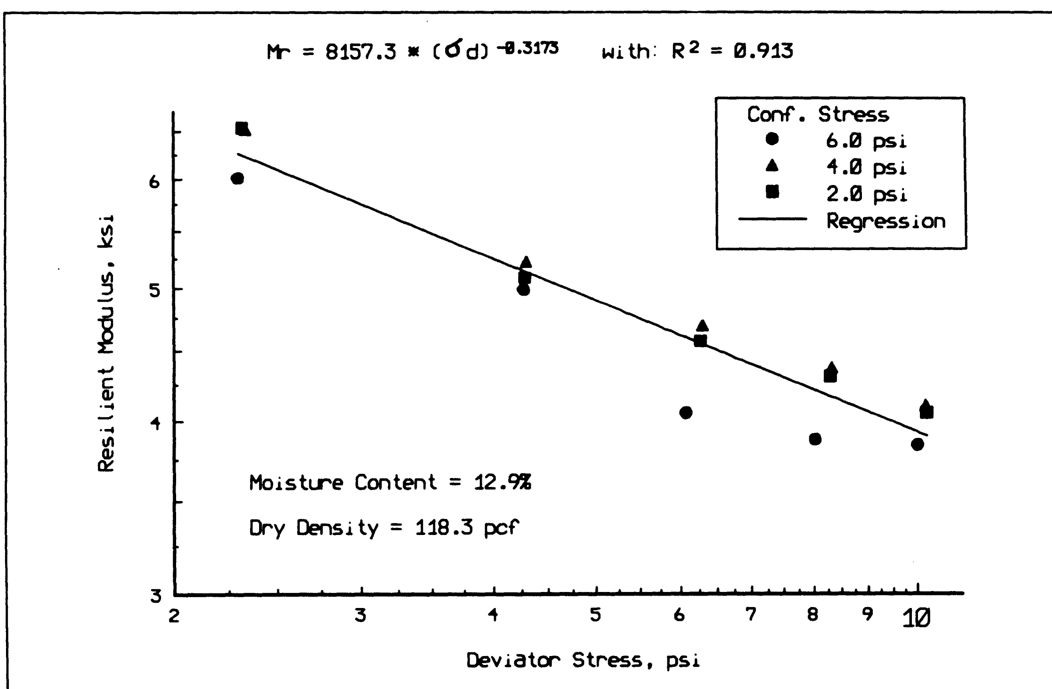

Figure A.52 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GN2 at 12.9% Optimum Moisture Content

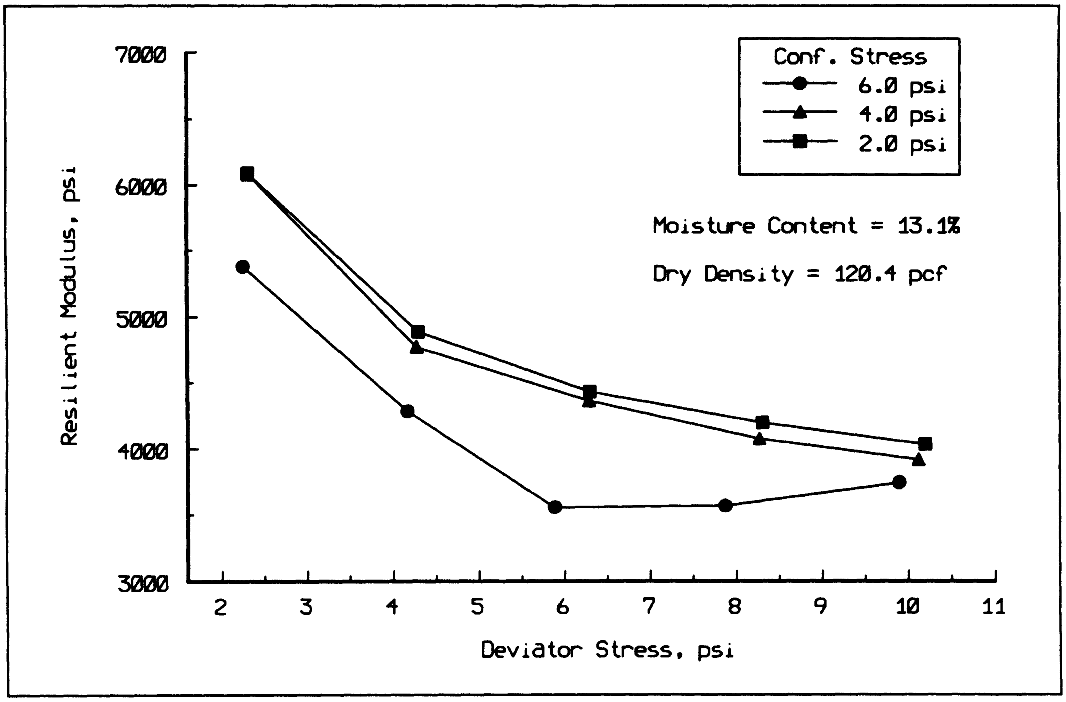

Figure A.53 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GN2 at Moisture Content 0.2% Above Optimum

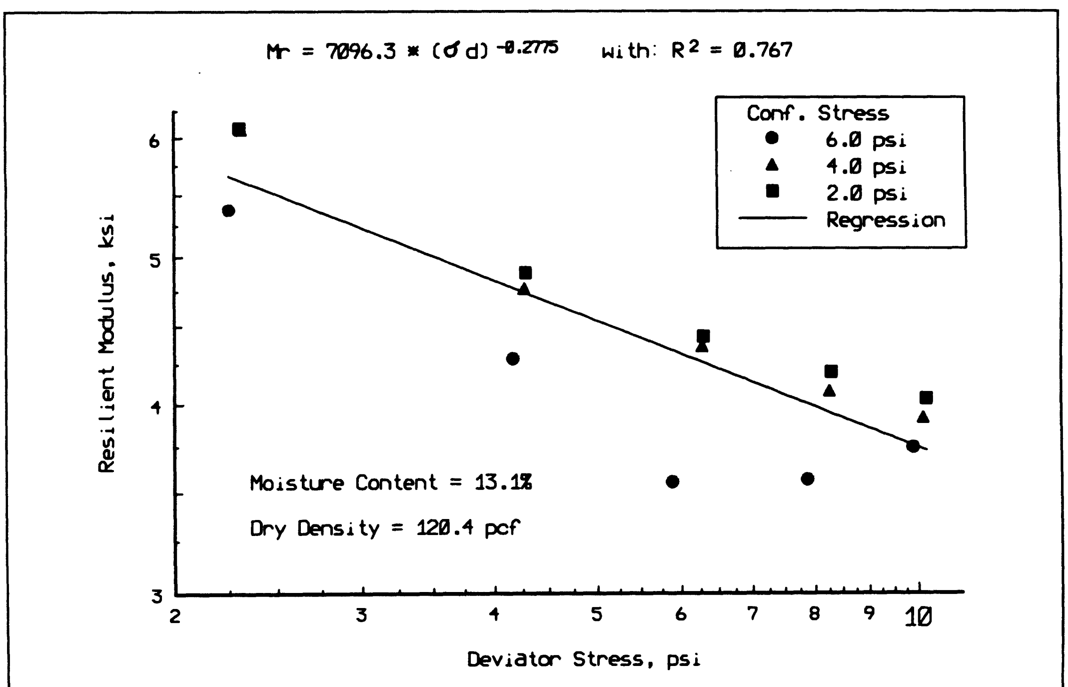

Figure A.54 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GN2 at Moisture Content 0.2% Above Optimum

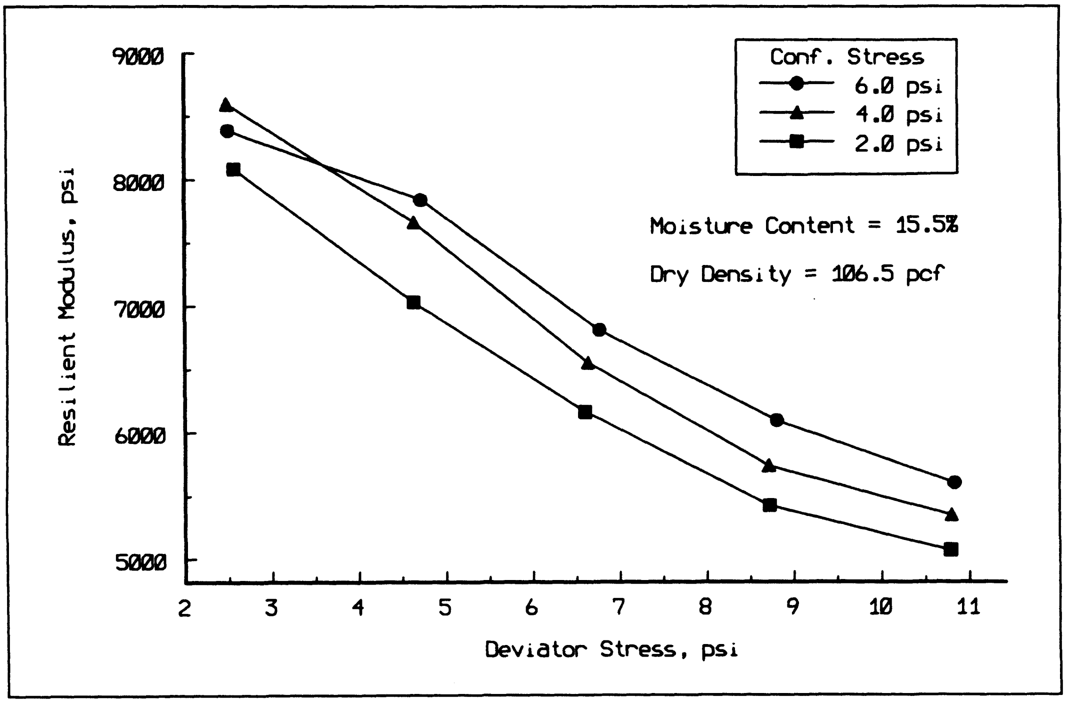

Figure A.55 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GS5 at Moisture Content 1.9% Below Optimum

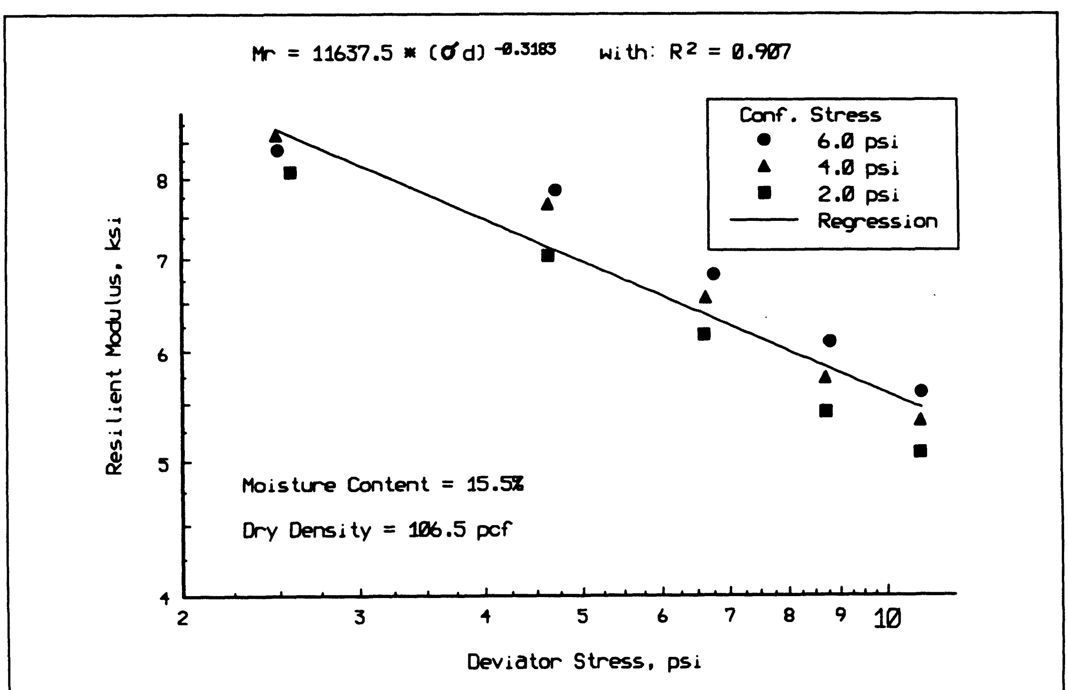

Figure A.56 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GS5 at Moisture Content 1.9% Below Optimum

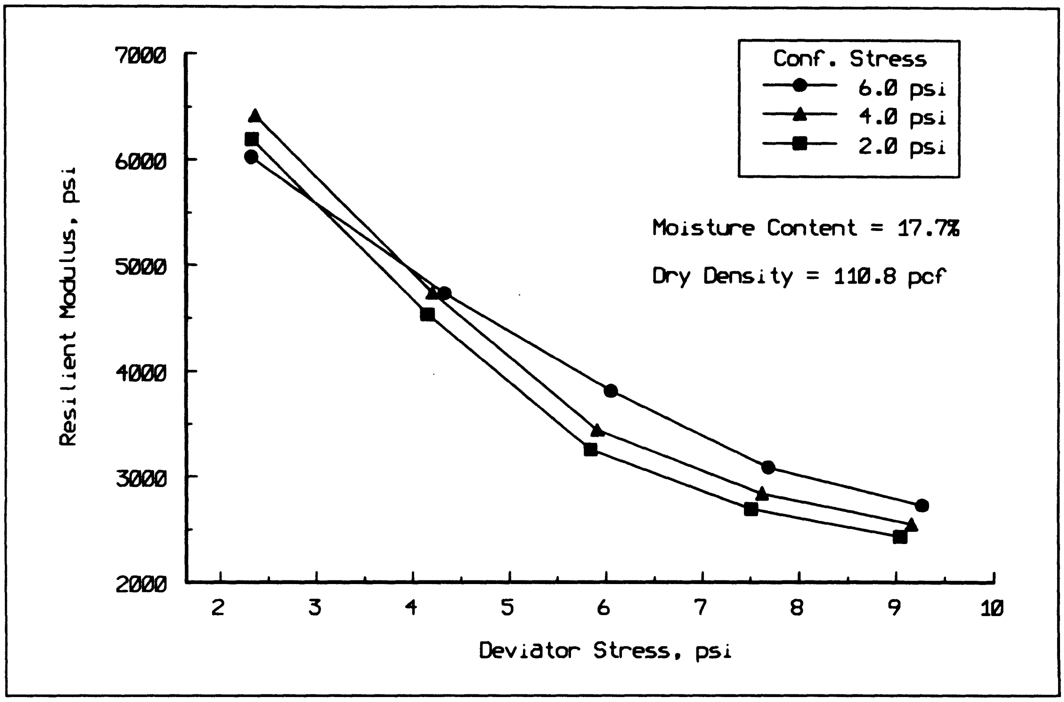

Figure A.57 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GS5 at Moisture Content 0.3% Above Optimum

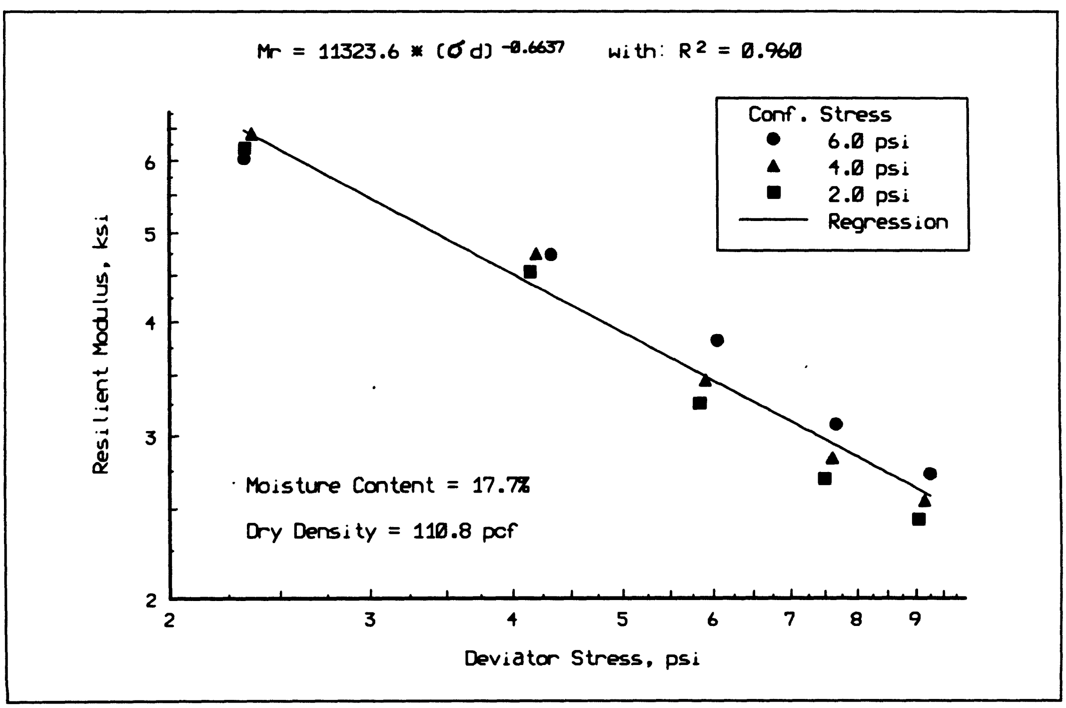

Figure A.58 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GS5 at Moisture Content 0.3% Above Optimum

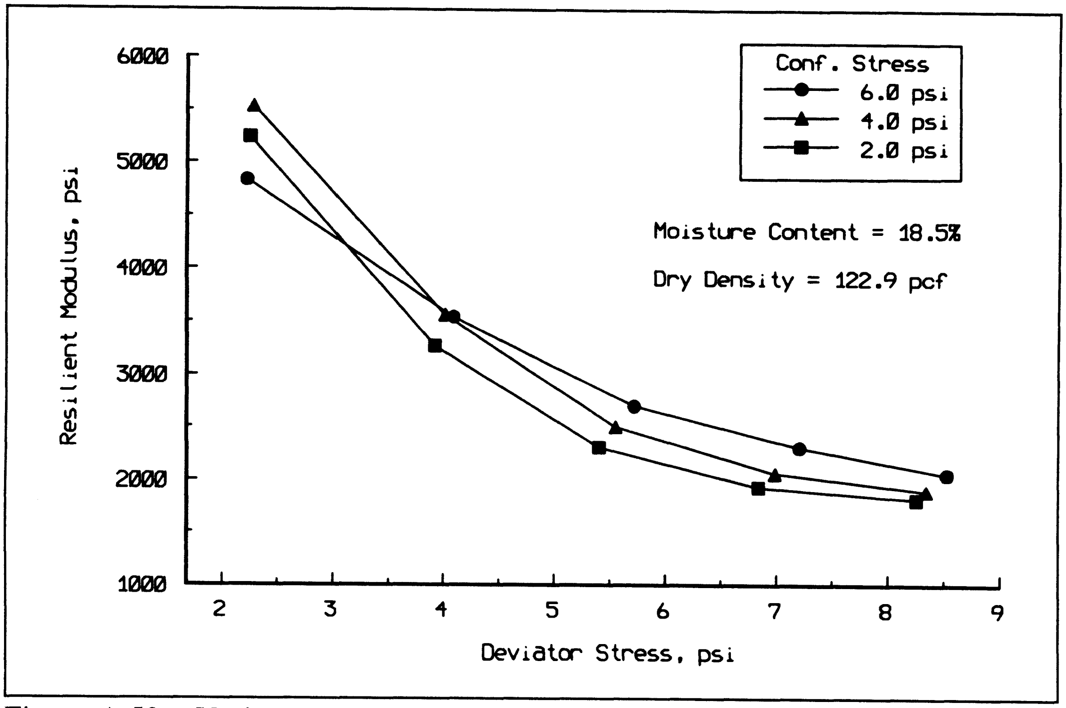

Figure A.59 Variation Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GS5 at Moisture Content 1.1% Above Optimum

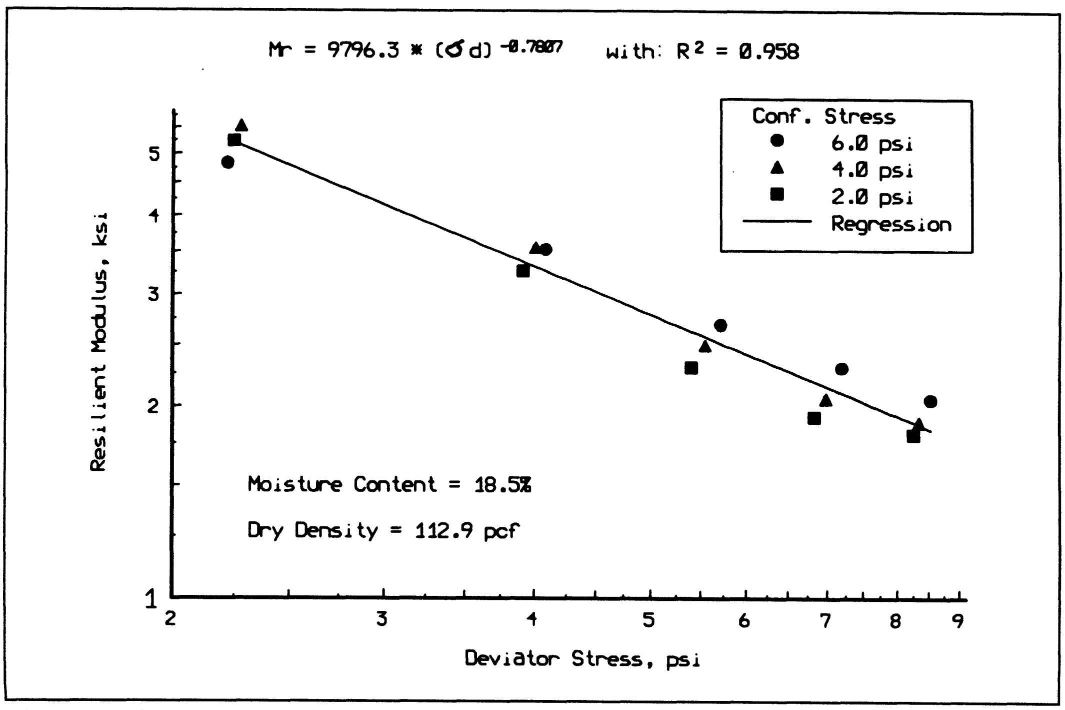

Figure A.60 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GS5 at Moisture Content 1.1% Above Optimum

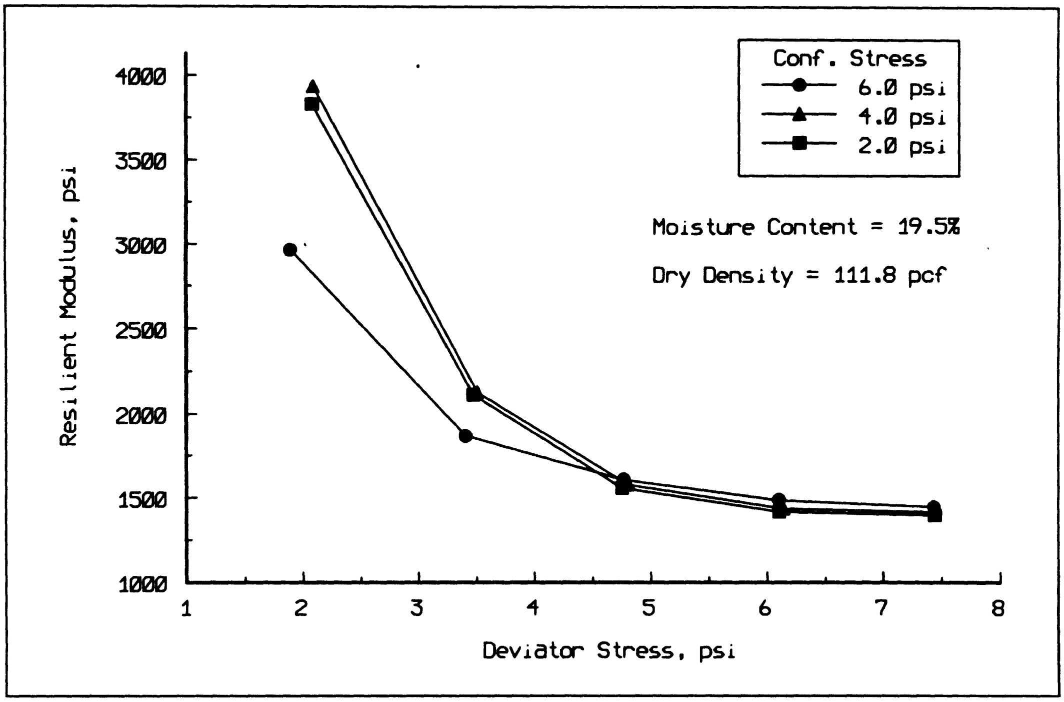

Figure A.61 Variation Plot of Resilient Modulus versus Deviator Stress for Soil Sample GS5 at Moisture Content 2.1% Below Optimum

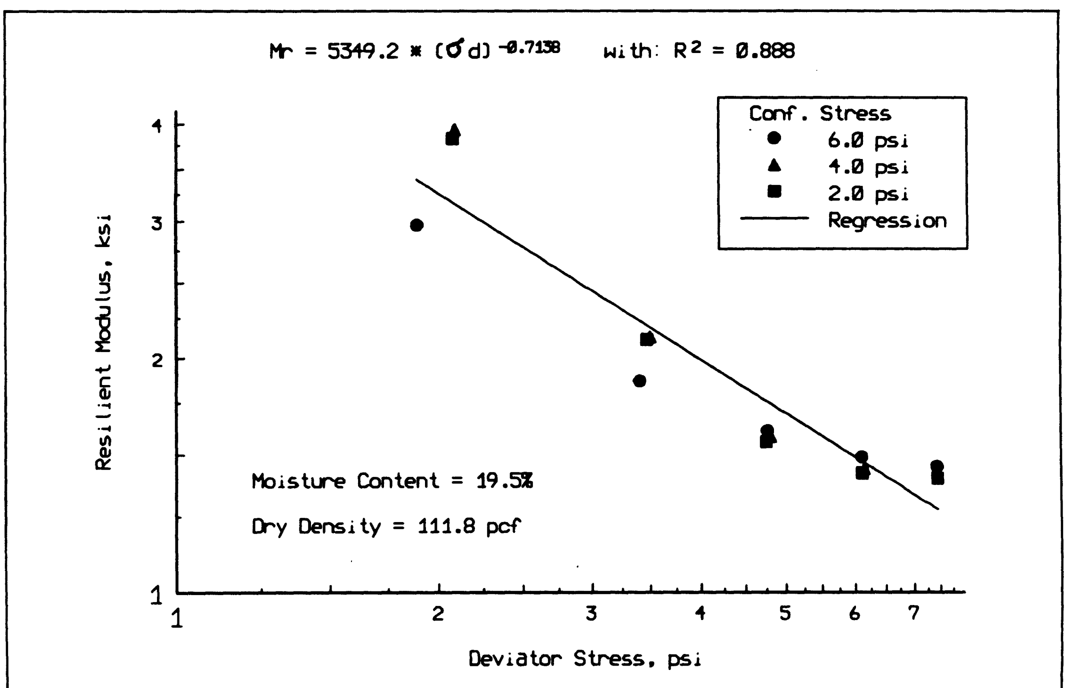

Figure A.62 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample GS5 at Moisture Content 2.1% Above Optimum

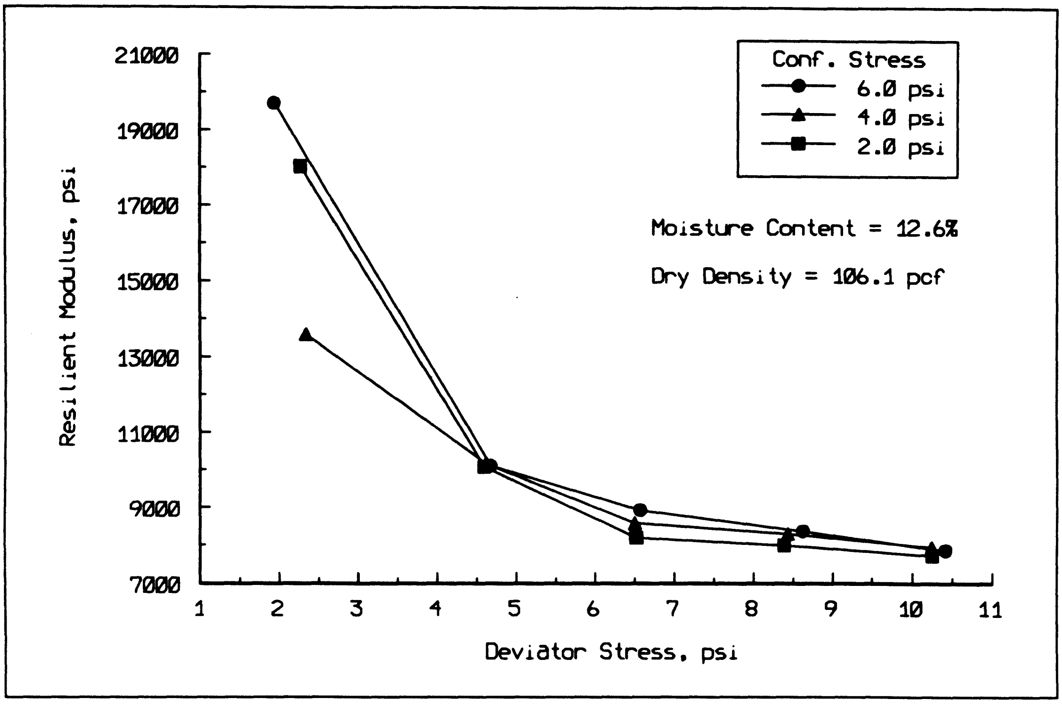

Figure A.63 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample BN3 at Moisture Content 2.6% Below Optimum

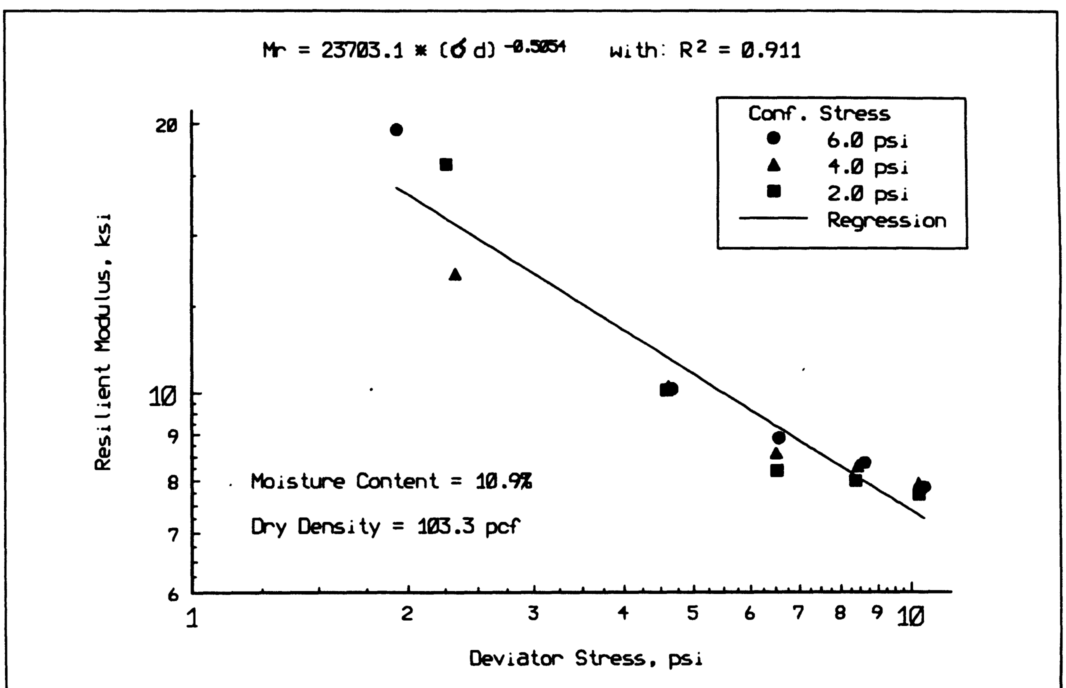

Figure A.64 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample BN3 at Moisture Content 2.6% Below Optimum

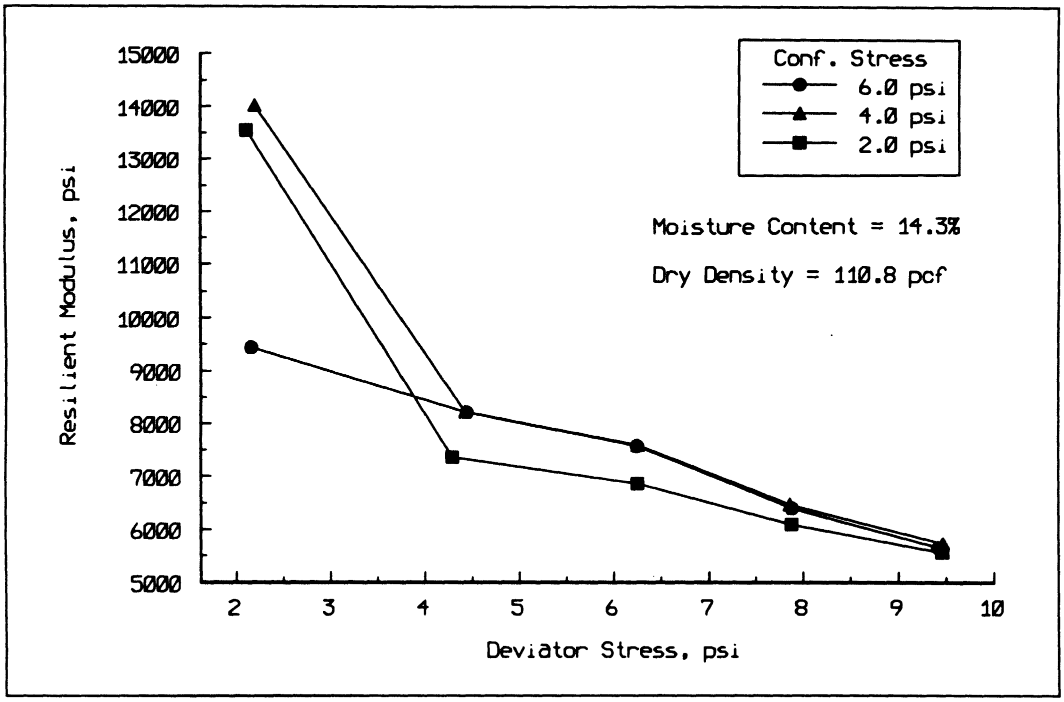

Figure A.65 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample BN3 at Moisture Content 0.9% Below Optimum

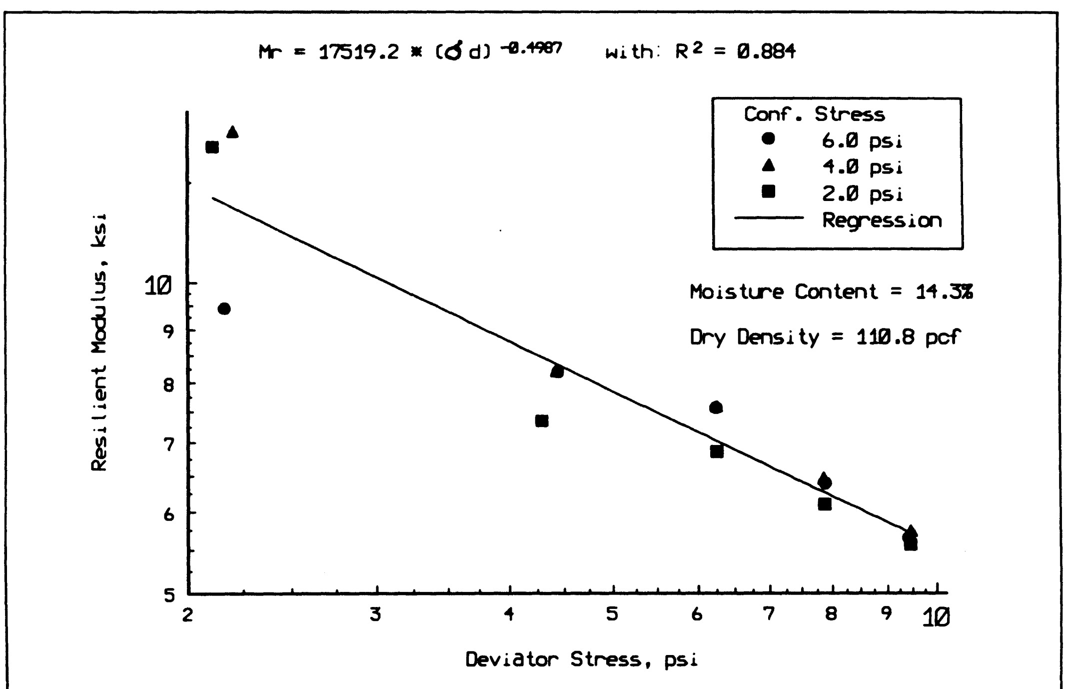

Figure A.66 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample BN3 at Moisture Content 0.9% Below Optimum

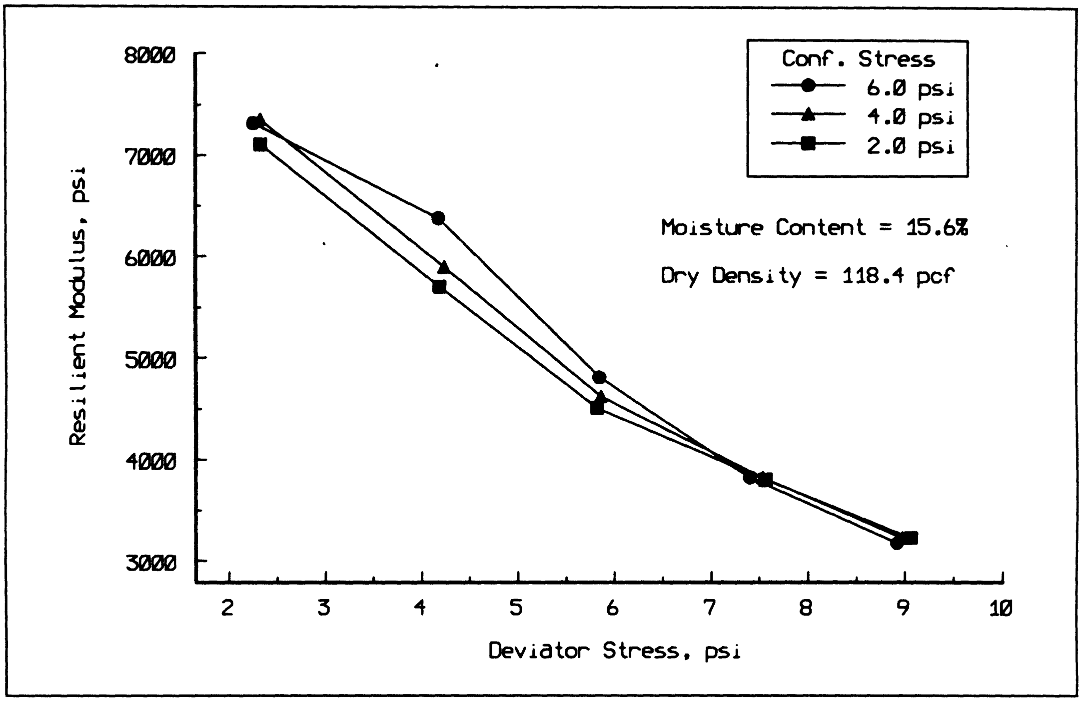

Figure A.67 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample BN3 at Moisture Content 0.4% Above Optimum

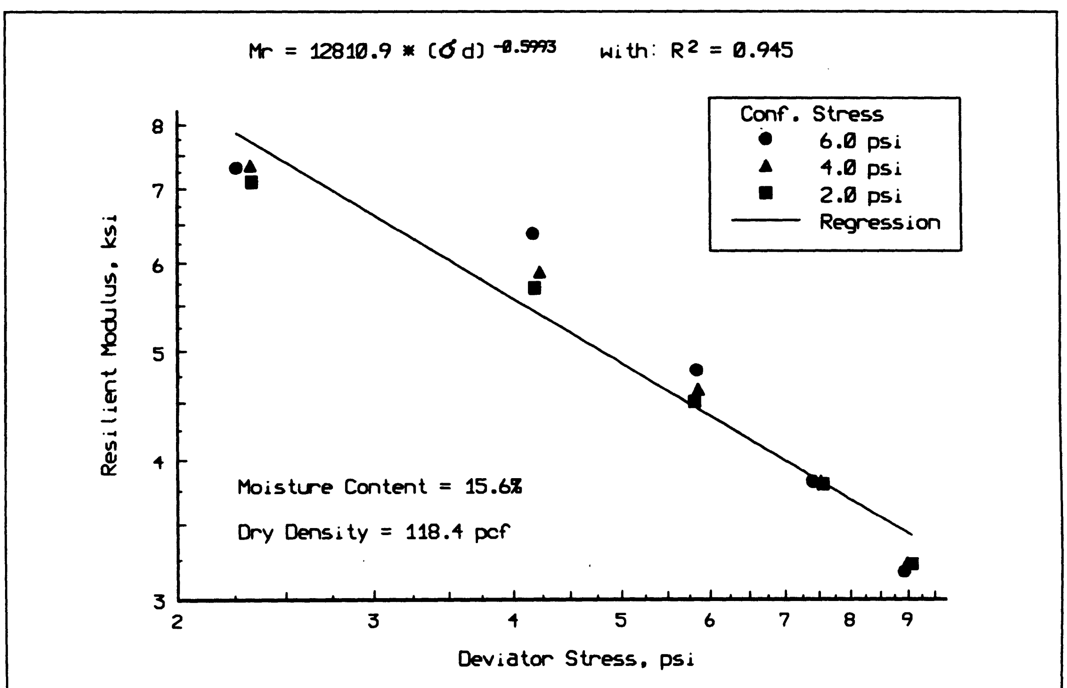

Figure A.68 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample BN3 at Moisture Content 0.4% Above Optimum

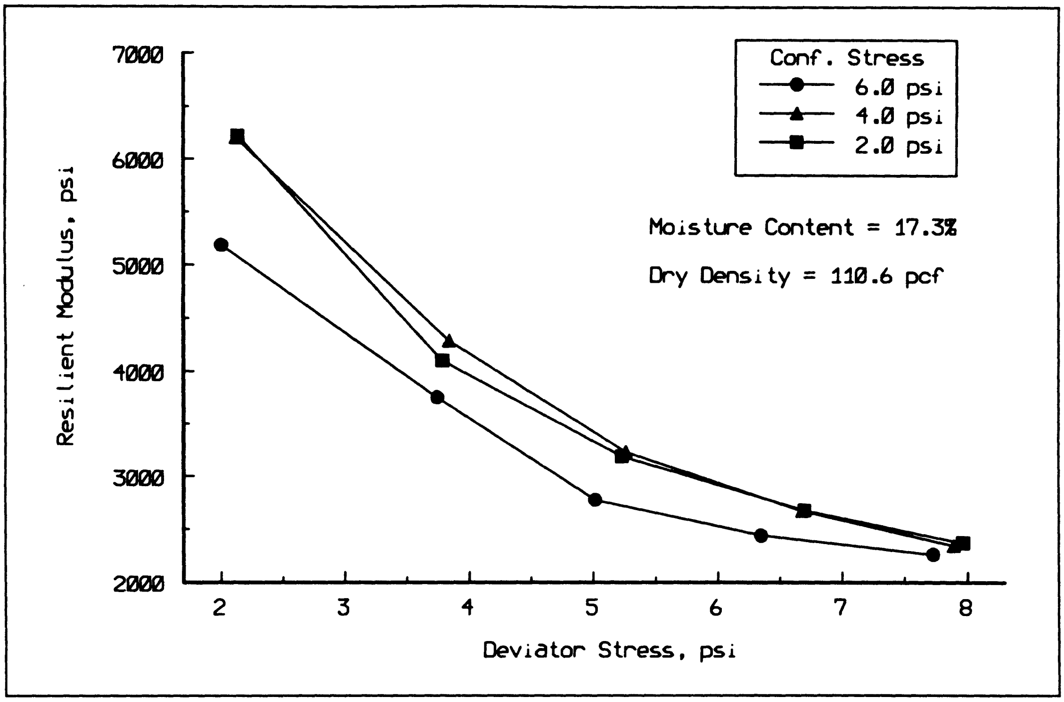

Figure A.69 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample BN3 at Moisture Content 2.1% Above Optimum

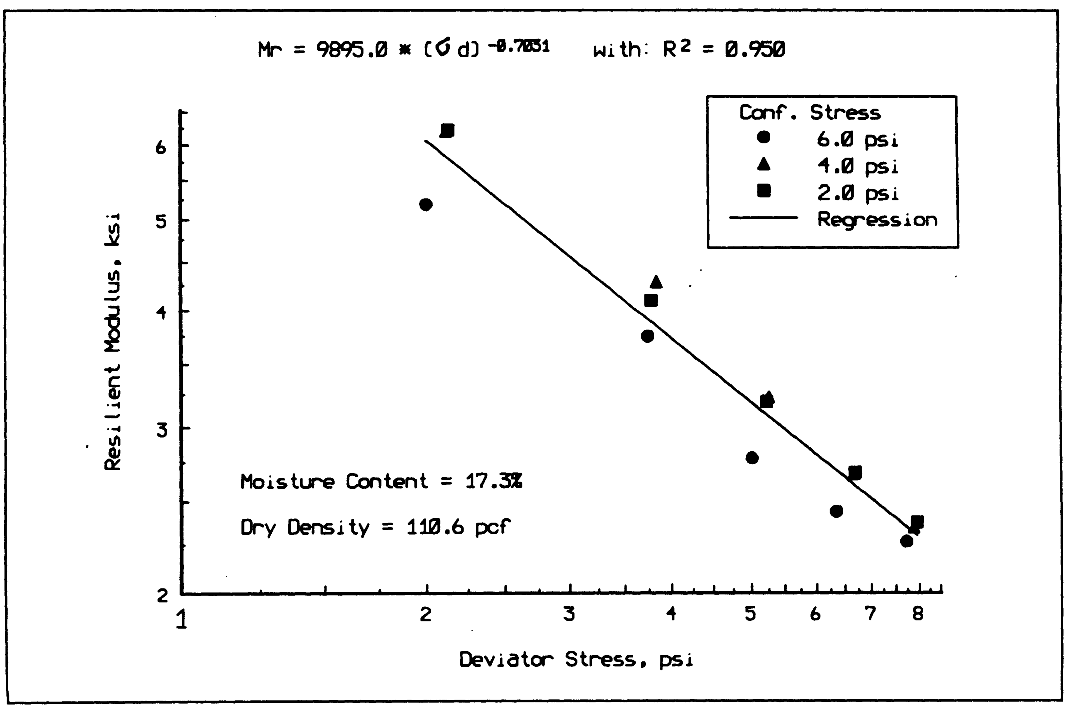

Figure A.70 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample BN3 at Moisture Content 2.1% Above Optimum

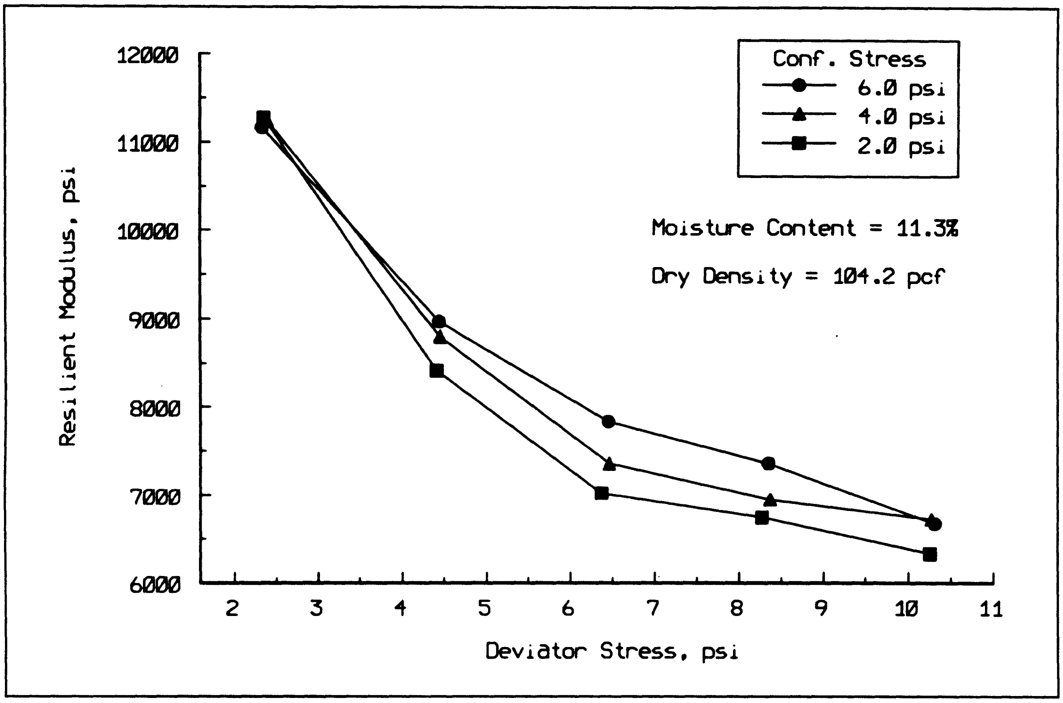

Figure A.71 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample BS2 at Moisture Content 1.9% Below Optimum

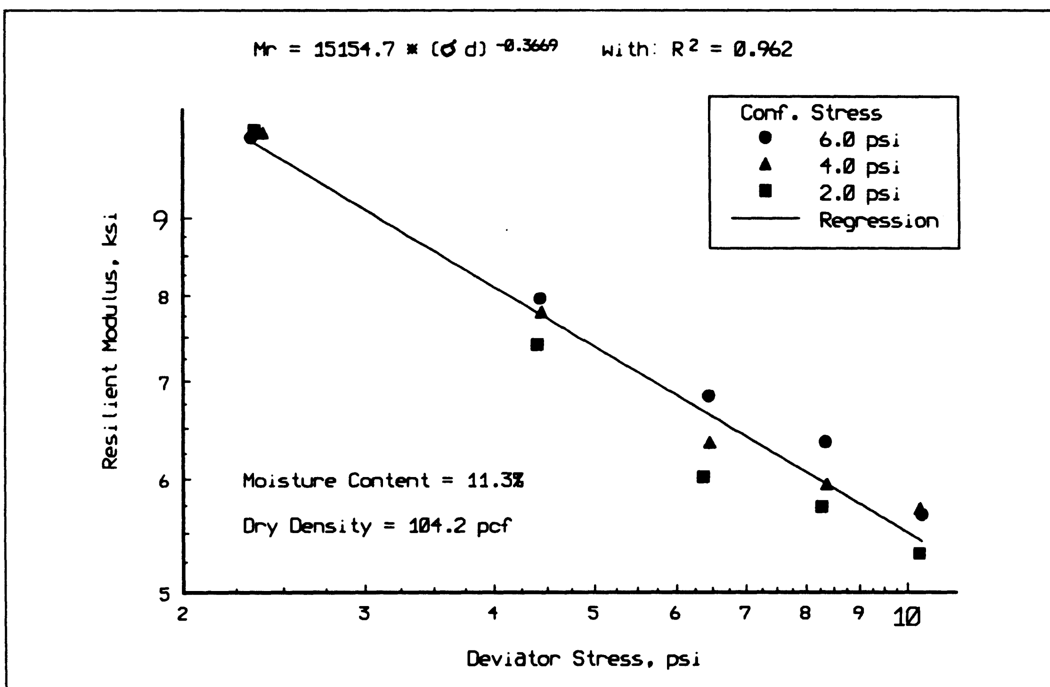

Figure A.72 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample BS2 at Moisture Content 1.9% Below Optimum

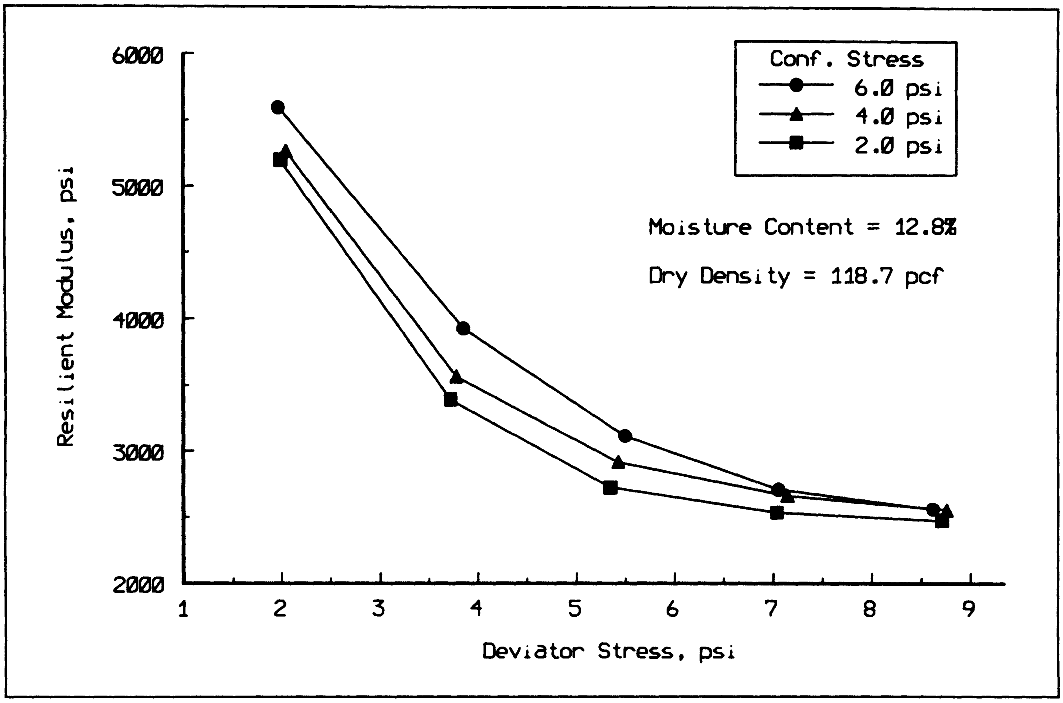

Figure A.73 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample BS2 at Moisture Content 0.4% Below Optimum

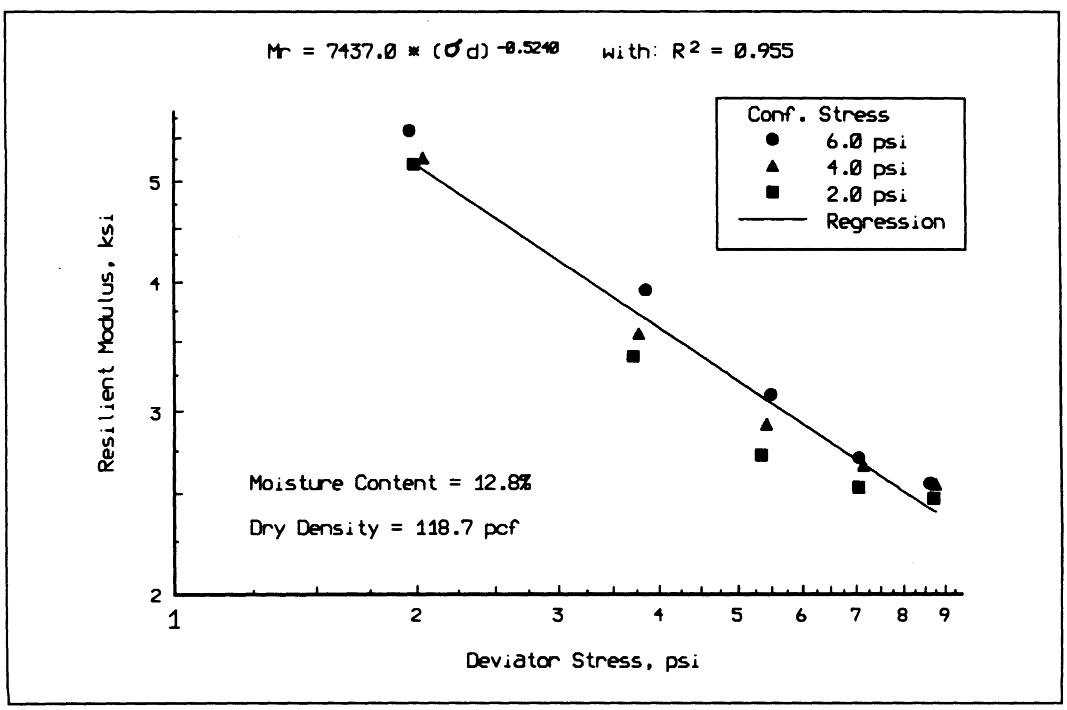

Figure A.74 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample BS2 at Moisture Content 0.4% Below Optimum

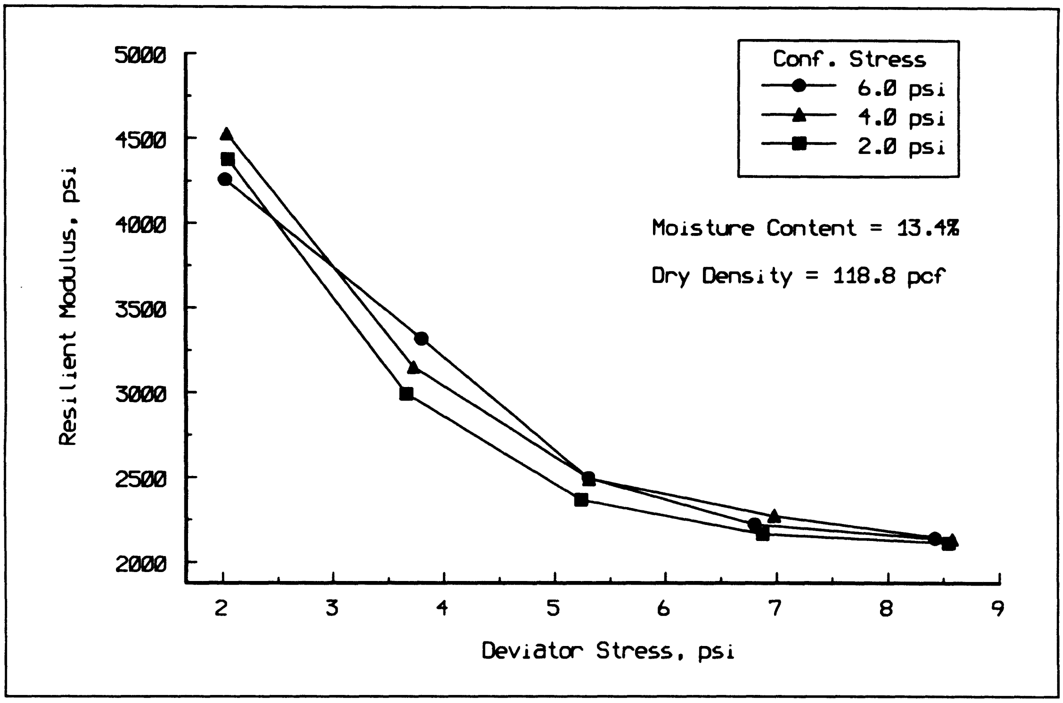

Figure A.75 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample BS2 at Moisture Content 0.2% Above Optimum

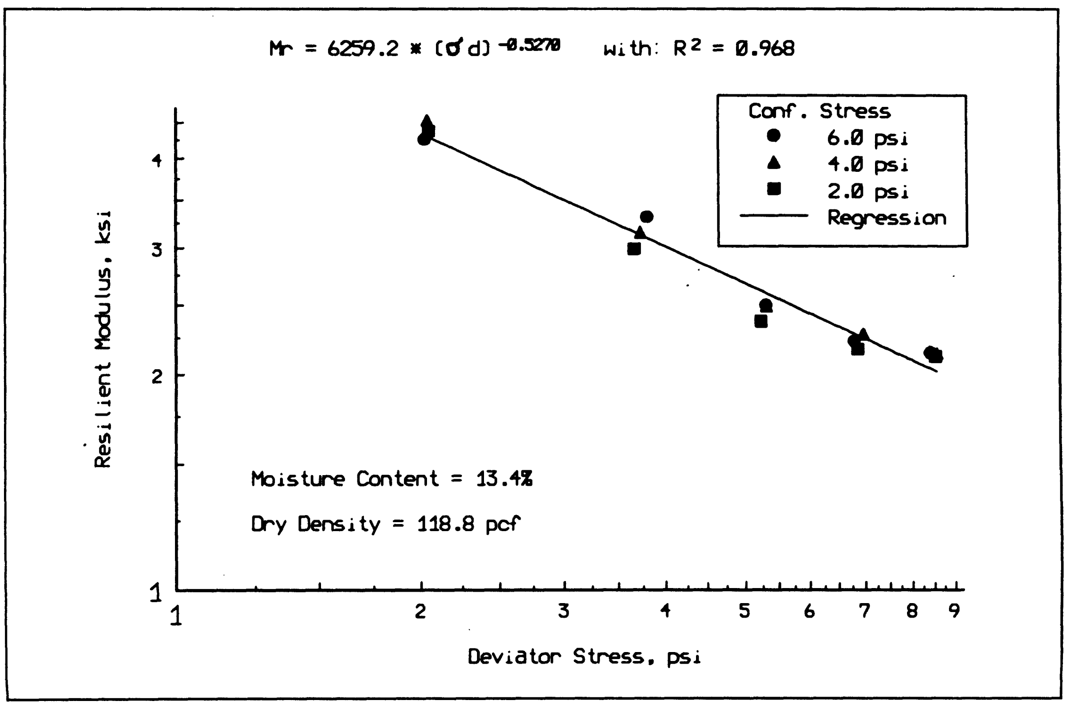

Figure A.76 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample BS2 at Moisture Content 0.2% Above Optimum

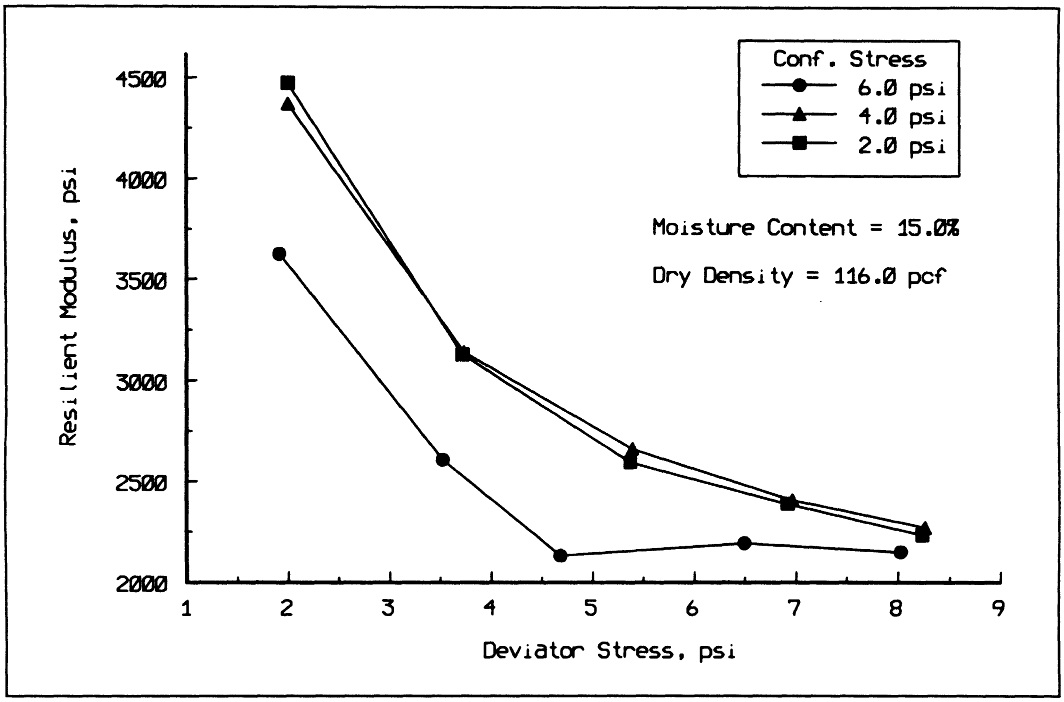

Figure A.77 Variation of Resilient Modulus Versus Deviator Stress for Soil Sample BS2 at Moisture Content 1.8% Above Optimum

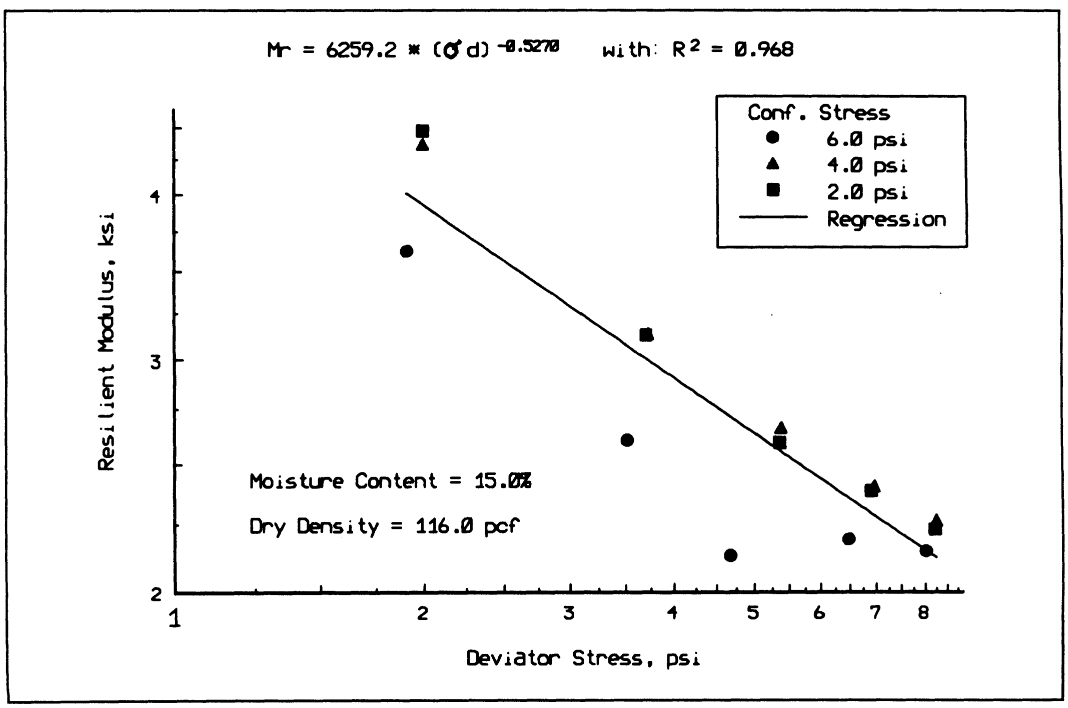

Figure A.78 Logarithmic Plot of Resilient Modulus Versus Deviator Stress for Soil Sample BS2 at Moisture Content 1.8% Above Optimum

APPENDIX B

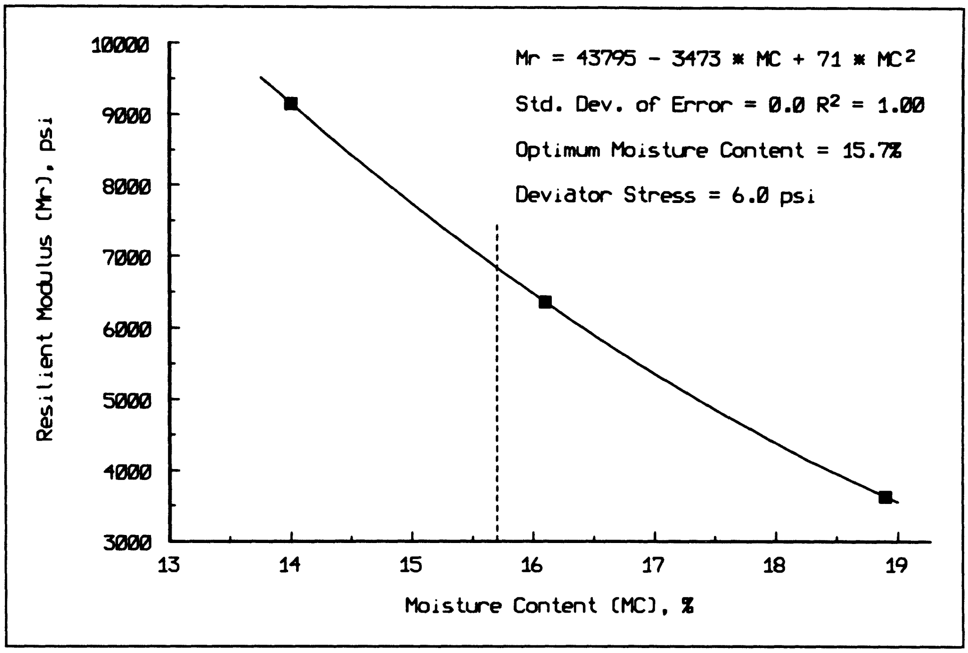

Figure B.1 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample NB4

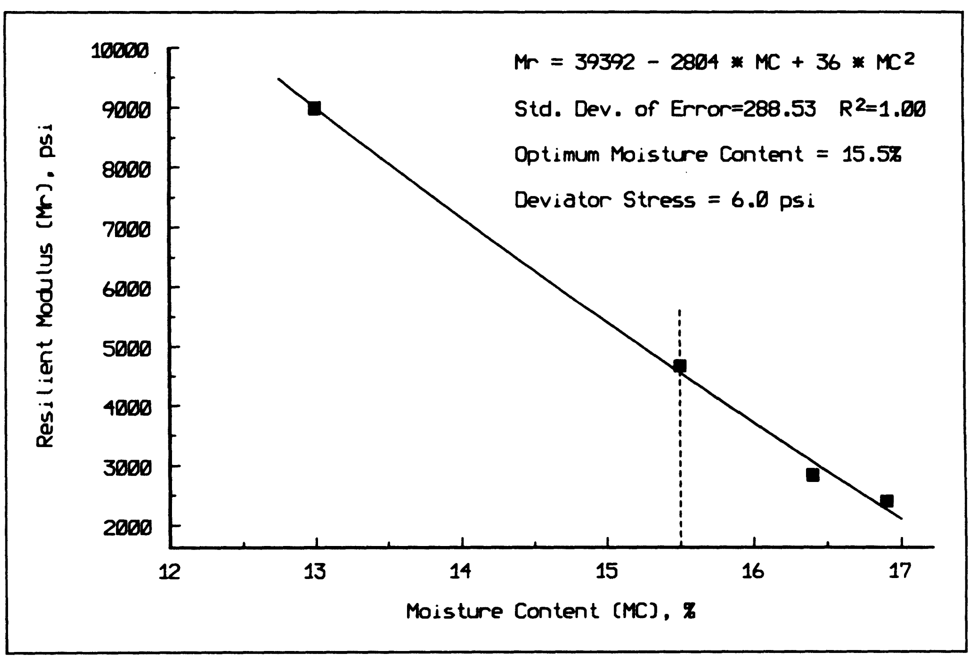

Figure B.2 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample NB6

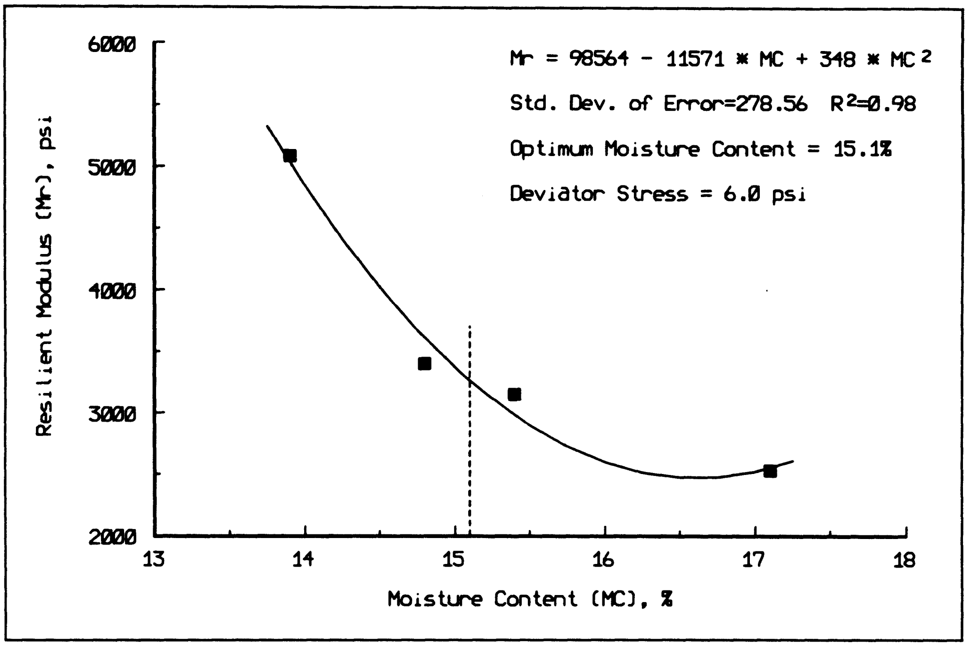

Figure B.3 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample SB3

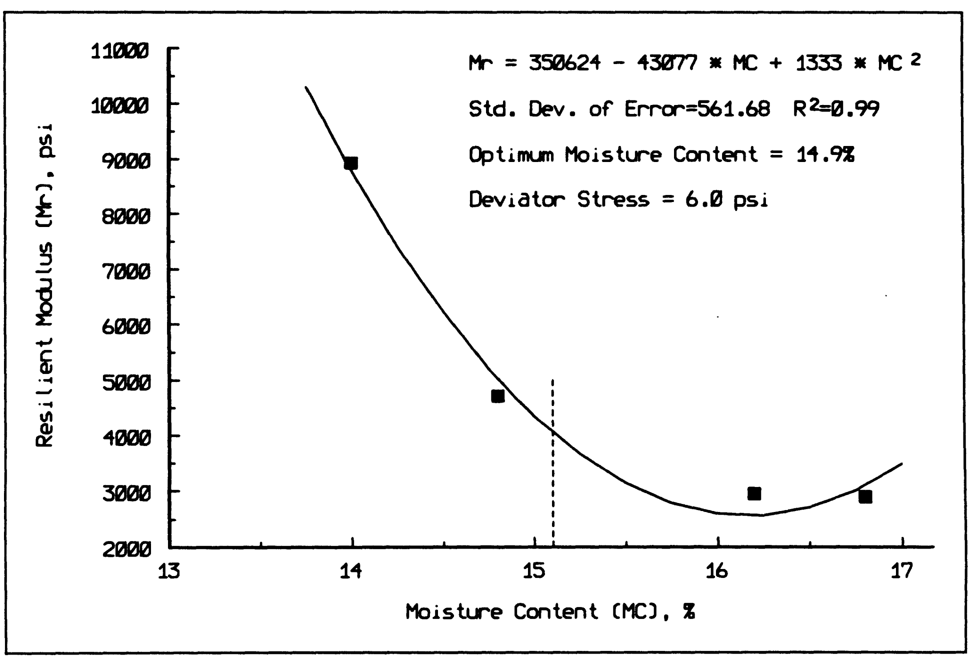

Figure B.4 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample SB4

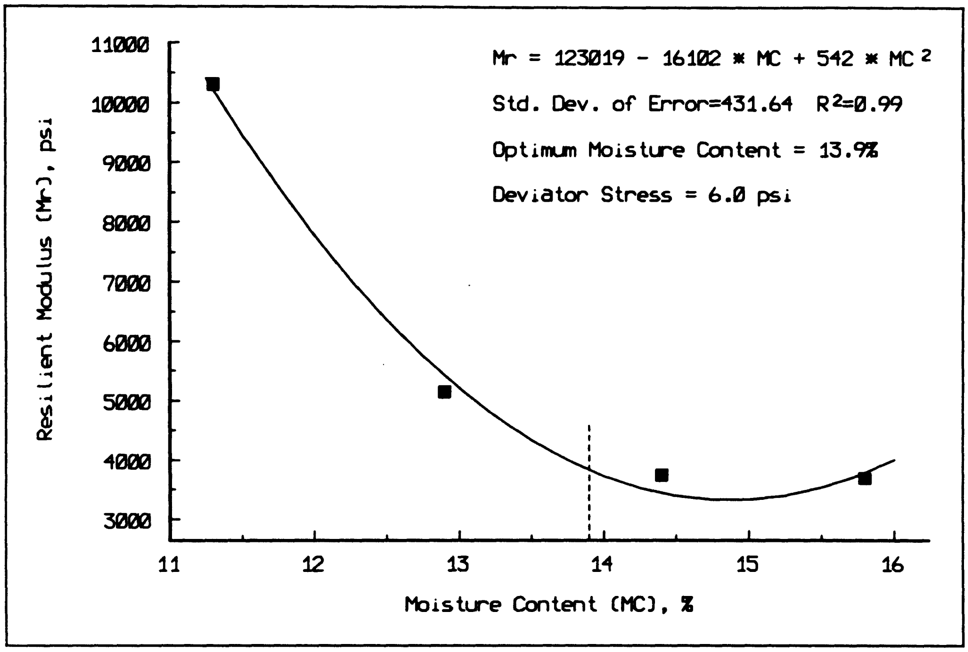

Figure B.5 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample MN2

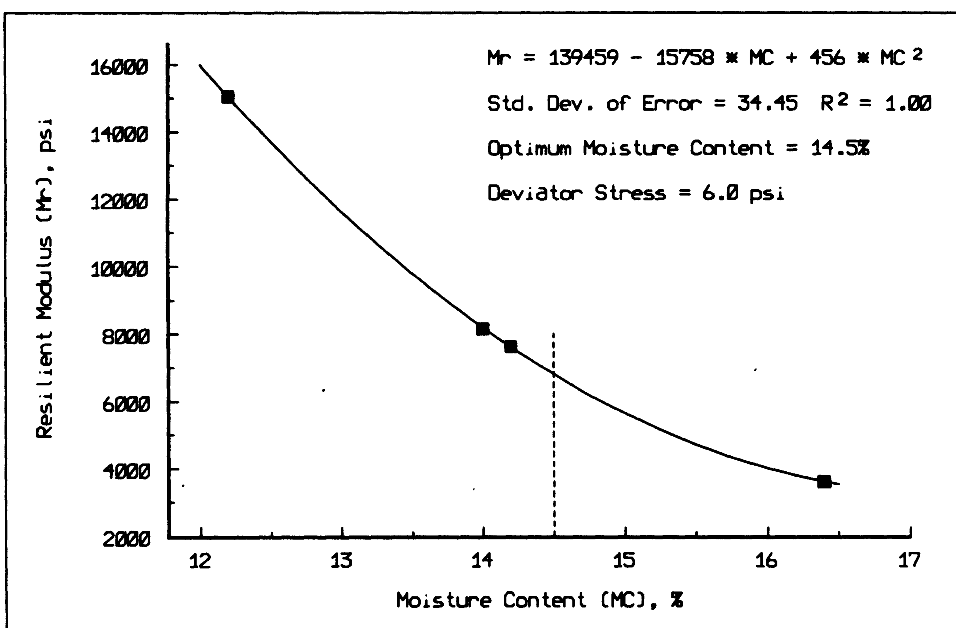

Figure B.6 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample MN4

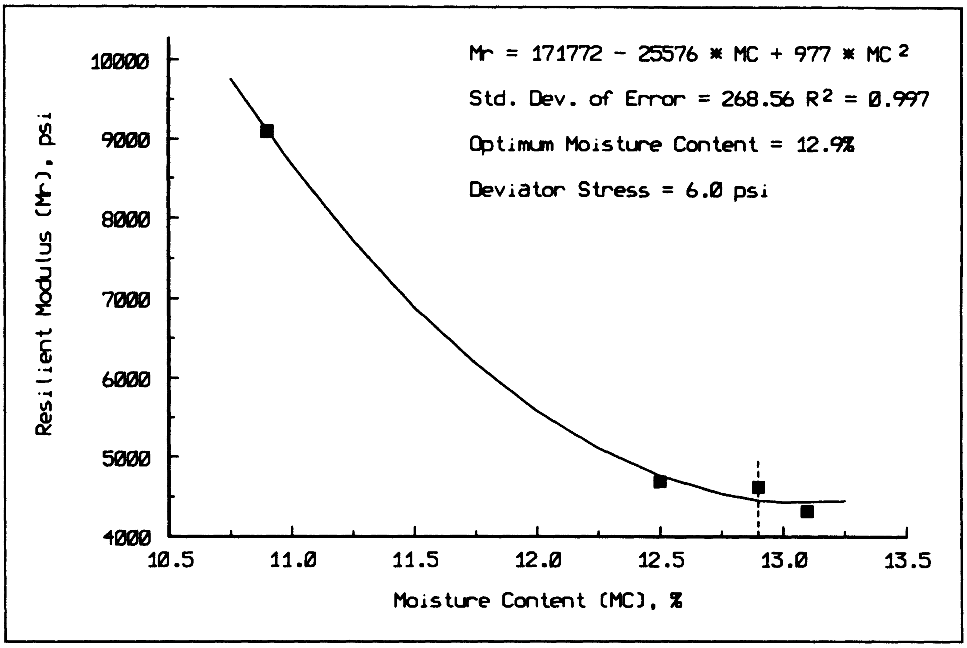

Figure B.7 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample GN2

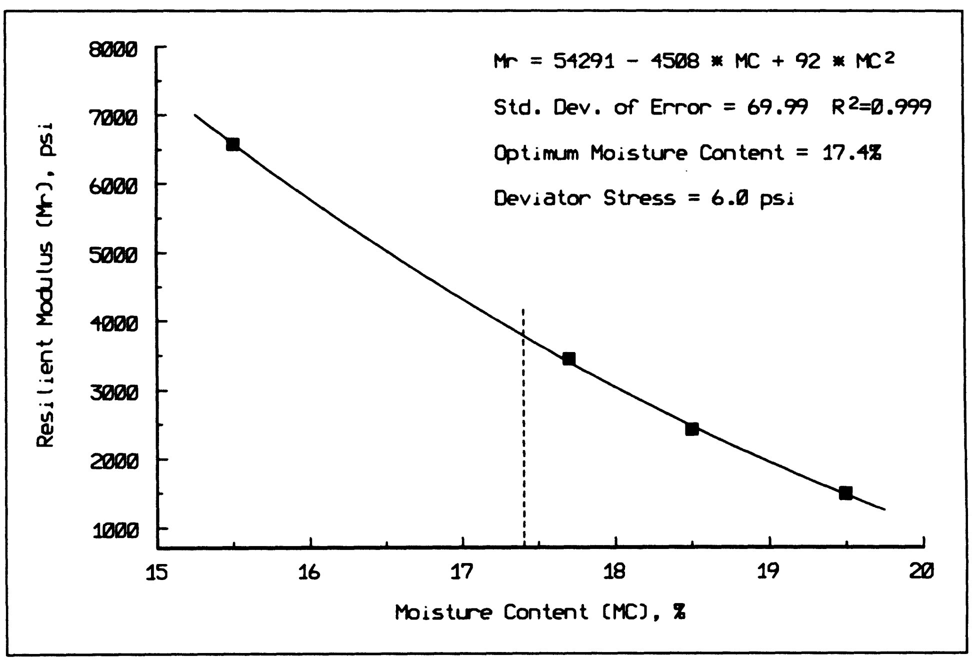

Figure B.8 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample GS5

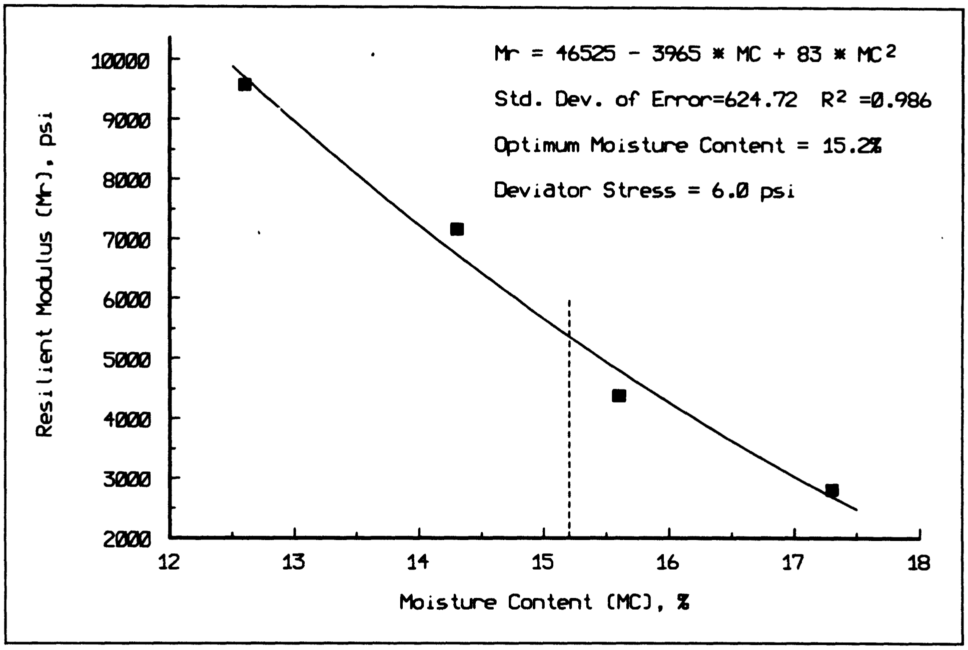

Figure B.9 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample BN3

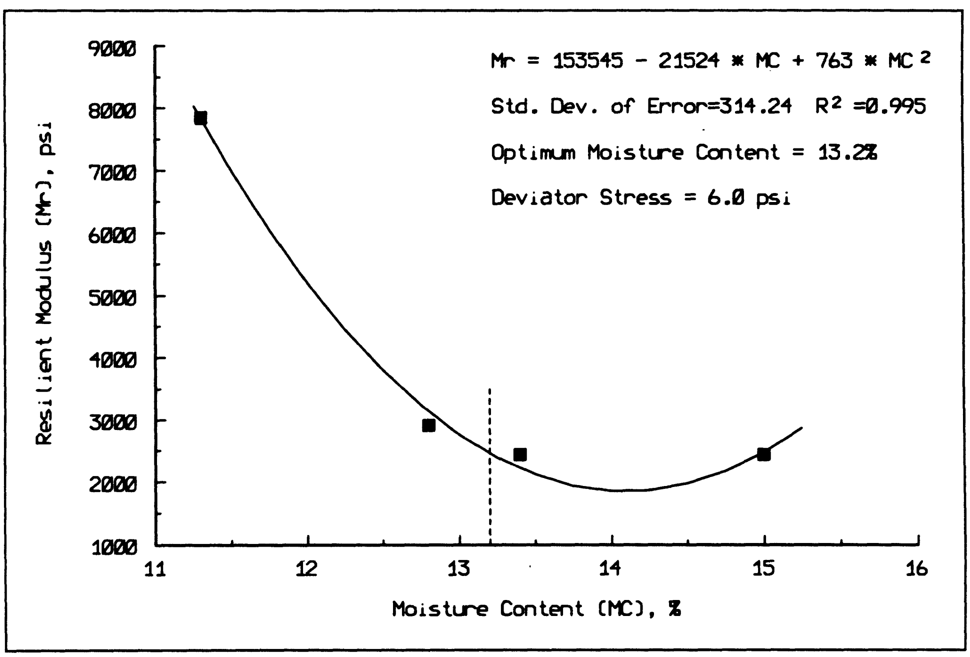

Figure B.10 Regression Plot of Resilient Modulus Versus Moisture Content for Soil Sample BS2

Table B.1 Simple Regression Statistical Analysis Output for Mr Vs. LL

Regression Analysis - Linear Model: Y = A + B X

Dependent variable: Mr			Independent Variable: OPTI.PI	
Parameter	Estimate	Standard Err.	T Value	Prob. Level
Intercept	-2.022	1.87092	-1.08075	0.31131
Slope	0.209172	0.058403	3.58153	0.00717

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	10.995268	1	10.995268	12.82732	0.00717
Error	6.8574052	8	0.8571757		
Total (Corr.)	17.8526732	9			

Correlation Coefficient = 0.784786 R - Squared = 61.59%

Standard. Error of Estimate = 0.925838

Table B.2 Simple Regression Statistical Analysis Output for Mr Vs. PI

Regression Analysis - Linear Model: Y = A + B X

Dependent variable: Mr			Independent Variable: OPTI.PI	
Parameter	Estimate	Standard Err.	T Value	Prob. Level
Intercept	0.435838	1.01388	0.429773	0.6787
Slope	0.00178	0.0706702	4.24758	0.00281

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	12.368392	1	12.368392	18.04195	0.00281
Error	5.4842813	8	0.6855352		
Total (Corr.)	17.8526733	9			

Correlation Coefficient = 0.832348 R - Squared = 69.28%

Standard. Error of Estimate = 0.827971

Table B.3 Simple Regression Statistical Analysis Output for Mr Vs. Silt C.

Regression Analysis - Linear Model: Y = A + B X

Dependent variable: Mr		Independent Variable: Opti.Silt		
Parameter	Estimate	Standard Err.	T Value	Prob. Level
Intercept	17.545	3.88125	4.52046	0.00195
Slope	-0.308452	0.0921689	-3.3466	0.01013

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	10.413956	1	10.413956	11.19973	0.01013
Error	7.4387178	8	0.9298397		
Total (Corr.)	17.8526738	9			

Correlation Coefficient = -0.763759 R - Squared = 58.33%

Standard. Error of Estimate = 0.964282

Table B.4 Simple Regression Statistical Analysis Output for Mr Vs. Clay C

Regression Analysis - Linear Model: Y = A + B X

Dependent variable: Mr		Independent Variable: Opti.Clay		
Parameter	Estimate	Standard Err.	T Value	Prob. Level
Intercept	3.2731	1.36117	2.40462	0.04287
Slope	0.0445488	0.0433244	1.02826	0.33391

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	2.0840648	1	2.0840648	1.057323	0.33391
Error	15.768609	8	1.971076		
Total (Corr.)	17.8526738	9			

Correlation Coefficient = 0.341668 R - Squared = 11.67%

Standard. Error of Estimate = 1.40395

Table B.5 Simple Regression Statistical Analysis Output for Mr Vs. GI

Regression Analysis - Linear Model: Y = A + B X

Dependent variable: Mr			Independent Variable: OPTI.GI	
Parameter	Estimate	Standard Err.	T Value	Prob. Level
Intercept	1.90349	0.680566	2.79692	0.02331
Slope	0.324423	0.0757588	4.28232	0.00268

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	12.430087	1	12.430087	18.33824	0.00268
Error	5.4225868	8	0.6778234		
Total (Corr.)	17.8526738	9			

Correlation Coefficient = 0.834421 R - Squared = 69.63%

Standard. Error of Estimate = 0.8233

Table B.6 Simple Regression Statistical Analysis Output for Mr Vs. Gs

Regression Analysis - Linear Model: Y = A + B X

Dependent variable: Mr			Independent Variable: OPTI.Gs	
Parameter	Estimate	Standard Err.	T Value	Prob. Level
Intercept	-89.0096	30.0436	-2.96268	0.01807
Slope	34.4646	11.0611	3.11584	0.01432

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	9.7875223	1	9.7875223	9.708458	0.01432
Error	8.0651513	8	1.0081439		
Total (Corr.)	17.8526736	9			

Correlation Coefficient = 0.740431 R - Squared = 54.82%

Standard. Error of Estimate = 1.00406

Table B.7 Simple Regression Statistical Analysis Output for Mr Vs. Unsoak

Regression Analysis - Linear Model: Y = A + B X

Dependent variable: Mr			Independent Variable: Opti.Uusoak	
Parameter	Estimate	Standard Err.	T Value	Prob. Level
Intercept	3.20394	1.0601	3.02231	0.0165
Slope	0.236818	0.165453	1.43133	0.19022

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	3.639767	1	3.639767	2.048711	0.19022
Error	14.212907	8	1.776613		
Total (Corr.)	17.852674	9			

Correlation Coefficient = 0.451528 R - Squared = 20.39%

Standard. Error of Estimate = 1.3329

Table B.8 Simple Regression Statistical Analysis Output for Mr Vs. Soak

Regression Analysis - Linear Model: Y = A + B X

Dependent variable: Mr			Independent Variable: Opti.Soak	
Parameter	Estimate	Standard Err.	T Value	Prob. Level
Intercept	3.6362	0.982158	3.70226	0.00602
Slope	0.230824	0.211056	1.09366	0.30594

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	2.3220165	1	2.3220165	1.196094	0.30594
Error	15.530657	8	1.941332		
Total (Corr.)	17.8526735	9			

Correlation Coefficient = 0.360646 R - Squared = 13.01%

Standard. Error of Estimate = 1.39332

Table B.9 Stepwise Regression Analysis Output for Equation 6

Stepwise Selection for OPTI.Mr

Selection: Backward	Maximum Steps: 500	F-to-Enter: 4.00
Control: Manual	Step: 1	F-to-Remove: 4.00

R-Squared = 0.96228 Adjusted (for d.f.) = 0.94342 D. F. = 6

Variables in Model	Coeff.	F-Remove	ariables out Mod	P. Corr.	F-Enter
1. OPTI.LL	0.24777	56.7257	2. OPTI.PI	0.4148	1.0388
3. OPTI.SILT	-0.20908	35.8111			
4. OPTI. CLAY	-0.06207	16.4815			

Model fitting results for: OPTI.Mr

Independent Variable	Coefficien	Std. Error	T-Value	Sig. Level
CONSTANT	7.377607	1.915756	3.851	0.0084
OPTI.LL	0.247767	0.032897	7.5316	0.0003
OPTI.SILT	-0.20908	0.034939	-5.9842	0.0010
OPTI.CLAY	-0.06207	0.015289	-4.0597	0.0067

R-SQ. (ADJ.) = 0.94342	SE= 0.335007	MAE = 0.214096
Previously = 0.0000	0.0000	0.0000

10 Observations fitted, forecast(s) computed for 0 missing value of dependent variable

Analysis of Variance for the Full Regression

Source	um of Square	DF	Mean Square	F-Ratio	P-Value
Model	17.1793	3	5.72643	51.0244	0.0001
Error	0.673376	6	0.112229		
Total (corr.)	17.852676	9			

R - Squared = 0.962281 Standard. Error of Estimate. = 0.335007

R-squared(Adj.)= 0.94342 Durbin - Watson Statistic = 30.8124

Table B.10 Stepwise Regression Analysis Output for Equation 7

Stepwise Selection for OPTI.Mr

Selection: Backward	Maximum Steps: 500	F-to-Enter: 4.00
Control: Manual	Step: 0	F-to-Remove: 4.00

R-Squared = 0.98975 Adjusted (for d.f.) = 0.97693 D. F. = 4

Variables in Model	Coeff.	F-Remove ariables out Mod	P. Corr.	F-Enter
1. OPTI.LL	0.58714	12.1324		
2. OPTI.PI	-0.80118	9.6742		
3. OPTI.SILT	-0.18399	54.8425		
4. OPTI. CLAY	-0.12922	26.1877		
5. OPTI.GI	0.51288	8.1834		

Model fitting results for: OPTI.Mr

Independent Variable	Coefficien	Std. Error	T-Value	Sig. Level
CONSTANT	4.428062	2.251909	1.9664	0.1207
OPTI.LL	0.587141	0.168566	3.4832	0.0253
OPTI.PI	-0.80118	0.257586	-3.1103	0.0359
OPTI.SILT	-0.18399	0.024845	-7.4056	0.0018
OPTI.CLAY	-0.12922	0.025251	-5.1174	0.0069
OPTI.GI	0.51288	0.179287	2.8607	0.0459

R-SQ. (ADJ.) =	0.97693	SE= 0.213921	MAE = 0.113406
Previously =	0.0000	0.0000	0.0000

10 Observations fitted, forecast(s) computed for 0 missing value of dependent variable

Analysis of Variance for the Full Regression

Source	um of Square	DF	Mean Square	F-Ratio	P-Value
Model	17.6696	5	3.53392	77.2236	0.0005
Error	0.183049	4	0.0457622		
Total (corr.)	17.852649	9			

R - Squared = 0.989747 Standard. Error of Estimate. = 0.213921

R-squared(Adj.)= 0.97693 Durbin - Watson Statistic = 2.7698

Table B.11 Stepwise Regression Analysis Output for Equation 8

Stepwise Selection for OPTI.Mr

Selection: Backward	Maximum Steps: 500	F-to-Enter: 4.00
Control: Manual	Step: 2	F-to-Remove: 4.00

R-Squared = 0.99169 Adjusted (for d.f.) = 0.98505 D. F. = 5

Variables in Model	Coeff.	F-Remove	ariables out Mod	P. Corr.	F-Enter
1. OPTI.LL	0.12712	14.5838	2. OPTI.PI	0.5512	1.7460
3. OPTI.SILT	-0.16604	64.5246	5. OPTI.GI	0.3876	0.7073
4. OPTI. CLAY	-0.10103	69.1929			
6. OPTI.Gs	35.7157	17.704			

Model fitting results for: OPTI.Mr

Independent Variable	Coefficien	Std. Error	T-Value	Sig. Level
CONSTANT	-86.4589	22.323304	-3.873	0.0117
OPTI.LL	0.127124	0.033288	3.8189	0.0124
OPTI.SILT	-0.16604	0.02067	-8.0327	0.0005
OPTI.CLAY	-0.10103	0.012146	-8.3182	0.0004
OPTI.Gs	35.7157	8.488343	4.2076	0.0084

R-SQ. (ADJ.) = 0.98505	SE= 0.172217	MAE =	0.085939
Previously = 0.9769	0.2139		0.1134

10 Observations fitted, forecast(s) computed for 0 missing value of dependent variable

Analysis of Variance for the Full Regression

Source	um of Square	DF	Mean Square	F-Ratio	P-Value
Model	17.7044	4	4.42609	149.233	0.0000
Error	0.148294	5	0.0296589		
Total (corr.)	17.852694	9			

R - Squared = 0.991693	Standard. Error of Estimate. = 0.172217
R-squared(Adj.)= 0.98505	Durbin - Watson Statistic = 0.22994

Table B.12 Stepwise Regression Analysis Output for Equation 9

Stepwise Selection for OPTI.Mr

Selection: Backward	Maximum Steps: 500	F-to-Enter: 4.00
Control: Manual	Step: 2	F-to-Remove: 4.00

R-Squared = 0.99931 Adjusted (for d.f.) = 0.99792 D. F. = 3

Variables in Model	Coeff.	F-Remove	ariables out Mod	P. Corr.	F-Enter
1. OPTI.LL	0.28137	27.1469	5. OPTI.GI	0.48	0.5988
2. OPTI.PI	-0.21475	13.714	. OPTI.UNSOA	0.6578	1.5253
3. OPTI.SILT	-0.19277	448.8378			
4. OPTI. CLAY	-0.13104	306.2601			
6. OPTI.Gs	37.0577	126.4559			
8. OPTI.SOAK	0.09904	22.0033			

Model fitting results for: OPTI.Mr

Independent Variable	Coefficien	Std. Error	T-Value	Sig. Level
CONSTANT	-90.4062	8.520219	-10.6108	0.0018
OPTI.LL	0.281373	0.054004	5.2103	0.0137
OPTI.PI	-0.21475	0.05799	-3.7032	0.0342
OPTI.SILT	-0.19277	0.009099	-21.1858	0.0002
OPTI.CLAY	-0.13104	0.007488	-17.5003	0.0004
OPTI.Gs	37.05767	3.295404	11.2453	0.0015
OPTI.SOAK	0.099041	0.021114	4.6908	0.0183

R-SQ. (ADJ.) = 0.99792	SE= 0.064256	MAE =	0.030467
Previously = 0.9907	0.1360		0.0931

10 Observations fitted, forecast(s) computed for 0 missing value of dependent variable

Analysis of Variance for the Full Regression

Source	um of Square	DF	Mean Square	F-Ratio	P-Value
Model	17.8403	6	2.97338	720.156	0.0001
Error	0.0123846	3	0.0041288		
Total (corr.)	17.8526846	9			

R - Squared = 0.999306	Standard. Error of Estimate. = 0.064256
R-squared(Adj.)= 0.99792	Durbin - Watson Statistic = 1.60296

Table B.13 Stepwise Regression Analysis Output for Equation 10

Stepwise Selection for OPTI.Mr

Selection: Backward	Maximum Steps: 500	F-to-Enter: 4.00
Control: Manual	Step: 3	F-to-Remove: 4.00

R-Squared = 0.99482 Adjusted (for d.f.) = 0.99068 D. F. = 5

Variables in Model	Coeff.	F-Remove	ariables out Mod	P. Corr.	F-Enter
3. OPTI.SILT	-0.19091	101.1059	1. OPTI.LL	0.6119	2.3947
4. OPTI. CLAY	-0.13602	218.6617	2.OPTI.PI	0.38	0.6749
6. OPTI.Gs	58.0872	264.4157	5. OPTI.GI	0.1617	0.1073
7. OPTI.UNSOAK	0.14279	26.4096			

Model fitting results for: OPTI.Mr

Independent Variable	Coefficien	Std. Error	T-Value	Sig. Level
CONSTANT	-143.213	9.847588	-14.543	0.0000
OPTI.SILT	-0.16092	0.016003	-10.0551	0.0002
OPTI.CLAY	-0.13602	0.009199	-14.7872	0.0000
OPTI.Gs	58.0872	3.572208	16.2609	0.0000
OPTI.UNSOAK	0.14279	0.027785	5.139	0.0036

R-SQ. (ADJ.) = 0.9907	SE= 0.135986	MAE =	0.093053
Previously = 0.9850	172217.0000		0.0859

10 Observations fitted, forecast(s) computed for 0 missing value of dependent variable

Analysis of Variance for the Full Regression

Source	um of Square	DF	Mean Square	F-Ratio	P-Value
Model	17.7602	4	4.44005	240.105	0.0000
Error	0.0924608	5	0.0184922		
Total (corr.)	17.8526608	9			

R - Squared = 0.994821 Standard. Error of Estimate. = 0.135986

R-squared(Adj.)= 0.99068 Durbin - Watson Statistic = 2.42303

Table B.14 Stepwise Regression Analysis Output for Equation 11

Stepwise Selection for OPTI.Mr

Selection: Backward	Maximum Steps: 500	F-to-Enter: 6.00
Control: Manual	Step: 1	F-to-Remove: 6.00

R-Squared = 0.96747 Adjusted (for d.f.) = 0.9512 D. F. = 6

Variables in Model	Coeff.	F-Remove	ariables out Mod	P. Corr.	F-Enter
1. OPTI.SILT	-0.14341	16.068	3. OPTI.GI	0.6925	4.6071
2. OPTI. CLAY	-0.1206	36.7462			
4. OPTI.Gs	63.6368	66.7197			

Model fitting results for: OPTI.Mr

Independent Variable	Coefficien	Std. Error	T-Value	Sig. Level
CONSTANT	-158.639	21.458985	-7.3927	0.0003
OPTI.SILT	-0.14341	0.035776	-4.0085	0.0071
OPTI.CLAY	-0.1206	0.019895	-6.0619	0.0009
OPTI.Gs	63.63684	7.7909789	8.1682	0.0002

R-SQ. (ADJ.) = 0.9512 SE= 0.311136 MAE = 1.846

Previously = 0.9695 0.2459 1.9395

10 Observations fitted, forecast(s) computed for 0 missing value of dependent variable

Analysis of Variance for the Full Regression

Source	um of Square	DF	Mean Square	F-Ratio	P-Value
Model	17.2718	3	5.75728	59.4727	0.0001
Error	0.580832	6	0.0968054		
Total (corr.)	17.852632	9			

R - Squared = 0.967465 Standard. Error of Estimate. = 0.311136

R-squared(Adj.)= 0.9512 Durbin - Watson Statistic = 1.84561