FINAL REPORT

For the Florida Department of Transportation

FIELD AND LABORATORY EVALUATION OF RESILIENT MODULUS MEASUREMENTS ON FLORIDA PAVEMENT SOILS

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by

W. V. Ping, P.E.
Yu Wang
Zenghai Yang

Department of Civil Engineering
FAMU-FSU COLLEGE OF ENGINEERING
Tallahassee, FL 32310

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16. Abstract

This study summarizes a field and laboratory study to evaluate the resilient modulus of Florida pavement soils. The objectives were to conduct field and laboratory experiment programs and to develop the correlation relationships from the test results. Based on all available experimental data, further analysis were performed: a) to develop reliable correlations between laboratory measured resilient modulus and in-situ layer modulus of pavement soils as measured by field plate bearing load test, b) to correlate field plate bearing values and laboratory resilient modulus measurements with LBR values and FWD test results, and c) to establish correlation between laboratory measured resilient modulus under optimum moisture condition and laboratory measured resilient modulus under in-situ moisture condition. All correlations are presented and recommendations are made based on the research and analysis from experimental results.

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METRIC CONVERSIONS

inches = 25.4 millimeters

feet = 0.305 meters

square inches = 645.1 millimeters squared

square feet = 0.093 meters squared

cubic feet = 0.028 meters cubed

pounds = 0.454 kilograms

poundforce = 4.45 newtons

poundforce per square inch = 6.89 kilopascals

pound per cubic inch = 16.02 kilograms per meters cubed

DISCLAIMER

"The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Department of Transportation or the U.S. Department of Transportation. This publication is prepared in cooperation with the State of Florida Department of Transportation and the U.S. Department of Transportation."

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The field experimental program was conducted by the Pavement Evaluation Section under the supervision of William G. Miley and Harold F. Godwin with the FDOT State Materials Office. The field logistics were provided by the District Materials and Maintenance Offices.

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EXECUTIVE SUMMARY

1. Introduction

The 1986 and 1993 AASHTO Guide for Design of Pavement Structures now uses the resilient modulus for roadbed soil strength determination and an AASHTO test procedure T-274 has been developed for laboratory testing. However, the resilient modulus of soils is non-linearly stress dependent and the test procedure provides for a range of confining and deviator stresses to be applied. As a result of criticism, a number of nationwide studies were undertaken to search for solutions and alternate test methods, such as the NCHRP 1-28 project. Several variations of the resilient modulus test procedure have also been proposed by researchers and agencies. The SHRP (Strategic Highway Research Program) Protocol P46 (AASHTO T294-92) and AASHTO T292-91I have been most commonly used in recent years. The early indications are that the AASHTO T294-92 (SHRP Protocol P46) is more convenient to perform when compared to the revised procedure AASHTO T292-91 I for the laboratory determination of resilient modulus. However, concerns continue about the sequence of loads, the measurement of the axial deformation, and the stress levels with regard to the T294-92 method.

The purpose of the laboratory determination of resilient modulus is to simulate field pavement layer behavior subject to dynamic traffic loadings. There are a number of field tests, which can be used such as plate bearing load, falling weight deflectometer (FWD), and Dynaflect. The plate bearing load test requires a relatively large set of test equipment and it has a higher cost. It is a destructive test. The FWD and Dynaflect are nondestructive tests that are easier to conduct in the field. The back-calculated results from the FWD and Dynaflect tests can provide in-situ layer moduli with a minimum amount of disturbance and a lower cost, although the values may not be always accurate.

2. Project Objectives

A major research project was undertaken to study the possible implementation of the 1986 AASHTO flexible pavement design procedure in Florida. The objectives of the project were as follows:

1. To develop reliable correlations between laboratory measured resilient modulus and in-situ layer modulus of pavement soils as measured by a field plate bearing load test on subgrade soils and untreated base/subbase materials.
2. To correlate field plate bearing values and laboratory resilient modulus measurements with LBR

values and FWD test results on subgrade soils and untreated base/subbase materials.

3. To evaluate testing methods for determining resilient modulus on subgrade soils and untreated base/subbase materials.
4. To investigate the effect of using a larger sample size (6-in diameter samples) on resilient modulus measurements.

The main thrust was to ultimately implement the 1986 & 1993 AASHTO design guide for pavement structures with the resilient modulus test for Florida conditions.

3. Project Plan

A field plate bearing load test was used during the initial phase of this major research project. A field experimental program was conducted to evaluate the bearing characteristics of in-place pavement layers. Twenty (20) field sites were tested throughout the state of Florida. At each site, a series of tests were conducted that included a plate bearing load test, an FWD test, and a Dynaflect test. Soil samples were transported to the laboratory in Tallahassee for further testing.

The second phase of the project, a laboratory experimental program, was undertaken to evaluate the resilient modulus of reconstituted and laboratory compacted pavement soils, and the LBR values. The resilient modulus

tests were conducted utilizing both the T 292-91I (T292) and T 294-92 (T294) procedures. The resilient modulus specimens were prepared under reconstituted in-situ and optimum laboratory compacted conditions. The LBR test followed the Florida test method: FM 5-515 in the Manual of Standard Test Methods (FDOT, 1986 & 1988). The effect of using a larger sample size (6-in diameter) was also investigated.

4. Interim Reports

Six interim reports were submitted for these large research projects. The following is a summary and brief description of those six interim reports:

1. Title: Field Plate Bearing Tests on Pavement Soils in Florida

   Report No. FL/DOT/RMC/0636 (1) - 4538

   This report presented a field experimental program on evaluating the bearing characteristics of existing pavement base, subgrade, and embankment soils using a field plate bearing load test. The field investigation was part of larger research project to study the existing pavement layer moduli, and to implement the laboratory resilient modulus test method in Florida.

   The plate bearing load tests were conducted on twenty flexible pavement sites across the state of Florida. At each selected site, field determination of the bearing characteristics was made on the base,

subgrade, and embankment layers. The plate load test results were summarized and presented in the report. An analysis was made to characterize the layer modulus of the pavement soils. The pavement layer moduli were verified through comparison with the results obtained from the elastic layered solution ELSYM5 program.

2. Title: Limerock Bearing Ratio on Laboratory Compacted Pavement Soils

   Report No. FL/DOT/RMC/0636 (2) - 4538

   This report presented a laboratory study that evaluated pavement bearing characteristics utilizing the Florida Limerock Bearing Ratio (LBR) test. The LBR is a modification of the California Bearing Ratio (CBR) test and has been widely used in Florida for the design of pavement structures. The LBR evaluation is part of a larger research project to study existing pavement conditions in Florida.

   The field experimental program was conducted on twenty selected pavement sites across the Florida. The LBR test was performed on pavement soils obtained from the field test sites. The LBR test results were analyzed and compared with the field test results. The AASHTO Road Test layer coefficient values (a_2) and Soil Support Values (SSV), which have become classic reference values over more than two decades, were evaluated by using the LBR and field test results.

Conclusions show that the LBR values could be used to estimate the SSV values for design of flexible pavements in Florida. The correlation relationships between the LBR and SSV values were evaluated to better characterize the pavement structures in Florida.

3. Title: Evaluation of Laboratory Resilient Modulus Measurements on Florida Pavement Soils

Report No. FL/DOT/RMC/0636 (3) - 4538

The resilient modulus of pavement soils was a required input parameter in pavement analysis and design. Most of the recent research concentrated on the laboratory resilient modulus test and its correlations with other engineering properties determined from laboratory tests. However, little effort has been focused on the calibration of the laboratory resilient modulus measurements using field performance data.

This study presented the results of an experimental program to conduct the laboratory resilient modulus measurements on the reconstituted soil samples simulating reliable correlations between laboratory measured resilient modulus and in-situ layer modulus of pavement soils as measured by field plate load tests on subgrade soils and untreated base/subbase materials in the Florida. The AASHTO T 292-91I test procedure was used for this study. Resilient modulus tests were performed in the laboratory. The test

results were presented and analyzed in this report. A simplified procedure was adopted for comparison of the laboratory equivalent resilient modulus values with the modulus of elasticity of the subgrade layer from the field plate bearing load test. The laboratory resilient modulus results were compared with the field plate layer moduli on subgrade and embankment layers.

4. Title: Effect of Laboratory Testing Procedure on Resilient Characteristics of Florida Subgrade Soils
   Report No. FL/DOT/RMC/0636 (4) - 4538

This study was conducted to measure the resilient modulus through a series of laboratory triaxial tests on the soils used for pavement subgrade and embankment in Florida. Two test procedures, AASHTO T 292-91I and T 294-92, were utilized to carry out the laboratory resilient modulus measurements. The primary objective was to compare the resilient response of subgrade soils resulting from the T 292-91I procedure with those of the T 294-92 procedure.

The experimental results indicated that both testing procedures provided repeatable results. For both cohesive and cohesionless soils, resilient modulus increased with the increasing confining pressure. The resilient modulus measured from the middle LVDTs was significantly different from that determined from the full length LVDTs because of the end effects and the

imperfect contacts between the platen and the specimen. The resilient modulus measured from the external LVDTs of the T294-92 procedure was found to be lower than that measured from the full length LVDTs of the T 292-91I procedure.

5. Title: Analysis of Granular Subgrade Modulus From Field and Laboratory Tests

   Report No. FL/DOT/RMC/0636 (5) - 4538

This study presented the results of field plate bearing load and laboratory resilient modulus tests on the reconstituted soil samples simulating the field moisture and density conditions. The objectives of this study were to evaluate the field load deformation characteristics of the sandy embankment (subgrade) soils and to further correlate the field test results with the laboratory resilient modulus measurements.

A simplified procedure was adopted for comparison of the laboratory equivalent resilient modulus values with the modulus of elasticity of the subgrade layer from the field plate bearing load test. Correlation relationships were established between the laboratory resilient modulus and field plate layer modulus on these pavement materials. The field modulus values were in close agreement with those of the computed equivalent resilient modulus from the laboratory test under the same loading pressure.

6. Title: Effect of Specimen Size on Resilient Characteristics of Pavement Soils

Report No. FL/DOT/RMC/0636 (6) - 4538

The measurement of resilient modulus has become more common recently because of its importance in determining properties of roadbed soils and pavement components. Several resilient modulus test procedures have been proposed by researchers and agencies. Among them AASHTO T 292-91I is one of the most commonly used test procedures. The most commonly used specimen size is 4.0-in. (101.6-mm) in diameter. The recommended specimen size was 4.0-in. diameter cylindrical specimen for use in the laboratory resilient modulus test. The primary objective of this study was to evaluate the effect of specimen size on both 6-in. and 4-in. diameter specimens with the T 292-91I procedure. The resilient moduli measured from the 6-in. and 4-in. diameter specimens were not significantly different for limerock and granular materials.

5. Final Report Organization

This final report summarizes both the field and laboratory experimental programs utilizing six different test methods that evaluate the engineering properties of the pavement base, subgrade, and embankment soils. This summary report is the final phase of a larger research project. The

final report consists of nine chapters. As in the first chapter, the background and objectives of this field and laboratory study serve as an introduction. Chapter 2 summarizes the field experimental program conducted during this study. A detailed description of the laboratory experimental program is the subject of Chapter 3. Chapter 4 presents test results of the field experimental program while Chapter 5 summarizes test results from the laboratory experimental program. Analyses of the field and laboratory test results are presented in Chapters 6 and 7. The development of correlations from the field and laboratory experimental results is presented in Chapter 8. Chapter 9 is devoted to the conclusions and recommendations of this research study.

6. Conclusions

The conclusions based on the research and analysis from field and laboratory experimental studies are summarized below.

Field Experimental Program

The field experimental program focused on investigating the bearing characteristics of in-place pavement layers. By analyzing the test results, the following conclusions have been made:

1. A hyperbolic model was used to represent the relationship of load-deformation curve

obtained from a field plate bearing load test. The average modulus of a load-deformation curve could be represented by the secant modulus at which the applied load would be equal to one-half of the ultimate load.

2. Results of the average plate layer (secant) modulus based on the hyperbolic model were considered to be representative of the layer modulus of pavement materials.

3. FWD backcalculated moduli are 1.5 times greater than plate layer moduli.

   The regression equation is:

$$M_{FWD} = 1.53 M_{PLT}$$

   The effective modulus range was: 50 ~ 650 MPa for plate layer modulus. This correlation should be used with caution, because both M_{FWD} and M_{PLT} depended on the type of soil.

4. Dynaflect deflection readings versus plate layer moduli did not show a strong correlation for all data. Within a certain type of material, no clear trend was established.

Laboratory Experimental Program

The laboratory experimental program was used to evaluate the laboratory test for resilient modulus measurement and to conduct the LBR test on pavement

materials. The following conclusions have been made based on the research results:

1. The resilient modulus measured from the middle LVDTs was significantly different from those of the full length LVDTs because of the end effects and system compliance. For the T 292-91I test procedure, the average ratios of the resilient modulus values between the 20.3-cm and 10.2-cm measurements ranged from about 0.75 at lower confining pressures to about 0.85 at higher confining pressures. The resilient modulus measured from the middle LVDTs was used for the purpose of comparison in this study.
2. The significant differences between T 292-91I and T 294-92 were attributed to the stress history and the positions of the LVDTs. The effect of stress history was evaluated for each procedure by testing at the same LVDT position. The T294-92 yielded slightly higher values than those of the T292-91I. However, resilient modulus values measured from the external measurements of T 294-92 were less than that of the internal full length measurements of T 292-91I because of the system compliance.
3. The conditioning partially eliminated the imperfect contacts between end platens and

minimized disturbance effects caused by laboratory preparation. Nevertheless, the conditioning changed the stress history of the specimen prior to testing by stiffening the specimen.

4. Based on the comparison of the two test methods, the effect of stress history resulted in only a 15 to 20% difference in resilient modulus, while the difference in the LVDT position was 25 to 30%.

5. The resilient moduli measured from the 6-in. diameter specimen and 4-in. diameter specimen were not significantly different for the limerock and granular pavement materials.

6. The comparison of LBR and laboratory resilient modulus values under optimum moisture conditions showed no clear correlation between them. However, a good correlation appeared to exist between the laboratory resilient modulus and LBR values for the A-2-4 soils. The correlation relationship is as follows:

$$MR_{lab(OMC)} = 0.62(LBR) + 112.59 \quad \text{(MPa)} \quad (R^2 = 0.75)$$

for A-2-4 soils.

7. The LBR and laboratory resilient modulus values under in-situ moisture conditions had a certain degree of correlation.

The regression equation is:

$$MR_{lab(In-situ)} = 0.77(LBR) + 112.57 \quad \text{(MPa)} \quad (R^2 = 0.31)$$

for range of LBR values from 20 to 150.

Correlation Relationships between Field and Laboratory Experimental Results

The bases of comparisons made in this study are grouped into two areas: moisture condition and state of stresses. The moisture condition was a major factor that influenced the values of resilient modulus of the pavement materials. This study considered two moisture conditions: optimum moisture content and in-situ moisture content.

The stress state was another important factor for determining the resilient modulus of the pavement materials. This study found through scientific computation that the 14 kPa (2 psi) confining pressure reflected the real state of confinement, which the subgrade and embankment may experience under traffic load. Bulk stress of each pavement layer was calculated according to the pavement profiles and layer system theory.

The comparison showed:

1. FWD backcalculated moduli were generally 1.5-1.9 times greater than laboratory resilient moduli. This is in agreement with the AASHTO guide, which suggests that the FWD backcalculated moduli are approximately two to three times higher than the laboratory determined moduli.

2. Laboratory resilient moduli under in-situ moisture condition were 1.03 times greater than plate layer moduli. This may imply that plate layer moduli were approximately equivalent to laboratory resilient moduli. However, the correlation relationship depended on the type of soil, and it should be used with caution.

3. The laboratory resilient modulus under optimum moisture content was 1.1 times higher than the laboratory resilient modulus under an in-situ moisture content. Observations showed that after construction the resilient modulus of the pavement materials tended to decrease due to the effects of many influencing factors.

4. Plate layer moduli (in MPa) were about 2.8 times higher than LBR values. The regression equation is:

$$M_{PLT} = 2.78(LBR) + 32.426 \quad (MPa)$$

(R^2=0.41, within the range of LBR values from 16 to 211).

5. The correlation relationship between FWD back-calculated moduli and LBR values was not very high.

The regression equation is:

$$M_{FWD} = 1.87(LBR) + 169.97 \quad (MPa)$$

(R^2=0.28, within the range of LBR values from 16 to 211).

However, the correlation relationship was dependent upon the type of material, and the correlation should be used with caution.

7. Recommendations

The main thrust of this research project was to ultimately implement the 1986 & 1993 AASHTO design guide for pavement structures with the resilient modulus test for Florida conditions. Under these major guidelines, the project objectives were planned, and the test and analyses were performed.

The following recommendations are made based on the findings and observations from this study:

1. The hyperbolic form for the nonlinear load-deformation response is a reasonable representation over a large range of deformation for the field plate load test and may be useful in design.
2. When the FWD backcalculated modulus or the plate layer modulus are known, the following relationships may be used to estimate the laboratory resilient modulus for granular materials:

   - $MR_{Lab} = 0.55 M_{FWD} \quad (MPa)$

- $MR_{Lab} = 1.03 M_{PLT} \quad (MPa)$

3. The relationship $MR_{OMC} = 1.10 MR_{insituMC} \quad (MPa)$ is recommended for converting between the laboratory resilient modulus under OMC and laboratory resilient modulus under in-situ moisture condition.
4. This study found three correlations related to LBR. Among the three, LBR versus plate layer moduli exhibited the correlation. LBR versus laboratory resilient moduli and LBR versus FWD moduli yielded some acceptable correlations. LBR is highly dependent upon the type of material used. Because LBR presents different aspects of characteristics of the pavement materials from the resilient modulus, this study suggests further investigation before adoption of any of the correlations.
5. A 4-in. diameter specimen test is recommended for conducting the resilient modulus test because no difference existed between 4-in. diameter and 6-in. diameter test results. However, specimen samples that are 4-in. are easier to prepare.
6. Test procedure T 292-91I is recommended for conducting the resilient modulus test according to the research results.

7. A resilient modulus test under different moisture levels is recommended for further research to investigate the relationship of resilient modulus and various moisture content.
8. From this research, the resilient moduli at an in-situ moisture content condition were more compatible with other field test results than the resilient moduli at an OMC condition.
9. One of the major concerns in resilient modulus measurement is the positioning of the deformation measurement devices. Non-contact measurement devices, such as an electro-optical biaxial tracking system, may be a possible solution to avoid errors and provide accurate measurements of the true resilient modulus.
10. For granular materials, vibratory or gyratory compaction may be a better choice for preparation of test specimens in the laboratory.
11. For clay materials, further research is needed to characterize the resilient properties of fine grain soils.
12. Pavement design procedures using the resilient modulus should be carried out with practical trials and calibrations prior to actual implementation. Pilot projects may be undertaken for calibration and verification.

CHAPTER 1

INTRODUCTION

1.1 Background

Pavement designers do not have an approved method in Florida for determining the resilient modulus of roadbed soils for new construction or lane addition projects. They must rely on correlations between Limerock Bearing Ratio (LBR) laboratory tests and the old AASHTO (American Association of State Highway and Transportation Officials) soil support values.

The 1986 and 1993 AASHTO Guide for Design of Pavement Structures now uses the resilient modulus for roadbed soil strength determination and an AASHTO test procedure T-274 has been developed for laboratory testing. However, the resilient modulus of soils is non-linearly stress dependent and the test procedure provides for a range of confining and deviator stresses to be applied. As a result of criticism, a number of nationwide studies were undertaken to search for

solutions and alternate test methods, such as the NCHRP 1-28 project. Several variations of the resilient modulus test procedure have also been proposed by researchers and agencies. The SHRP (Strategic Highway Research Program) Protocol P46 (AASHTO T294-92) and AASHTO T292-91I have been most commonly used in recent years. The early indications are that the AASHTO T294-92 (SHRP Protocol P46) is more convenient to perform when compared to the revised procedure AASHTO T292-91 I for the laboratory determination of resilient modulus. However, concerns continue about the sequence of loads, the measurement of the axial deformation, and the stress levels with regard to the T294-92 method.

The purpose of the laboratory determination of resilient modulus is to simulate field pavement layer behavior subject to dynamic traffic loadings. There are a number of field tests, which can be used such as plate bearing load, falling weight deflectometer (FWD), and Dynaflect. The plate bearing load test requires a relatively large set of test equipment and it has a higher cost. It is a destructive test. The FWD and Dynaflect are nondestructive tests that are easier to conduct in the field. The back-calculated results from the FWD and Dynaflect tests can provide in-situ layer moduli with a minimum amount of

disturbance and a lower cost, although the values may not be always accurate.

1.2 Project Objectives

A major research project was undertaken to study the possible implementation of the 1986 AASHTO flexible pavement design procedure in Florida. The objectives of the project were as follows:

1. To develop reliable correlations between laboratory measured resilient modulus and in-situ layer modulus of pavement soils as measured by a field plate bearing load test on subgrade soils and untreated base/subbase materials.
2. To correlate field plate bearing values and laboratory resilient modulus measurements with LBR values and FWD test results on subgrade soils and untreated base/subbase materials.
3. To evaluate testing methods for determining resilient modulus on subgrade soils and untreated base/subbase materials.
4. To investigate the effect of using a larger sample size (6-in diameter samples) on resilient modulus measurements.

The main thrust was to ultimately implement the 1986 & 1993 AASHTO design guide for pavement structures with the resilient modulus test for Florida conditions.

1.3 Project Plan

A field plate bearing load test was used during the initial phase of this major research project. A field experimental program was conducted to evaluate the bearing characteristics of in-place pavement layers. Twenty (20) field sites were tested throughout the state of Florida. At each site, a series of tests were conducted that included a plate bearing load test, an FWD test, and a Dynaflect test. Soil samples were transported to the laboratory in Tallahassee for further testing.

The second phase of the project, a laboratory experimental program, was undertaken to evaluate the resilient modulus of reconstituted and laboratory compacted pavement soils, and the LBR values. The resilient modulus tests were conducted utilizing both the T 292-91I (T292) and T 294-92 (T294) procedures. The resilient modulus specimens were prepared under reconstituted in-situ and optimum laboratory compacted conditions. The LBR test followed the Florida test method: FM 5-515 in the Manual of Standard Test

Methods (FDOT, 1986 & 1988). The effect of using a larger sample size (6-in diameter) was also investigated.

1.4 Previous Reports

Six interim reports were submitted for these large research projects. The following is a summary and brief description of those six interim reports:

1. Title: Field Plate Bearing Tests on Pavement Soils in Florida

   Report No. FL/DOT/RMC/0636 (1) - 4538

   This report presented a field experimental program on evaluating the bearing characteristics of existing pavement base, subgrade, and embankment soils using a field plate bearing load test. The field investigation was part of larger research project to study the existing pavement layer moduli, and to implement the laboratory resilient modulus test method in Florida.

   The plate bearing load tests were conducted on twenty flexible pavement sites across the state of Florida. At each selected site, field determination of the bearing characteristics was made on the base, subgrade, and embankment layers. The plate load test results were summarized and presented in the report. An

analysis was made to characterize the layer modulus of the pavement soils. The pavement layer moduli were verified through comparison with the results obtained from the elastic layered solution ELSYM5 program.

2. Title: Limerock Bearing Ratio on Laboratory Compacted Pavement Soils

   Report No. FL/DOT/RMC/0636 (2) - 4538

   This report presented a laboratory study that evaluated pavement bearing characteristics utilizing the Florida Limerock Bearing Ratio (LBR) test. The LBR is a modification of the California Bearing Ratio (CBR) test and has been widely used in Florida for the design of pavement structures. The LBR evaluation is part of a larger research project to study existing pavement conditions in Florida.

   The field experimental program was conducted on twenty selected pavement sites across the Florida. The LBR test was performed on pavement soils obtained from the field test sites. The LBR test results were analyzed and compared with the field test results. The AASHTO Road Test layer coefficient values (a_2) and Soil Support Values (SSV), which have become classic

reference values over more than two decades, were evaluated by using the LBR and field test results.

Conclusions show that the LBR values could be used to estimate the SSV values for design of flexible pavements in Florida. The correlation relationships between the LBR and SSV values were evaluated to better characterize the pavement structures in Florida.

3. Title: Evaluation of Laboratory Resilient Modulus Measurements on Florida Pavement Soils

Report No. FL/DOT/RMC/0636 (3) - 4538

The resilient modulus of pavement soils was a required input parameter in pavement analysis and design. Most of the recent research concentrated on the laboratory resilient modulus test and its correlations with other engineering properties determined from laboratory tests. However, little effort has been focused on the calibration of the laboratory resilient modulus measurements using field performance data.

This study presented the results of an experimental program to conduct the laboratory resilient modulus measurements on the reconstituted soil samples simulating reliable correlations between laboratory measured resilient modulus and in-situ layer

modulus of pavement soils as measured by field plate load tests on subgrade soils and untreated base/subbase materials in the Florida. The AASHTO T 292-91I test procedure was used for this study. Resilient modulus tests were performed in the laboratory. The test results were presented and analyzed in this report. A simplified procedure was adopted for comparison of the laboratory equivalent resilient modulus values with the modulus of elasticity of the subgrade layer from the field plate bearing load test. The laboratory resilient modulus results were compared with the field plate layer moduli on subgrade and embankment layers.

4. Title: Effect of Laboratory Testing Procedure on Resilient Characteristics of Florida Subgrade Soils

   Report No. FL/DOT/RMC/0636 (4) - 4538

   This study was conducted to measure the resilient modulus through a series of laboratory triaxial tests on the soils used for pavement subgrade and embankment in Florida. Two test procedures, AASHTO T 292-91I and T 294-92, were utilized to carry out the laboratory resilient modulus measurements. The primary objective was to compare the resilient response of subgrade soils

resulting from the T 292-91I procedure with those of the T 294-92 procedure.

The experimental results indicated that both testing procedures provided repeatable results. For both cohesive and cohesionless soils, resilient modulus increased with the increasing confining pressure. The resilient modulus measured from the middle LVDTs was significantly different from that determined from the full length LVDTs because of the end effects and the imperfect contacts between the platen and the specimen. The resilient modulus measured from the external LVDTs of the T294-92 procedure was found to be lower than that measured from the full length LVDTs of the T 292-91I procedure.

5. Title: Analysis of Granular Subgrade Modulus From Field and Laboratory Tests

   Report No. FL/DOT/RMC/0636 (5) - 4538

This study presented the results of field plate bearing load and laboratory resilient modulus tests on the reconstituted soil samples simulating the field moisture and density conditions. The objectives of this study were to evaluate the field load deformation characteristics of the sandy embankment (subgrade)

soils and to further correlate the field test results with the laboratory resilient modulus measurements.

A simplified procedure was adopted for comparison of the laboratory equivalent resilient modulus values with the modulus of elasticity of the subgrade layer from the field plate bearing load test. Correlation relationships were established between the laboratory resilient modulus and field plate layer modulus on these pavement materials. The field modulus values were in close agreement with those of the computed equivalent resilient modulus from the laboratory test under the same loading pressure.

6. Title: Effect of Specimen Size on Resilient Characteristics of Pavement Soils

Report No. FL/DOT/RMC/0636 (6) - 4538

The measurement of resilient modulus has become more common recently because of its importance in determining properties of roadbed soils and pavement components. Several resilient modulus test procedures have been proposed by researchers and agencies. Among them AASHTO T 292-91I is one of the most commonly used test procedures. The most commonly used specimen size is 4.0-in. (101.6-mm) in diameter. The recommended

specimen size was 4.0-in. diameter cylindrical specimen for use in the laboratory resilient modulus test. The primary objective of this study was to evaluate the effect of specimen size on both 6-in. and 4-in. diameter specimens with the T 292-91I procedure. The resilient moduli measured from the 6-in. and 4-in. diameter specimens were not significantly different for limerock and granular materials.

1.5 Final Report Organization

This report summarizes both the field and laboratory experimental programs utilizing six different test methods that evaluate the engineering properties of the pavement base, subgrade, and embankment soils. This summary report is the final phase of a larger research project. The final report consists of nine chapters. As in the first chapter, the background and objectives of this field and laboratory study serve as an introduction. Chapter 2 summarizes the field experimental program conducted during this study. A detailed description of the laboratory experimental program is the subject of Chapter 3. Chapter 4 presents test results of the field experimental program while Chapter 5 summarizes test results from the laboratory experimental program.

Analyses of the field and laboratory test results are presented in Chapters 6 and 7. The development of correlations from the field and laboratory experimental results is presented in Chapter 8. Chapter 9 is devoted to the conclusions and recommendations of this research study.

CHAPTER 2

FIELD EXPERIMENTAL PROGRAM

2.1 General

The primary objective of the field experimental program was to characterize the in-situ bearing behavior of pavement layers on selected types of pavement soils in Florida. To achieve the objective, a series of tests were conducted on twenty flexible pavement sites around Florida. The sites were evenly scattered within the state to better represent different soil conditions in Florida (Figure 2.1). The selection of sites took into account the following considerations: a) soil type and history, b) pavement layer homogeneity, c) layer thickness, d) field operational considerations. A detailed description of each of the twenty selected site locations is summarized in Table 2.1 for reference.

2.2 Field Test Methods

Many different types of tests have been devised for measuring the characteristics of pavement structures in place. In Florida, plate bearing, Falling Weight Deflectometer (FWD), and Dynaflect tests are commonly used for evaluating pavement structures at the Florida Department of Transportation (FDOT). While the field plate bearing test is a destructive test, FWD and Dynaflect are non-destructive tests. For this field study, these tests were used to determine the modulus of elasticity of pavement layers at the tested site under its natural moisture content and density. Ultimately, the field experimental results will be correlated with laboratory experimental results.

2.3 Field Testing Program

The field testing program was performed to investigate the supporting characteristics of pavement soils. The field investigation was jointly carried out by the FDOT Pavement Evaluation Section with the State Materials Office and the research team. Twenty selected sites scattered around Florida were tested.

At each selected site, the following tests were conducted:

1. Falling Weight Deflectometer test
2. Plate bearing load test
3. Dynaflect test
4. Nuclear density and moisture content test
5. Speedy moisture content test

2.3.1 Falling Weight Deflectometer Test

The field testing program uses a Dynatest 8000 FWD test system, which is primarily utilized by the FDOT for pavement evaluation. The system consists of a Dynatest 8002E FWD trailer, a table top computer with a printer, and a Dynatest 8600 system processor interfaced with the FWD trailer as well as with the computer. A certain weight is mounted on a vertical shaft and housed in the trailer. The weight is hydraulically lifted to a predetermined height (ranging from 0 to 15.7 inches or 0 to 400 mm) and then dropped onto a rubber buffer system resulting in a load pulse of 25 to 30 msec. The load is applied to the surface of pavement through a load cell and a circular plate. The standard load plate has a 300 mm (11.8 in.) diameter. By use of different drop weights and heights, it can vary the impulse load to the pavement structure form about 6.7 to 120 kN (1,500 to 27,000 lb.). For flexible pavements, drops result in loads of

approximately 27 kN (6,000 lb.), 40 kN (9,000 lb.), 53 kN (12,000 lb.), and 71 kN (16,000 lb.). The Dynatest 8000 has seven geophones spaced at radial distances of 0, 8, 12, 18, 24, and 36 inches apart from the center of the loading plate. The first sensor is always mounted at the center of the foot plate. Peak values of surface deflections are collected by the sensors and stored in or printed by the computer system. The FWD set up is shown in Figure 2.2.

The FWD test was performed, prior to excavation, in the very beginning of the field program at each test site. The test was performed primarily in wheel paths since the pavement response at these locations reflects the effect of accumulated damage. But later, the test involved deflection measurement within different positions in the lane for comparative purposes.

After arriving at the test site, the maintenance crew from the district set up the traffic control signals to direct the traffic through the work zone. One lane was usually closed for the test. A five and one-half foot by eleven foot rectangular pavement surface area was marked for the test. Then the FWD was set up for testing. The FWD test was performed nine times for most test sites. Three tests were in wheel-paths and three were in out-of-wheel-paths.

The other three tests were in between wheel paths. The FWD test data were saved on a PC computer. Meanwhile, the temperatures were measured both at the surface of the asphalt concrete pavement and inside the pavement.

2.3.2 Field Plate Bearing Load Test

Plate bearing load tests have been used for the design and evaluation of pavement structures since the 1940's. The test procedures employed may vary somewhat depending on the adopted agencies, but the method is generally in close agreement with the ASTM D-1195. The FDOT routinely uses the plate load test to evaluate the in-situ layer modulus of flexible pavement subbase and subgrade soils. In Florida, the plate load test is designated as FM 5-527 in the Manual of Florida Sampling and Testing Methods.

The testing apparatus consisted of a water tanker with a total of 60,000 pounds, and a hydraulic jack with a spherical bearing attachment, which was capable of applying and releasing the load increments. The hydraulic jack had sufficient capacity for applying the maximum load required and was equipped with an accurately calibrated gauge that indicated the magnitude of the applied load. A 12-inch

diameter circular steel plate was used for applying the load. The test setup is shown in Figure 2.3.

An aluminum alloy deflection beam was used to mount two graduated (in units of 0.001 inch) dial gauges for measuring deflections. Prior to applying the incremental testing loads, three seating loads were applied to seat the loading system and bearing plate. Each seating load was expected to produce a total deflection of about 0.03 inch. Each of the three seating loads was applied in four or five uniform increments. After each increment of test load was applied, the deflection was allowed to continue at a rate of no more than 0.001 in. per minute. The load and deflections were then recorded. This procedure continued until the average total deflection of 0.05 inch plus average rebound deflection from third seating load was reached. A close-up of the plate bearing test is schematically illustrated in Figure 2.4.

The actual field plate load test took place in three stages at each selected site. In the first stage, the asphalt concrete structural layer was cut, approximately five and one-half foot by eleven foot, and subsequently removed to expose the underlying base layer. The asphalt concrete slab was saved for possible future testing. The

plate bearing load test was conducted on the base layer. Prior to testing, the in-situ density and moisture content of the base layer were obtained using a nuclear gauge device (Figure 2.5). In addition, the speedy moisture content was conducted to check the nuclear moisture content data. After completion of the plate bearing test, representative bag samples of the base material were taken for future testing of the resilient modulus in laboratory.

In the second stage, the base materials were excavated and the stabilized subgrade layer was exposed and leveled. Care was taken not to disturb the soil in the test layer. Prior to the plate load test, the in-situ moisture and density were again measured. Sufficient bag samples were taken from the subgrade layer after the plate load test for further laboratory evaluation.

In the third stage of the plate load test, the stabilized subgrade layer was again removed to expose the embankment layer. The moisture and density of the embankment layer were measured prior to the plate load test. The soil samples were taken after the test. After completion of the load-testing program, the embankment soil layer was excavated down to three or four feet below the tested stratum to check the layer homogeneity. The three-stage

field plate load testing procedures are schematically illustrated in Figure 2.6. A plan view of the loading areas induced by the three-stage procedure is also illustrated in Figure 2.7.

2.3.3 Dynaflect Test

Dynaflect is used for calculating dynamic deflections of the pavement due to a steady state dynamic loading. This testing device consists of a dynamic force generator and sensor assembly mounted on a small two-wheel trailer, calibration unit and a digital control device with printer carried in a light towing vehicle. The light weight design of Dynaflect permits one person to make pavement deflection measurements easily and quickly. Figure 2.8(a) shows the Dynaflect apparatus in an operating position.

Loading is accomplished through two counter-rotating steel weights, which deliver a 1,000-pound dynamic force. The dynamic force is transmitted to the pavement surface through the two rigid wheels.

The resulting deflection basin (Figure 2.9) is measured by five geophones mounted on the trailer draw bar at 12-inch (0.3 m) intervals. These geophones are raised and lowered to

the pavement surface. Figure 2.8(b) illustrates the configuration of the Dynaflect loading wheels and geophones.

2.4 Pavement Layer Profiles

After completion of the plate bearing load test, the embankment soil layer was excavated and the layer profile could be seen. Thus, the thickness of each soil layer was measured again. The pavement layer profile was idealized by using the average thickness of each soil layer. The actual thickness may vary up to about half of an inch for most of the in-situ soil layers. The layer profiles are shown in Figure 2.10 through 2.19 for the twenty selected sites.

After completion of the field-testing program at each site, the excavated pavement layers were put back to normal by the maintenance crew. According to the selection criteria, each test site should be scheduled for resurfacing or repairing within about two years. Therefore, the repaired pavement test sections will be rehabilitated soon enough, not causing further deterioration on the pavements.

Table 2.1 Description of Test Sites

Location of Test Site	General Description	Straight Line Mile Post
Dist. 3, Jefferson Co., U.S. 17, Site #1A	Approx. 2.3 miles E. of U.S. 19 at Capps W.B. Outside Lane	12.300
Dist. 3, Jefferson Co., U.S. 17, Site #2A	Approx. 0.7 mile E. of U.S. 19 at Capps W.B. Outside Lane	10.700
Dist. 3, Gadsden Co., U.S. 17, Site #3B	Approx. 0.4 mile N. of Rich Bay Road N.B. Outside Lane	12.106
Dist. 3, Gadsden Co., U.S. 17, Site #2B	Approx. 1.3 miles N. of Rich Bay Road N.B. Outside Lane	11.206
Dist. 2, Alachua Co., U.S. 301, Site #4	Sta. No. 119 + 50 N.B. Outside Lane	21.088
Dist. 2, Alachua Co., U.S. 301, Site #3	Sta. No. 183 + 00 N.B. Outside Lane	22.291
Dist. 2, Clay Co., U.S. 17, Site #5	Sta. No. 928 + 57 N.B. Lane, Opposite the SHRP Control Lane	6.183
Dist. 2, Clay Co., U.S. 17, Site #6	Sta. No. 970 + 00 N.B. Lane, Opposite the SHRP Control Lane	6.968
Dist. 5, Seminole Co., U.S. 414, Site #2	Approx. 0.346 mile W. of Interstate 4 W.B. Passing Lane	38.407
Dist. 5, Seminole Co., U.S. 414, Site #1	Approx. 0.346 mile W. of Interstate 4 E.B. Passing Lane	38.407
Dist. 5, Osceola Co., U.S. 414, Site #3	Approx. 0.983 mile from Intersection of S.R. 15 and S.R. 60	3.350
Dist. 5, Osceola Co., U.S. 414, Site #4	Approx. 2.683 miles from Intersection of S.R. 15 and S.R. 60	1.650
Dist. 6, Dade Co., U.S. 41, Site #1	Approx. 0.6 mile E. of Krome Avenue E.B. Outside Lane	0.600
Dist. 6, Dade Co., U.S. 41, Site #2	Approx. 1.0 mile E. of Krome Avenue E.B. Outside Lane	1.000
Dist. 4, Martin Co., U.S. 1, Site #3	Approx. 2.5 miles N. of County Line Road N.B. Outside Lane	2.500
Dist. 4, Martin Co., U.S. 1, Site #4	Approx. 3.2 miles N. of County Line Road N.B. Outside Lane	3.200
Dist. 1, Polk Co., U.S. 17, Site #1A	Approx. 3.088 miles W. of Intersection of U.S. 17 & 92 and U.S. 27 E.B. Outside Lane	18.100
Dist. 1, Polk Co., U.S. 17, Site #2A	Approx. 1.888 miles W. of Intersection of U.S. 17 & 92 and U.S. 27 E.B. Outside Lane	19.300
Dist. 1, Lee Co., S.R. 884, Site #1B	Approx. 4.380 miles S. of Intersection of S.R. 884 & S.R. 80	21.850
Dist. 1, Lee Co., S.R. 884, Site #2B	Approx. 3.455 miles S. of Intersection of S.R. 884 & S.R. 80	22.775

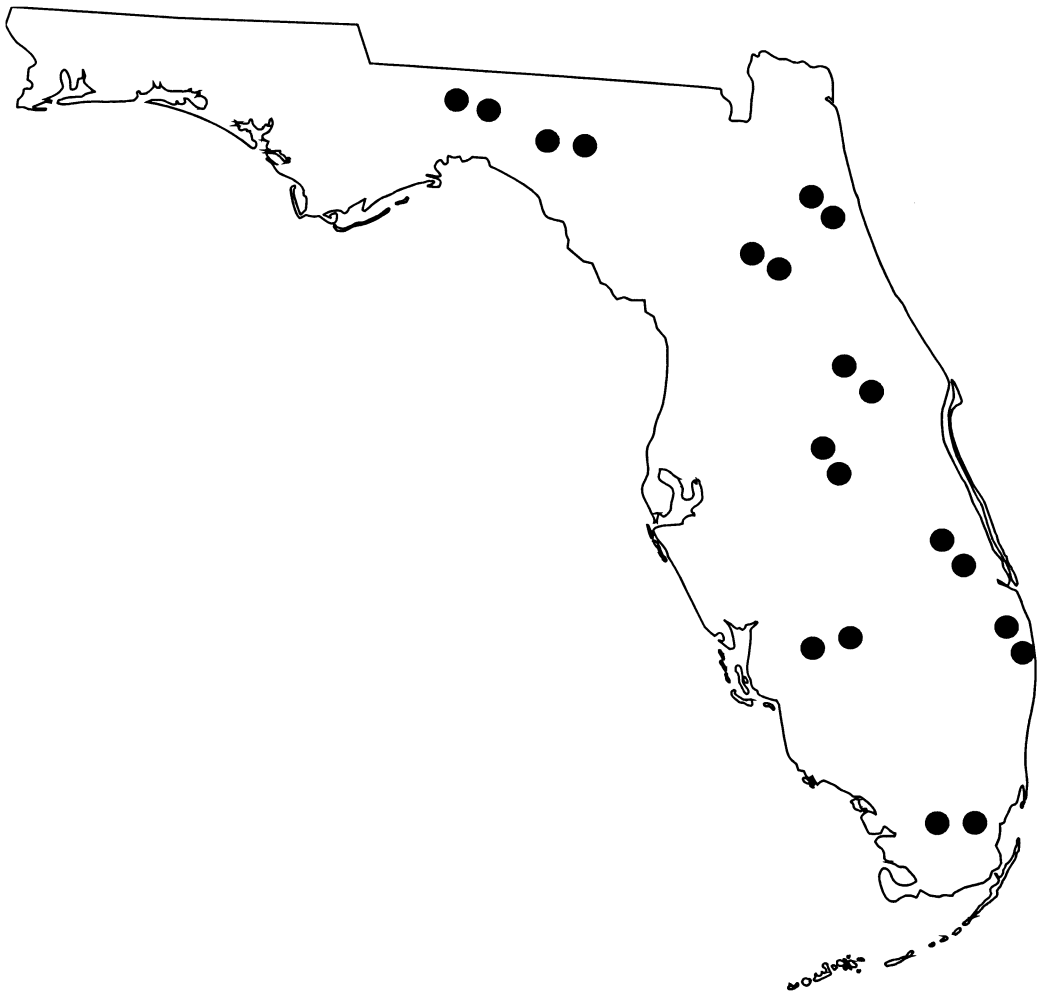


Figure 2.1: Site locations

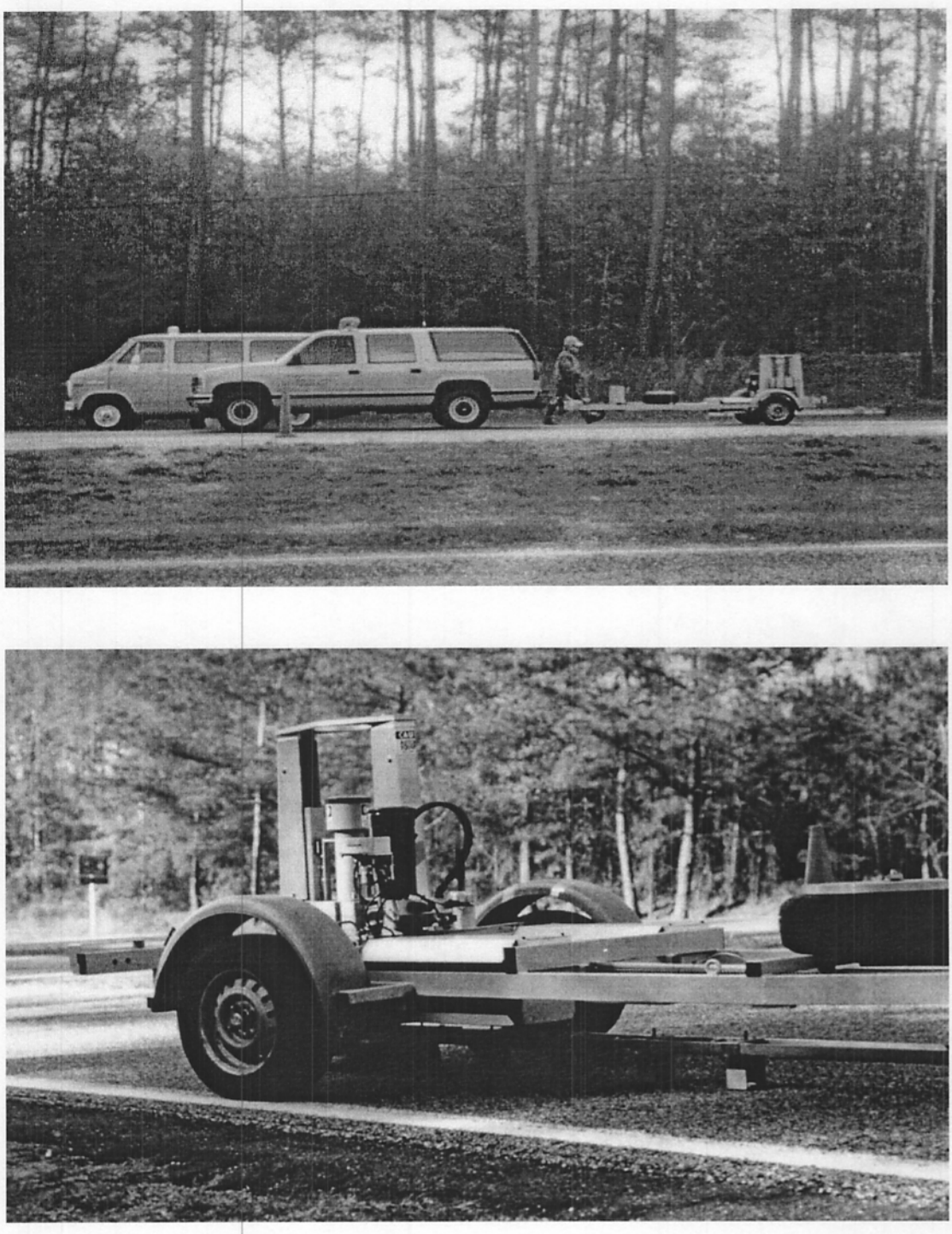


Figure 2.2. Falling Weight Deflectometer test setup

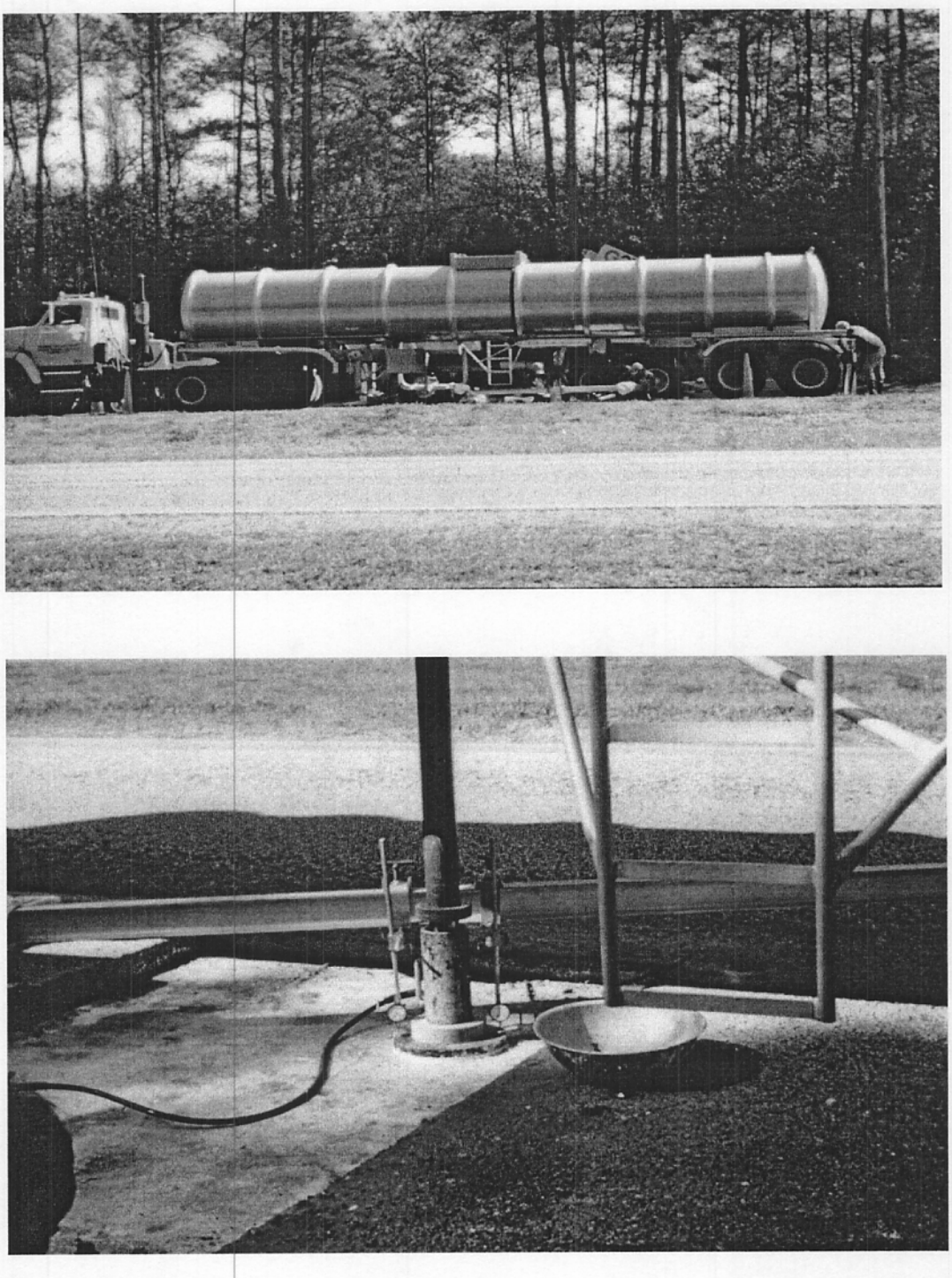


Figure 2.3. Field plate load test setup

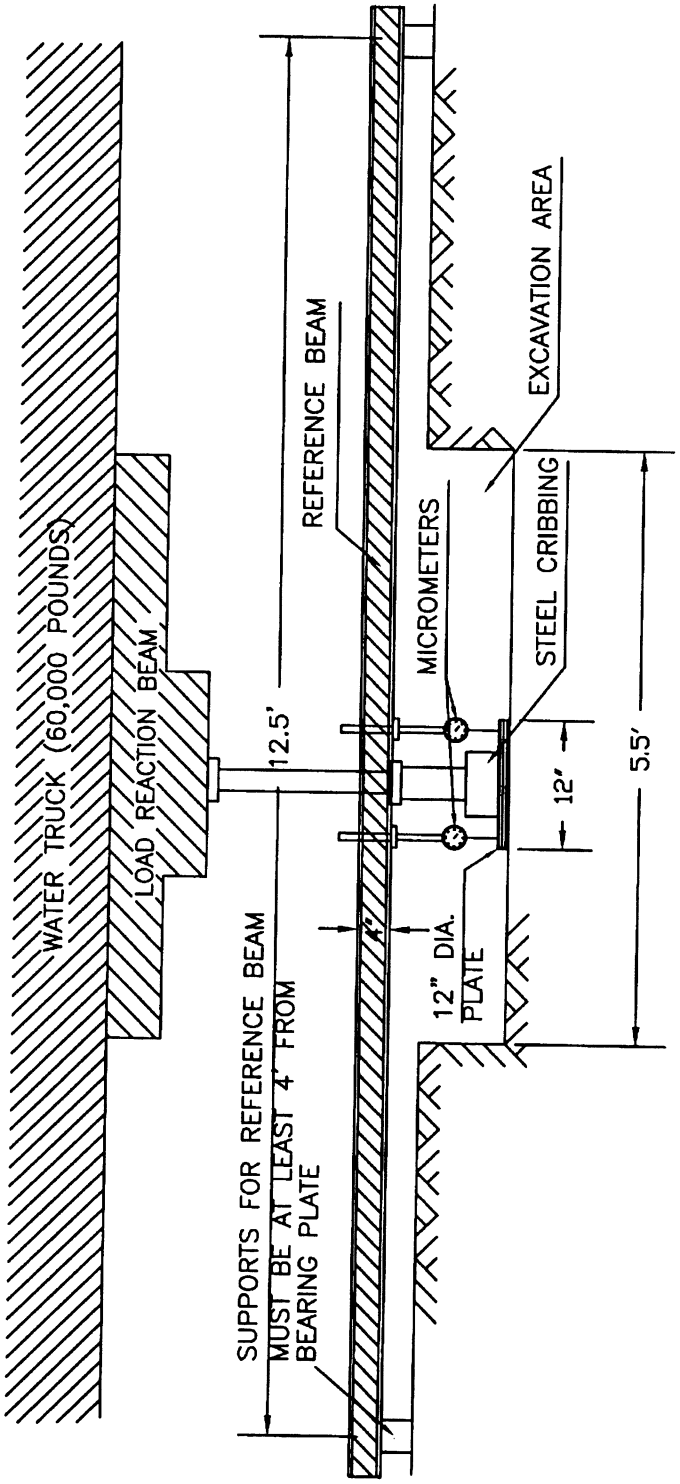
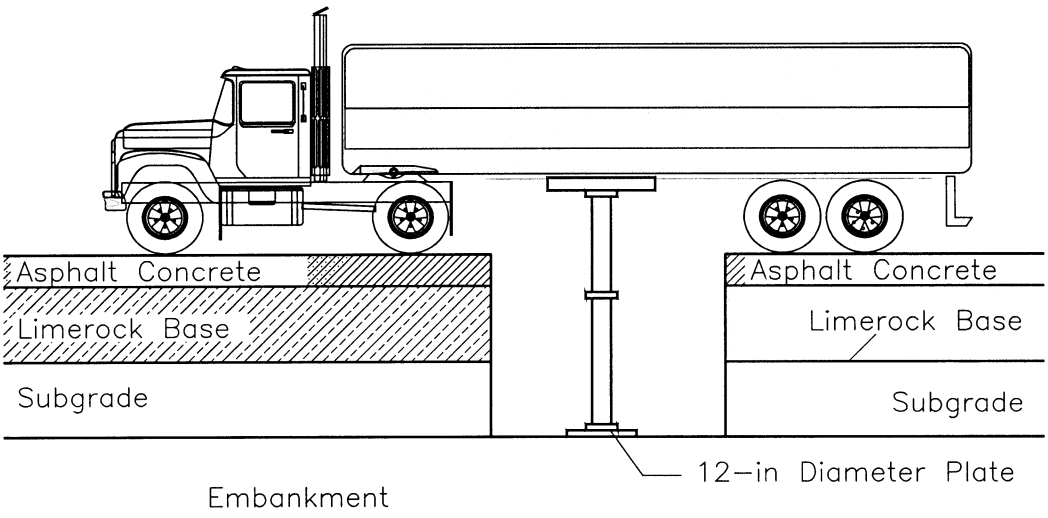


Figure 2.4: Close-up of the plate bearing test



Figure 2.5. Nuclear density test setup



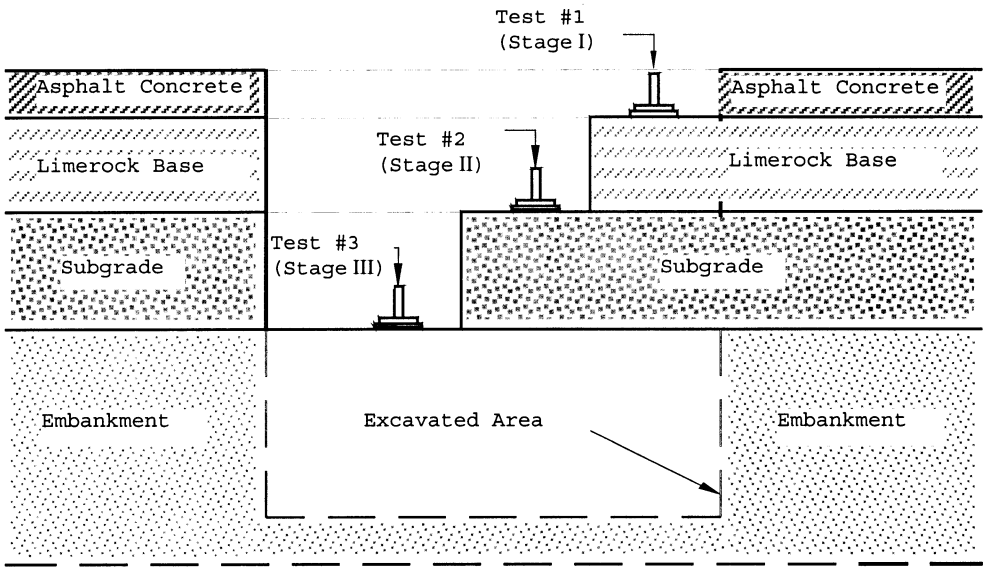


Figure 2.6 Schematic illustration of field test procedure

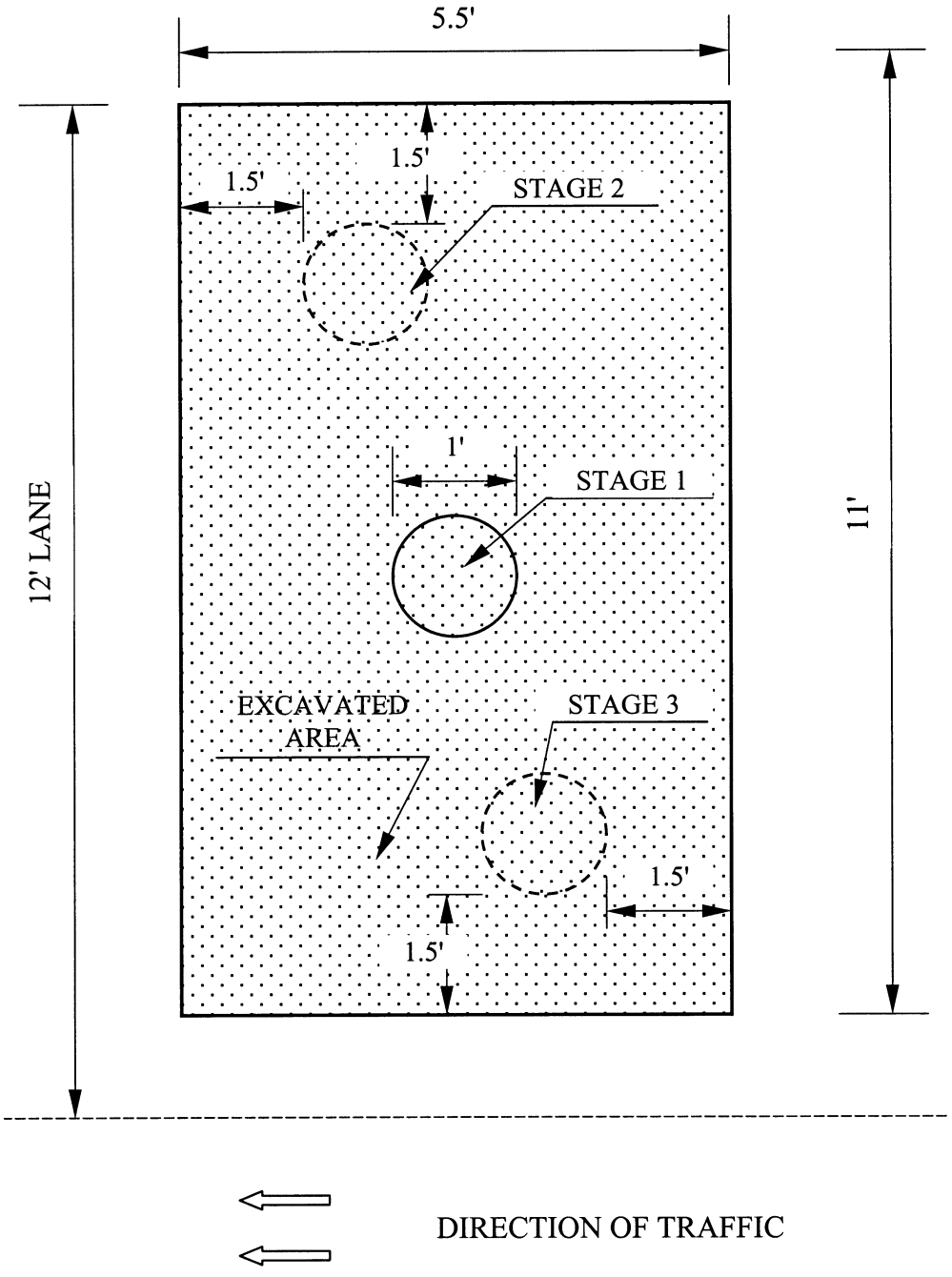
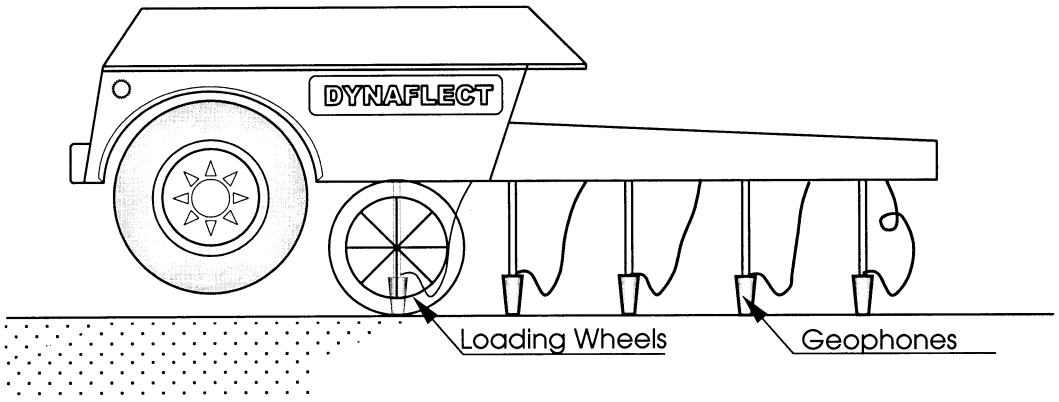
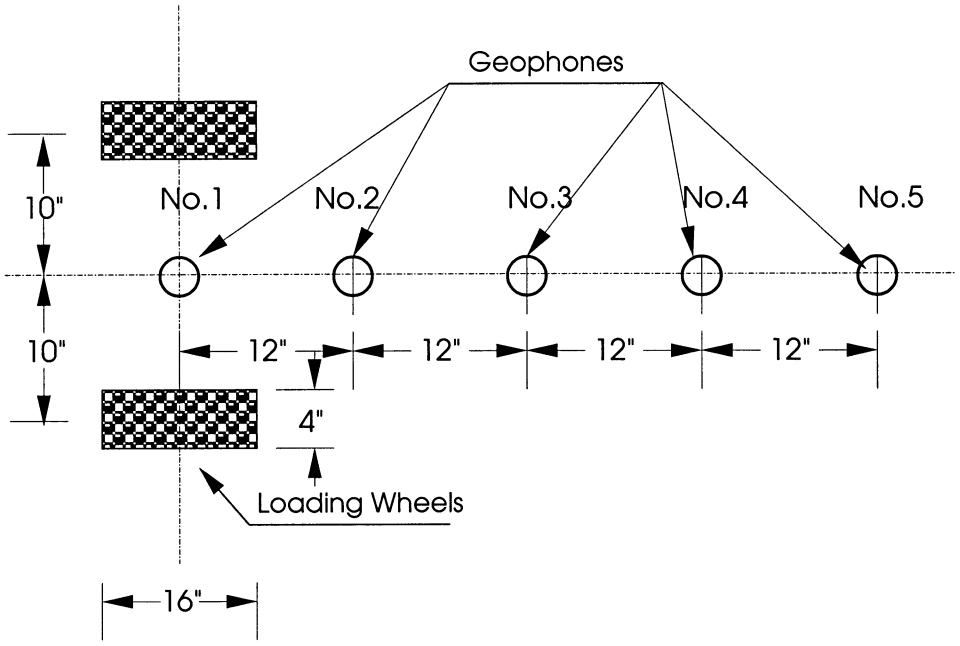


Figure 2.7 Plan view of the loading area



(a) The Dynaflect System in Operating Position.



(b) Configuration of Dynaflect Load Wheel Geophones

Figure 2.8 Configuration of Dynaflect Load Wheel Geophones in Operation Position

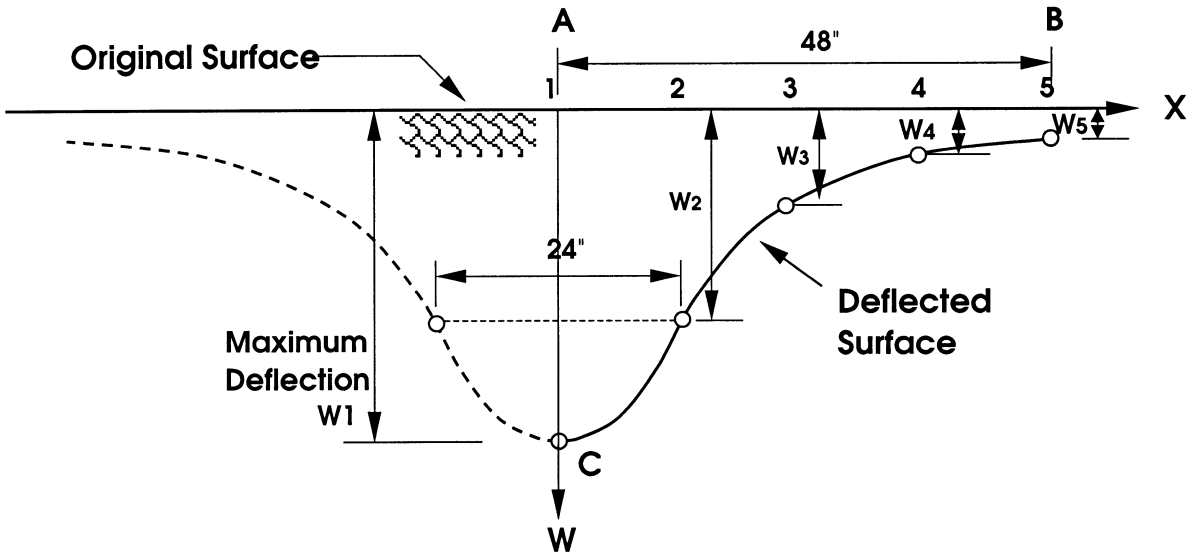


Figure 2.9 Typical deflection basin reconstructed from Dynaflect readings. Only half of the basin is measured.

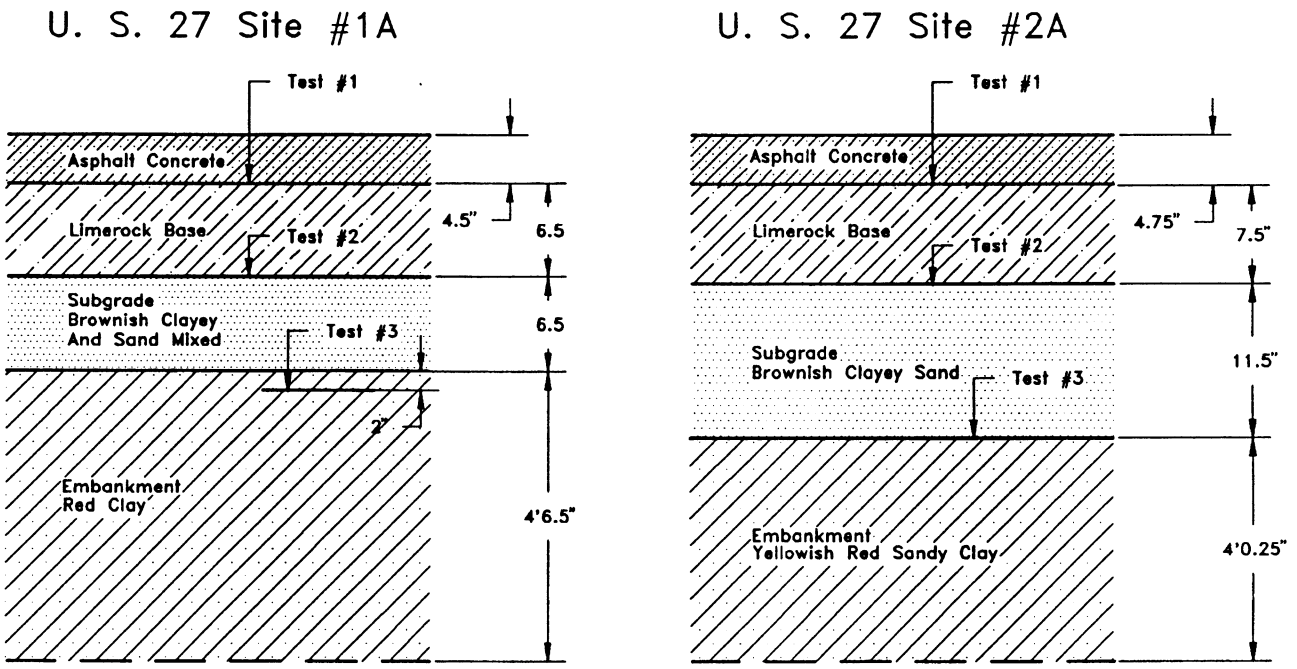


Figure 2.10: Soil Profiles at Jefferson County (District 3)

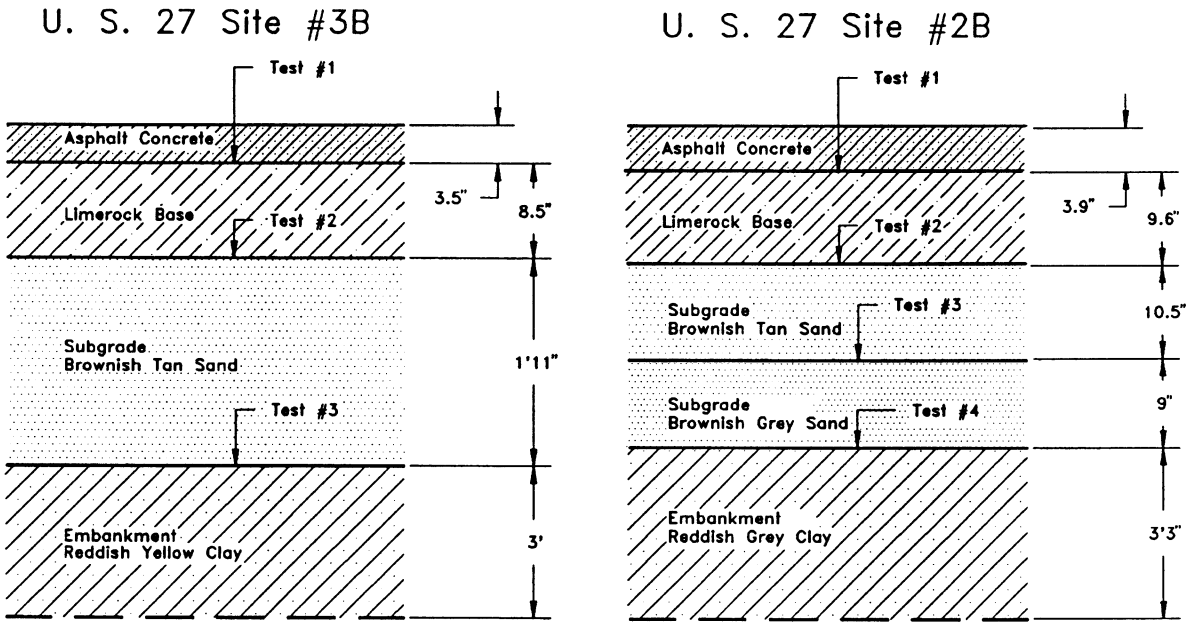


Figure 2.11: Soil Profiles at Gadsden County (District 3)

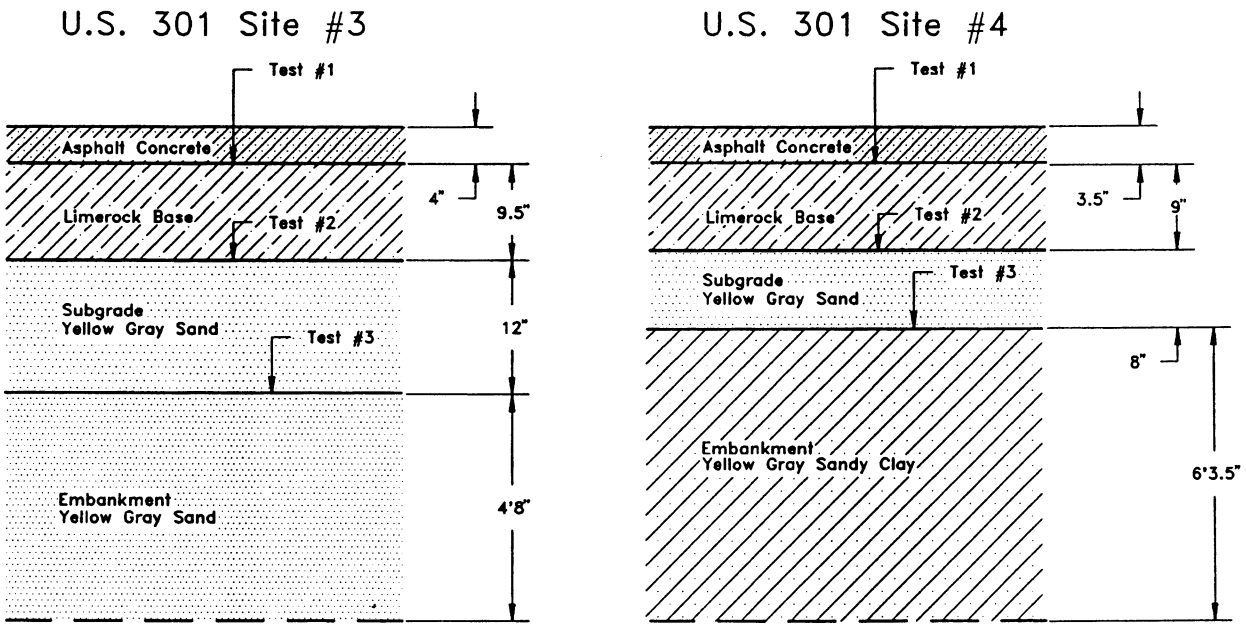


Figure 2.12: Soil Profiles at Alachua County (District 2)

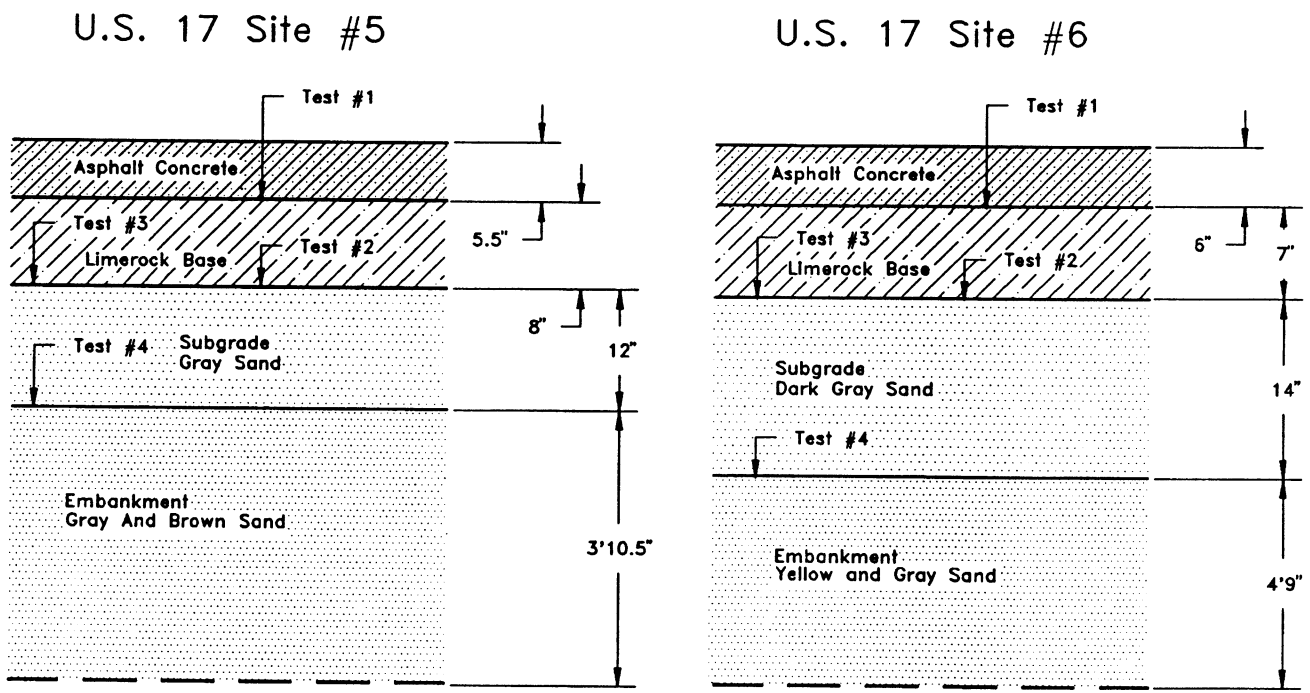


Figure 2.13: Soil Profiles at Clay County (District 2)

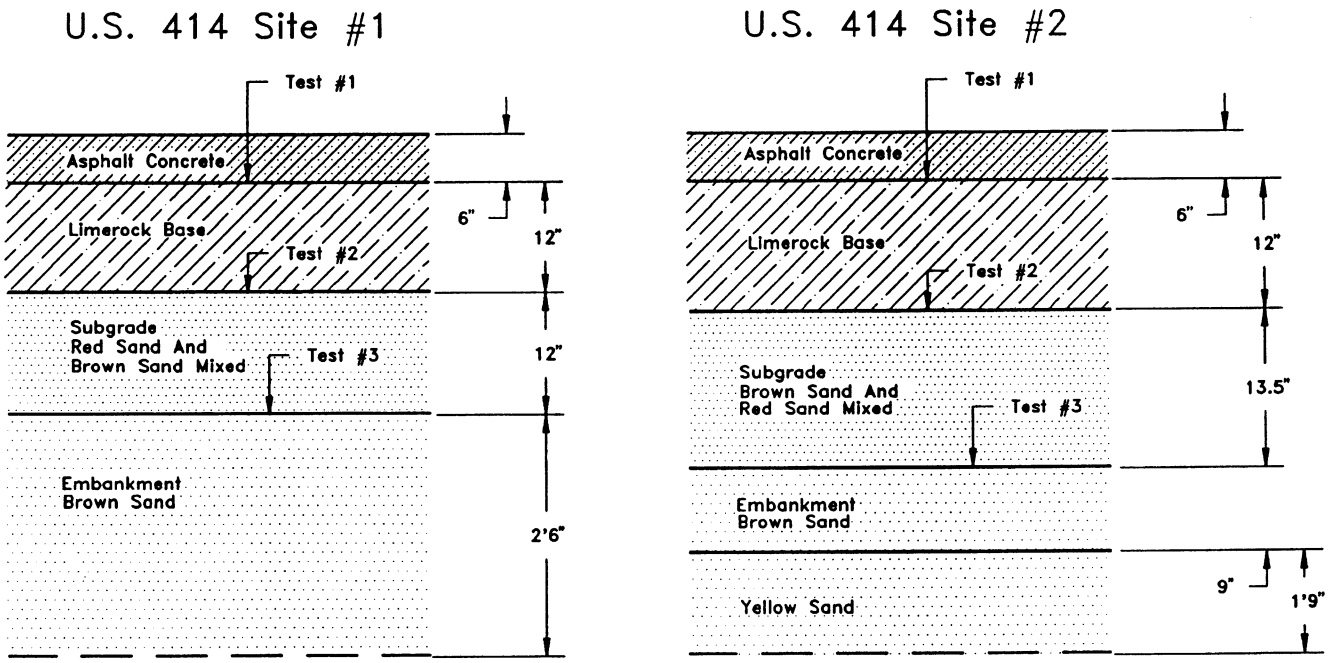


Figure 2.14: Soil Profiles at Seminole County (District 5)

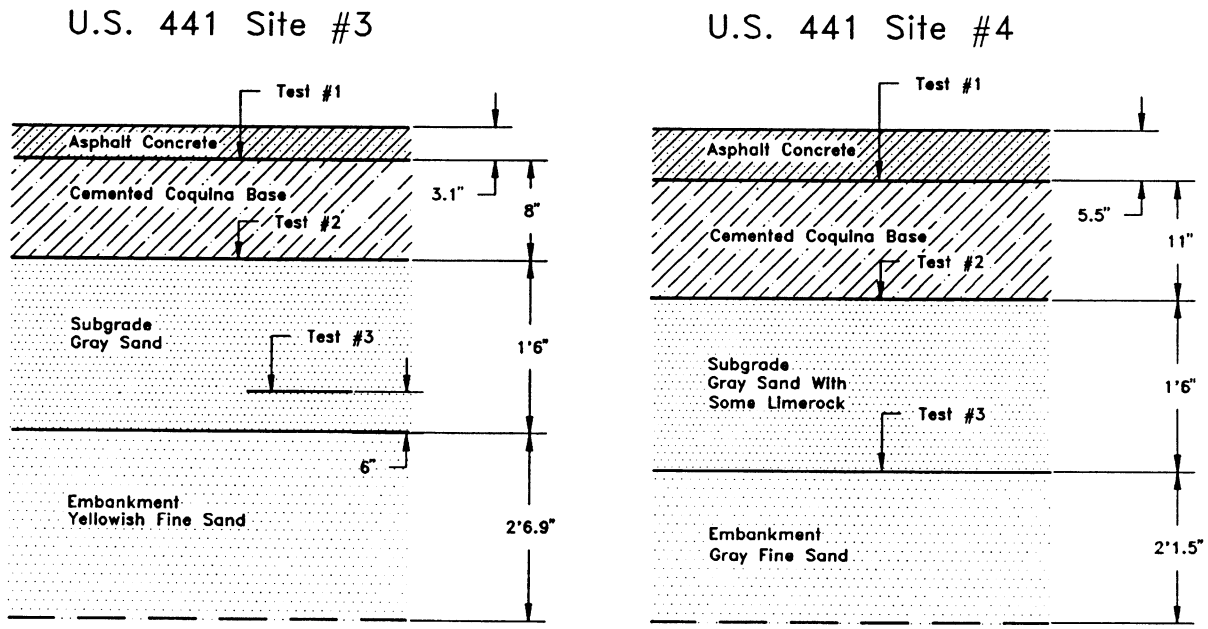


Figure 2.15: Soil Profiles at Osceola County (District 5)

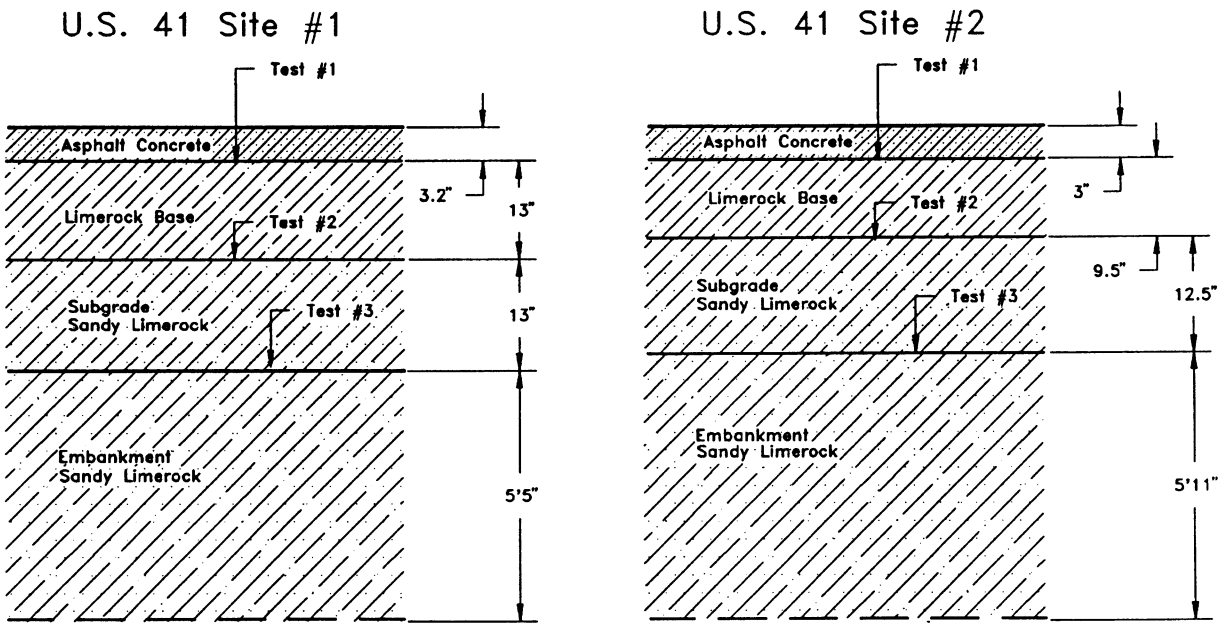


Figure 2.16: Soil Profiles at Dade County (District 4 & 6)

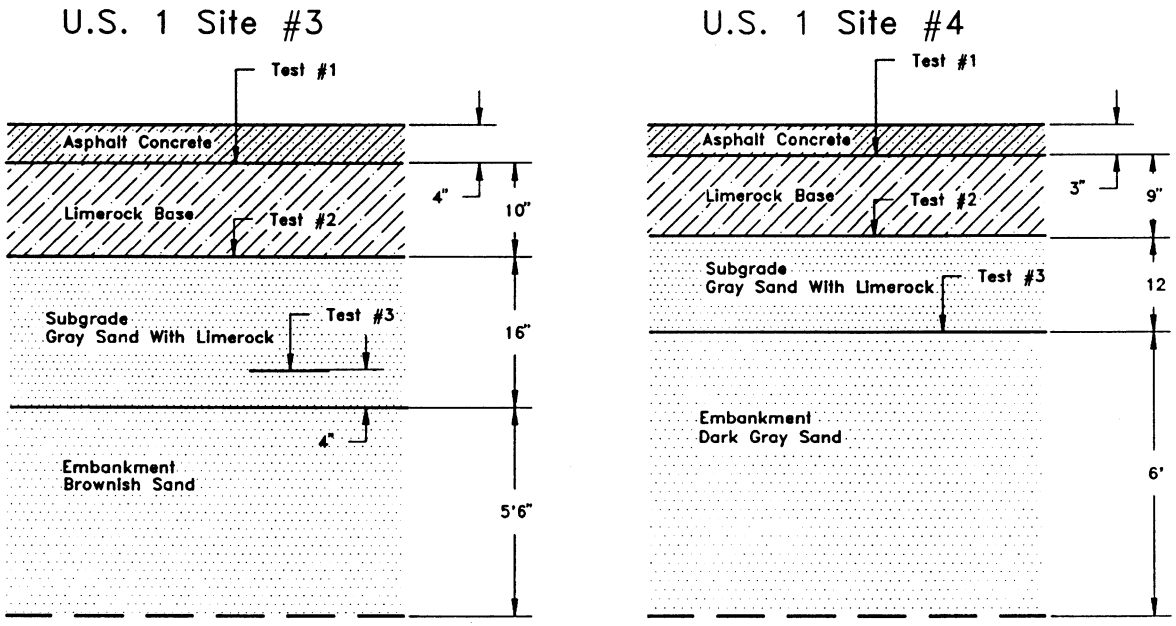


Figure 2.17: Soil Profiles at Martin County (District 4 & 6)

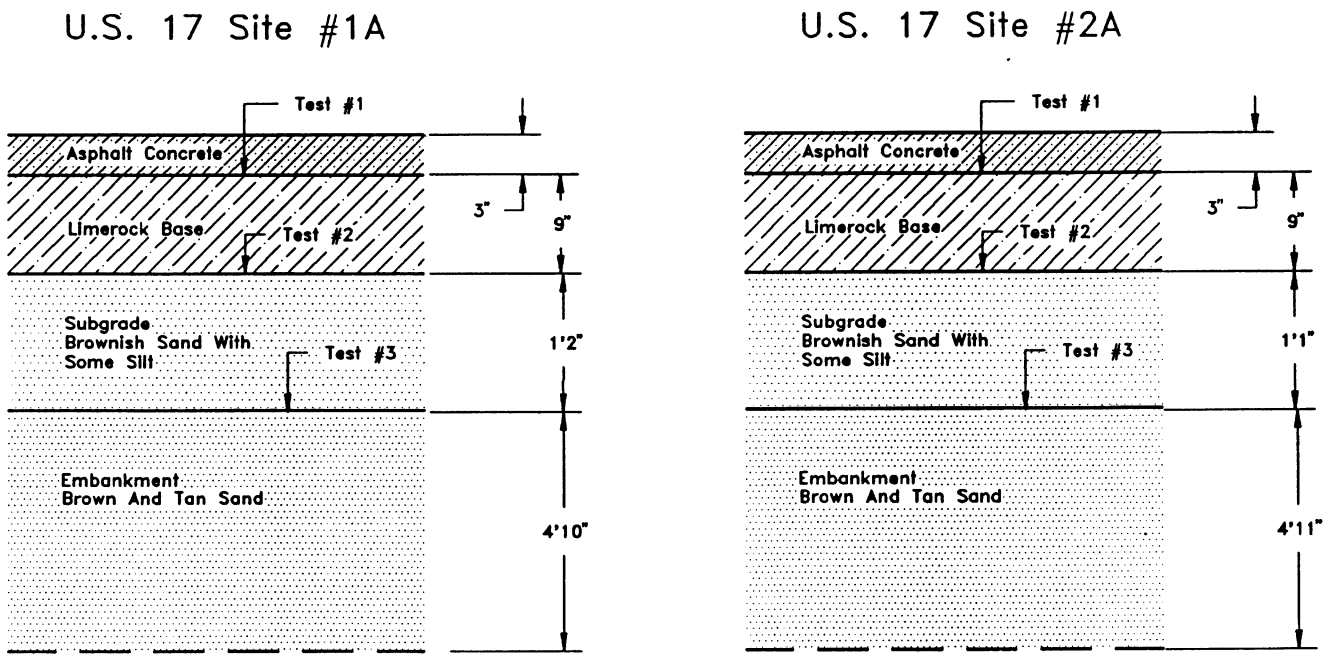


Figure 2.18: Soil Profiles at Polk County (District 1)

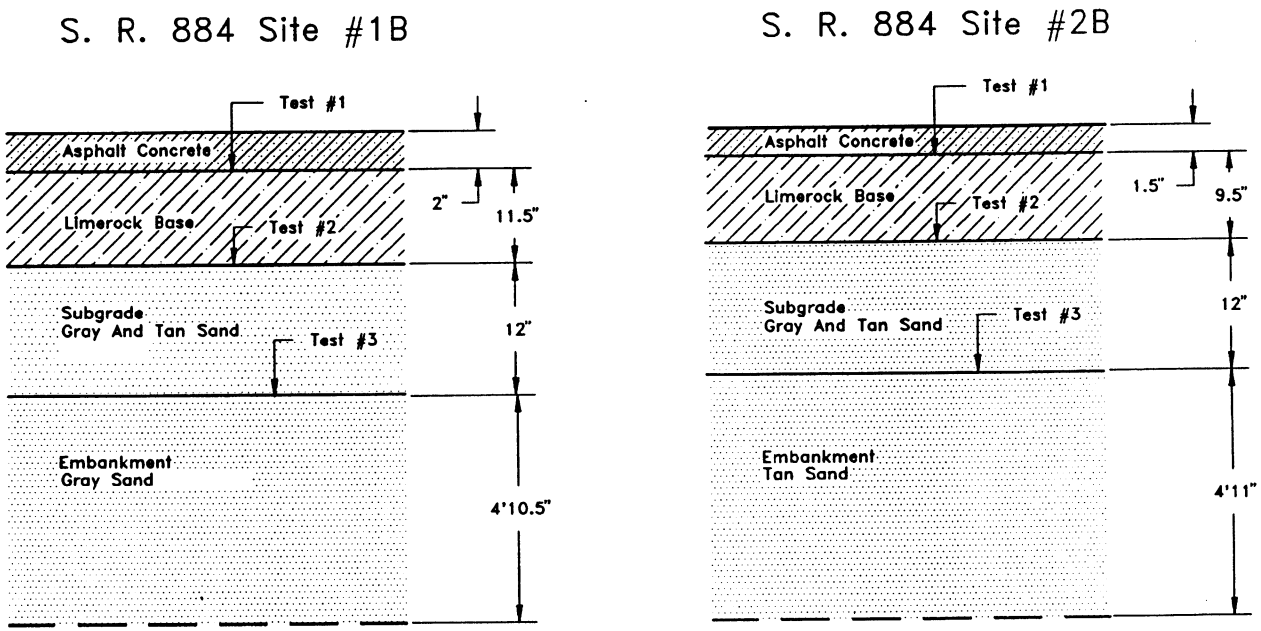


Figure 2.19: Soil Profiles at Lee County (District 1)

CHAPTER 3

LABORATORY EXPERIMENTAL PROGRAM

3.1 General

The primary objectives of the laboratory experimental program were to evaluate the laboratory testing methods for resilient modulus measurement and to conduct the LBR test on pavement materials. To achieve the objectives, the laboratory tests were conducted on the soil samples taken from the test sites where the field experimental program was performed. The soil materials consisted of twenty-two types of limerock, two types of coquina, thirty-two types of granular soils, and five types of cohesive soils. A summary of the soil materials from the field test projects is presented in Table 3.1.

A laboratory testing program using both 152.4-mm (6.0-in.) and 101.6-mm (4.0-in.) diameter specimens and the T 292-91I procedure was also conducted to evaluate the specimen size effect on the resilient modulus of granular base and sub-base soils.

3.2 Laboratory Test Methods

The resilient modulus test and Limerock Bearing Ratio (LBR) test were used to characterize the pavement materials in the laboratory for this project. The resilient modulus test was used to evaluate the behavior of pavement materials under simulated dynamic loading conditions in the laboratory, while the LBR test was used as a measurement of the bearing capacity of pavement materials.

Since the resilient modulus can represent the engineering characteristics of pavement materials, this experimental program focused mainly on analyzing the correlation between laboratory resilient modulus and other field or laboratory experimental results.

3.2.1 Resilient Modulus Test Method

The resilient modulus test methods adopted for this project were AASHTO T 292-91I, "Resilient Modulus of Subgrade Soils and Untreated Base/Subbase Materials", and AASHTO T 294-92, "Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils-SHRP Protocol P46". These methods are considered as an improvement of the AASHTO T 274-82 method. Both methods cover procedures for preparing and testing untreated subgrade and untreated

base/subbase materials for determination of resilient modulus under conditions and stress states of materials beneath flexible pavements subjected to moving wheel loads.

3.2.2 Limerock Bearing Ratio Test Method

The Limerock Bearing Ratio (LBR) test, a modified CBR test, was adopted for use in construction for subgrade strength in the early 1960's and for soil materials used in base courses in the mid 1970's in Florida (FM 5-515). The LBR test, as used in flexible pavement design in Florida, is a measure of the bearing capacity of a soil. The test consists of measuring the load required to cause a standard circular plunger (area of 3 square inches) to penetrate a standard specimen at a specified rate. The LBR is the load, in psi, required to force the plunger into the soil 0.1 inch, which is expressed as a percentage of the load, in psi, required to force the same plunger the same depth into a standard sample of crushed limerock. The average penetration load for typical crushed limerock found in Florida was standardized to 800 psi. The resulting ratio multiplied by 100 is known as the Limerock Bearing Ratio (with percent omitted). The test results are intended to provide the relative bearing values of base and subgrade materials.

3.3 Resilient Modulus Testing Program

The laboratory testing program was performed to acquire the resilient characteristics and bearing capacity of pavement soils. All soil materials taken from the field test sites were tested in the laboratory. For each type of soil, specimens were assembled under optimum compacted condition and under in-situ moisture content and density conditions to conduct the resilient modulus test.

Since the pavement soils are constructed under optimum moisture content and density conditions, using the specimen prepared under optimum moisture content and density for determining the laboratory resilient modulus can represent the resilient characteristics of pavement soils under as constructed conditions. In order to correlate the field experimental results with the laboratory resilient modulus values, the laboratory tests were also performed on the reconstituted soil samples obtained from the field test sites under in-situ moisture content and density conditions.

Limerock is the most commonly used base material in Florida. Since large aggregates exist in some of the limerock material, concern was expressed whether the test results of 101.6-mm (4.0-in.) diameter specimens were representative of the limerock base materials. A laboratory

testing program was undertaken to evaluate the effect of specimen size on the resilient properties of base materials.

Equipment and procedures for the tests are described as in the following selections.

3.3.1 Resilient Modulus Testing Equipment

An MTS model 810 closed-loop servo-hydraulic testing system and a resilient modulus triaxial testing system were used in this study. The major components of these systems are a loading system, digital controller, workstation computer, triaxial cell, and linear variable differential transducer (LVDT) deformation measurements system. The resilient modulus testing equipment is schematically shown in Figure 3.1. The following sections describe some of the most noteworthy equipment with respect to a loading system, triaxial cell, deformation measurement devices, and data acquisition and control systems.

Loading system. An MTS series 318 load unit consisting of a load frame and a hydraulic actuator was provided by MTS System Corporation. An MTS TestStar System was used to control the loading system from a workstation computer. A repeated dynamic load was programmed by a function generator

in the TestStar software from the computer. In this study, a haversine waveform of load shape was used. The loading pulse duration and the rest period were set at 0.1 and 0.9 seconds, respectively.

Triaxial cell. The triaxial cell (Figure 3.2) and transducers were provided by Research Engineering Inc. The external chamber is made of cast acrylic and can resist the maximum confining pressure of 689 kPa (100 psi). The confining fluid is limited by the air only. The cell is fitted with a safety release valve that is set to release at approximately 758 kPa (110 psi).

The cell came equipped with two pore pressure lines to the cap and two to the base. These four lines are connected to the pore pressure transducer stand through a 3.2 mm (1/8") tube from the valves on the cell to the fittings. The pore pressure to the cap or the base or both at same time can be monitored during the test from the transducer panel meter. This pressure is the inside pore pressure of the test sample. There are two valves attached to the transducer stand to release the air in the testing sample.

The cell or chamber pressure is provided by an air compressor and is adjusted by a pressure regulator. There is

also another pore pressure line connected from the valve on the bottom of the cell to the fitting on the pore pressure transducer stand. The cell pressure can be monitored by both a conventional gauge and a pressure transducer.

Deformation measurement devices. In this study, for the *T 292-91I* procedure, four LVDTs were mounted inside the triaxial cell. Two of them were positioned in the middle half length of the specimen (10.2-cm) by using 180-degree diametrically-opposed clamps around the specimen's axis (Figure 3.2). The other two diametrically-opposed LVDTs were attached to the top platen of the test specimen and rested on the top of the cell. For the *T 294-92* procedure, two LVDTs were attached to the piston rod outside of the chamber instead of using the LVDTs for the 20.3-cm measurement (Figure 3.3). Two extra LVDTs were positioned in the middle half length of the specimen (10.2-cm) by using of 180-degree diametrically-opposed clamps around the specimen's axis as for the *T 292-91I* procedure. In both procedures, all four LVDTs were adjustable and arranged around the specimen evenly. Calibrations were made periodically during the laboratory testing program. This setup was used to compare the resilient modulus measurements obtained from the LVDTs at

different locations. A ten-channel signal conditioner was used to condition, amplify, filter, and transmit the signal from the LVDTs to the TestStar data recording system.

Data acquisition and control system. The TestStar control system is designed in such a way that signal functioning, data acquisition, function generation, closed-loop servo-control, and hydraulic-pressure control are all provided within a single unit; thus, the user interacts with the control console entirely through the keyboard of a personal computer. A Compaq Deskpro 4/33i personal computer (486/33 processor) was used to control closed-loop servo feedback systems. The computer can be programmed to scan analog input channels, digitize the signal data, and compare the most recent data to the most current value of intended signal in a fracture of a millisecond.

There are three data modes to define how data is collected: 1) peak/valley levels of each cycle; 2) data at a specified time interval; and 3) data at each time an input channel signal changes a specified amount. Each of these modes can be used to acquire certain data. The mode of the peak and valley levels of each cycle were used in this study. The output of the data acquisition system included a graphic

display of sampled dynamic load and displacement waveforms and a data file. The data file format was selected for use with spreadsheet programs (Excel). The collected data were further processed by analyzing, plotting, or through a word processing program.

3.3.2 Resilient Modulus Test Procedures

The resilient modulus test procedures basically follow *AASHTO T 292-91I* and *T 294-92*. A deviation from the test procedure was made by using the two additional internally-mounted LVDTs for the full length measurements (*T 292-91I*) and two additional diametrically-opposed LVDTs around the axis of the specimen at the middle half length (*T 294-92*). The test procedures are described in the following sections.

Test setup (*T 292-91I*). Prior to testing, the compacted soil specimens were removed from the mold using an extruder. Using a vacuum membrane expander, the membrane was pulled over the specimen and perforated stones. The membrane-enclosed soil specimen with the perforated stones on the top and the bottom was placed onto the bottom platen in the triaxial chamber. The top platen was fitted in place, and the specimen membrane ends were folded over the platens and

secured with an O-ring. Two LVDT clamps were affixed to the upper and lower quarter points of the specimen (for 10.2-cm measurements). Special precaution was taken to ensure that the LVDT clamps were in a horizontal position. Then, two LVDTs were installed to the clamps. The other two LVDTs were mounted on the top platen to measure the resilient deformation of the entire 20.3-cm (8 in) long specimen. These four LVDTs were adjusted to the appropriate positions to permit enough travel distance during the testing. The assembly of the triaxial cell was completed by closing the triaxial chamber (Figure 3.2). The drainage valve to the specimen was left open.

Test setup (*T 294-92*). The test setup in this procedure is similar to the T 292 procedure except for the installation of two externally-mounted LVDTs instead of full length LVDTs. Two LVDT clamps were attached to the piston rod outside the chamber. Special precaution was taken to ensure that the LVDT clamps were in a horizontal position. Then, two LVDTs were installed to the clamps (Figure 3.3).

Specimen conditioning. Specimen conditioning was applied to simulate the stress history that exists in field

conditions. The procedures for specimen conditioning in both tests are described as follows:

1. Load the MTS load frame to the triaxial load cell, be sure that the load frame is firmly contacted with the triaxial load cell.

2. Turn on the air compressor machine to produce a confining chamber pressure of
   - 137.9 kPa for limerock base materials; 103.4 kPa for granular subgrade and embankment soils; and 20.7 kPa for cohesive soils (*T292-91I*) or
   - 103.42 kPa for granular material; 41.37 kPa for cohesive soil (*T 294-92*).

3. Zero the load reading from the control panel. Open a programmed templet from Testware program according to the test material. The programmed templets enable the loading device to produce a haversine wave with a fixed load duration of 0.1 second with a 0.9 second period of relaxation.

4. Begin the conditioning by applying 1000 repetitions of a corresponding deviator stress. Monitor the permanent axial deformation occurring during conditioning.

5. After completion of the specimen conditioning phase, monitor the permanent axial deformation occurring to the specimen throughout the remainder of the test. If the permanent axial strain exceeds five percent, the test should be terminated.

Confining pressure and loading sequences. Both AASHTO *T 292-91I* and *T 294-92* specify that after the specimen conditioning phase is completed, the testing phase should begin immediately. However, the resilient modulus values are very much affected by the deviatoric stresses in some cases, especially when a lower deviatoric stress follows a much higher one. Therefore, for this study, a 15- to 20-minute rest period was taken prior to the testing phase as suggested by Ping and Ge (1996).

Cohesive soils. In this study, cohesive specimens were tested at 20.7 kPa (*T 292-91I*) and 41.4 kPa (*T 294-92*), the

confining pressure, which represents a median value for subgrade and embankment. The test sequence for cohesive specimens is illustrated in Table 3.2. According to this table, a templet was created in the Testware software program to control the loading system and collect the load and deflection data.

Granular subgrade soils. Resilient properties of granular specimens are significantly affected by confining pressure. Therefore, granular specimens need to be tested over the range of confining pressures expected within the subgrade layer. The test sequence for granular subgrade soils is shown in Table 3.3. Also, a templet was created in the TestStar software program. In this test sequence, the confining pressures decrease while the deviatoric stresses increase during each confining pressure stage. A few of the specimens failed during the last several test sequences, however this failure did not affect data acquired from all previous data phases.

Cyclic loading procedures. After a 15- to 20-minute rest period from the specimen conditioning, the test phase was completed. The following procedures are suggested:

1. Open a templet, apply 50 repetitions (*T 292-91I*) or 100 repetitions (*T 294-92*) of smallest deviator stress at the highest (T 292-91I) or lowest (T 294 - 92) confining pressure. The average recoverable deformation of each repetition is recorded automatically.

2. Apply the same repetitions of each of the remaining deviator stresses to be used at the present confining pressure.

3. Decrease (T 292-91I) or increase (T 294-92) the confining pressure to the next desired level and adjust the deviator stress to the smallest value to be applied at this confining pressure. Prior to applying 50 repetitions (T 292-91I) or 100 repetitions (T 294-92) to the specimen, a 15 to 20-minute rest period was used.

4. Increase the deviator stress to the next desired level and continue the process of Steps 2 and 3

until testing has been completed for all desired stress states.

5. Disassemble the triaxial chamber and remove all apparatus from the specimen.

3.3.3 Large Diameter Specimen Testing Program

The primary objective of the large diameter specimen testing program was to investigate the specimen size effect on the resilient modulus of granular base and sub-base soils under in-situ moisture and density conditions. The equipment and procedures for the program were the same as for other laboratory resilient modulus testing programs to keep consistency. The only exception is the split mold used for the 152.4-mm (6.0-in.) diameter specimen preparation. The split mold has 152.4-mm (6.0-in.) in diameter and 304.8-mm (12-in.) in height. The sample extruder has a corresponding size plate adopter and a long travel length. It works well with both 4.0 inch and 6.0 inch split molds.

3.4 LBR Testing Program

The LBR testing program was performed to evaluate pavement bearing characteristics in Florida. All soil materials were taken from the field test sites. For each

type of soil, four to five specimens were compacted to perform the LBR test.

3.4.1 LBR Test Equipment and Procedures

Apparatus. The compaction test apparatus included: an automatic tester & recorder, a mechanical soil compactor, cylinder molds, spacer discs which are 5-15/16 inches in diameter and 1.41 inches in height, balances, a drying oven, a microwave oven, surcharge weight, a soak tank, a straight edge, a No. 4 sieve, mixing tools, filter papers, and miscellaneous tools such as mixing pans, spoon, trowel, and spatula.

Sample Preparation. The soil sample was damp when received from the field. It was dried overnight in a drying oven. Then the material passed through No. 4 sieves, taking care to thoroughly break up the aggregates in such a manner as to avoid reducing the natural size of the individual particles. Then the material was separated into four or five portions. Each weighed about 12.5 pounds and was thought to be a representative of the total. Each of the separate portions was thoroughly mixed with amounts of water sufficient to cause each of the moisture contents of the

samples to vary by one percentage point with the lowest moisture content being approximately two percentage points below the optimum moisture content so the moisture contents selected bracket the optimum moisture content.

Compaction. Immediately prior to compacting the material, a representative sample was taken from each portion for moisture content determination. The sample was weighed immediately before and after dried in a microwave oven and the results were recorded. Four or five molds were weighted separately and the results recorded. Then the spacer disc was inserted into the bottom of a mold and a specimen was formed by compacting the prepared soil in the six inch diameter mold (with collar attached) in five approximate equal layers to give a total compacted depth of about five inches. Each layer was compacted with 56 uniformly distributed blows from the rammer, dropping free from a height of 18 inches above the elevation of each finally compacted layer. A mechanical soil compactor manufactured by Rainhart Co. was used to achieve this purpose. After compaction, the extension collar was removed, and the compacted soil carefully trimmed even with the top of the mold by means of a straight edge. Holes in

the surface were patched with smaller sized material. A coarse filter paper was placed over the top surface. The mold was inverted. The spacer disc was removed and a filter paper inserted. The mold and moist soil were then weighed and the weight recorded. The above procedure was repeated for each increment of moisture content of soil samples.

Soaking and Penetration Testing. Four or five compacted specimens were placed in a soaking tank so that the height of the water remained 0.25 inches of the same elevation as the top of the soil sample in the mold. The soaking time was about two days. A surcharge of 2.5 pounds was placed on top of each sample during the entire soaking time. Before the actual penetration test was run, the specimen was removed from the soaking tank and allowed to drain for about 15 minutes. After draining, the swell plate was removed and the specimen tested immediately.

An automatic compression machine with automatic recording devices were in use in the laboratory (Figures 3.4 & 3.5). This equipment could eliminate hand recordings and the plotting of penetration tests.

Data Reduction and Plotting. During the test, the load-penetration curve was plotted on the recorder. In order to obtain true penetration loads from the test data, the zero point of the curve was adjusted to correct for any irregular shape of the curve if it was present.

If the curve was uniform as in example No. 1 of Figure 3.6, the LBR value was calculated from the recorded loads. For surface irregularities as in example No. 3 of Figure 3.6 the straight line portion of the curve was extended to the base to obtain a corrected origin, or zero. If the curve had a reverse bend, or concave upward shape, as in example No. 2, a line tangent to the steepest point of the curve (point A) was drawn to the base to obtain a corrected load values for 0.1 inches penetration (point C) and 0.2 in. penetration.

The corrected load obtained at 0.1 inch penetration was converted to the corrected stress by dividing three square inches, which was the area of the piston. The corrected stress was divided by 800 psi, which was the standard strength of limerock. The ratio was then multiplied by 100 to obtain the LBR value.

3.5 Other Routine Laboratory Tests

The soil properties measured in the laboratory were moisture content, wet unit weight, dry unit weight, sieve analysis, and index properties. These properties were required for analysis.

The procedures for the laboratory testing were generally in accordance with those suggested by the American Society for Testing and Materials (ASTM) with appropriate modification depending upon the type and nature of the soil samples.

Table 3.1 Summary of field test soils for experimental program

DISTRICT 1	Layer Modulus (MPa)	LBR	Wet Density (kN/m^3)	Dry Density (kN/m^3)	M.C (%)	AASHTO Classification
Lee Co., Site #1B, S.R. 884						
Base (Limerock)	336.4	65	20.08	17.47	15.1	Limerock
Subgrade (Fine Sand)	208.5	43	17.25	16.45	5.0	A-3
Embankment (Fine Sand)	71.9	19	17.46	15.60	12.0	A-3
Lee Co., Site #2B, S.R. 884						
Base (Limerock)	320.4	113	20.74	18.03	15.0	Limerock
Subgrade (Fine Sand)	334.9	49	17.51	17.09	2.5	A-3
Embankment (Fine Sand)	152.2	33	17.57	17.01	3.3	A-3
Polk Co., Site #1A, U.S. 17						
Base (Limerock)	365.3	110	21.59	19.87	8.8	Limerock
Subgrade (Silty Sand)	301.9	47	19.20	17.47	10.0	A-2-4
Embankment (Fine Sand)	107.8	16	18.67	17.04	9.6	A-3
Polk Co., Site #2A, U.S. 17						
Base (Limerock)	485.2	90	20.71	18.77	10.3	Limerock
Subgrade (Silty Sand)	287.5	64	19.03	17.53	8.6	A-2-4
Embankment (Fine Sand)	239.6	30	19.33	17.67	9.4	A-3

Table 3.1 (Continued)

DISTRICT 2	Layer Modulus (MPa)	LBR	Wet Density (kN/m^3)	Dry Density (kN/m^3)	M.C. (%)	AASHTO Classification
Alachua Co., Site #3, U.S. 301						
Base (Limerock)	930.7	118	21.07	19.12	10.2	Limerock
Subgrade (Fine Sand)	517.6	38	18.89	16.95	11.5	A-3
Embankment (Fine Sand)	86.3	29	18.34	16.37	12.1	A-2-4
Alachua Co., Site #4, U.S. 301						
Base (Lime rock)	943.8	90	20.60	18.63	10.6	Limerock
Subgrade (Silty Sand)		46	18.71	17.20	8.9	A-2-4
Embankment (Clay)	48.7	29	19.73	16.68	18.4	A-6
Clay Co., Site #5, U.S. 17						
Base (Limerock)	713.1	126	20.03	18.17	10.3	Limerock
Subgrade (Fine Sand)			17.10	15.89	8.2	A-2-4
Subgrade (Fine Sand)	310.5	49	16.78	15.43	8.9	A-2-4
Embankment (Silty Sand)	172.5	53	17.36	15.91	9.2	A-3
Clay Co., Site #6, U.S. 17						
Base (Limerock)	711.7	132	20.91	18.84	11.0	Limerock
Subgrade (Fine Sand)			17.99	16.01	12.3	A-3
Subgrade (Fine Sand)	287.5	43	17.72	15.76	12.4	A-3
Embankment (Fine Sand)	179.7	68	17.43	15.90	9.6	A-3

Table 3.1 (Continued)

DISTRICT 3	Layer Modulus (MPa)	LBR	Wet Density (kN/m^3)	Dry Density (kN/m^3)	M.C. (%)	AASHTO Classification
Jefferson Co. Site #1A, U.S. 27						
Base (Limerock)	495.0	128	20.75	18.46	12.5	Limerock
Subgrade (Silty Clay)	345.1	69	19.84	17.11	16.1	A-4
Embankment (Silty Clay)	90.8	61	18.12	16.24	11.6	A-2-6
Jefferson Co. Site #2A, U.S. 27						
Base (Limerock)	560.7	138	20.69	18.55	11.6	Limerock
Subgrade (Silty Clay)	258.8	116	21.18	19.34	9.6	A-4
Embankment (Silty Sand)	161.7	87	21.08	18.82	12.1	A-2-4
Gadsden Co. Site #2B, U.S. 27						
Base (Limerock)	805.1	96	20.94	18.90	10.8	Limerock
Subgrade (Silty Sand)	207.0	145	20.47	18.52	10.6	A-2-4
Embankment #1 (Silty Sand)	201.3	81	19.66	17.66	11.4	A-2-4
Embankment #2 (Clay)	143.8	59	19.64	16.72	17.5	A-6
Gadsden Co. Site #3B, U.S. 27						
Base (Limerock)	754.8	84	20.38	18.39	10.8	Limerock
Subgrade (Fine Sand)	355.8	121	20.05	18.60	7.9	A-3
Embankment (Clay)	107.8	54	19.80	16.27	21.7	A-6

Table 3.1 (Continued)

DISTRICTS 4 AND 6	Layer Modulus (MPa)	LBR	Wet Density (kN/m^3)	Dry Density (kN/m^3)	M.C. (%)	AASHTO Classification
Dade Co., Site #1, U.S. 41						
Base (Limerock)	924.9	128	22.04	20.75	6.2	Limerock
Subgrade (Limerock)	640.8	147	19.83	18.63	7.3	Limerock
Embankment (Limerock)	492.9	172	20.86	19.09	9.2	Limerock
Dade Co., Site #2, U.S. 41						
Base (Limerock)	796.3	121	22.59	21.02	7.5	Limerock
Subgrade (Limerock)	766.8	125	21.98	20.31	7.9	Limerock
Embankment (Limerock)	479.2	100	20.33	18.74	8.5	Limerock
Martin Co., Site #3, U.S. 1						
Base (Limerock)	546.3	191	21.35	20.18	5.8	Limerock
Subgrade (Fine Sand)	985.8	70	18.67	18.03	3.6	A-3
Embankment (Fine Sand)	82.1	21	17.55	17.20	2.1	A-3
Martin Co., Site #4, U.S. 1						
Base (Limerock)	628.5	122	20.83	19.46	7.1	Limerock
Subgrade (Silty Clay)	271.1	45	19.08	18.25	4.6	A-4
Embankment (Fine Sand)	123.2	29	17.88	17.22	3.9	A-3

Table 3.1 (Continued)

DISTRICT 5	Layer Modulus (MPa)	LBR	Wet Density (kN/m^3)	Dry Density (kN/m^3)	M.C. (%)	AASHTO Classification
Seminole Co., Site #1, U.S. 414						
Base (Limerock)	431.3	109	21.15	19.43	8.8	Limerock
Subgrade (Silty Sand)	143.8	79	18.86	17.59	7.2	A-2-4
Embankment (Silty Sand)	172.5	20	18.90	17.67	7.0	A-2-4
Seminole Co., Site #2, U.S. 414						
Base (Limerock)	362.3	112	19.94	18.21	9.4	Limerock
Subgrade (Silty Sand)	188.2	93	19.73	17.81	10.8	A-2-4
Embankment (Fine Sand)	156.8	31	18.31	16.54	10.7	A-3
Osceola Co., Site #3, U.S. 441						
Base (Coquina)	608.9	146	21.05	20.15	4.5	Coquina
Subgrade (Fine Sand)	258.8	56	19.34	18.61	4.0	A-3
Embankment (Fine Sand)	143.8	18	16.88	16.31	3.6	A-3
Osceola Co., Site #4, U.S. 441						
Base (Coquina)	388.2	211	21.70	20.81	4.2	Coquina
Subgrade (Fine Sand)	214.5	85	20.47	19.18	6.8	A-3
Embankment (Fine Sand)	93.3	60	18.71	18.02	3.9	A-3

Table 3.2 Comparison of Three M_R Test Procedures for Cohesive Soils

Test Procedure	AASHTO T 274-82			AASHTO T 292-91I			AASHTO T 294-92		
	Conf. Pressure	Dev. Stress	Reps.	Conf. Pressure	Dev. Stress	Reps.	Conf. Pressure	Dev. Stress	Reps.
	kPa	kPa		kPa	kPa		kPa	kPa	
Specimen Condition	41.3	6.9	200	20.7	20.7*	1000	41.3	27.5	1000
		13.8	200		41.3**	1000			
		27.5	200						
		55.1	200						
		68.9	200						
Testing	41.3	6.9	200	20.7	20.7	50	41.3	13.8	100
	20.7	6.9	200	20.7	34.5	50	41.3	27.5	100
	0	6.9	200	20.7	48.2	50	41.3	41.3	100
	41.3	13.8	200	20.7	68.9	50	41.3	55.1	100
	20.7	13.8	200	20.7	103.4	50	41.3	68.9	100
	0	13.8	200				20.7	13.8	100
	41.3	27.5	200				20.7	27.5	100
	20.7	27.5	200				20.7	41.3	100
	0	27.8	200				20.7	55.1	100
	41.3	55.1	200				20.7	68.9	100
	20.7	55.1	200				0	13.8	100
	0	55.1	200				0	27.5	100
	41.3	68.9	200				0	41.3	100
	20.7	68.9	200				0	55.1	100
	0	68.9	200				0	68.9	100

* for specimen with shearing strength less than or equals to 6890 kPa

** for specimen with shearing strength more than 6890 kPa

Table 3.3 Comparison of Three M_R Test Procedures for Granular Soils

Test Procedure	AASHTO T 274-82			AASHTO T 292-91I						AASHTO T 294-92		
				Subgrade Soils			Base/Subbase Materials					
	Conf. Pressure	Dev. Stress	Reps.	Conf. Pressure	Dev. Stress	Reps.	Conf. Pressure	Dev. Stress	Reps.	Conf. Pressure	Dev. Stress	Reps.
	kPa	kPa		kPa	kPa		kPa	kPa		kPa	kPa	
Specimen Condition	34.5	34.5	200	103.4	82.3	1000	137.8	103.4	1000	103.4	103.4	1000
	34.5	68.9	200									
	68.9	68.9	200									
	68.9	103.4	200									
	103.4	103.4	200									
	103.4	137.8	200									
Testing	137.8	6.9	200	103.4	48.2	50	137.8	68.9	50	20.7	20.7	100
	137.8	13.8	200	103.4	68.9	50	137.8	137.8	50	20.7	41.3	100
	137.8	34.5	200	103.4	103.4	50	137.8	206.7	50	20.7	62	100
	137.8	68.9	200	68.9	34.5	50	137.8	275.6	50	34.5	34.5	100
	137.8	103.4	200	68.9	48.2	50	103.4	68.9	50	34.5	68.9	100
	137.8	137.8	200	68.9	68.9	50	103.4	137.8	50	34.5	103.4	100
	103.4	6.9	200	68.9	103.4	50	103.4	206.7	50	68.9	68.9	100
	103.4	13.8	200	34.5	20.7	50	103.4	275.6	50	68.9	137.8	100
	103.4	34.5	200	34.5	34.5	50	68.9	34.5	50	68.9	206.7	100
	103.4	68.9	200	34.5	48.2	50	68.9	68.9	50	103.4	68.9	100
	103.4	103.4	200	34.5	68.9	50	68.9	137.8	50	103.4	103.4	100
	103.4	137.8	200	13.8	20.7	50	68.9	206.7	50	103.4	206.7	100
	68.9	6.9	200	13.8	34.5	50	34.5	34.5	50	137.8	103.4	100
	68.9	13.8	200	13.8	48.2	50	34.5	68.9	50	137.8	206.7	100
	68.9	34.5	200				34.5	103.4	50	137.8	275.6	100
	68.9	68.9	200				20.7	34.5	50			
	68.9	103.4	200				20.7	48.2	50			
	34.5	6.9	200				20.7	62	50			
	34.5	13.8	200									
	34.5	34.5	200									
	34.5	68.9	200									
	34.5	103.4	200									
	6.9	6.9	200									
	6.9	13.8	200									
	6.9	34.5	200									
	6.9	51.7	200									
	6.9	68.9	200									

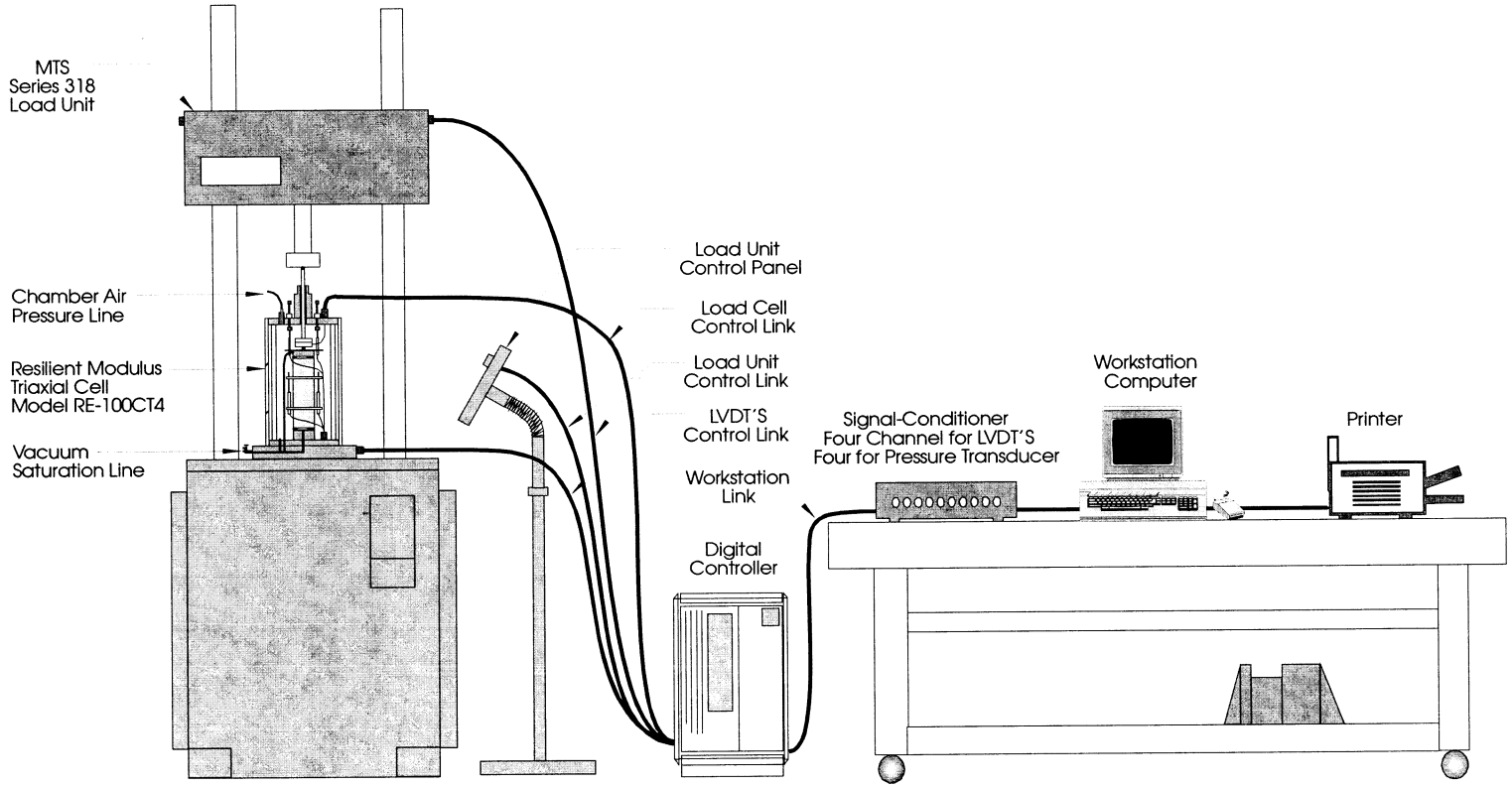


Figure 3.1 Sketch of the resilient modulus testing equipment

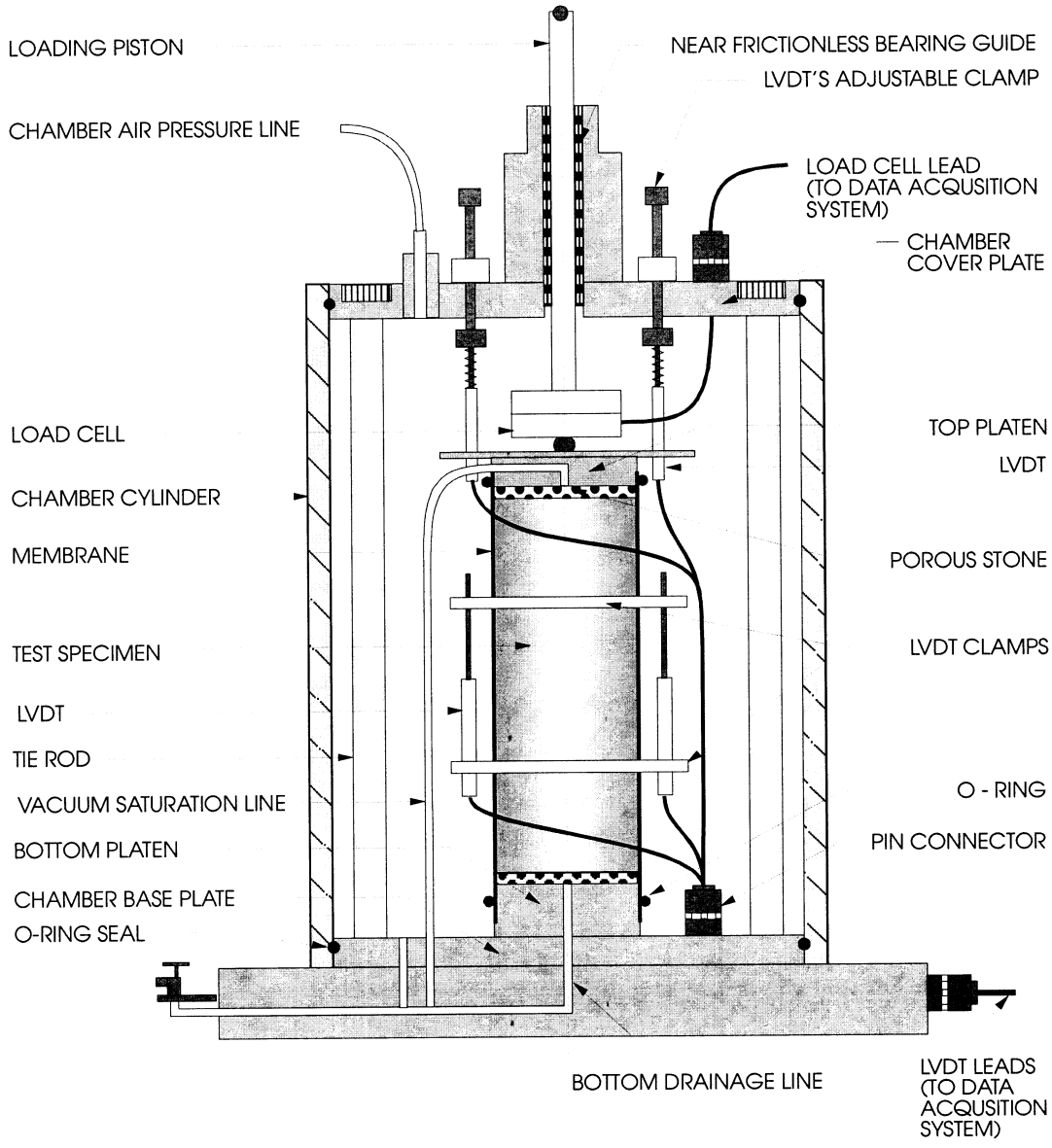


Figure 3.2 Triaxial chamber with internal LVDTs and load cell

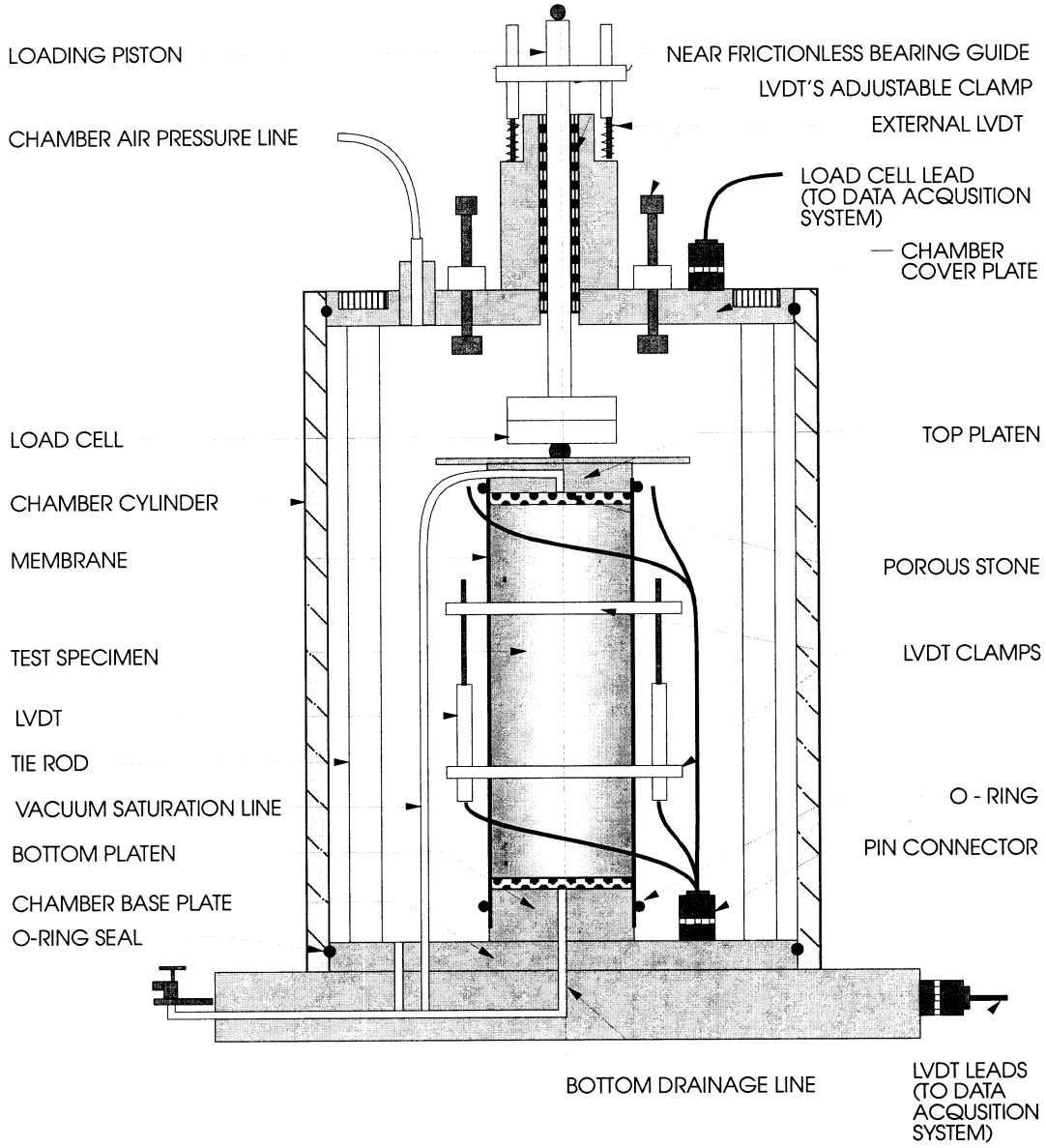


Figure 3.3 Triaxial chamber with middle and external LVDTs (T294)

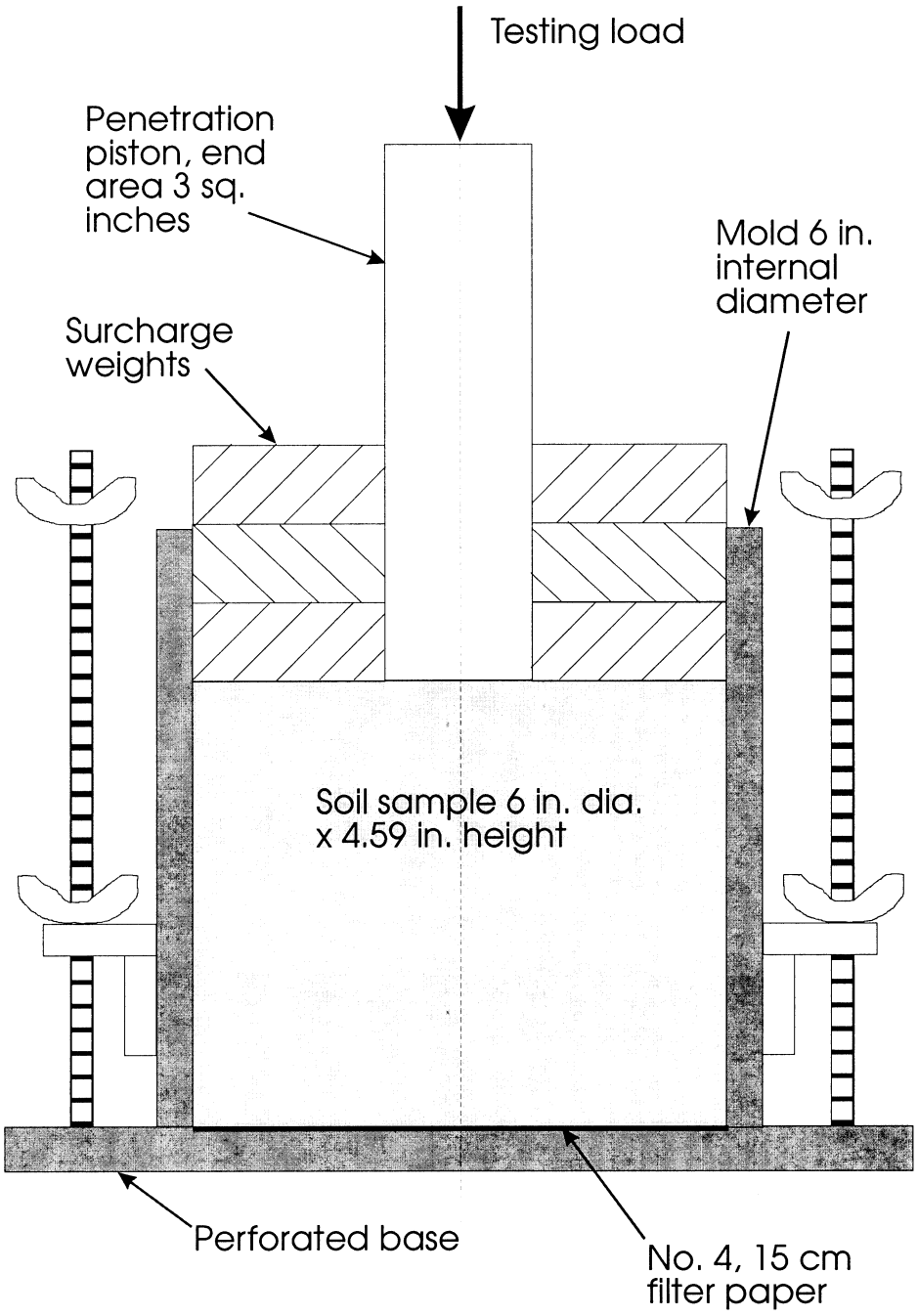


Figure 3.4 Penetration machine

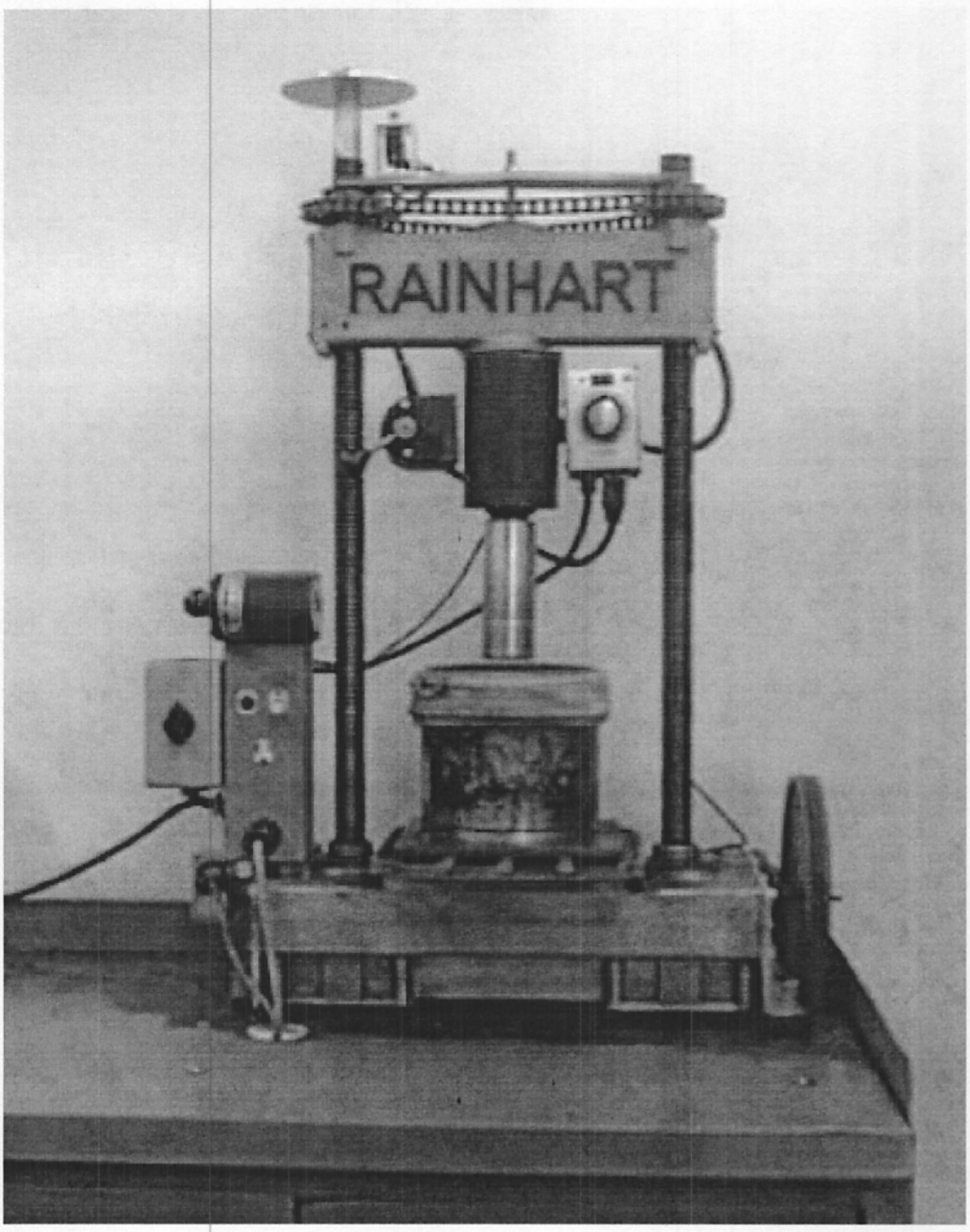


Figure 3.5 Automatic tester

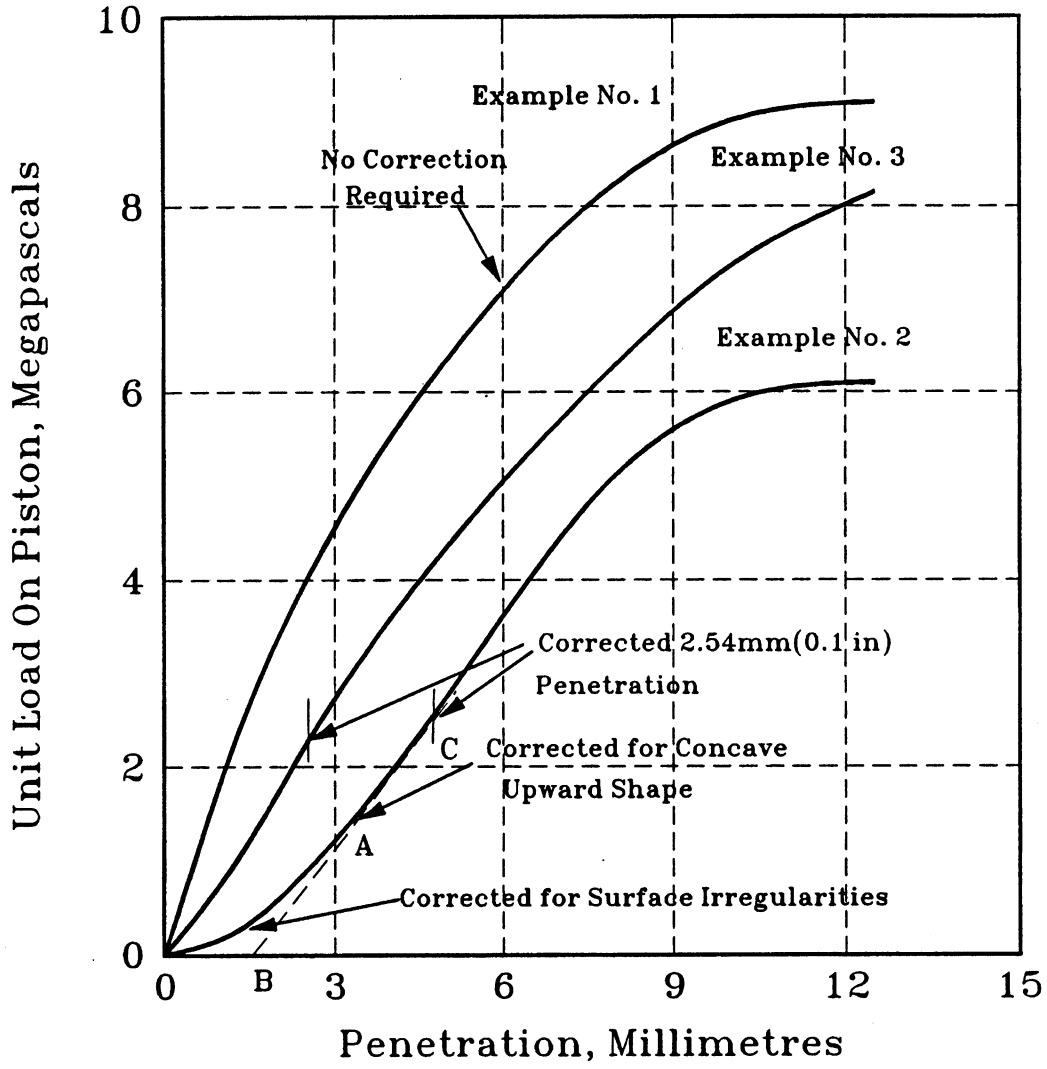


Figure 3.6 Correction of load-penetration curves

CHAPTER 4

SUMMARY AND PRESENTATION OF FIELD TEST RESULTS

4.1 General

A field experimental program was conducted to evaluate the supporting characteristics of in-situ pavement layers. The field tests are described in Chapter 2. This chapter summarizes the test results obtained from the field experimental program. Raw FWD deflection data were backcalculated to determine the pavement moduli. The plate load test results were calibrated by using secant modulus concept. Dynaflect deflection sensor No.4 readings were used for analysis. All the field test results are summarized in Table 4.1 for ease of comparison.

4.2 Falling Weight Deflectometer Test Results

The falling weight deflectometer test was performed in the very beginning of the field investigation at each test site. The test was primarily conducted in wheel-paths since the pavement response at these paths reflected the effect of traffic damage that had been accumulated. After obtaining

raw deflection data from the FWD field test, a backcalculation method was used to determine the modulus of pavement layers. The raw data of the FWD tests and the results of the FWD backcalculation for each district are presented in Appendix A.

4.2.1 Method of Backcalculation

The main principle of all the available procedures of back-calculation analysis is to assume a set of pavement moduli in a hypothetical multilayer elastic system and then use iteration or optimization procedures to calculate theoretical deflections by varying layer moduli until a tolerable match of measured deflection is made. Varieties of computerized programs based on the elastic behavior of multilayer pavement structure have been suggested for backcalculating layer moduli. In these programs, such as ELSDEF, MODCOMP4, EVERCALC, and MODULUS, the theoretical deflection basin and pertaining pavement parameters can be obtained by using a closed form solution.

The principle is illustrated in Figure 4.1 in which measured deflections are results obtained from the field FWD test. Pavement layer thickness and loads are known. By giving seed moduli and Poisson's ratios of all pavement

layers, the program will perform a certain number of trial backcalculations to best match measured deflection basins. Finally, a set of suggested layer elastic moduli and computation error are presented.

Only two material parameters (Young's modulus and Poisson's ratio) are needed to describe the possible deformation in linear elastic theory, which is one of the major reasons why layer elastic theory is used by many backcalculation programs. In backcalculation, the less important parameter, Poisson's ratio is usually assumed with the typical value and only the Young's modulus of each layer must be calculated to match the surface deflections.

4.2.2 Backcalculation Results

In this study, the backcalculation program MODULUS 5.0 was selected to determine the moduli of the tested pavement sections. There are two main reasons for selecting MODULUS 5.0 program for this study. The first one is the acquaintance of the FDOT pavement evaluation division with the program and the large data base of pavement evaluation compiled through years of using MODULUS. The second reason is the favorable conclusion of several studies on the reliability and repeatability of backcalculation methods for

the pavement evaluation. In addition, the converge time and convenient-for-use features are also among the consideration factors when MODULUS 5.0 was chosen as a backcalculation program. The backcalculation results are presented in Table 4.1.

4.3 Plate Bearing Load Test Results

Load-deflection curves were obtained from the plate bearing load test. Typical load versus deflection curves of the plate load test for the embankment layer, subgrade/embankment layers, and base/subgrade/embankment layers are presented in Figures 4.2 through 4.4 for illustration. The residual deflection was determined by connecting the straight portion of the load-deflection curve with a straight line that intersected the X-Coordinate. The intercept deflection value was the corrected deflection value induced by the seating loads. The first portion of the load-deflection curve was a straight line and, then, the curve started to have relatively slight curvatures before any break or considerable increase in curvature occurred. In order to interpret the modulus from load-deflection curve, a theory using hyperbolic model is introduced as follows.

4.3.1 Analysis of Load-Deformation Characteristics

In the field testing program the number of load applications, the angle of internal friction, and the geometry of the bearing plate are constant. Based on this information, after analyzing the data obtained from the field plate load test, a two-constant hyperbolic model that may represent the relation of the load-deformation is given below:

$$P = \frac{\Delta}{a + b\Delta} \qquad (4.1)$$

Where p = load

Δ = deformation

a, b = constant

or rearranging Equation 4.1 yields:

$$\frac{\Delta}{P} = a + b\Delta \qquad (4.2)$$

Corresponding to this model, Figure 4.5 is a rectangular hyperbola passing through the origin of the coordinate in a load-deformation curve.

By differentiating Equation 4.1 with respect to the deformation and evaluation the derivative at Δ equal to zero gives:

$$\left(\frac{dP}{d\Delta}\right)_{\Delta\to 0} = 1/a \qquad (4.3)$$

4.3.1.1 Hyperbolic Model Study

In order to determine the modulus of materials in situ by means of plate load tests, some assumptions concerning material behavior must be made. For example, from the results of a plate load test on a circular rigid plate at the surface of a homogeneous, isotropic elastic solid, an apparent modulus of the material can be determined from the following expression derived from the theory of elasticity:

$$E = \frac{\pi\sigma_0 r}{2\Delta}(1-\nu^2) \qquad (4.4)$$

where

E = the modulus of elasticity of the material

σ_0 = the pressure applied to the surface of the plate

r = the radius of the plate = 152.4 mm (6 in.)

Δ = the deflection of the plate associated with the pressure

ν = Poisson's ratio.

If ν=0.35, Equation 4.4 becomes the familiar expression,

$$\mathbf{E = 1.38}\,\frac{\sigma_0 r}{\Delta} \qquad (4.5a)$$

If ν=0.5,

$$\mathbf{E = 1.18}\,\frac{\sigma_0 r}{\Delta} \qquad (4.5b)$$

while

$$\sigma_0 = \frac{P}{\pi r^2} \qquad (4.6)$$

So Equation 4.5 (assuming $\nu = 0.35$ for granular soils) can be written as:

$$\mathbf{E} = \mathbf{288.23}\frac{P}{\Delta} \quad \text{(MPa)} \qquad (4.7)$$

where

E = the modulus of elasticity of the material (MPa)

P = load ($X10^3$ N)

Δ = the deformation of the plate associated with the load P ($X10^{-5}$ m)

Replacing Equation 4.3 $[(P/\Delta)_{\Delta\rightarrow} = 1/a]$ into Equation 4.7, the initial tangent modulus, E_i is given by Equation 4.8 as the inverse of the intercept, a, of the straight line form on the Δ/P axis of Figure 4.6 times 288.23.

$$E_i = \frac{\mathbf{288.23}}{a} \quad \text{(MPa)} \qquad (4.8)$$

The ultimate value of the load can be obtained by taking the mathematical limit of Equation 4.1 as the deformation becomes excessive:

$$\mathbf{P_{ult}} = \lim_{\Delta \to \infty} \mathbf{P} = \frac{1}{b} \quad (\text{x}10^3 \text{ N}) \qquad (4.9)$$

Thus, the ultimate load of the soil is measured by the inverse of the slope of the straight line as given in Figure 4.6.

Present knowledge in the field clearly indicates that if Equation 4.2 can be used to represent the response of sand in the plate load test, the intercept, a, and the slope, b, will both be functions of the relative density of the sand and test conditions.

A good agreement between the observed and computed deformations of the plate load tests under different loads for sandy embankment soils in Florida is shown in Figures 4.7 and 4.8.

From Equation 4.1 we know

$$\frac{P}{\Delta} = \frac{1 - bP}{a} \qquad (4.10)$$

Replacing Equation 4.10 into Equation 4.7, it can be seen that the modulus of elasticity is the function of load P, that is

$$E = 288.23(\frac{1-bP}{a}) = f(P) \quad \text{(MPa)} \qquad (4.11)$$

Integrating f (P) in the whole load range from zero to the ultimate load, the average modulus can be obtained as the following:

$$\overline{E} = \frac{\int_0^{P_{ult}} EdP}{P_{ult}} = \frac{288.23}{P_{ult}} \int_0^{P_{ult}} \frac{1-bP}{a} dP \qquad (4.12)$$

Replacing Equation 4.9 into Equation 4.12 and integrating:

$$\overline{E} = \frac{288.23}{2a} = \frac{144.12}{a} \qquad \text{(MPa)} \qquad (4.13)$$

Comparing Equation 4.8 with Equation 4.13, the relation between the average modulus and initial tangent modulus can be expressed as:

$$E_i = 2\overline{E} \qquad (4.14)$$

4.3.1.2 Secant Modulus Concept

In the two-constant hyperbolic model, the strength parameter was assumed to be related to the shape of the load-deformation parameter curve. From Equation 4.11, the modulus was dependent on the load P so that various modulus values were obtained due to the different applied load. Therefore, the use of a secant modulus seemed to be a logical approach to the analysis. The modulus in Equation 4.7 can be considered as a secant modulus. It is necessary to find out the load that makes a secant modulus to be equal to the average modulus. That is:

$$\overline{E} = E_{Secant} \qquad (4.15)$$

From Equations 4.7 and 4.13, the Equation 4.15 can be rewritten as:

$$288.23\frac{P}{\Delta} = \frac{144.12}{a} \qquad (4.16)$$

Replacing Equation 4.10 into Equation 4.16 and simplifying, it yields:

$$2(1 - bP) = 1 \qquad (4.17)$$

Thus:

$$P = \frac{1}{2b} \qquad (4.18)$$

while 1/b = P_{ult} , the Equation 4.18 can be expressed as:

$$P = \frac{1}{2}P_{ult} \qquad (4.19)$$

From Equation 4.19, it can be seen that the secant modulus will be equal to the average modulus when the applied load is equal to half of the ultimate load applied to the soil. That is:

$$E_{secant}(at\ P = \frac{1}{2}P_{ult}) = \overline{E} \qquad (4.20)$$

Figure 4.9 is a rectangular hyperbolic representation of secant modulus in a load-deformation curve.

4.3.2 Method of Computation for Layer System

The theory of stresses and displacements in a two-layer system was developed in accordance with the method of the theory of elasticity by D. M. Burmister in the early 1940s. The general solution of the two-layer problem is based on following assumptions and conditions:

(1) Each layer is homogeneous, isotropic, and linearly elastic with an elastic modulus E and a Poisson ratio ν.

(2) The material is weightless.

(3) The surface layer No. 1 is assumed to be infinite in extent in the horizontal direction, but of finite thickness (h). The underlying layer No. 2 is assumed to be infinite in extent in the horizontal and vertical (downward) directions.

(4) The boundary and continuity conditions require that the layers are in continuous contact and that the surface

layer is free of shearing and normal stresses outside the loaded area.

Figure 4.10 illustrates a two-layer system.

When Poisson's ratio ν = 0.5, the settlement equations given by D.M. Burmister are:

for flexible plate:

$$\Delta = 1.5pa\,F_2 / E_2 \tag{4.21a}$$

for rigid plate:

$$\Delta = 1.18\,paF_2 / E_2 \tag{4.22a}$$

When Poisson's ratio ν = 0.35, the settlement equations given by D.M. Burmister are:

for flexible plate:

$$\Delta = 1.755pa\,F_2 / E_2 \tag{4.21b}$$

for rigid plate

$$\Delta = 1.38\,paF_2 / E_2 \tag{4.22b}$$

Where Δ = surface deflection at the center of the circular plate

p = unit load on circular plate

a = radius of plate

E_2 = modulus of elasticity of lower layer

F_2 = dimensionless factor depending on the ratio of moduli of elasticity of No. 2 layer and No. 1 layer as well as the depth to radius ratio

The modulus of elasticity (E_{eR}) of the equivalent base/subgrade layer or subgrade/embankment layer of plate bearing test can be obtained by rewriting the basic D. M. Burmister's equation for rigid plate test as the following:

$$E_{eR} = 1.18pa/\Delta \quad (\nu = 0.5) \tag{4.23a}$$

$$E_{eR} = 1.38pa/\Delta \quad (\nu = 0.35) \tag{4.23b}$$

Where E_{eR} = modulus of elasticity of combined base/subgrade layer or subgrade/embankment

Δ = deflection

Burmister's two-layer deflection factor can be expressed as:

$$F_2 = E_{2R}/E_{eR} \tag{4.24}$$

Where E_{2R} = modulus of elasticity of lower layer

The equivalent modulus (E_{eR}) of combined pavement layers were obtained from the field plate bearing tests as presented in Table 4.1.

4.3.3 Computational Procedure

From the plate load test results, the deflection curves of embankment, subgrade/embankment, and base/subgrade/ embankment were plotted. By using regression methods, the parameters *a* and *b* from these curves were obtained. Then using equation 4.9 ($P_{ult} = \frac{1}{b}$), P_{ult} was calculated from equations 4.10 and 4.19, the deflection value Δ and the corresponding unit load p were determined and used to get secant layer modulus values.

To determine the secant layer modulus for each pavement layer, Burmister's two-layer theory was repeatedly used. At the third stage of the plate load test, the secant modulus of the embankment layer was calculated directly from the equation (4.23) and at the second stage of the test (as a typical two-layer problem), F_2 was determined by using equations (4.23) and (4.24). Then from Burmister's curves of F_2, the ratio of the elastic moduli was obtained and the

secant modulus of subgrade was determined. At the first stage of the test, the subgrade and embankment soils were considered as one layer of soil with an equivalent modulus, which combined subgrade and embankment modulus with an infinite depth. Equations (4.23) and (4.24) and Burmister's curves of F_2 were used again to obtain the secant modulus of elasticity of the base layer.

Computer program ELSYM5 was used to calculate the load-deflection curve based on the field test condition.

The ELSYM5 program is based on an elastic layered computer model. The program assumes that each layer is composed of weightless, homogeneous, isotropic materials. The materials behave in an ideally elastic manner, according to Hooke's law. Each layer needs to be uniform thickness and infinite width in all horizontal directions. The bottom elastic layer may be semi-infinite in thickness or may be given a finite thickness, in which case the program assumes the bottom elastic layer is supported by a rigid base. The boundaries between the layers are assumed to be full friction. The surface is free of shear and the loads applied there are assumed to be identical, vertical, and uniform over a circular area.

The modulus of elasticity for each layer along with the load data were input into the computer program, then the deflections were obtained as output. It should be noted that since the field test was performed on a rigid plate, a factor of non-uniform pressure of 1.18/1.5 or 1.38/1.755, i.e. 0.787, was used to modify the deflection values, which refer to the equations (4.21) and (4.22). When the deflection value matched the Δ that was obtained from equation 4.10, the modulus value then can be used as secant modulus. The results are presented in Table 4.1.

4.4 Dynaflect Test Results

4.4.1 Method of Backcalculation

In 1981, the Florida Department of Transportation conducted an extensive study to correlate the Dynaflect deflections to the in-situ elastic moduli of the natural subgrade or embankment soils as determined by the 12-inch field plate bearing test. It was found that a relationship exists between the Dynaflect deflection sensor No.4 readings and the plate layer modulus of elasticity (E) value. Based on this study, the FDOT has developed correlation curves between the Dynaflect deflections and the Soil Support Value (SSV) and the resilient modulus of the roadbed soil. FDOT

has been successfully using these curves for the design and rehabilitation of pavements over the last decade.

Dynaflect method, however, has had its technical limitations. Among these limitations, a peak-to-peak load was limited to 1,000 lb. (4.45 kN), the load could not be varied, and the frequency of loading could not be changed. The deflection directly under the load could not be measured, and it was difficult to determine the contact area. Additionally, the available back-calculation methods could not be used directly to obtain the geometrical and mechanical properties of the pavement layers. Use of some empirical or semi-empirical back-calculation analysis may involve some uncertainties.

4.4.2 Backcalculation Results

After deflection data was obtained from Dynaflect field tests, great efforts were made to use the MODCOMP program for backcalculating pavement layer moduli. However, all the backcalculated values were beyond the error tolerance. The results were not very usable. Therefore, the FDOT's method was adopted which uses Dynaflect deflection sensor No.4 reading data that correlates directly with

plate layer moduli of embankment soils. The deflections of No.4 sensor reading data are presented in Table 4.1.

Table 4.1 Summary of Modulus of Field Test Results

DISTRICT 1	Thickness	Depth	PLT		FWD		DYN	
			Modulus		Modulus		No.4 Sensor Reading	
	cm	cm	MPa	ksi	MPa	ksi	10^{-3}mm	mils
Lee Co., Site #1B, S.R.884	5.1	5.1						
Base(Limerock)	24.1	29.2	171.01	24.82	335.10	48.60		
Subgrade(Fine Sand)	30.5	59.7	131.53	19.09	217.88	31.60		
Embankment(Fine Sand)	148.6	208.3	48.68	7.07	143.42	20.80	3.81	0.15
Lee Co., Site #2B, S.R.884	3.8	3.8						
Base(Limerock)	24.1	27.9	187.34	27.19				
Subgrade(Fine Sand)	30.5	58.4	186.10	27.01				
Embankment(Fine Sand)	149.9	208.3	103.18	14.98			3.30	0.13
Polk Co., Site #1A, U.S. 17	7.6	7.6						
Base(Limerock)	22.9	30.5	261.54	37.96	416.46	60.40		
Subgrade(Silty Sand)	35.6	66.0	211.25	30.66	253.05	36.70		
Embankment(Fine Sand)	147.3	213.4	48.68	7.07	279.94	40.60	4.57	0.18
Polk Co., Site #2A, U.S. 17	7.6	7.6						
Base(Limerock)	22.9	30.5	286.62	41.60	439.90	63.80		
Subgrade(Silty Sand)	33.0	63.5	183.62	26.65	303.38	44.00		
Embankment(Fine Sand)	149.9	213.4	141.20	20.49	269.59	39.10	4.06	0.16

Table 4.1 (continued)

DISTRICT 2	Thickness	Depth	PLT		FWD		DYN	
			Modulus		Modulus		No.4 Sensor Reading	
	cm	cm	MPa	ksi	MPa	ksi	10^{-3}mm	mils
Alachua Co., Site #3, U.S. 301	10.2	10.2						
Base(Limerock)	24.1	34.3	518.06	75.19				
Subgrade(Fine Sand)	30.5	64.8	268.16	38.92				
Embankment(Fine Sand)	142.2	207.0	67.58	9.81			4.06	0.16
Alachua Co., Site #4, U.S. 301	8.9	8.9						
Base(Limerock)	22.9	31.8	573.94	83.30				
Subgrade(Silty Sand)	20.3	52.1	1350.44	196.00				
Embankment(Fine Sand)	191.8	243.8	54.47	7.91			3.30	0.13
Clay Co., Site #5, U.S. 17	14.0	14.0						
Base(Limerock)	20.3	34.3	216.62	31.44				
Subgrade(Fine Sand)	30.5	64.8	135.39	19.65				
Embankment(Fine Sand)	118.1	182.9	119.77	17.38			5.84	0.23
Clay Co., Site #6, U.S. 17	15.2	15.2						
Base(Limerock)	17.8	33.0	276.19	40.09				
Subgrade(Fine Sand)	35.6	68.6	129.97	18.86				
Embankment(Fine Sand)	144.8	213.4	110.10	15.98			5.59	0.22

Table 4.1 (continued)

DISTRICT 3	Thickness	Depth	PLT		FWD		DYN	
			Modulus		Modulus		No.4 Sensor Reading	
	cm	cm	MPa	ksi	MPa	ksi	10^{-3}mm	mils
Jefferson Co., Site #1A, U.S.27	11.4	11.4						
Base(Limerock)	16.5	27.9	171.22	24.85	255.12	37.00		
Subgrade(Silty Clay)	16.5	44.5	131.19	19.04	208.23	30.20		
Embankment(Silty Clay)	138.4	182.9	82.33	11.95	188.23	27.30	2.79	0.11
Jefferson Co., Site #2A, U.S.27	12.1	12.1						
Base(Limerock)	19.1	31.1	192.92	28.00				
Subgrade(Silty Clay)	29.2	60.3	141.59	20.55				
Embankment(Silty Sand)	122.6	182.9	115.06	16.70			3.05	0.12
Gadsden Co., Site #2B, U.S. 27	9.9	9.9						
Base(Limerock)	24.4	34.3	219.45	31.85	226.85	32.90		
Subgrade(Silty Sand)	49.5	83.8	108.04	15.68	146.86	21.30		
Embankment #1 (Silty Sand)	99.1	182.9	82.27	11.94	126.87	18.40	2.54	0.10
Gadsden Co., Site #3B, U.S. 27	8.9	8.9						
Base(Limerock)	21.6	30.5	212.21	30.80	219.26	31.80		
Subgrade(Fine Sand)	58.4	88.9	120.58	17.50	122.04	17.70		
Embankment(Clay)	91.4	180.3	94.46	13.71	113.77	16.50	2.29	0.09

Table 4.1 (continued)

DISTRICT 4 AND6	Thickness	Depth	PLT		FWD		DYN	
			Modulus		Modulus		No.4 Sensor Reading	
	cm	cm	MPa	ksi	MPa	ksi	10^{-3}mm	mils
Dade Co., Site #1, U.S. 41	8.1	8.1						
Base(Limerock)	33.0	41.1	647.52	93.98	601.24	87.20		
Subgrade(Limerock)	33.0	74.2	441.30	64.05	493.68	71.60		
Embankment(Limerock)	165.1	239.3	421.79	61.22	483.34	70.10	1.02	0.04
Dade Co., Site #2, U.S. 41	7.6	7.6						
Base(Limerock)	24.1	31.8	557.80	80.96				
Subgrade(Limerock)	31.8	63.5	498.23	72.31				
Embankment(Limerock)	180.3	243.8	346.57	50.30				
Martin Co., Site#3, U.S. 1	10.2	10.2						
Base(Limerock)	25.4	35.6	245.97	35.70	511.61	74.20		
Subgrade(Fine Sand)	40.6	76.2	178.45	25.90	383.36	55.60		
Embankment(Fine Sand)	167.6	243.8	58.22	8.45	346.13	50.20	3.30	0.13
Martin Co., Site#4, U.S. 1	7.6	7.6						
Base(Limerock)	22.9	30.5	255.62	37.10	590.90	85.70		
Subgrade(Silty Clay)	30.5	61.0	125.40	18.20	457.14	66.30		
Embankment(Fine Sand)	182.9	243.8	90.42	13.12	262.70	38.10	5.08	0.20

Table 4.1 (continued)

DISTRICT 5	Thickness	Depth	PLT		FWD		DYN	
			Modulus		Modulus		No.4 Sensor Reading	
	cm	cm	MPa	ksi	MPa	ksi	10^{-3}mm	mils
Seminole Co., Site #1, U.S.414	15.2	15.2						
Base(Limerock)	30.5	45.7	266.71	38.71	393.70	57.10		
Subgrade(Silty Sand)	30.5	76.2	110.58	16.05	367.50	53.30		
Embankment(Silty Sand)	76.2	152.4	109.91	15.95	214.43	31.10	4.83	0.19
Seminole Co., Site #2, U.S.414	15.2	15.2						
Base(Limerock)	30.5	45.7	248.38	36.05	419.91	60.90		
Subgrade(Silty Sand)	34.3	80.0	99.15	14.39	300.62	43.60		
Embankment(Fine Sand)	76.2	156.2	95.01	13.79	164.10	23.80	4.32	0.17
Osceola Co., Site #3, U.S. 441	7.9	7.9						
Base(Coquina)	20.3	28.2	337.61	49.00	1003.91	145.60		
Subgrade(Fine Sand)	45.7	73.9	114.79	16.66	346.82	50.30		
Embankment(Fine Sand)	78.5	152.4	58.22	8.45	188.92	27.40	5.08	0.20
Osceola Co., Site #4, U.S. 441	14.0	14.0						
Base(Coquina)	27.9	41.9	295.17	42.84	489.55	71.00		
Subgrade(Fine Sand)	45.7	87.6	111.89	16.24	206.85	30.00		
Embankment(Fine Sand)	64.8	152.4	57.28	8.31	148.93	21.60	4.57	0.18

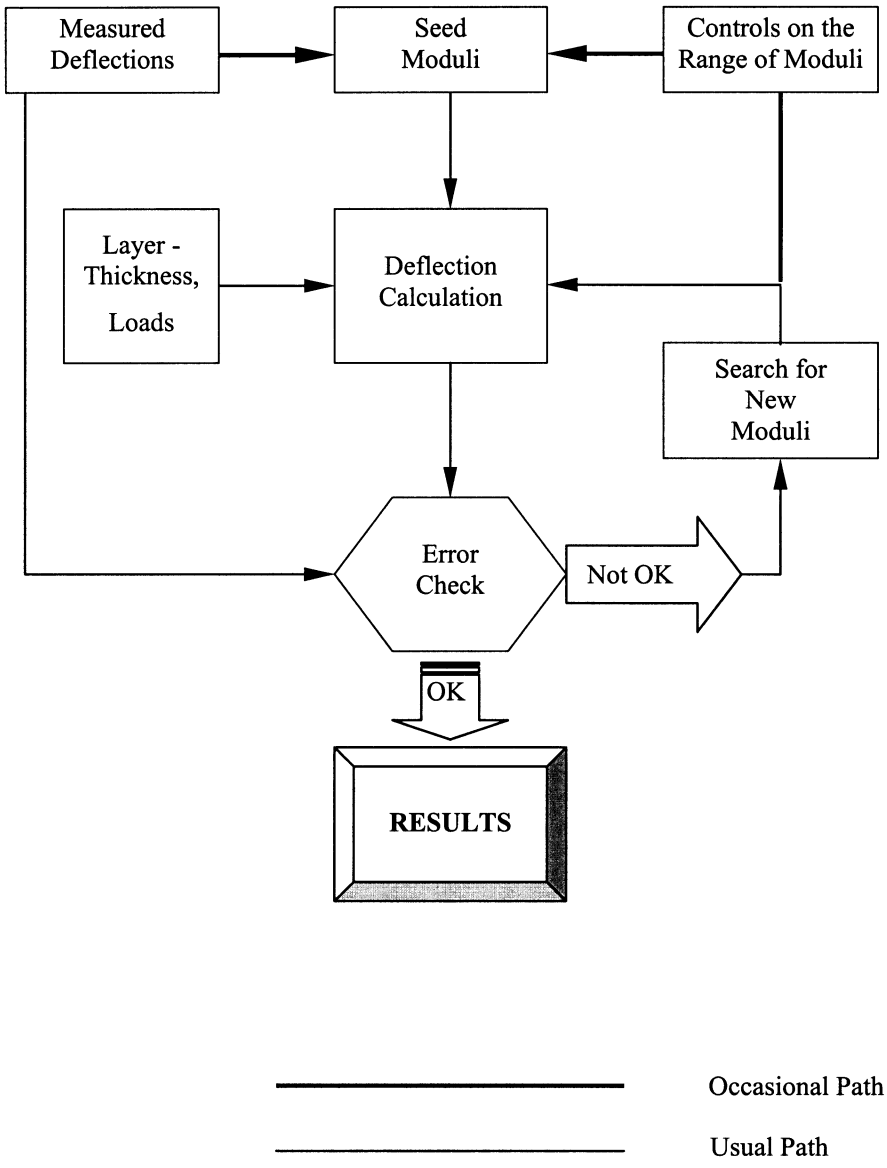


Figure 4.1 Common elements of backcalculation programs

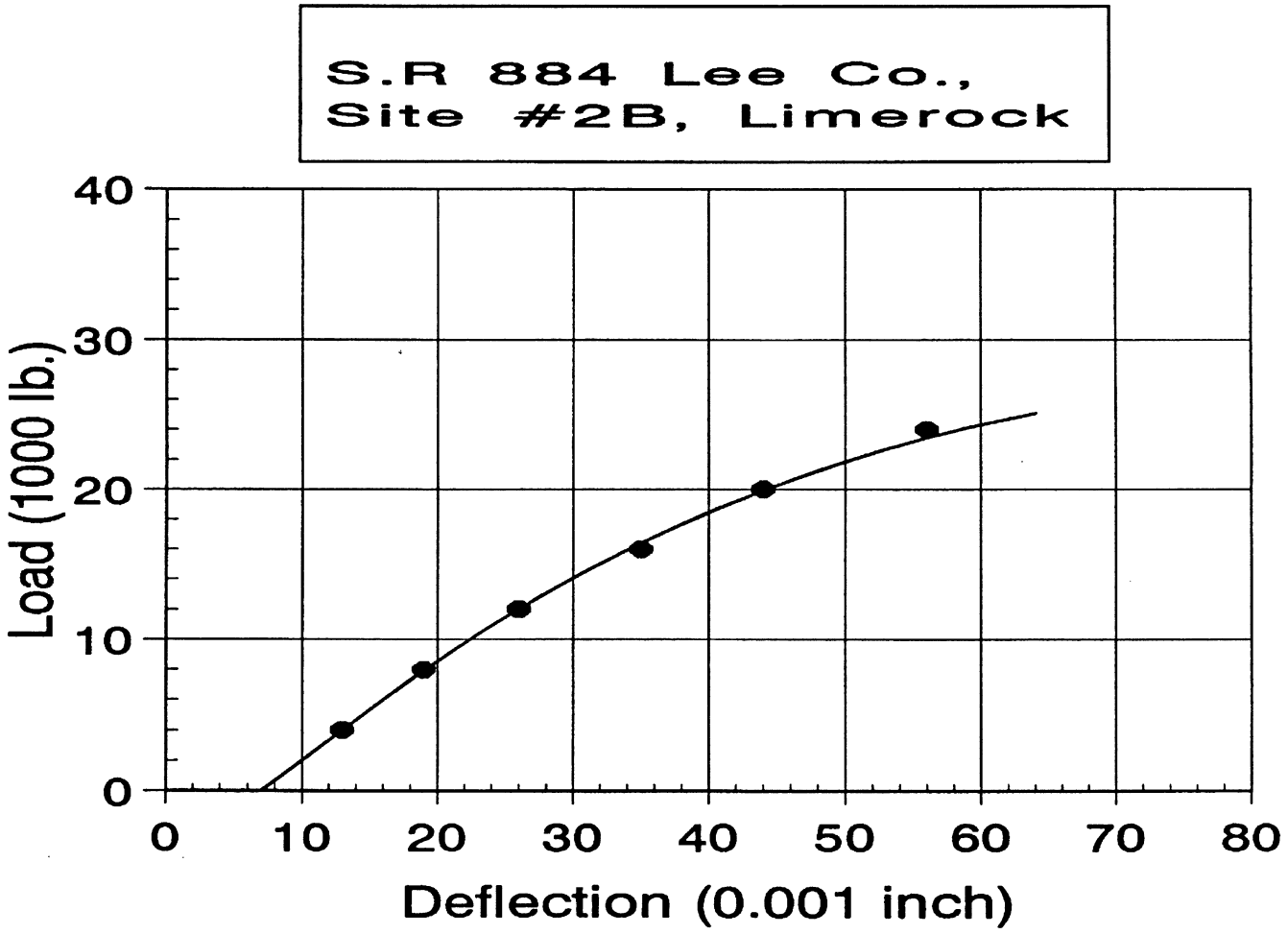


Figure 4.2 Typical load-deflection curve of base/subgrade/embankment layers

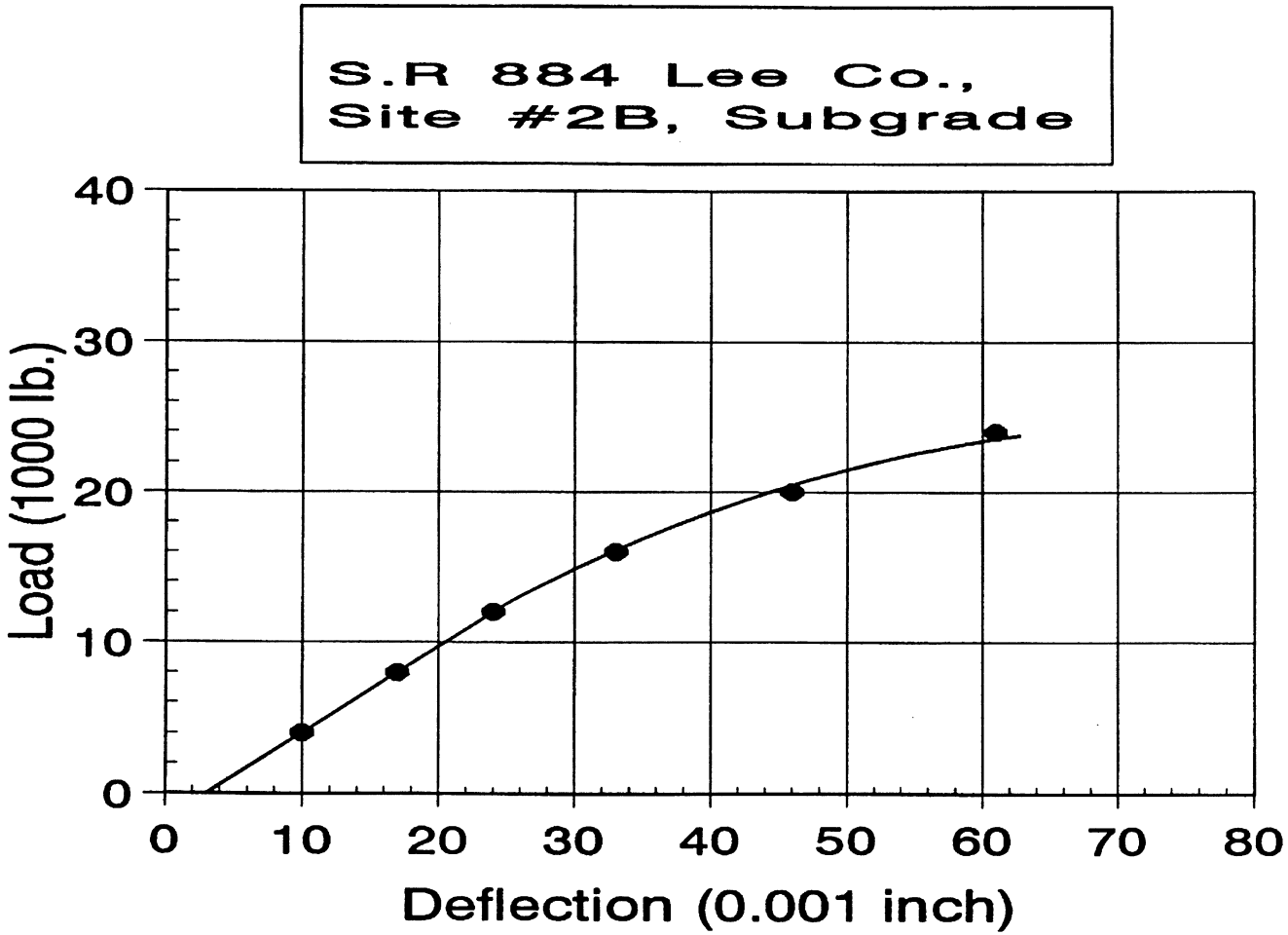


Figure 4.3 Typical load-deflection curve of subgrade/embankment layers

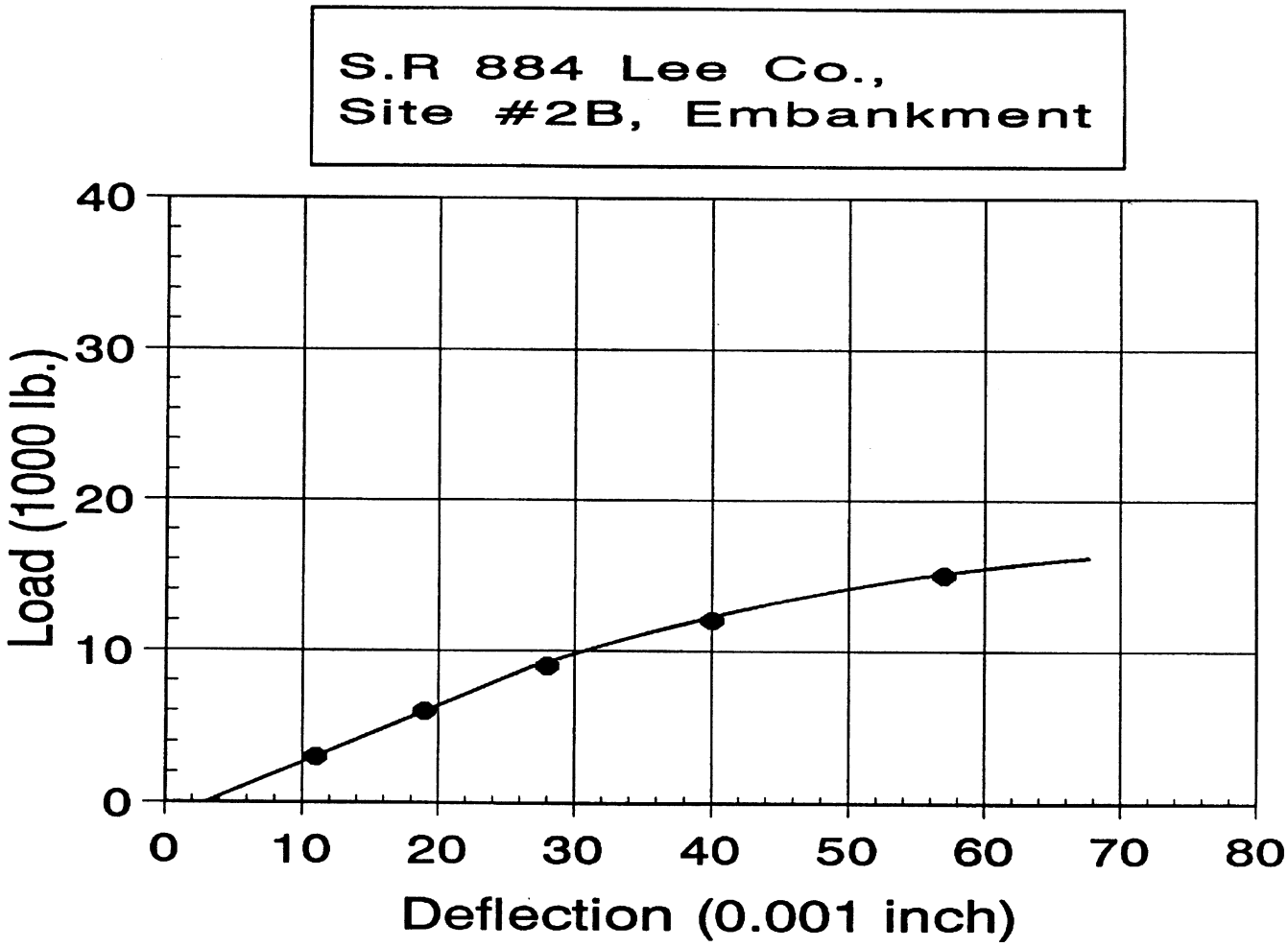


Figure 4.4 Typical load-deflection curve of embankment layers

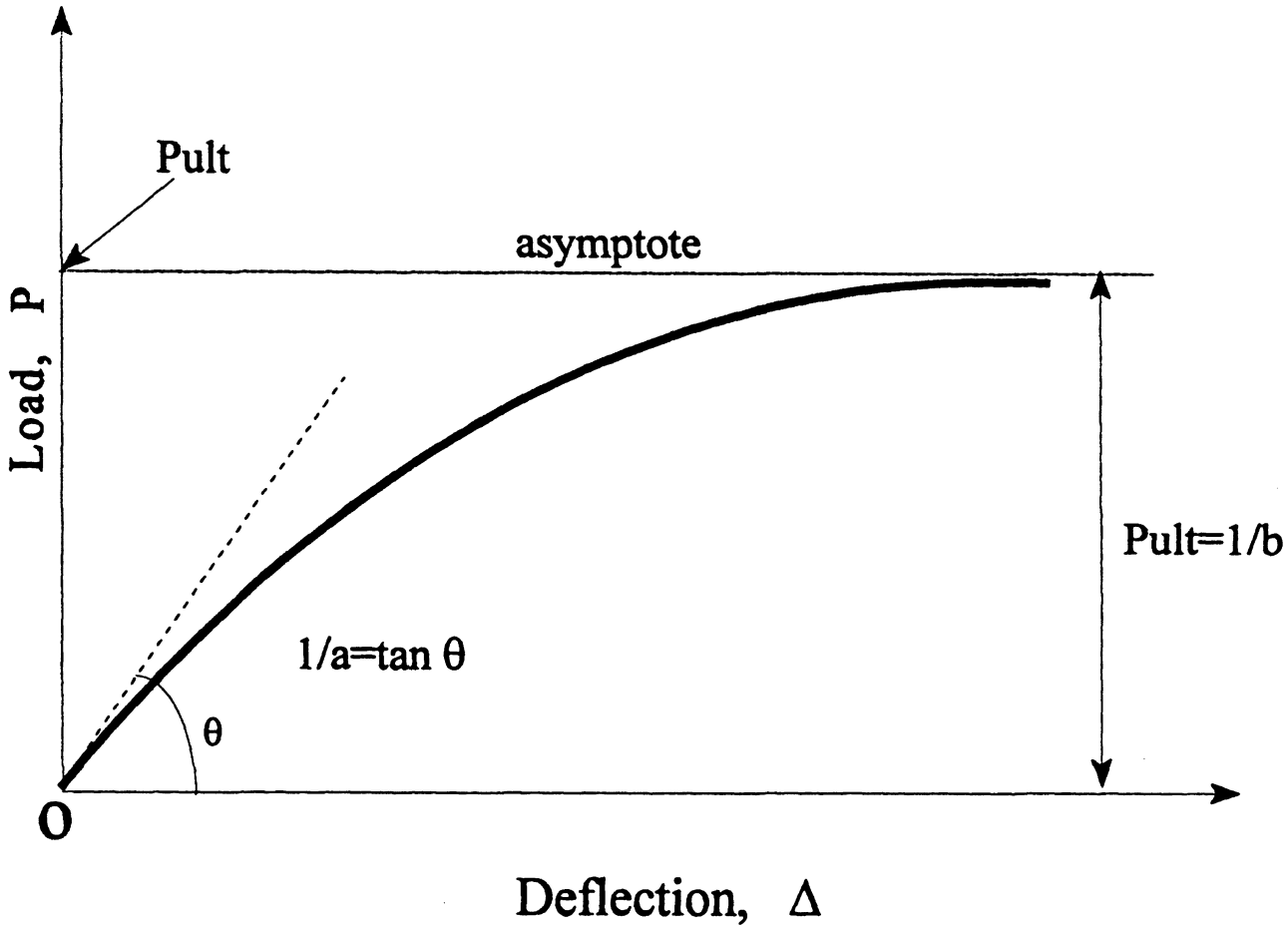


Figure 4.5 Rectangular hyperbolic representation of load-deflection curve

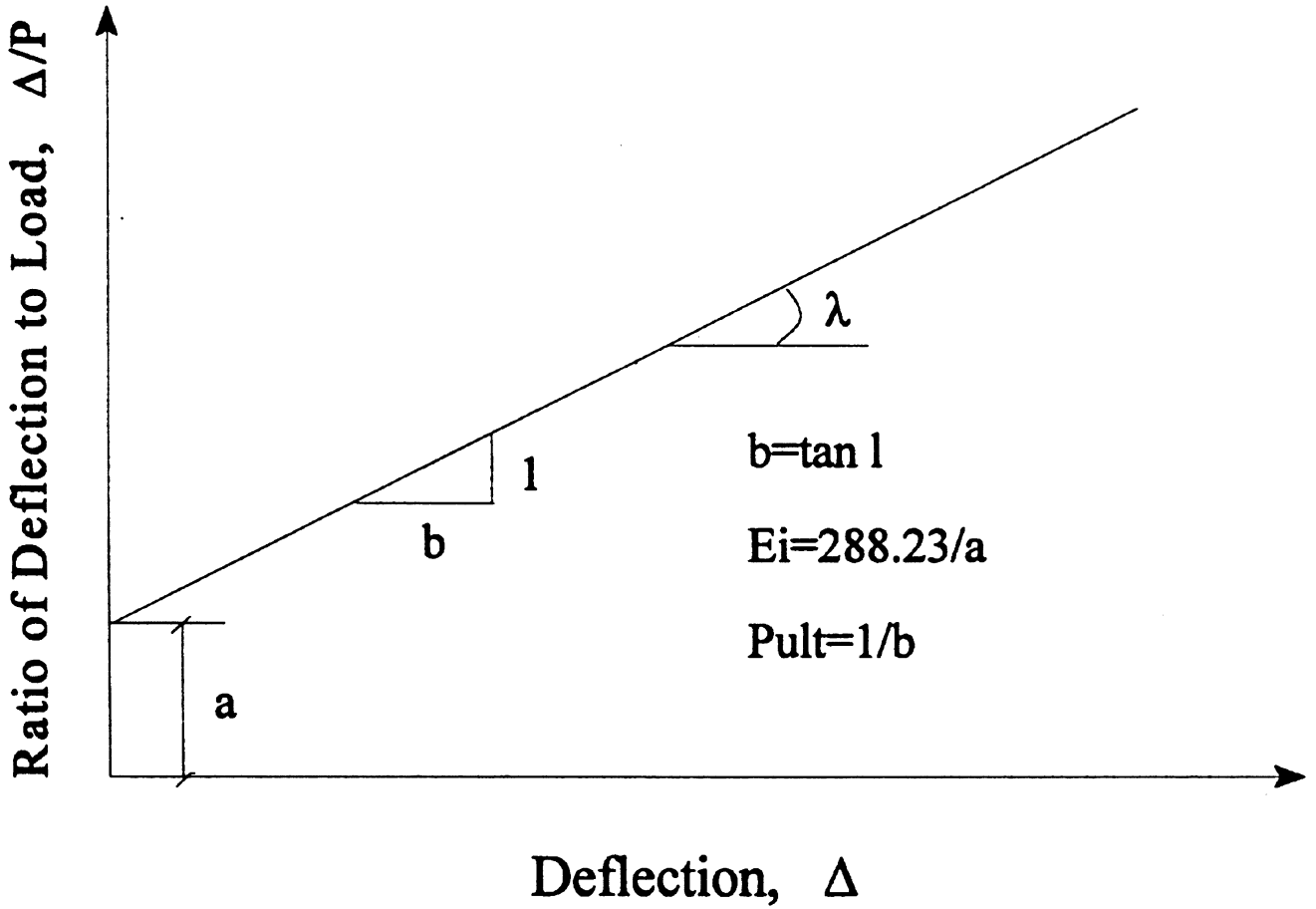


Figure 4.6 Transformed hyperbolic representation of load-deflection

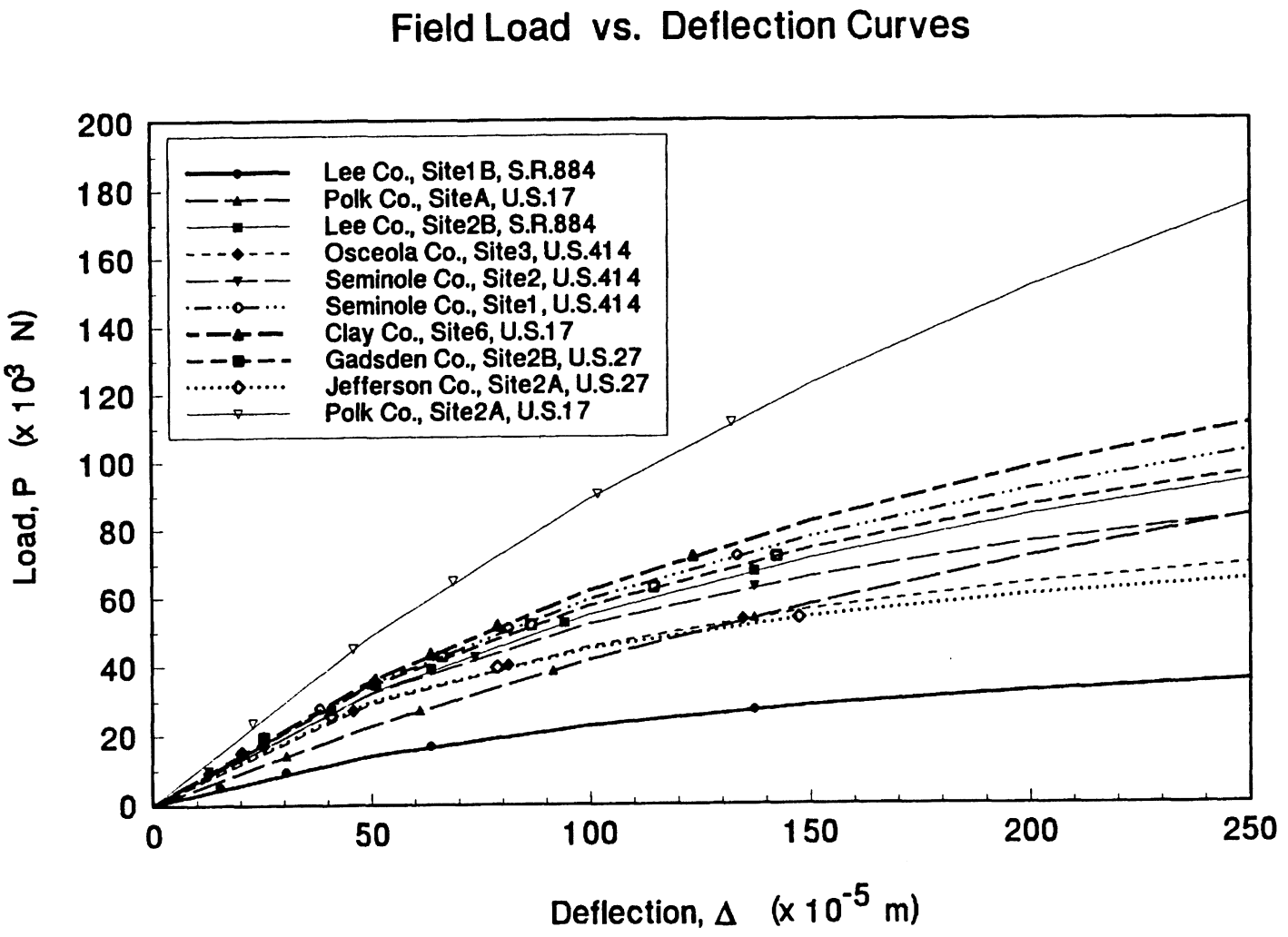


Figure 4.7 Actual field Test curves for embankment sandy soils in Florida

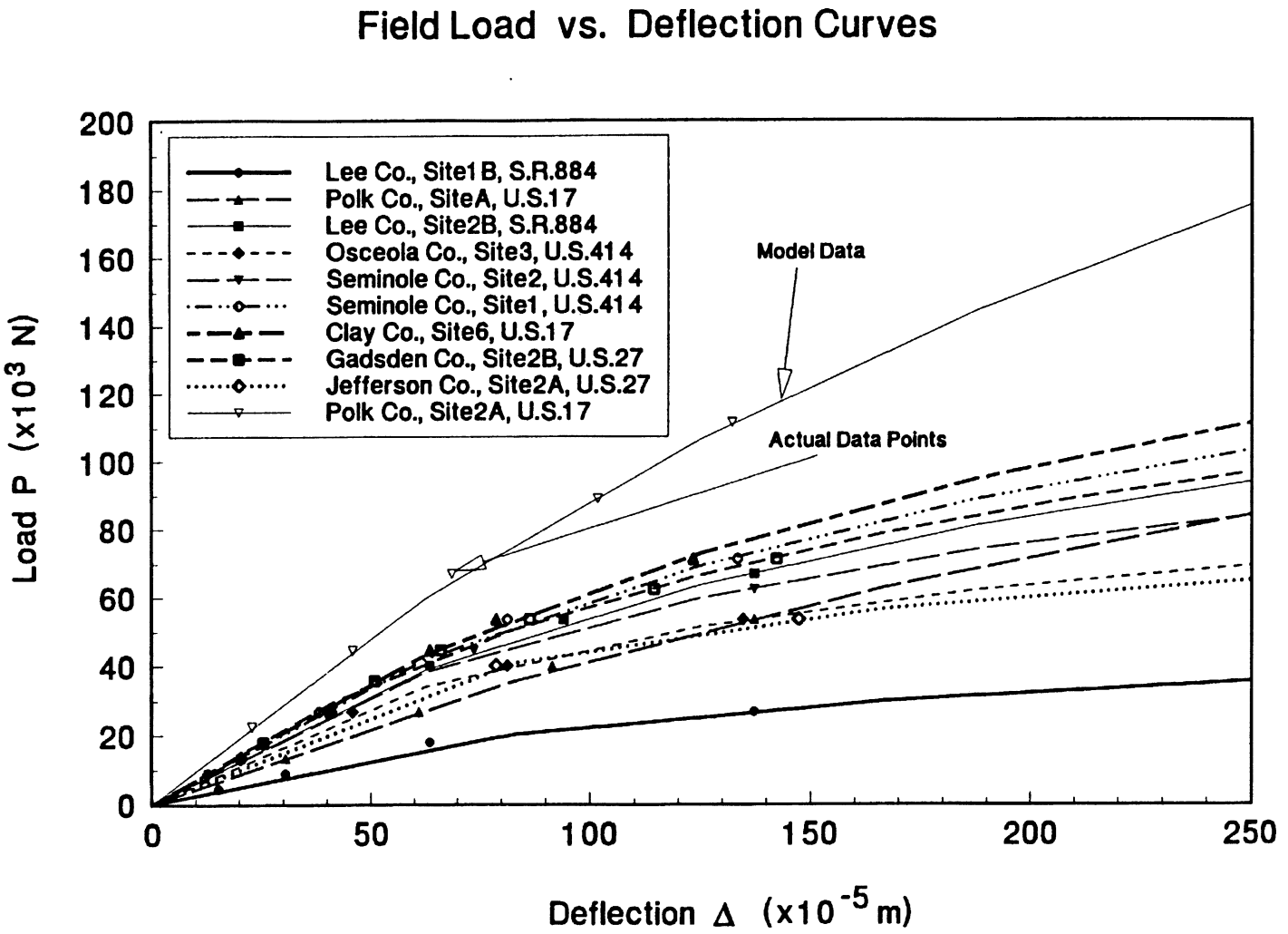


Figure 4.8 Comparison of actual load-deflection data with hyperbolic model data

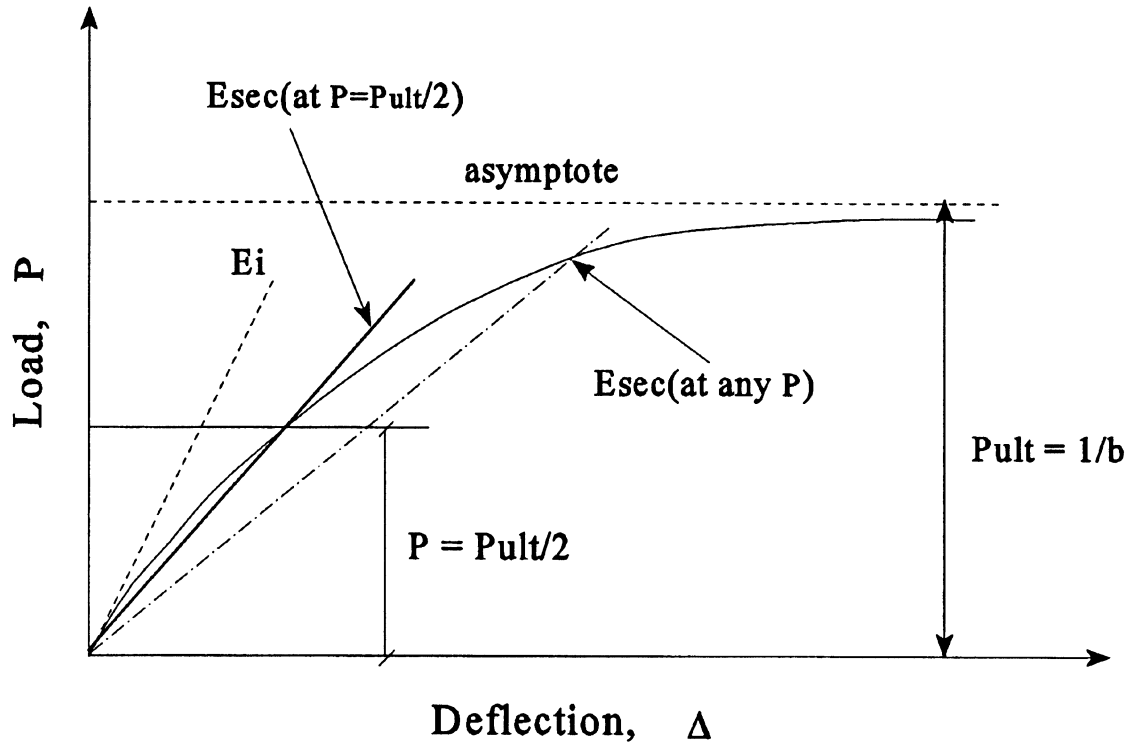


Figure 4.9 Rectangular hyperbolic representation of secant modulus

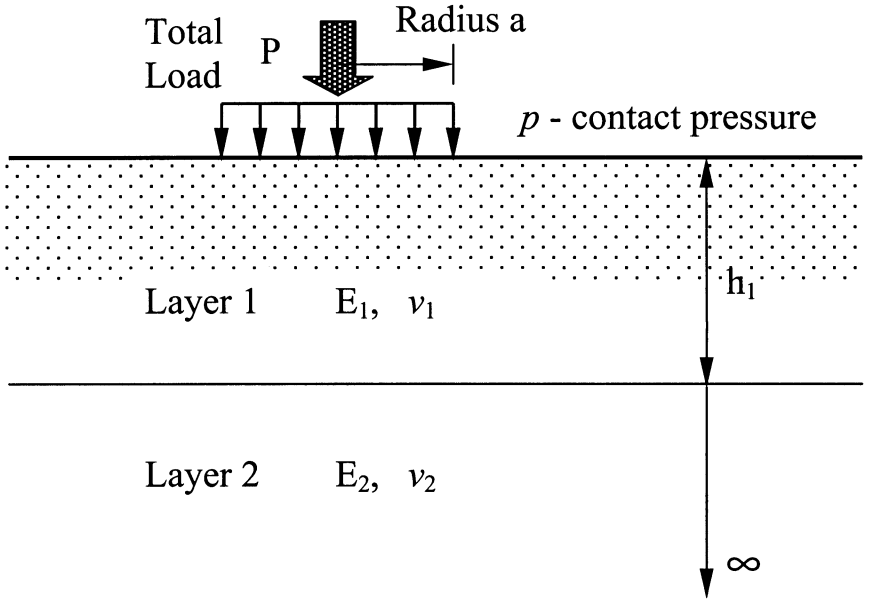


Figure 4.10 Two-layer system pavement model

CHAPTER 5

SUMMARY AND PRESENTATION OF LABORATORY TEST RESULTS

5.1 General

Pavement soils from the field test sites within Florida were evaluated in the laboratory where two moisture content and density conditions were simulated. Of each condition, two replicate resilient modulus tests were conducted on each type of soil. The specimen diameter was 101.6-mm (4.0-in.). The *T 292-91I* was used to test both subgrade and embankment soils under both conditions, but only subgrade soils were tested utilizing the *T 294-92* procedure under optimum moisture content and density conditions. Large diameter specimen tests were conducted to evaluate the effect of specimen size on the resilient modulus of granular base and sub-base soils. The laboratory testing program used both 152.4-mm (6.0-in.) and 101.6-mm (4.0-in.) diameter specimens and the T292-91I procedure. The experimental results from the laboratory resilient modulus tests were determined and are summarized in this chapter.

5.2 Determination of Resilient Modulus

During the resilient modulus test, after finishing the specimen conditioning stage, a series of tests with different deviator stresses at different confining pressures were performed and the data were recorded for every cycle of each test. However, only the last five cycles of each test were used for analyses. The resilient modulus (M_R) was calculated from the load and deformation using the following equation:

$$M_R = \frac{\sigma_d}{\varepsilon_r} \qquad (5.1)$$

Where σ_d is the deviator stress and ε_r is the resilient or recoverable strain.

5.2.1 Computational Procedure

The raw data from the resilient modulus test was processed using the Excel program on a tabular arrangement. For each test, the resilient modulus was calculated as follows: first, at each test, the difference between the 20th and 49th cycle strains was compared. The difference had to be less than or equal to five percent. If the difference was more than five percent, the data was not used for further analyses. Second, deviator stresses of the last five cycles were calculated by dividing the average applied forces by the

nominal area of the specimen, which equals 81.07 cm^2 (12.566 in^2). Third, the last five cycle strains from four LVDTs, two for 10.2-cm measurements and two for 20.3-cm measurements, were averaged. Fourth, the resilient modulus values for both 10.2-cm measurements and 20.3-cm measurements were calculated using the equation (5.1). Finally, the resilient modulus values at the different deviator stresses and confining pressures were obtained by repeating the aforementioned procedures.

5.2.2 Sample Computation

The application of the computational procedures may be illustrated by an example. Table 5.1 shows part of the raw data from Panama sand at the optimum condition and the calculation results. The confining pressure was 103.4 kPa (15 psi) and the deviator stress was 48.2 kPa (7 psi). The calculation procedures are described as follows:

1. The 10.2-cm measurements and 20.3-cm measurements strains at the 20th and 49th cycles were calculated.

   Segments 58 and 59 consisted of the 20th cycle. Strains at the 20th cycle were:

10.2-cm measurements:

(0.904 + 0.814 - 0.889 - 0.798)/(2 x 101.6) = 0.000152

20.3-cm measurements:

(6.499 + 6.933 - 6.461 - 6.898)/(2 x 203.2) = 0.000178

Segments 145 and 146 consisted of the 49th cycle. Strains at the 49th cycle were:

10.2-cm measurements:

(0.905 + 0.814 - 0.890 - 0.798)/(2 x 101.6) = 0.00015

20.3-cm measurements:

(6.498 + 6.932 - 6.461 - 6.898)/(2 x 203.2) = 0.000174

The differences of strains:

10.2-cm measurements:

(0.000152 - 0.00015)/0.000152 = 1.3 % < 5% OK

20.3-cm measurements:

(0.000178 - 0.000174)/0.000178 = 2.2 % < 5% OK

2. A typical stress and strain relationship for the last fifty cycles is shown in Figure 5.1. The deviator stresses of the last five cycles were averaged.

Segments 133 through 146 consisted of the last five cycles. (0.3914 - 0.0052 + 0.3932 - 0.0006 + 0.396 - 0.0044

+ 0.3907 - 0.0031 + 0.3945 - 0.008)/5/(3.14 x 0.0508^2)

= 47.98 kPa

3. The strains of the last five cycles were averaged.

10.2-cm measurements:

(0.9048 - 0.8898 + 0.9046 - 0.8896 + 0.9046 - 0.8896

+ 0.9046 - 0.8892 + 0.9048 - 0.8898 + 0.8142 - 0.7987

+ 0.8144 - 0.7981 + 0.8139 - 0.7985 + 0.8142 - 0.7980

- 0.8139 - 0.7985)/(5/2/101.6) = 0.000152

20.3-cm measurements:

(6.4986 - 6.4623 + 6.4995 - 6.4614 + 6.4986 - 6.4618

+ 6.4986 - 6.4618 + 6.4977 - 6.4610 + 6.9333 - 6.8983

+ 6.9333 - 6.8978 + 6.9324 - 6.8983 + 6.9337 - 6.8983

+ 6.9324 - 6.8983)/(5/2/203.3) = 0.000177

4. The resilient modulus values were calculated.

10.2-cm measurements: 47.98/0.000152 = 315.20 MPa

20.3-cm measurements: 47.98/0.000177 = 271.22 MPa

5. Steps 1 through 4 were repeated to calculate all the resilient modulus values at different deviator stress and confining pressure conditions.

The calculated results for the sample computation are illustrated in Table 5.2.

5.2.3 Regression Analysis

The test results are reported in a tabular form and in plots of logarithmic graphs that show the variation of the M_R versus the bulk stress (θ). In some cases, the plots required are logarithmic graphs showing the variation of the M_R versus the confining pressure. The regression models are presented as follows:

1. Modulus dependent on bulk stress:

$$M_R = k_1 \theta^{k_2} \qquad (5.2)$$

2. Modulus dependent on confining pressure:

$$M_R = k_3 \sigma_3^{k_4} \qquad (5.3)$$

Where θ = bulk stress, sum of the principal stresses,

$(\sigma_1 + \sigma_2 + \sigma_3)$

σ_3 = confining pressure or minor principal stress

k_1, k_2, k_3, k_4 = regression constants

A regression model was required to get the regression equation of M_R from either the confining pressure, or sum of principal stresses. For cohesionless soils, the regression model may be expressed in terms of the confining pressure as presented in Equation (5.3).

5.3 Laboratory Resilient Modulus Test Results under In-situ Moisture Content Conditions

A series of tests at different deviatoric stresses and confining pressures were performed after finishing the specimen in-situ moisture content conditioning stage, and data were recorded for every cycle of the test. Similar to the resilient modulus test under optimum moisture content condition, only the last five cycles were used for computation of resilient modulus. The resilient modulus (M_R) under in-situ moisture content condition was calculated from

the deviatoric stress and resilient strain using the same equation (5.1).

Two replicate resilient modulus tests were conducted on each type of soil. The results of the two replicate tests were averaged for analysis. The resilient modulus results were reported in a tabular form including the deviator stress, axial strain, confining pressure, and bulk stress. A regression model was used to get the regression equation of M_R from the confining pressure, bulk stress, or deviator stress. For granular soils, the regression model was expressed in terms of either the confining pressure or the bulk stress. For cohesive soils, the regression model was expressed in terms of the deviator stress.

Typical resilient modulus test results on two replicate samples are shown in Tables 5.3 through 5.5, and Figures 5.2 through 5.5. The results include the confining pressure, deviator stress, bulk stress, axial strain, and their corresponding resilient modulus values. The resilient modulus test results for all materials are summarized in Tables 5.6 and 5.7. Detailed test results were presented in the Research Report No. FL/DOT/RMC/0636 (3)-4538, Appendices A through E.

5.3.1 Resilient Modulus of Base Materials

Twenty-two types of limerock and two types of coquina materials were tested in this study. The resilient modulus regression coefficients for the Florida limerock materials are summarized in Table 5.8.

The Florida limerock materials display a wide range of resilient behavior in the field as shown in the table. For the tested limerock materials, the values of k_1 ranged from 2.43 to 28.97, whereas the k_2 values varied from 0.4483 to 0.7712. Most of the k_2 values fell within the range of typical values for base materials given in the *AASHTO Design Guide* (1993). Given the wide variations of limerock materials under in-situ density and moisture conditions, the resilient modulus values obtained from this study were considered to be representative of in-service pavement conditions.

5.3.2 Resilient Modulus of Granular Materials

Twenty-nine types of granular materials were tested in the laboratory. These granular materials were classified as A-3 or A-2-4 soils by the AASHTO classification. A-3 and A-2-4 soils are most commonly used as pavement subgrades and

embankments in Florida. A summary of the test results is given in Table 5.9.

The values of coefficient k_1 range from 6.7 to 28.4. The range of k_2 values was from 0.3895 to 0.6124. These wide ranges demonstrated that the resilient characteristics of granular materials varied considerably. The R^2 values were from 0.93 to 0.99. It indicated a strong linear relationship between the logarithm of resilient modulus and the logarithm of the bulk stress.

5.3.3 Resilient Modulus of Cohesive Materials

Six types of cohesive soils were tested in this investigation (three types of A-4 soil, two types of A-6, and one type of A-2-6 soil). Most of the cohesive soils were from District 3. The A-2-6 and A-4 soils were silty soils, and the A-6 was a clayey soil. The tests on the A-2-6 and A-4 soils followed the resilient modulus test procedures for granular specimens of subgrade soils, whereas the test on the A-6 soil followed the resilient modulus test procedure for cohesive specimens. However, three types of soils failed during the test. Typical results for A-4 soil are presented in Tables 5.10 through 5.12 and Figures 5.6 through 5.9.

Typical results for A-6 soil are presented in Table 5.13 and Figures 5.10 and 5.11.

5.4 Laboratory Resilient Modulus Test Results under Optimum Moisture Content Conditions

Prior to the resilient modulus test, the basic engineering properties of each soil were evaluated in the laboratory, such as the moisture content, optimum moisture content, wet unit weight, dry unit weight, sieve analysis, and index properties. As a result, the AASHTO classifications were used to classify the soils.

During the resilient modulus test, after finishing the specimen optimum moisture content conditioning stage, a series of tests at different deviatoric stresses and confining pressure were performed, and data were recorded for every cycle of the test. However, only the last five cycles were used for computation of resilient modulus. The resilient modulus (M_R) under an optimum moisture content condition was calculated from the deviatoric stress and the resilient strain using an equation (5.1).

Typical resilient modulus test (*T 292-91I*) results on two replicate samples are shown in Tables 5.14 through 5.16, and Figures 5.12 through 5.15. The results included the

confining pressure, deviator stress, bulk stress, axial strain, and their corresponding resilient modulus values. The measured resilient modulus values for all materials are summarized (based on the individual district) in Tables 5.17 through 5.21 for the *T 292-91I* and Tables 5.22 through 5.26 for the *T 294-92*. The basic soil properties are also presented in the tables. In addition, the resilient modulus test results for both procedures were presented and illustrated in the Research Report No. FL/DOT/RMC/0636 (4)-4538, Appendices A through E based on each individual district.

The materials tested in the laboratory served as subgrade and embankment layers in the field pavement structures. These layers exhibited a different behavior of strength in a pavement structure. For subgrade materials, most were stabilized. The embankment layer refers to the roadbed soils. The following sections present a discussion of the resilient modulus test on subgrade and embankment materials, accordingly.

5.4.1 Resilient Modulus of Granular Materials

There were thirty-two types of granular materials tested for the resilient modulus in the laboratory. All of these

materials were classified as A-3 or A-2-4 soils in AASHTO classification, and most commonly used as pavement subgrades and embankments in Florida.

The range of average values of the coefficients k_1 and k_2 for *the T 292-91I* and *T 294-92* procedures are summarized in Table 5.27.

These wide range of values indicated that the resilient characteristics of granular materials varied considerably. The values of R^2 ranged from 0.90 to 0.99, where an R^2 equal to one indicates a perfect correlation, and an R^2 equal to zero indicates no correlation. The R^2 values exhibited a strong linear correlation relationship between the logarithm of resilient modulus and the logarithm of the bulk stress.

5.4.2 Resilient Modulus of Cohesive Materials

A total of eight types of cohesive soils were tested in this study. Most of the cohesive soils were from District 3. One type of soil failed in the *T 294-92* procedure at zero confining pressure. Two types of soils could not be compacted due to the optimum condition with the standard Proctor method. Five of these soils, after compacted to the optimum moisture content and density conditions, were too strong to obtain reasonable resilient modulus values. The

other one was too weak to conduct the *T 292-91I* resilient modulus test. The reasons may be due to the testing procedure or an improperly measured compaction condition.

With the *T 294-92*, the value of coefficient k_1 was 46.20 (MPa) and k_2 was 0.34 for the middle half LVDT measurements for the cohesive soils. In the full length external LVDT measurement, k_1 was 26.25 (MPa) and k_2 was 0.33 for the cohesive materials. The R^2 values were 0.64 and 0.83 for the middle half and full length external measurement systems, respectively.

5.5 Large Diameter Specimen Test Results

The soils consisted of nine types of limerock materials and two types of granular subgrades. T 292-91I was used for all tests. During the resilient modulus test, specimen conditioning was conducted first. Then, a series of tests at different deviator stresses and confining pressures were performed and the data were recorded for every cycle of the test. However, only the last five cycles were used for computation of resilient modulus. The resilient modulus (M_R) was calculated from the deviator stress and resilient strain using an equation (5.1).

Two replicate resilient modulus tests were conducted on each type of soil. The results of the two replicate tests were averaged for analysis. The resilient modulus results were reported in a tabular form including the deviator stress, axial strain, confining pressure, and bulk stress. A regression model was used to get the regression equation of M_R from the confining pressure and bulk stress.

Typical resilient modulus test results on two replicate samples are shown in Tables 5.28 through 5.30, and Figures 5.16 through 5.19. The results included the confining pressure, deviator stress, bulk stress, axial strain, and their corresponding resilient modulus values. The resilient modulus test results for all materials are summarized in Tables 5.31 through 5.36.

5.5.1 Resilient Modulus Values for Limerock Materials

Nine types of limerock were tested for this study. The resilient modulus regression coefficients for the Florida limerock materials are summarized in Tables 5.37 through 5.42.

The Florida limerock materials displayed a wide ranged of resilient behavior as shown in the tables. For the 4-in. diameter specimens, the values of k_1 ranged from 4.77 to

28.97, whereas the k_2 values varied from 0.4483 to 0.7256. For the 6-in. diameter specimens, the values of k_1 ranged from 2.82 to 15.75, and the k_2 values ranged from 0.5035 to 0.9129. Most of the k_2 values fell within the range of typical values for base materials given in the *AASHTO Design Guide* (1993). Given the wide variations of limerock materials under field density and moisture conditions, the resilient modulus values obtained from this study were considered to be representative of pavement conditions.

5.5.2 Resilient Modulus Values for Granular Materials

Two types of sandy subgrade materials were tested in the laboratory. These materials were classified as A-3 or A-2-4 soils by the AASHTO classification. A-3 and A-2-4 soils are most commonly used as pavement subgrade and embankment in Florida. A summary of the test results is given in Tables 5.37 through 5.42. Typical test results for sandy soils are shown in Tables 5.43 through 5.45, and Figures 5.20 through 5.23.

For the 4-in. diameter specimens, the values of coefficient k_1 ranged from 11.54 to 15.84, and the values of k_2 ranged from 0.4736 to 0.5998. For the 6-in. diameter specimens, the values of coefficient k_1 ranged from 7.12 to

14.92, and the values of k_2 ranged from 0.4736 to 0.5998. These wide ranges demonstrate that the resilient characteristics of granular materials varied considerably. The R^2 values were from 0.93 to 0.99. It indicated a strong linear relationship between the logarithm of resilient modulus and the logarithm of the bulk stress.

5.6 Limerock Bearing Ratio Test Results

Laboratory compaction and LBR penetration tests were conducted on the soil samples obtained from the twenty field test sites as described in Chapter 3. Typical results from the LBR test are illustrated in Figure 5.24. The compaction curve is shown in Figure 5.24(a), and the LBR versus moisture content curve is shown in Figure 5.24(b). The maximum dry density as well as the maximum LBR value are also indicated in the figure. The LBR test results are summarized based on individual district and presented in Table 5.46. Pertinent soil information is also presented in the tables. In addition, the LBR test results were illustrated and presented in the figures in the research report No. FL/DOT/RMC/0636 (2) - 4538, Appendices A through E based on each district.

5.7 Discussion of Anomalies

The resilient modulus test for both moisture conditions was conducted successfully on most of soils. However, there are several anomalies in the resilient modulus test results and preparation of samples.

For optimum moisture condition test, under the *T 294-92* procedure, some cohesive soil samples collapsed at zero confining pressure. Therefore, for the cohesive soils with little cohesion, the T 292-91I procedure is a better choice.

In some cohesive soil samples, the moisture content was too high. Water leaked out when the specimen was compacted. Therefore, at the time of testing, the water content was not consistent with the optimum moisture condition.

For the in-situ moisture condition test, some in-situ moisture content conditions were too high to compact the test specimen for the resilient modulus test. Water leaked out when the specimens were compacted, and the prepared soil samples failed during sample conditioning stage. Meanwhile, some in-situ moisture content conditions were too low. A lower compaction effect (15 blows per layer for four equally-divided layers of sample) was used to reconstitute the soil samples to be the in-situ conditions. The test conducted on these samples resulted in inconsistent resilient modulus

values. The reason for this could be due to the incorrectly measured field density and moisture conditions.

There was an anomaly in the resilient modulus test results in large diameter specimen tests. The anomaly involved the base material (limerock) from test site #6 at U.S. 17 in Clay County. The R^2 of the regression line from middle half LVDT measurements for 6-inch diameter specimens was only 0.38 (based on $M_R = k_1\theta^{k2}$ model), which was much smaller than that of any other measurements. The reason of this anomaly is unknown.

Table 5.1 Raw Data and Calculation Procedure

MATERIAL: PANAMA SAND
OPT. MOISTURE: 8.5%
MAX. DRY DEN.: 19.64 kN/m^3
LBR: 88.00

LOCATION: PANAMA CITY BEACH, FLORIDA
DRY DENSITY: 19.37 kN/m^3
MOISTURE: 7.63%
TEST DATE: 05/09/1995

Confining Pressure	Raw Data							Calculation Results		
	Axial Load	LVDT (10.2-cm)	LVDT (10.2-cm)	LVDT (20.3-cm)	LVDT (20.3-cm)	Axial Segments	Load Cycles	Axial Strain (10.2-cm)	Axial Strain (20.3-cm)	Deviator Stress
kPa	kN	mm	mm	mm	mm	segments	Cycles			kPa
103.35	-0.3433	0.902544	0.811618	6.466652	6.903526	1				
103.35	-0.0015	0.889247	0.798318	6.499898	6.935017	2	1	0.000131	0.000159	42.188
103.35	-0.3515	0.902894	0.812143	6.466214	6.902651	4				
103.35	-0.0015	0.889247	0.797968	6.500335	6.934580	5	2	0.000137	0.000163	43.191
103.35	-0.356	0.902894	0.812143	6.465339	6.902651	7				
103.35	-0.0032	0.889597	0.798318	6.499898	6.934143	8	3	0.000133	0.000163	43.541
103.35	-0.3589	0.902894	0.812318	6.465339	6.902213	10				
103.35	-0.0025	0.889422	0.798668	6.499898	6.934580	11	4	0.000133	0.000165	43.985
103.35	-0.3645	0.903244	0.812843	6.465339	6.901339	13				
103.35	-0.0019	0.889247	0.798318	6.499460	6.935017	14	5	0.000140	0.000167	44.751
103.35	-0.3718	0.903594	0.813018	6.463589	6.900464	16				
103.35	-0.003	0.889597	0.798318	6.499898	6.935017	17	6	0.000141	0.000174	45.517
103.35	-0.3753	0.903768	0.813193	6.464027	6.900027	19				
103.35	-0.0026	0.889422	0.798493	6.499460	6.935454	20	7	0.000143	0.000174	45.999
103.35	-0.3737	0.903768	0.813193	6.463589	6.901339	22				
103.35	-0.0016	0.889422	0.798318	6.499460	6.934580	23	8	0.000144	0.000170	45.914
103.35	-0.3794	0.903594	0.813368	6.463589	6.900027	25				
103.35	-0.0042	0.889772	0.798318	6.499023	6.933705	26	9	0.000142	0.000170	46.293
103.35	-0.3818	0.904293	0.813543	6.463152	6.900027	28				
103.35	-0.0017	0.889422	0.798493	6.499898	6.934143	29	10	0.000147	0.000174	46.907
103.35	-0.3904	0.904293	0.813893	6.462277	6.899152	31				
103.35	-0.005	0.889772	0.798668	6.499460	6.934580	32	11	0.000146	0.000179	47.560
103.35	-0.382	0.904468	0.813543	6.461840	6.899152	34				
103.35	-0.0042	0.889597	0.798318	6.499023	6.933705	35	12	0.000148	0.000177	46.624
103.35	-0.3899	0.904643	0.813718	6.462277	6.898714	37				
103.35	-0.0056	0.889772	0.798493	6.498148	6.934143	38	13	0.000148	0.000175	47.427
103.35	-0.3847	0.904293	0.813893	6.462715	6.900027	40				
103.35	-0.0028	0.889422	0.798318	6.499023	6.934580	41	14	0.000150	0.000174	47.134
103.35	-0.3862	0.904118	0.813718	6.463152	6.899152	43				
103.35	-0.0039	0.889422	0.798143	6.498585	6.933705	44	15	0.000149	0.000172	47.172
103.35	-0.3909	0.904293	0.813893	6.461402	6.898714	46				
103.35	-0.0026	0.889422	0.798493	6.499023	6.934143	47	16	0.000149	0.000180	47.919
103.35	-0.3904	0.904293	0.813718	6.461840	6.899152	49				
103.35	-0.0026	0.889597	0.798318	6.499460	6.934143	50	17	0.000148	0.000179	47.853
103.35	-0.3895	0.904293	0.814068	6.460965	6.898714	52				
103.35	-0.005	0.889597	0.798493	6.498585	6.934143	54	18	0.000149	0.000180	47.456
103.35	-0.3889	0.904468	0.814068	6.461840	6.898714	55				
103.35	-0.0064	0.889772	0.798843	6.499023	6.934143	56	19	0.000147	0.000179	47.210
103.35	-0.3917	0.904468	0.814068	6.461402	6.898277	58				
103.35	-0.0045	0.889422	0.798318	6.498585	6.933268	59	20	0.000152	0.000178	47.777
103.35	-0.3935	0.904818	0.813893	6.460965	6.897403	61				
103.35	0.0008	0.889597	0.798318	6.499023	6.934580	62	21	0.000152	0.000185	48.657
103.35	-0.3961	0.904993	0.814593	6.461402	6.897840	64				
103.35	0.0005	0.889597	0.798493	6.499460	6.935017	66	22	0.000155	0.000185	48.950
103.35	-0.3918	0.904468	0.814068	6.461402	6.898714	67				
103.35	-0.0039	0.889597	0.798143	6.498585	6.933268	68	23	0.000152	0.000177	47.863
103.35	-0.3892	0.904643	0.814243	6.460965	6.899152	70				
103.35	-0.0036	0.889772	0.798318	6.498585	6.934580	71	24	0.000152	0.000180	47.579
103.35	-0.3925	0.904293	0.814243	6.461402	6.898714	73				
103.35	-0.004	0.889772	0.798493	6.499023	6.933705	74	25	0.000149	0.000179	47.938

Table 5.1 (Continued)

Confining Pressure	Raw Data							Caculation Results		
	Axial Load	LVDT (10.2-cm)	LVDT (10.2-cm)	LVDT (20.3-cm)	LVDT (20.3-cm)	Axial Segments	Load Cycles	Axial Strain (10.2-cm)	Axial Strain (20.3-cm)	Deviator Stress
kPa	kN	mm	mm	mm	mm	segments	Cycles			kPa
103.35	-0.3884	0.904468	0.813893	6.461402	6.899152	76				
103.35	-0.0035	0.889597	0.798493	6.499023	6.933705	77	26	0.000149	0.000178	47.494
103.35	-0.3944	0.904468	0.814243	6.460965	6.898714	79				
103.35	-0.0046	0.889772	0.798143	6.498585	6.933705	80	27	0.000152	0.000179	48.099
103.35	-0.3902	0.904643	0.813893	6.460965	6.898714	82				
103.35	-0.0042	0.889772	0.798493	6.498148	6.934143	83	28	0.000149	0.000179	47.626
103.35	-0.3971	0.904818	0.814418	6.460965	6.897403	85				
103.35	-0.0058	0.889947	0.798493	6.498148	6.933705	87	29	0.000152	0.000181	48.288
103.35	-0.3919	0.904468	0.814068	6.461402	6.898277	88				
103.35	-0.0055	0.889772	0.798318	6.498585	6.934143	89	30	0.000150	0.000180	47.683
103.35	-0.3848	0.904468	0.813718	6.460965	6.898714	91				
103.35	-0.0039	0.889247	0.798143	6.498585	6.934143	92	31	0.000152	0.000180	47.002
103.35	-0.3991	0.904993	0.814068	6.460527	6.897403	94				
103.35	-0.0068	0.889772	0.798493	6.498148	6.933268	95	32	0.000152	0.000181	48.411
103.35	-0.3968	0.904468	0.814243	6.460965	6.897403	97				
103.35	-0.0085	0.889772	0.798493	6.498585	6.933705	98	33	0.000150	0.000182	47.919
103.35	-0.3906	0.904468	0.814068	6.461840	6.898277	100				
103.35	-0.0019	0.889597	0.798318	6.498585	6.934143	101	34	0.000151	0.000179	47.976
103.35	-0.3919	0.904468	0.814243	6.460965	6.898714	103				
103.35	-0.0065	0.889772	0.798493	6.499023	6.933705	104	35	0.000150	0.000180	47.569
103.35	-0.4046	0.905343	0.814593	6.460090	6.897403	106				
103.35	-0.0048	0.889772	0.798318	6.499023	6.933705	107	36	0.000157	0.000185	49.338
103.35	-0.3916	0.904818	0.814068	6.461840	6.898277	109				
103.35	-0.0055	0.889772	0.798318	6.498585	6.934143	110	37	0.000152	0.000179	47.645
103.35	-0.3882	0.904643	0.813893	6.460965	6.899152	112				
103.35	-0.0012	0.889597	0.798143	6.498585	6.934143	113	38	0.000152	0.000179	47.758
103.35	-0.3876	0.904643	0.813718	6.462277	6.898714	115				
103.35	-0.0066	0.889947	0.798843	6.497711	6.932830	116	39	0.000146	0.000171	47.011
103.35	-0.3925	0.904468	0.814068	6.461402	6.897840	118				
103.35	-0.0039	0.889947	0.798493	6.499023	6.933705	119	40	0.000148	0.000181	47.957
103.35	-0.3898	0.904643	0.813893	6.461840	6.898277	121				
103.35	-0.0029	0.889597	0.798318	6.499023	6.933705	122	41	0.000151	0.000179	47.740
103.35	-0.3851	0.904468	0.813718	6.461840	6.898277	124				
103.35	-0.0063	0.890122	0.798668	6.499023	6.933705	125	42	0.000145	0.000179	46.747
103.35	-0.3942	0.904468	0.814418	6.461402	6.898714	127				
103.35	-0.0065	0.889772	0.798493	6.498148	6.934143	129	43	0.000151	0.000178	47.844
103.35	-0.3964	0.904643	0.814243	6.460965	6.898714	130				
103.35	-0.0075	0.889772	0.798668	6.498148	6.933268	131	44	0.000150	0.000177	47.995
103.35	-0.3914	0.904818	0.814243	6.462277	6.898277	133				
103.35	-0.0052	0.889772	0.798668	6.498585	6.933268	134	45	0.000151	0.000175	47.664
103.35	-0.3932	0.904643	0.814418	6.461402	6.897840	136				
103.35	-0.0006	0.889597	0.798143	6.499460	6.933268	137	46	0.000154	0.000181	48.458
103.35	-0.396	0.904643	0.813893	6.461840	6.898277	139				
103.35	-0.0044	0.889597	0.798493	6.498585	6.932830	140	47	0.000150	0.000175	48.326
103.35	-0.3907	0.904643	0.814243	6.461840	6.898277	142				
103.35	-0.0031	0.889247	0.797968	6.498585	6.933705	143	48	0.000156	0.000178	47.834
103.35	-0.3945	0.904818	0.813893	6.460965	6.898277	145				
103.35	-0.0087	0.889772	0.798493	6.497711	6.932393	146	49	0.000150	0.000174	47.607
Average of the last five cycles										
103.35	-0.3932	0.904713	0.814138	6.461665	6.898189					
103.35	-0.0044	0.889597	0.798353	6.498585	6.933093			0.000152	0.000177	47.978
Resilient modulus from 10.2-cm measurement = 47.977/0.000152 = 315493.29 kPa = 315.20 MPa										
Resilient modulus from 20.3-cm measurement = 47.977/0.000176 = 271473.26 kPa = 271.22 MPa										

Table 5.2 Calculation Results for Sample Computation

Test Type:	**T292-91I**				**Soil Identification**		
Date:	05/09/1995				Panama Sand		
Sample:	#1				Panama City Beach, FL		
Mold:	#3				SR 30A		
Lab. Moisture:		7.63%			Opt. Moisture:		8.50%
Lab. Den.:		19.37 kN/m^3			Max. Dry Den.:		19.64 kN/m^3
					Conditioning Information		
					Deviator Stress:		82.74 kPa
					Confining Pressure:		103.42 kPa
					Number of Repetition:		1000

Confining Pressure	Axial Load	Deviator Stress	Bulk Stress	Strain (10.2-cm)	Strain (20.3-cm)	Modulus (10.2-cm)	Modulus (20.3-cm)
kPa	kN	kPa	kPa			MPa	MPa
103.42	0.38860	47.934	358.194	0.00015	0.00018	315.204	271.224
103.42	0.55336	68.258	378.518	0.00022	0.00026	307.711	264.683
103.42	0.83356	102.820	413.080	0.00033	0.00039	311.432	263.894
68.95	0.27361	33.750	240.600	0.00012	0.00015	271.799	223.024
68.95	0.38598	47.611	254.461	0.00018	0.00022	257.641	218.986
68.95	0.55396	68.331	275.181	0.00027	0.00032	251.432	215.647
68.95	0.83456	102.943	309.793	0.00039	0.00046	261.474	222.842
34.47	0.16338	20.154	123.564	0.00009	0.00012	212.764	172.734
34.47	0.27294	33.667	137.077	0.00017	0.00020	196.072	165.150
34.47	0.38563	47.567	150.977	0.00025	0.00029	192.069	161.766
34.47	0.55529	68.496	171.906	0.00035	0.00042	194.482	164.272
13.79	0.16126	19.891	61.261	0.00013	0.00017	149.994	116.229
13.79	0.27375	33.767	75.137	0.00023	0.00029	145.882	118.120
13.79	0.38426	47.399	88.769	0.00031	0.00039	151.303	121.519

Table 5.3 Typical resilient modulus test results (A-2BE, Sample 1)

		Summary of Resilient Modulus Test Results					
	Test Type	**T 292-91I**			**Soil Identification**		
	Date:	01/25/1996			Lee County, Site #2B		
	Sample:	#2			S.R. 884, Embankment		
	Mold:	#5			Fine Sand		
	Lab.Moist:	3.3%			Insitu Moist:	3.3%	
	Lab.Den:	16.84	kN/m^3		Insitu Den:	17.01	kN/m^3
	Compaction Effort:		90 blows per layer (8 layers)				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. Stress	82.74	kPa
					Conf. Pres.	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa			MPa	MPa
103.42	0.376375	46.425919	356.6859	0.000168	0.00018662	276.3448	248.76581
103.42	0.541889	66.842138	377.1021	0.000241	0.00026156	277.9299	255.54939
103.42	0.823558	101.58599	411.846	0.00035	0.00038231	289.935	265.71453
68.95	0.263469	32.498897	239.3489	0.000142	0.00015931	229.4715	203.99465
68.95	0.375609	46.331434	253.1814	0.000203	0.00022688	228.5151	204.21568
68.95	0.543682	67.063231	273.9132	0.00029	0.00032156	231.5519	208.55427
68.95	0.82224	101.42347	308.2735	0.000415	0.000459	244.2468	220.96617
34.47	0.151466	18.683371	122.0934	0.000111	0.00013325	168.1293	140.21291
34.47	0.263407	32.491338	135.9013	0.000194	0.00022856	167.6972	142.15516
34.47	0.375517	46.320097	149.7301	0.000271	0.00031875	170.8441	145.31795
34.47	0.542962	66.974418	170.3844	0.000374	0.000431	179.2557	155.39308
13.79	0.151389	18.673922	60.04392	0.000159	0.00019781	117.3538	94.402133
13.79	0.262917	32.430868	73.80087	0.000263	0.0003255	123.1942	99.634003
13.79	0.375502	46.318205	87.6882	0.000351	0.00043163	131.9137	107.31122

Table 5.4 Typical resilient modulus test results (A-2BE, Sample 2)

		Summary of Resilient Modulus Test Results					
	Test Type	**T 292-91I**			**Soil Identification**		
	Date:	01/25/1996			Lee County, Site #2B		
	Sample:	#1			S.R .884, Embankment		
	Mold:	#4			Fine Sand		
	Lab.Moist:	3.3%			Insitu Moist:	3.3%	
	Lab.Den:	16.84	kN/m^3		Insitu Den:	17.01	kN/m^3
	Compaction Effort:		100 blows per layer (8 layers)				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. Stress	82.74	kPa
					Conf. Pres.	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa			MPa	MPa
103.42	0.37662	46.456152	356.7162	0.000169	0.000192	274.8885	241.95912
103.42	0.542931	66.9706369	377.2306	0.000243	0.0002749	276.0253	243.64033
103.42	0.82224	101.423474	411.6835	0.000351	0.0004019	288.6474	252.37567
68.95	0.264127	32.5801537	239.4302	0.000141	0.000172	231.0649	189.4195
68.95	0.375149	46.274743	253.1247	0.000205	0.0002426	225.5929	190.77451
68.95	0.542931	66.9706391	273.8206	0.000295	0.000343	227.3081	195.24968
68.95	0.823404	101.567093	308.4171	0.00042	0.0004865	241.8264	208.771
34.47	0.151389	18.673922	122.0839	0.00011	0.0001418	169.9561	131.68037
34.47	0.262718	32.406301	135.8163	0.000197	0.0002426	164.6034	133.56538
34.47	0.375517	46.3200954	149.7301	0.000278	0.0003414	166.8441	135.68684
34.47	0.543345	67.0216597	170.4317	0.000378	0.0004651	177.1888	144.09387
13.79	0.152033	18.7532892	60.12329	0.00016	0.0002067	117.4834	90.732576
13.79	0.262963	32.4365377	73.80654	0.000261	0.0003404	124.2184	95.296475
13.79	0.375471	46.3144255	87.68443	0.000346	0.0004516	134.002	102.55062

Table 5.5 Typical resilient modulus test results (A-2BE, Average)

		Summary of Resilient Modulus Test Results					
	Test Type	**T 292-91I**			**Soil Identification**		
	Date:	01/25/1996	01/25/1996		Lee County, Site #2B		
	Sample:	#2	#1		S.R. 884, Embankment		
	Mold:	#5	#4		Fine Sand		
	Lab.Moist:	3.3%			Insitu Moist:	3.3%	
	Lab.Den:	16.84	kN/m^3		Insitu Den:	17.01	kN/m^3
	Compaction Effort:		95 blows per layer (8 layers)				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. Stress	82.74	kPa
					Conf. Pres.	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa			MPa	MPa
103.42	0.376497	46.441035	356.70104	0.000169	0.00018931	275.6166	245.36247
103.42	0.54241	66.906387	377.16639	0.000242	0.00026822	276.9776	249.59486
103.42	0.822899	101.50473	411.76473	0.000351	0.00039209	289.2912	259.0451
68.95	0.263798	32.539525	239.38953	0.000141	0.00016566	230.2682	196.70707
68.95	0.375379	46.303088	253.15309	0.000204	0.00023472	227.054	197.4951
68.95	0.543306	67.016935	273.86694	0.000292	0.00033228	229.43	201.90197
68.95	0.822822	101.49528	308.34528	0.000418	0.00047275	243.0366	214.86859
34.47	0.151428	18.678646	122.08865	0.000111	0.00013753	169.0427	135.94664
34.47	0.263063	32.448819	135.85882	0.000195	0.00023559	166.1503	137.86027
34.47	0.375517	46.320096	149.7301	0.000274	0.00033006	168.8441	140.5024
34.47	0.543153	66.998039	170.40804	0.000376	0.00044806	178.2223	149.74347
13.79	0.151711	18.713606	60.083606	0.000159	0.00020225	117.4186	92.567355
13.79	0.26294	32.433703	73.803703	0.000262	0.00033294	123.7063	97.465239
13.79	0.375486	46.316315	87.686315	0.000348	0.00044163	132.9578	104.93092

Table 5.6 Summary of Laboratory Resilient Modulus Test Results Based on $*M_R = k_1\theta^{k_2}$ Model

Locations	Test #	M_R from 10.2-cm Measurements (MPa)	R^2	M_R from 20.3-cm Measurements (MPa)	R^2	Lab. Density (kN/m^3)	Lab. Moisture Content (%)
DISTRICT #1							
Lee Co., Site #1B, S.R.884 (L.R. Base)	A-1BL	$M_R = 5.80\theta^{0.624}$	0.70	$M_R = 5.65\theta^{0.6104}$	0.75	17.53	15.3
Subgrade (A-3)	A-1BS	$M_R = 16.18\theta^{0.4887}$	0.97	$M_R = 9.64\theta^{0.5413}$	0.98	16.57	4.3
Embankment (A-3)	A-1BE	$M_R = 23.11\theta^{0.3895}$	0.98	$M_R = 10.17\theta^{0.513}$	0.99	15.70	11.9
Lee Co., Site #2B, S.R.884 (L.R. Base)	A-2BL	$M_R = 4.69\theta^{6844}$	0.61	$M_R = 2.68\theta^{7355}$	0.80	18.00	15.0
Subgrade (A-3)	A-2BS	$M_R = 18.46\theta^{0.4894}$	0.97	$M_R = 6.86\theta^{0.6142}$	0.99	16.57	4.3
Embankment (A-3)	A-2BE	$M_R = 15.72\theta^{0.4822}$	0.98	$M_R = 8.86\theta^{0.5601}$	0.99	16.84	3.3
Polk Co., Site #1A, U.S. 17 (L.R. Base)	A-1AL	$M_R = 4.24\theta^{0.7259}$	0.65	$M_R = 2.64\theta^{0.7712}$	0.72	19.51	10.6
Subgrade (A-2-4)	A-1AS	$M_R = 11.54\theta^{0.535}$	0.96	$M_R = 7.24\theta^{0.5998}$	0.98	17.60	10.1
Embankment (A-3)	A-1AE	$M_R = 11.70\theta^{0.5047}$	0.94	$M_R = 6.71\theta^{0.5747}$	0.98	17.02	9.6
Polk Co., Site #2A, U.S. 17 (L.R. Base)	**A-2AL	Erratic data		$M_R = 9.71\theta^{0.5872}$	0.80	18.68	10.3
Subgrade (A-2-4)	A-2AS	$M_R = 14.50\theta^{0.523}$	0.96	$M_R = 7.91\theta^{0.5776}$	0.98	17.69	7.9
Embankment (A-3)	A-2AE	$M_R = 28.48\theta^{0.4123}$	0.95	$M_R = 9.14\theta^{0.5705}$	0.94	17.28	11.2
DISTRICT #2							
Alachua Co., Site #3, U.S. 301 (L.R. Base)	B-3L	$M_R = 5.24\theta^{0.7145}$	0.77	$M_R = 3.16\theta^{0.7448}$	0.84	19.18	10.2
Subgrade (A-3)	B-3S	$M_R = 12.14\theta^{0.4865}$	0.98	$M_R = 7.81\theta^{0.5455}$	0.98	16.93	11.5
Embankment (A-2-4)	B-3E	Can't achieve in-situ density					
Alachua Co., Site #4, U.S. 301 (L.R. Base)	B-4L	$M_R = 6.36\theta^{0.6738}$	0.74	$M_R = 5.01\theta^{0.6828}$	0.78	18.82	10.4
Subgrade (A-2-4)	B-4S	$M_R = 16.15\theta^{0.4691}$	0.98	$M_R = 8.35\theta^{0.558}$	0.99	17.18	9.0
Embankment (A-6)	B-4E	Sample failed		Sample failed			
Clay Co., Site #5, U.S. 17 (L.R. Base)	B-5L	$M_R = 28.97\theta^{0.4483}$	0.68	$M_R = 14.55\theta^{0.5257}$	0.76	18.21	10.4
Subgrade (A-2-4)	B-5S	$M_R = 13.37\theta^{0.4763}$	0.97	$M_R = 8.35\theta^{0.5213}$	0.99	15.60	7.2
Embankment (A-3)	B-5E	$M_R = 15.08\theta^{0.4567}$	0.98	$M_R = 10.23\theta^{0.498}$	0.98	15.86	8.9
Clay Co., Site #6, U.S. 17 (L.R. Base)	B-6L	$M_R = 16.75\theta^{0.5339}$	0.57	$M_R = 13.47\theta^{0.5418}$	0.71	18.86	11.0
Subgrade (A-3)	B-6S	$M_R = 14.62\theta^{0.4534}$	0.99	$M_R = 7.01\theta^{0.5556}$	0.99	15.92	11.0
Embankment (A-3)	B-6E	$M_R = 16.08\theta^{0.4625}$	0.99	$M_R = 12.69\theta^{0.4872}$	0.98	16.05	8.9

Table 5.6 Summary of Laboratory Resilient Modulus Test Results Based on $*M_R = k_1\theta^{k_2}$ Model (continued)

DISTRICT #3							
Jefferson Co., Site #1A, U.S. 27 (L.R. Base)	**C-1AL	$M_R = 10.34\,\theta^{0.5994}$		$M_R = 4.95\,\theta^{0.6801}$	0.80	18.36	12.6
Subgrade (A-4)	**C-1AS	$M_R = 17.93\,\theta^{0.4269}$		$M_R = 13.77\,\theta^{0.465}$		17.41	14.7
Embankment (A-2-6)	C-1AE	Sample failed		Sample failed			
Jefferson Co., Site # 2A, U.S. 27 (L.R. Base)	C-2AL	$M_R = 7.79\,\theta^{0.6599}$	0.77	$M_R = 6.44\,\theta^{0.6627}$	0.80	18.62	11.5
Subgrade (A-4)	**C-2AS	Sample failed		Sample failed			
Embankment (A-2-4)	C-2AE	$M_R = 9.67\,\theta^{0.5005}$	0.98	$M_R = 6.86\,\theta^{0.5533}$	0.99	17.22	13.3
Gadsden Co., Site # 2B, U.S. 27 (L.R. Base)	C-2BL	$M_R = 4.77\,\theta^{0.6829}$	0.77	$M_R = 3.56\,\theta^{0.7256}$	0.80	19.03	10.8
Subgrade (A-2-4)	C-2BS	$M_R = 12.33\,\theta^{0.4915}$	0.96	$M_R = 7.28\,\theta^{0.5652}$	0.97	18.41	10.7
Embankment #1 (A-2-4)	C-2BE	$M_R = 12.69\,\theta^{0.4696}$	0.98	$M_R = 7.67\,\theta^{0.5422}$	0.98	17.64	11.3
Gadsden Co., Site # 3B, U.S. 27 (L.R. Base)	C-3BL	$M_R = 2.99\,\theta^{0.7367}$	0.74	$M_R = 2.43\,\theta^{0.7580}$	0.76	18.38	10.8
Subgrade (A-3)	C-3BS	$M_R = 15.84\,\theta^{0.4736}$	0.96	$M_R = 9.86\,\theta^{0.5381}$	0.97	18.65	7.9
Embankment (A-6)	***C-3BE	$M_R = 1333\,\delta_d^{-0.6802}$	0.97	$M_R = 491\,\delta_d^{-0.4662}$		16.48	21.7
DISTRICTS #4 & 6							
Dade Co., Site #1, U.S. 41 (L.R. Base)	F-1L	Erratic data		Erratic data		20.10	6.2
Subgrade (Limerock)	**F-1S	$M_R = 39.05\,\theta^{0.409}$		$M_R = 22.33\,\theta^{0.472}$		18.60	7.3
Embankment (Limerock)	F-1E	$M_R = 10.61\,\theta^{0.5729}$	0.62	$M_R = 10.13\,\theta^{0.581}$	0.78	19.20	9.3
Dade Co., Site #2, U.S. 41 (L.R. Base)	**F-2L	$M_R = 28.61\,\theta^{0.501}$		$M_R = 8.02\,\theta^{0.6693}$		20.27	7.5
Subgrade (Limerock)	F-2S	$M_R = 16.30\,\theta^{0.5675}$	0.65	$M_R = 14.39\,\theta^{0.5713}$	0.71	20.50	7.9
Embankment (Limerock)	F-2E	$M_R = 18.13\,\theta^{0.5208}$	0.58	$M_R = 14.17\,\theta^{0.5291}$	0.72	18.90	8.6
Martin Co., Site #3, U.S. 1 (L.R. Base)	D-3L	Erratic data		Erratic data		20.25	5.7
Subgrade (A-3)	D-3S	$M_R = 24.16\,\theta^{0.4613}$	0.96	$M_R = 10.99\,\theta^{0.564}$	0.98	17.86	3.6
Embankment (A-3)	D-3E	$M_R = 21.83\,\theta^{0.4425}$	0.98	$M_R = 9.37\,\theta^{0.5578}$	0.99	17.04	2.1
Martin Co., Site #4, U.S. 1 (L.R. Base)	D-4L	$M_R = 20.23\,\theta^{0.5157}$	0.62	$M_R = 15.87\,\theta^{0.5252}$	0.73	19.50	7.1
Subgrade (A-4)	D-4S	$M_R = 25.07\,\theta^{0.4592}$	0.98	$M_R = 10.17\,\theta^{0.5819}$	0.98	18.23	4.6
Embankment (A-3)	D-4E	$M_R = 28.61\,\theta^{0.4346}$	0.97	$M_R = 16.18\,\theta^{0.5024}$	0.98	17.10	3.8

Table 5.6 Summary of Laboratory Resilient Modulus Test Results Based on $*M_R = k_1\theta^{k_2}$ Model (continued)

DISTRICT #5							
Seminole Co., Site #1, U.S. 414 (L.R. Base)	E-1L	$M_R = 17.91\,\theta^{0.5371}$	0.73	$M_R = 12.94\,\theta^{0.5631}$	0.78	19.35	8.8
Subgrade (A-2-4)	E-1S	$M_R = 24.71\,\theta^{0.4091}$	0.96	$M_R = 13.75\,\theta^{0.494}$	0.97	17.71	7.3
Embankment (A-2-4)	E-1E	$M_R = 22.64\,\theta^{0.454}$	0.99	$M_R = 13.05\,\theta^{0.512}$	0.99	17.43	7.8
Seminole Co., Site #1, U.S. 414 (L.R. Base)	E-2L	$M_R = 9.12\,\theta^{0.5973}$	0.77	$M_R = 7.95\,\theta^{0.6056}$	0.78	18.21	9.3
Subgrade (A-2-4)	E-2S	$M_R = 23.14\,\theta^{0.4085}$	0.97	$M_R = 11.05\,\theta^{0.5107}$	0.98	17.76	10.7
Embankment (A-3)	E-2E	$M_R = 22.86\,\theta^{0.4397}$	0.97	$M_R = 11.71\,\theta^{0.5317}$	0.98	16.43	10.7
Osceola Co., Site #3, U.S. 441 (Coquina Base)	E-3L	$M_R = 18.29\,\theta^{0.532}$	0.88	$M_R = 14.83\,\theta^{0.541}$	0.86	20.25	4.6
Subgrade (A-3)	E-3S	$M_R = 24.32\,\theta^{0.4985}$	0.93	$M_R = 18.83\,\theta^{0.5087}$	0.96	18.62	4.2
Embankment (A-3)	E-3E	$M_R = 18.49\,\theta^{0.4733}$	0.97	$M_R = 11.88\,\theta^{0.5166}$	0.98	16.40	3.8
Osceola Co., Site #4, U.S. 441 (Coquina Base)	E-4L	$M_R = 16.82\,\theta^{0.538}$	0.90	$M_R = 13.02\,\theta^{0.5526}$	0.90	20.77	4.3
Subgrade (A-3)	E-4S	$M_R = 28.66\,\theta^{0.4409}$	0.96	$M_R = 15.60\,\theta^{0.5135}$	0.98	19.07	6.8
Embankment (A-3)	E-4E	$M_R = 18.18\,\theta^{0.4667}$	0.98	$M_R = 12.07\,\theta^{0.504}$	0.99	16.74	12.1

*M_R is MPa and θ is kPa

** Bad correlations

*** Based on $M_R = k_5\,\sigma_d^{k_6}$ Model, where M_R is MPa and σ_d is kPa

Table 5.7 Summary of Laboratory Resilient Modulus Test Results Based on $*M_R = k_3\sigma_3^{k_4}$ Model

Locations	Test #	M_R from 10.2-cm Measurements (MPa)	R^2	M_R from 20.3-cm Measurements (MPa)	R^2	Lab. Density (kN/m^3)	Lab. Moisture Content (%)
DISTRICT #1							
Lee Co., Site #1B, S.R. 884 (L.R. Base)	A-1BL	$M_R = 16.21\,\sigma_3^{0.6061}$	0.98	$M_R = 15.89\,\sigma_3^{0.5855}$	0.99	17.53	15.3
Subgrade (A-3)	A-1BS	$M_R = 44.39\,\sigma_3^{0.4083}$	0.99	$M_R = 29.64\,\sigma_3^{0.4273}$	1.00	16.57	4.3
Embankment (A-3)	A-1BE	$M_R = 54.06\,\sigma_3^{0.3144}$	1.00	$M_R = 29.49\,\sigma_3^{0.4273}$	1.00	15.70	11.9
Lee Co., Site #2B, S.R. 884 (L.R. Base)	A-2BL	$M_R = 14.13\,\sigma_3^{0.6705}$	1.00	$M_R = 10.07\,\sigma_3^{0.6855}$	1.00	18.00	15.0
Subgrade (A-3)	A-2BS	$M_R = 51.02\,\sigma_3^{0.4073}$	0.99	$M_R = 25.03\,\sigma_3^{0.5066}$	0.99	16.57	4.3
Embankment (A-3)	A-2BE	$M_R = 42.47\,\sigma_3^{0.4023}$	0.99	$M_R = 28.20\,\sigma_3^{0.4667}$	0.99	16.84	3.3
Polk Co., Site #1A, U.S. 17 (L.R. Base)	A-1AL	$M_R = 15.24\,\sigma_3^{0.6842}$	0.98	$M_R = 9.62\,\sigma_3^{0.7442}$	0.98	19.51	10.6
Subgrade (A-2-4)	A-1AS	$M_R = 33.92\,\sigma_3^{0.4535}$	0.99	$M_R = 24.44\,\sigma_3^{0.5062}$	0.99	17.60	10.1
Embankment (A-3)	A-1AE	$M_R = 37.85\,\sigma_3^{0.5906}$	0.98	$M_R = 21.61\,\sigma_3^{0.4838}$	0.99	17.02	9.6
Polk Co., Site #2A, U.S. 17 (L.R. Base)	A-2AL	$M_R = 31.41\,\sigma_3^{0.4351}$	0.93	$M_R = 27.61\,\sigma_3^{0.5512}$	0.99	18.68	10.3
Subgrade (A-2-4)	A-2AS	$M_R = 42.05\,\sigma_3^{0.4412}$	0.99	$M_R = 26.34\,\sigma_3^{0.4800}$	0.99	17.69	7.9
Embankment (A-3)	A-2AE	$M_R = 67.48\,\sigma_3^{0.3421}$	0.99	$M_R = 27.79\,\sigma_3^{0.4762}$	0.99	17.28	11.2
DISTRICT #2							
Alachua Co., Site #3, U.S. 301 (L.R. Base)	B-3L	$M_R = 18.13\,\sigma_3^{0.6769}$	0.99	$M_R = 12.01\,\sigma_3^{0.6951}$	0.99	19.18	10.2
Subgrade (A-3)	B-3S	$M_R = 32.35\,\sigma_3^{0.4122}$	1.00	$M_R = 23.63\,\sigma_3^{0.4602}$	1.00	16.93	11.5
Embankment (A-2-4)	B-3E	Can't achieve in-situ density					
Alachua Co., Site #4, U.S. 301 (L.R. Base)	B-4L	$M_R = 20.08\,\sigma_3^{0.6446}$	0.98	$M_R = 16.37\,\sigma_3^{0.6481}$	0.99	18.82	10.4
Subgrade (A-2-4)	B-4S	$M_R = 42.01\,\sigma_3^{0.3945}$	1.00	$M_R = 26.17\,\sigma_3^{0.4681}$	0.99	17.18	9.0
Embankment (A-6)	B-4E	Sample failed		Sample failed			
Clay Co., Site #5, U.S. 17 (L.R. Base)	B-5L	$M_R = 58.68\,\sigma_3^{0.4433}$	0.98	$M_R = 35.10\,\sigma_3^{0.5063}$	0.99	18.21	10.4
Subgrade (A-2-4)	B-5S	$M_R = 34.91\,\sigma_3^{0.4037}$	1.00	$M_R = 24.59\,\sigma_3^{0.4347}$	1.00	15.60	7.2
Embankment (A-3)	B-5E	$M_R = 38.29\,\sigma_3^{0.3843}$	1.00	$M_R = 28.32\,\sigma_3^{0.4148}$	1.00	15.86	8.9
Clay Co., Site #6, U.S. 17 (L.R. Base)	B-6L	$M_R = 36.68\,\sigma_3^{0.5429}$	0.98	$M_R = 32.39\,\sigma_3^{0.5294}$	0.99	18.86	11.0
Subgrade (A-3)	B-6S	$M_R = 35.28\,\sigma_3^{0.3915}$	1.00	$M_R = 20.84\,\sigma_3^{0.4773}$	1.00	15.92	11.0
Embankment (A-3)	B-6E	$M_R = 42.35\,\sigma_3^{0.3831}$	1.00	$M_R = 34.70\,\sigma_3^{0.4072}$	1.00	16.05	8.9

Table 5.7 Summary of Laboratory Resilient Modulus Test Results Based on $*M_R = k_3\sigma_3^{k_4}$ Model (continued)

DISTRICT #3							
Jefferson Co., Site #1A, U.S. 27 (L.R. Base)	C-1AL	$M_R = 23.88\,\sigma_3^{0.6143}$	0.98	$M_R = 16.63\,\sigma_3^{0.6361}$	1.00	18.36	12.6
Subgrade (A-4)	C-1AS	$M_R = 33.77\,\sigma_3^{0.4197}$	1.00	$M_R = 29.29\,\sigma_3^{0.4458}$	0.99	17.41	14.7
Embankment (A-2-6)	C-1AE	Sample failed		Sample failed			
Jefferson Co., Site #2A, U.S. 27 (L.R. Base)	C-2AL	$M_R = 24.17\,\sigma_3^{0.6290}$	0.99	$M_R = 20.34\,\sigma_3^{0.6281}$	0.99	18.62	11.5
Subgrade (A-4)	C-2AS	Sample failed		Sample failed			
Embankment (A-2-4)	C-2AE	$M_R = 28.10\,\sigma_3^{0.4107}$	0.98	$M_R = 21.89\,\sigma_3^{0.4585}$	0.99	17.22	13.3
Gadsden Co., Site #2B, U.S. 27 (L.R. Base)	C-2BL	$M_R = 16.25\,\sigma_3^{0.6375}$	0.99	$M_R = 13.18\,\sigma_3^{0.6754}$	0.99	19.03	10.8
Subgrade (A-2-4)	C-2BS	$M_R = 33.23\,\sigma_3^{0.4165}$	0.99	$M_R = 22.87\,\sigma_3^{0.4779}$	0.99	18.41	10.7
Embankment #1 (A-2-4)	C-2BE	$M_R = 34.37\,\sigma_3^{0.3858}$	0.98	$M_R = 23.89\,\sigma_3^{0.4488}$	0.98	17.64	11.3
Gadsden Co., Site #3B, U.S. 27 (L.R. Base)	C-3BL	$M_R = 10.54\,\sigma_3^{0.7032}$	0.99	$M_R = 8.95\,\sigma_3^{0.7213}$	0.99	18.38	10.8
Subgrade (A-3)	C-3BS	$M_R = 40.74\,\sigma_3^{0.4039}$	0.99	$M_R = 29.04\,\sigma_3^{0.4570}$	0.99	18.65	7.9
Embankment (A-6)	C-3BE					16.48	21.7
DISTRICTS #4 & 6							
Dade Co., Site #1, U.S. 41 (L.R. Base)	F-1L	Erratic data		Erratic data		20.10	6.2
Subgrade (Limerock)	F-1S	$M_R = 66.05\,\sigma_3^{0.4354}$	0.96	$M_R = 47.58\,\sigma_3^{0.4634}$	0.99	18.60	7.3
Embankment (Limerock)	F-1E	$M_R = 29.33\,\sigma_3^{0.5808}$	0.97	$M_R = 26.58\,\sigma_3^{0.5620}$	0.99	19.20	9.3
Dade Co., Site #2, U.S. 41 (L.R. Base)	F-2L	$M_R = 55.60\,\sigma_3^{0.5283}$	0.97	$M_R = 24.60\,\sigma_3^{0.6450}$	0.99	20.27	7.5
Subgrade (Limerock)	F-2S	$M_R = 39.78\,\sigma_3^{0.5614}$	0.99	$M_R = 36.58\,\sigma_3^{0.5559}$	0.99	20.50	7.9
Embankment (Limerock)	F-2E	$M_R = 39.19\,\sigma_3^{0.5280}$	0.97	$M_R = 33.61\,\sigma_3^{0.5156}$	0.98	18.90	8.6
Martin Co., Site #3, U.S. 1 (L.R. Base)	D-3L	Erratic data		Erratic data		20.25	5.7
Subgrade (A-3)	D-3S	$M_R = 60.75\,\sigma_3^{0.3930}$	0.99	$M_R = 34.60\,\sigma_3^{0.4753}$	0.99	17.86	3.6
Embankment (A-3)	D-3E	$M_R = 55.07\,\sigma_3^{0.3668}$	0.99	$M_R = 30.37\,\sigma_3^{0.4598}$	0.99	17.04	2.1
Martin Co., Site #4, U.S. 1 (L.R. Base)	D-4L	$M_R = 44.54\,\sigma_3^{0.5159}$	0.98	$M_R = 37.28\,\sigma_3^{0.5125}$	0.99	19.50	7.1
Subgrade (A-4)	D-4S	$M_R = 64.82\,\sigma_3^{0.3833}$	0.99	$M_R = 34.16\,\sigma_3^{0.4838}$	0.99	18.23	4.6
Embankment (A-3)	D-4E	$M_R = 68.11\,\sigma_3^{0.3705}$	1.00	$M_R = 44.56\,\sigma_3^{0.4253}$	1.00	17.10	3.8

Table 5.7 Summary of Laboratory Resilient Modulus Test Results Based on $*M_R = k_3\sigma_3^{k_4}$ Model (continued)

DISTRICT #5							
Seminole Co., Site #1, U.S. 414 (L.R. Base)	E-1L	$M_R = 43.66\,\sigma_3^{0.5201}$	0.98	$M_R = 33.80\,\sigma_3^{0.5387}$	0.98	19.35	8.8
Subgrade (A-2-4)	E-1S	$M_R = 55.90\,\sigma_3^{0.3496}$	0.99	$M_R = 37.15\,\sigma_3^{0.4191}$	0.99	17.71	7.3
Embankment (A-2-4)	E-1E	$M_R = 59.17\,\sigma_3^{0.3739}$	0.99	$M_R = 38.22\,\sigma_3^{0.4235}$	1.00	17.43	7.8
Seminole Co., Site #1, U.S. 414 (L.R. Base)	E-2L	$M_R = 25.96\,\sigma_3^{.5640}$	0.97	$M_R = 22.86\,\sigma_3^{0.5729}$	0.98	18.21	9.3
Subgrade (A-2-4)	E-2S	$M_R = 53.01\,\sigma_3^{0.3447}$	0.99	$M_R = 31.43\,\sigma_3^{0.4288}$	0.99	17.76	10.7
Embankment (A-3)	E-2E	$M_R = 55.48\,\sigma_3^{0.3727}$	0.99	$M_R = 34.64\,\sigma_3^{0.4474}$	0.99	16.43	10.7
Osceola Co., Site #3, U.S. 441 (Coquina Base)	E-3L	$M_R = 48.14\,\sigma_3^{0.4937}$	0.99	$M_R = 39.10\,\sigma_3^{0.5056}$	0.99	20.25	4.6
Subgrade (A-3)	E-3S	$M_R = 66.82\,\sigma_3^{0.4222}$	1.00	$M_R = 53.74\,\sigma_3^{0.4263}$	0.99	18.62	4.2
Embankment (A-3)	E-3E	$M_R = 48.72\,\sigma_3^{0.3980}$	1.00	$M_R = 34.41\,\sigma_3^{0.4327}$	1.00	16.40	3.8
Osceola Co., Site #4, U.S. 441 (Coquina Base)	E-4L	$M_R = 44.20\,\sigma_3^{0.5012}$	0.99	$M_R = 34.90\,\sigma_3^{0.5160}$	1.00	20.77	4.3
Subgrade (A-3)	E-4S	$M_R = 69.24\,\sigma_3^{0.3754}$	0.99	$M_R = 44.09\,\sigma_3^{0.4341}$	0.99	19.07	6.8
Embankment (A-3)	E-4E	$M_R = 47.63\,\sigma_3^{0.3904}$	1.00	$M_R = 34.25\,\sigma_3^{0.4209}$	1.00	16.74	12.1

*M_R is MPa and σ_3 is kPa

Table 5.8 Summary of k_1 and k_2 Values for Limerock and Coquina Materials

Locations	Laboratory Resilient Modulus Test Results ($*M_R = k_1\theta^{k_2}$)						
		k_1	k_2	R^2	k_1	k_2	R^2
	Test #	10.2-cm measurements			20.3-cm measurements		
Lee Co., Site #1B, S.R. 884 (L.R. Base)	A-1BL	5.80	0.6240	0.70	5.65	0.6104	0.75
Lee Co., Site #2B, S.R. 884 (L.R. Base)	A-2BL	4.69	0.6844	0.61	2.68	0.7355	0.80
Polk Co., Site #1A, U.S. 17 (L.R. Base)	A-1AL	4.24	0.7259	0.65	2.64	0.7712	0.72
Polk Co., Site #2A, U.S. 17 (L.R. Base)	A-2AL				9.71	0.5872	0.80
Alachua Co., Site #3, U.S. 301 (L.R. Base)	B-3L	5.24	0.7145	0.77	3.16	0.7448	0.84
Alachua Co., Site #4, U.S. 301 (L.R. Base)	B-4L	6.36	0.6738	0.74	5.01	0.6828	0.78
Clay Co., Site #5, U.S. 17 (L.R. Base)	B-5L	28.97	0.4483	0.68	14.55	0.5257	0.76
Clay Co., Site #6, U.S. 17 (L.R. Base)	B-6L	16.75	0.5339	0.57	13.47	0.5418	0.71
Jefferson Co., Site #1A, U.S. 27 (L.R. Base)	C-1AL				4.95	0.6801	0.80
Jefferson Co., Site #2A, U.S. 27 (L.R. Base)	C-2AL	7.79	0.6599	0.77	6.44	0.6627	0.80
Gadsden Co., Site #2B, U.S. 27 (L.R. Base)	C-2BL	4.77	0.6829	0.77	3.56	0.7256	0.80
Gadsden Co., Site #3B, U.S. 27 (L.R. Base)	C-3BL	2.99	0.7367	0.74	2.43	0.7580	0.76
Dade Co., Site #1, U.S. 41 (L.R. Base)	F-1L						
Subgrade (Limerock)	F-1S						
Embankment (Limerock)	F-1E	10.61	0.5729	0.62	10.13	0.5810	0.78
Dade Co., Site #2, U.S. 41 (L.R. Base)	F-2L						
Subgrade (Limerock)	F-2S	16.30	0.5675	0.65	14.39	0.5713	0.71
Embankment (Limerock)	F-2E	18.13	0.5208	0.58	14.17	0.5291	0.72
Martin Co., Site #3, U.S. 1 (L.R. Base)	D-3L						
Martin Co., Site #4, U.S. 1 (L.R. Base)	D-4L	20.23	0.5157	0.62	15.87	0.5252	0.73
Seminole Co., Site #1, U.S. 414 (L.R. Base)	E-1L	17.91	0.5371	0.73	12.94	0.5631	0.78
Osceola Co., Site #3, U.S. 441 (Coquina Base)	E-3L	18.29	0.5320	0.88	14.83	0.5410	0.86
Osceola Co., Site #4, U.S. 441 (Coquina Base)	E-4L	16.82	0.5380	0.90	13.02	0.5526	0.90

*M_R in units of MPa and θ in units of kPa

Table 5.9 Summary of k_1 and k_2 Values for A-2-4 and A-3 Soils

Locations	Laboratory Resilient Modulus Test Results (*$M_R = k_1\theta^{k_2}$)						
		k_1	k_2	R^2	k_1	k_2	R^2
	Test #	10.2-cm measurements			20.3-cm measurements		
Lee Co., Site #1B, S.R. 884 (Subgrade, A-3)	A-1BS	16.18	0.4887	0.97	9.64	0.5413	0.98
Lee Co., Site #1B, S.R. 884 (Embankment, A-3)	A-1BE	23.11	0.3895	0.98	10.17	0.5130	0.99
Lee Co., Site #2B, S.R. 884 (Subgrade, A-3)	A-2BS	18.46	0.4894	0.97	6.86	0.6142	0.99
Lee Co., Site #2B, S.R. 884 (Embankment, A-3)	A-2BE	15.72	0.4822	0.98	8.86	0.5601	0.99
Polk Co., Site #1A, U.S. 17 (Subgrade, A-2-4)	A-1AS	11.54	0.5350	0.96	7.24	0.5998	0.98
Polk Co., Site #1A, U.S. 17 (Embankment, A-3)	A-1AE	11.70	0.5047	0.94	6.71	0.5747	0.98
Polk Co., Site #2A, U.S. 17 (Subgrade, A-2-4)	A-2AS	14.50	0.5230	0.96	7.91	0.5776	0.98
Polk Co., Site #2A, U.S. 17 (Embankment, A-3)	A-2AE	28.48	0.4123	0.95	9.14	0.5705	0.94
Alachua Co., Site #3, U.S. 301 (Subgrade, A-3)	B-3S	12.14	0.4865	0.98	7.81	0.5455	0.98
Alachua Co., Site #4, U.S. 301 (Subgrade, A-2-4)	B-4S	16.15	0.4691	0.98	8.35	0.5580	0.99
Clay Co., Site #5, U.S. 17 (Embankment, A-3)	B-5S	13.37	0.4763	0.97	8.36	0.5213	0.99
Clay Co., Site #5, U.S. 17 (Subgrade, A-2-4)	B-5E	15.08	0.4567	0.98	10.23	0.4980	0.98
Clay Co., Site #6, U.S. 17 (Subgrade, A-3)	B-6S	14.62	0.4534	0.99	7.01	0.5556	0.99
Clay Co., Site #6, U.S. 17 (Embankment, A-3)	B-6E	16.08	0.4625	0.99	12.69	0.4872	0.98
Jefferson Co., #2A, U.S. 27 (Embankment, A-2-4)	C-2AE	9.67	0.5005	0.98	6.86	0.5533	0.99
Gadsden Co., Site #2B, U.S. 27 (Subgrade, A-2-4)	C-2BS	12.33	0.4915	0.96	7.28	0.5652	0.97
Gadsden Co., Site #2B, U.S. 27 (Embankment #1, A-2-4)	C-2BE	12.69	0.4696	0.98	7.67	0.5422	0.98
Gadsden Co., Site #3B, U.S. 27 (Subgrade, A-3)	C-3BS	15.84	0.4736	0.96	9.86	0.5381	0.97
Martin Co., Site #3, U.S. 1 (Subgrade, A-3)	D-3S	24.16	0.4613	0.96	10.99	0.5640	0.98
Martin Co., Site #3, U.S. 1 (Embankment, A-3)	D-3E	21.83	0.4425	0.98	9.37	0.5578	0.99
Martin Co., Site #4, U.S. 1 (Embankment, A-3)	D-4E	28.61	0.4346	0.97	16.18	0.5024	0.98
Seminole Co., Site #1, U.S. 414 (Subgrade, A-2-4)	E-1S	24.71	0.4091	0.96	13.75	0.4940	0.97
Seminole Co., Site #1, U.S. 414 (Embankment, A-2-4)	E-1E	22.64	0.4540	0.99	13.05	0.5120	0.99
Seminole Co., Site #2, U.S. 414 (Subgrade, A-2-4)	E-2S	23.14	0.4085	0.97	11.05	0.5107	0.98
Seminole Co., Site #2, U.S. 414 (Embankment, A-3)	E-2E	22.86	0.4397	0.97	11.71	0.5317	0.98
Osceola Co., Site #3 U.S. 441 (Subgrade, A-3)	E-3S	24.32	0.4985	0.93	18.83	0.5087	0.96
Osceola Co., Site #3 U.S. 441 (Embankment, A-3)	E-3E	18.49	0.4733	0.97	11.88	0.5166	0.98
Osoceola Co., Site #4, U.S. 441 (Subgrade, A-3)	E-4S	28.66	0.4409	0.96	15.60	0.5135	0.98
Osoceola Co., Site #4, U.S. 441 (Embankment, A-3)	E-4E	18.18	0.4667	0.98	12.07	0.5040	0.99

* M_R in units of MPa and θ in units of kPa

Table 5.10 Typical Resilient Modulus Test Results for A-4 Soil (D-4S, Sample1)

		Summary of Resilient Modulus Test Results					
	Test Type	**T292-91I**			**Soil Identification**		
	Date:	2/4/96			Martin County, Site #4		
	Sample:	#2			U.S. 1, Subgrade		
	Mold:	#4			Silty Clay		
	Lab.Moist:	4.6%			Insitu Moist	4.6%	
	Lab.Den:	18.30	kN/m^3		Insitu Den:	18.26	kN/m^3
	Compaction Effort:		210 blows per layer (8 layers)				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. Stress	82.74	kPa
					Conf. Pres.	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa			MPa	MPa
103.42	0.378756	46.71964	356.9796	0.0001	0.0001381	395.0921	338.2417
103.42	0.545529	67.29116	377.5512	0.0002	0.0001971	397.8782	341.3629
103.42	0.826776	101.983	412.243	0.0003	0.0003013	398.1768	338.4627
68.95	0.268241	33.08759	239.9376	0.0001	0.0001285	318.1499	257.491
68.95	0.376639	46.45847	253.3085	0.0001	0.0001821	314.9727	255.0911
68.95	0.548883	67.70485	274.5548	0.0002	0.0002611	321.2567	259.2814
68.95	0.823654	101.5979	308.4479	0.0003	0.0003664	335.8607	277.3057
34.47	0.155342	19.16146	122.5715	8E-05	0.0001096	243.707	174.8907
34.47	0.267423	32.98664	136.3966	0.0001	0.0001853	235.4086	178.0055
34.47	0.379752	46.84254	150.2525	0.0002	0.0002608	236.2801	179.6023
34.47	0.547943	67.58886	170.9989	0.0003	0.0003575	250.7935	189.0597
13.79	0.156498	19.30411	60.67411	0.0001	0.0001607	170.2678	120.0878
13.79	0.267592	33.00748	74.37748	0.0002	0.0002622	178.6603	125.8927
13.79	0.38229	47.15549	88.52549	0.0002	0.0003516	192.865	134.1312

Table 5.11 Typical Resilient Modulus Test Results for A-4 Soil (D-4S, Sample2)

		Summary of Resilient Modulus Test Results					
	Test Type	**T292-91I**			**Soil Identification**		
	Date:	2/4/96			Martin County, Site #4		
	Sample:	#1			U.S. 1, Subgrade		
	Mold:	#5			Silty Clay		
	Lab.Moist:	4.6%			Insitu Moist	4.6%	
	Lab.Den:	18.16	kN/m^3		Insitu Den:	18.26	kN/m^3
	Compaction Effort:		180 blows per layer (8 layers)				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. Stress	82.74	kPa
					Conf. Pres.	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa			MPa	MPa
103.42	0.376327	46.42007	356.6801	0.0001	0.0001427	394.6446	325.3267987
103.42	0.54343	67.03219	377.2922	0.0002	0.0002015	392.8626	332.6659478
103.42	0.823503	101.5792	411.8392	0.0003	0.0002998	399.3286	338.8091489
68.95	0.263651	32.52137	239.3714	0.0001	0.0001304	322.3928	249.3253142
68.95	0.375634	46.33448	253.1845	0.0001	0.0001847	317.6314	250.8804136
68.95	0.54399	67.10132	273.9513	0.0002	0.0002634	316.7024	254.7143814
68.95	0.823165	101.5375	308.3875	0.0003	0.0003701	334.5553	274.379381
34.47	0.151721	18.71485	122.1248	8E-05	0.0001079	241.872	173.4864324
34.47	0.263037	32.44566	135.8557	0.0001	0.0001881	236.6137	172.4685999
34.47	0.374904	46.2445	149.6545	0.0002	0.0002626	237.1513	176.0856578
34.47	0.543412	67.02999	170.44	0.0003	0.0003617	251.284	185.325713
13.79	0.151526	18.69071	60.06071	0.0001	0.0001602	176.1197	116.680189
13.79	0.27147	33.48592	74.85592	0.0002	0.0002723	179.4289	122.9687137
13.79	0.384218	47.39339	88.76339	0.0002	0.0003488	193.838	135.8950347

Table 5.12 Typical resilient modulus test results for A-4 soil (D-4S, Average)

		Summary of Resilient Modulus Test Results					
	Test Type	**T292-91I**			**Soil Identification**		
	Date:	2/4/96	2/4/96		Martin County, Site #4		
	Sample:	#2	#1		U.S. 1, Subgrade		
	Mold:	#4	#5		Silty Clay		
	Lab.Moist.	4.6%			Insitu Moist.	4.6%	
	Lab.Den.	18.23	kN/m^3		Insitu Den.	18.26	kN/m^3
	Compaction Effort:		195 blows per layer (8 layers)				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. Stress	82.74	kPa
					Conf. Pres.	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa			MPa	MPa
103.42	0.377542	46.56985	356.8299	0.000118	0.0001404	394.8683	331.7843
103.42	0.54448	67.16167	377.4217	0.00017	0.0001993	395.3704	337.0144
103.42	0.82514	101.7811	412.0411	0.000255	0.0003006	398.7527	338.6359
68.95	0.265946	32.80448	239.6545	0.000102	0.0001295	320.2713	253.4081
68.95	0.376136	46.39648	253.2465	0.000147	0.0001834	316.302	252.9858
68.95	0.546437	67.40308	274.2531	0.000211	0.0002623	318.9795	256.9979
68.95	0.823409	101.5677	308.4177	0.000303	0.0003682	335.208	275.8425
34.47	0.153532	18.93815	122.3482	7.8E-05	0.0001087	242.7895	174.1886
34.47	0.26523	32.71615	136.1261	0.000139	0.0001867	236.0112	175.237
34.47	0.377328	46.54352	149.9535	0.000197	0.0002617	236.7157	177.844
34.47	0.545678	67.30943	170.7194	0.000268	0.0003596	251.0387	187.1927
13.79	0.154012	18.99741	60.36741	0.00011	0.0001605	173.1938	118.384
13.79	0.269531	33.2467	74.6167	0.000186	0.0002673	179.0446	124.4307
13.79	0.383254	47.27444	88.64444	0.000245	0.0003502	193.3515	135.0131

Table 5.13 Typical resilient modulus test results for A-6 soil (C-3BE, One Sample)

		Summary of Resilient Modulus Test Results					
	Test Type	**T292-91I**			**Soil Identification**		
	Date:	2/8/96			Embankment (Clay)		
	Sample:	#1			Gadsden County, Site #3B		
	Mold:	#4			U.S. 27		
	Lab.Moist.	21.7%			Insitu Moist.	21.7%	
	Lab.Den.	16.46	kN/m^3		Insitu Den.	16.28	kN/m^3
	Compaction Effort:		200 blows per layer(8 layers)				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. Stress	82.74	kPa
					Conf. Pres.	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa			MPa	MPa
20.69	0.164	20.286	82.356	0.00013	0.00018	159.417	109.727
20.69	0.277	34.198	96.268	0.00028	0.00037	123.513	93.341
20.69	0.389	47.928	109.998	0.00045	0.00056	107.132	85.140
20.69	0.556	68.567	130.637	0.00095	0.00106	72.214	64.587
20.69	0.841	103.678	165.748	0.00197	0.00195	52.568	53.114

Table 5.14 Summary Resilient Modulus Test Results, Test 1

		Summary Resilient Modulus Test Results					
	Test Type	**T292-91I**			**Soil Identification**		
	Date:	09/07/1995			Embankment (Fine Sand)		
	Sample:	A-1ES1			U.S.17		
	Mold:	#3			Polk County, Site #1		
	Lab.Moist.	12.4%			Opt.Moist.	12.4%	
	Lab.Den.	17.17	kN/m^3		Opt.Den.	17.08	kN/m^3
	Compaction Effort:		20 blows/layer				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. σ	82.74	kPa
					Conf. σ	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa	%	%	MPa	MPa
103.42	0.376	46.344	356.604	0.00019	0.00023	243.054	199.320
103.42	0.546	67.361	377.621	0.00028	0.00033	243.116	203.309
103.42	0.825	101.723	411.983	0.00041	0.00049	249.765	209.269
68.95	0.263	32.432	239.282	0.00016	0.00020	199.492	160.786
68.95	0.376	46.422	253.272	0.00024	0.00029	197.437	159.280
68.95	0.543	66.929	273.779	0.00034	0.00041	199.431	162.543
68.95	0.825	101.801	308.651	0.00048	0.00059	210.964	172.602
34.47	0.152	18.754	122.164	0.00013	0.00017	147.934	112.259
34.47	0.264	32.518	135.928	0.00022	0.00029	145.788	113.077
34.47	0.376	46.421	149.831	0.00031	0.00040	147.885	115.630
34.47	0.544	67.157	170.567	0.00043	0.00055	155.854	122.774
13.79	0.152	18.743	60.113	0.00019	0.00027	99.527	70.279
13.79	0.264	32.555	73.925	0.00031	0.00042	106.634	76.922
13.79	0.382	47.109	88.479	0.00048	0.00061	99.010	77.852

Table 5.15 Summary Resilient Modulus Test Results, Test 2

		Summary Resilient Modulus Test Results					
	Test Type	**T292-91I**			**Soil Identification**		
	Date:	09/08/1995			Embankment (Fine Sand)		
	Sample:	A-1AES2			U.S.17		
	Mold:	#1			Polk County, Site #1		
	Lab.Moist.	12.3%			Opt.Moist.	12.4%	
	Lab.Den.	16.92	kN/m^3		Opt.Den.	17.08	kN/m^3
	Compaction Effort:		15 blows/layer				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. σ	82.74	kPa
					Conf. σ	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa	%	%	MPa	MPa
103.42	0.375	46.313	356.573	0.00019	0.00023	237.762	203.157
103.42	0.543	67.041	377.301	0.00028	0.00033	236.491	203.287
103.42	0.825	101.762	412.022	0.00042	0.00049	241.665	209.637
68.95	0.262	32.369	239.219	0.00017	0.00021	193.757	156.795
68.95	0.377	46.466	253.316	0.00025	0.00029	189.598	158.717
68.95	0.544	67.112	273.962	0.00035	0.00042	192.056	161.538
68.95	0.825	101.754	308.604	0.00050	0.00059	202.338	172.265
34.47	0.153	18.857	122.267	0.00013	0.00019	142.754	101.390
34.47	0.263	32.414	135.824	0.00023	0.00031	140.140	105.226
34.47	0.377	46.462	149.872	0.00033	0.00042	140.289	110.290
34.47	0.546	67.371	170.781	0.00046	0.00058	145.747	117.130
13.79	0.151	18.680	60.050	0.00019	0.00028	97.450	67.164
13.79	0.264	32.603	73.973	0.00032	0.00044	101.071	73.487
13.79	0.385	47.492	88.862	0.00052	0.00065	91.462	72.789

Table 5.16 Summary of Average Resilient Modulus Test Results

		Summary Resilient Modulus Test Results					
	Test Type	**T292-91I**			**Soil Identification**		
	Date:	09/07/1995			Embankment (Fine Sand)		
	Sample:	A-1AES			U.S.17		
	Mold #:	1&3			Polk County, Site #1		
	Lab.Moist.	12.4%			Opt.Moist.	12.4%	
	Lab.Den.	17.04	kN/m^3		Opt.Den.	17.08	kN/m^3
	Compaction Effort:		18 blows/layer				
					Conditioning Information		
					Load Type	Dynamic	
					Dev. σ	82.74	kPa
					Conf. σ	103.42	kPa
					No. Reps.	1000	

Confining Pressure	Axial Load	Dev. Stress	Bulk Stress	Middle Strain	Total Strain	Middle Modulus	Full Length Modulus
kPa	kN	kPa	kPa	%	%	MPa	MPa
103.42	0.376	46.328	356.588	0.00019	0.00023	240.408	201.238
103.42	0.545	67.201	377.461	0.00028	0.00033	239.804	203.298
103.42	0.825	101.742	412.002	0.00041	0.00049	245.715	209.453
68.95	0.263	32.400	239.250	0.00016	0.00020	196.625	158.791
68.95	0.377	46.444	253.294	0.00024	0.00029	193.517	158.998
68.95	0.543	67.021	273.871	0.00034	0.00041	195.744	162.041
68.95	0.825	101.778	308.628	0.00049	0.00059	206.651	172.434
34.47	0.152	18.806	122.216	0.00013	0.00018	145.344	106.825
34.47	0.263	32.466	135.876	0.00023	0.00030	142.964	109.151
34.47	0.377	46.441	149.851	0.00032	0.00041	144.087	112.960
34.47	0.545	67.264	170.674	0.00045	0.00056	150.800	119.952
13.79	0.152	18.711	60.081	0.00019	0.00027	98.488	68.722
13.79	0.264	32.579	73.949	0.00031	0.00043	103.852	75.204
13.79	0.383	47.300	88.670	0.00050	0.00063	95.236	75.320

Table 5.17 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T292-91I) District 1

District 1	Optimum Condition			Mr Tests	Middle Half Measurements			Full Length Measurements		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)		k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Lee Co., Site #1B, S.R. 884										
Subgrade (Fine Sand)	A-3	16.35	12.0	2A1BSS	26.35	0.4003	0.96	12.17	0.5019	0.98
Embankment (Fine Sand)	A-3	16.95	10.8	2A1BES	26.02	0.4290	0.97	14.83	0.4927	0.98
Lee Co., Site #2B, S.R. 884										
Subgrade (Fine Sand)	A-3	16.60	10.8	2A2BSS	23.18	0.4338	0.96	12.51	0.5073	0.98
Embankment (Fine Sand)	A-3	16.50	13.3	2A2BES	19.46	0.4520	0.99	12.23	0.5034	0.98
Polk Co., Site #1A, U.S. 17										
Subgrade (Fine Sand)	A-2-4	18.30	10.1	2A1ASS	15.59	0.4945	0.96	9.06	0.5661	0.97
Embankment (Fine Sand)	A-3	17.08	12.4	2A1AES	11.04	0.5172	0.97	5.4	0.6097	0.98
Polk Co., Site #2A, U.S. 17										
Subgrade (Fine Sand)	A-2-4	18.69	10.5	2A2ASS	18.48	0.4794	0.95	10.24	0.5536	0.98
Embankment (Fine Sand)	A-3	17.31	10.8	2A2AES	20.13	0.4734	0.95	11.67	0.5282	0.98

Table 5.18 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T292-91I) District 2

District 2	Optimum Condition			Mr Tests	Middle Half Measurements			Full Length Measurements		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)		k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Alachua Co., Site #3, U.S. 301										
Subgrade (Fine Sand)	A-3	17.78	11.7	2B3ASS	17.19	0.4478	0.96	12.81	0.4841	0.98
Embankment (Fine Sand)	A-3	18.36	12.4							
Alachua Co., Site #4, U.S. 301										
Subgrade (Silty Sand)	A-2-4	17.61	11.2	2B4ASS	23.71	0.4333	0.96	14.29	0.4977	0.97
Embankment (Clay)	A-6	19.57	11.7	2B4AEC						
Clay Co., Site #5, U.S. 17										
Subgrade (Fine Sand)	A-3	15.79	13.5	2B5CSS	14.01	0.4500	0.97	9.16	0.5024	0.98
Embankment (Silty Sand)	A-2-4	16.45	12.8	2B5CES	19.80	0.4159	0.96	12.83	0.4647	0.98
Clay Co., Site #6, U.S. 17										
Subgrade (Fine Sand)	A-3	15.85	14.3	2B6CSS	13.73	0.4450	0.95	8.79	0.4989	0.98
Embankment (Fine Sand)	A-3	15.98	12.4	2B6CES	20.58	0.4102	0.97	14.22	0.4597	0.97

Table 5.19 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T292-91I) District 3

District 3	Optimum Condition				Middle Half Measurements			Full Length Measurements		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)	Mr Tests	k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Jefferson Co., Site #1A, U.S. 27										
Subgrade (Silty Clay)	A-4	19.97	9.4	2C1JSC						
Embankment (Silty Clay)	A-2-6	20.60	8.6	2C1JEC						
Jefferson Co., Site #2A, U.S. 27										
Subgrade (Silty Clay)	A-4	20.45	7.4	2C2JSC						
Embankment (Silty Sand)	A-2-4	20.60	8.3	2C2JEC						
Gadsden Co., Site #2B, U.S. 27										
Subgrade (Fine Sand)	A-2-4	20.20	6.9	2C2GSS	38.26	0.3712	0.90	23.15	0.4373	0.93
Embankment #1 (Silty Sand)	A-2-4	18.27	9.7	2C2GES	20.52	0.4509	0.98	11.26	0.5139	0.99
Embankment #2 (Clay)	A-6	18.32	15.1	2C2GEC						
Gadsden Co., Site #3B, U.S. 27										
Subgrade (Fine Sand)	A-3	20.00	8.9	2C3GSS	19.0	0.4532	0.96	13.35	0.4969	0.96
Embankment (Clay)	A-6	17.74	11.3	2C3GES						

Table 5.20 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T292-91I) District 4

District 4	Optimum Condition			Mr Tests	Middle Half Measurements			Full Length Measurements		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)		k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Martin Co., Site #3, U.S. 1										
Subgrade (Fine Sand)	A-3	18.57	8.9	2D3MSS	35.14	0.4200	0.96	16.38	0.5105	0.98
Embankment (Fine Sand)	A-3	16.70	9.6	2D3MES	21.63	0.4554	0.99	11.15	0.5284	0.99
Martin Co., Site #4, U.S. 1										
Subgrade (Silty Sand)	A-4	18.51	9.7	2D4MSS	30.13	0.4403	0.97	14.30	0.5336	0.99
Embankment (Fine Sand)	A-3	17.82	9.5	2D4MES	34.56	0.4291	0.96	15.01	0.5267	0.97

Table 5.21 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T292-91I) District 5

District 5	Optimum Condition				Middle Half Measurements			Full Length Measurements		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)	Mr Tests	k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Seminole Co., Site #1, U.S. 414										
Subgrade (Silty Sand)	A-2-4	18.74	6.3	2E1SSS	38.37	0.3663	0.90	20.36	0.4475	0.94
Embankment (Silty Sand)	A-2-4	17.05	8.4	2E1SES	25.21	0.4096	0.98	15.57	0.4692	0.98
Seminole Co., Site #2, U.S. 414										
Subgrade (Silty Sand)	A-2-4	18.57	8.0	2E2SSS	33.17	0.3815	0.95	14.91	0.4994	0.97
Embankment (Fine Sand)	A-3	16.86	12.7	2E2SES	28.57	0.4159	0.96	14.1	0.5085	0.98
Osceola Co., Site #3, U.S. 414										
Subgrade (Fine Sand)	A-3	18.57	9.0	2E3OSS	40.73	0.4057	0.96	18.87	0.5017	0.97
Embankment (Fine Sand)	A-3	16.86	12.7	2E3OES	21.63	0.4554	0.99	9.53	0.5586	0.99
Osceola Co., Site #4, U.S. 414										
Subgrade (Fine Sand)	A-3	19.01	8.9	2E4OSS	31.61	0.4380	0.94	12.56	0.5480	0.98
Embankment (Fine Sand)	A-3	16.24	12.8	2E4OES	13.12	0.4714	0.98	8.86	0.5118	0.99

Table 5.22 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T294-92) District 1

District 1	Optimum Condition			Mr Tests	Middle Half Measurements			Full Length Measurements (Ex)		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)		k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Lee Co., Site #1B, S.R. 884										
Subgrade (Fine Sand)	A-3	16.35	12.0	4A1BSS	16.72	0.4959	0.88	11.49	0.4674	0.95
Lee Co., Site #2B, S.R. 884										
Subgrade (Fine Sand)	A-3	16.60	10.8	4A2BSS	20.27	0.4698	0.92	11.87	0.4700	0.95
Polk Co., Site #1A, U.S. 17										
Subgrade (Fine Sand)	A-2-4	18.30	10.1	4A1ASS	11.12	0.5525	0.89	10.27	0.4901	0.94
Polk Co., Site #2A, U.S. 17										
Subgrade (Fine Sand)	A-2-4	18.69	10.5	4A2ASS	9.69	0.5350	0.85	9.42	0.6377	0.84

Table 5.23 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T294-92) District 2

District 2	Optimum Condition				Middle Half Measurements			Full Length Measurements (Ex)		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)	Mr Tests	k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Alachua Co., Site #3, U.S. 301										
Subgrade (Fine Sand)	A-3	17.78	11.7	4B3ASS	7.06	0.6094	0.90	8.57	0.4967	0.95
Alachua Co., Site #4, U.S. 301										
Subgrade (Silty Sand)	A-2-4	17.61	11.2	4B4ASS	13.89	0.5262	0.92	17.15	0.3941	0.95
Clay Co., Site #5, U.S. 17										
Subgrade (Fine Sand)	A-3	15.79	13.5	4B5CSS	10.63	0.5414	0.85	7.26	0.5349	0.85
Clay Co., Site #6, U.S. 17										
Subgrade (Fine Sand)	A-3	15.85	14.3	4B6CSS	10.13	0.5068	0.92	7.75	0.4932	0.95

Table 5.24 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T294-92) District 3

District 3	Optimum Condition				Middle Half Measurements			Full Length Measurements (Ex)		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)	Mr Tests	k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Jefferson Co., Site #1A, U.S. 27										
Subgrade (Silty Clay)	A-4	19.97	9.4	4C1JSC						
Jefferson Co., Site #2A, U.S. 27										
Subgrade (Silty Clay)	A-4	20.45	7.4	4C2JSC	46.20	0.3367	0.64	26.25	0.3334	0.83
Gadsden Co., Site #2B, U.S. 27										
Subgrade (Fine Sand)	A-2-4	20.20	6.9	4C2GSS	30.18	0.4254	0.86	24.55	0.3632	0.95
Gadsden Co., Site #3B, U.S. 27										
Subgrade (Clay)	A-3	20.00	8.9	4C3GSS	4.59	0.6986	0.86	7.82	0.5182	0.93

Table 5.25 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T294-92) District 4

District 4	Optimum Condition			Mr Tests	Middle Half Measurements			Full Length Measurements (Ex)		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)		k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Martin Co., Site #3, U.S. 1										
Subgrade (Fine Sand)	A-3	18.57	8.9	4D3MSS	23.84	0.4834	0.92	17.34	0.4301	0.95
Martin Co., Site #4, U.S. 1										
Subgrade (Silty Sand)	A-4	18.51	9.7	4D4MSS	34.82	0.4314	0.89	18.67	0.4225	0.95

Table 5.26 Summary of Pertinent Engineering Parameters from Resilient Modulus Laboratory Measurements (T294-92) District 5

District 5	Optimum Condition			Mr Tests	Middle Half Measurements			Full Length Measurements (Ex)		
Locations	AASHTO Type	Dry Density (kN/m^3)	M.C. (%)		k_1 (MPa)	k_2	R^2	k_1 (MPa)	k_2	R^2
Seminole Co., Site #1, U.S. 414										
Subgrade (Silty Sand)	A-2-4	18.74	6.3	4E1SSS	23.75	0.4668	0.91	16.62	0.4328	0.95
Seminole Co., Site #2, U.S. 414										
Subgrade (Silty Sand)	A-2-4	18.57	8.0	4E2SSS	21.92	0.4623	0.90	20.16	0.3930	0.95
Osceola Co., Site #3, U.S. 414										
Subgrade (Fine Sand)	A-3	18.57	9.0	4E3OSS	24.51	0.4931	0.92	17.75	0.4353	0.95
Osceola Co., Site #4, U.S. 414										
Subgrade (Fine Sand)	A-3	19.01	8.9	4E4OSS	26.06	0.4751	0.89	18.62	0.4147	0.96

Table 5.27 Summary of the Coefficients k1 and k2 for the T292 and T294 Test Procedures

	T 292-91I Procedure		T 294-92 Procedure	
	Middle Half LVDTs	Full Length LVDTs	Middle Half LVDTs	Full Length (Ex) LVDTs
k_1 (MPa)	11.04 - 40.73	5.40 - 23.15	4.59 - 30.18	7.26 - 24.45
k_2	0.37 - 0.52	0.44 - 0.61	0.43 - 0.70	0.36 - 0.64
R^2	0.90 - 0.99	0.93 - 0.99	0.85 - 0.92	0.84 - 0.96

Table 5.28 Typical resilient modulus test results (A-1BL, sample 1)

		Summary of Resilient Modulus Test Results					
			(152 mm diameter)				
Test Type:	**T292-91I**				**Soil Identification**		
Date:	03/11/1997				Lee County, Site #1B		
Sample:	#1				S.R. 884, Base		
Mold:	#1				Limerock		
Lab. Moisture:		15.00%			Opt. Moisture:		15.10%
Lab. Den.:	17.63 kN/m^3				Max. Dry Den.:		17.47 kN/m^3
Compaction Effect:		20 blows/layer (8 layers)					
					Conditioning Information		
					Load Type:		Dynamic
					Deviator Stress:		103.5 kPa
					Confining Pressure:		138 kPa
					Number of Repetition:		1000
Confining Pressure	Axial Load	Deviator Stress	Bulk Stress	Strain (152 mm)	Strain (305 mm)	Modulus (152 mm)	Modulus (305 mm)
kPa	kN	kPa	kPa			MPa	MPa
137.8	1.194	65.428	479.275	0.00005	0.00018	643.991	359.274
137.8	2.494	136.718	551.085	0.00032	0.00044	422.634	311.541
137.8	3.757	205.923	619.877	0.00069	0.00080	297.802	257.941
103.4	1.239	67.922	378.539	0.00021	0.00029	316.772	232.235
103.4	2.496	136.820	447.646	0.00051	0.00060	269.453	228.798
103.4	3.757	205.933	516.417	0.00091	0.00100	225.540	206.088
68.9	0.616	33.783	240.645	0.00014	0.00020	248.300	168.268
68.9	1.244	68.176	275.130	0.00039	0.00045	176.987	151.730
68.9	2.501	137.115	343.988	0.00077	0.00084	177.845	162.631
68.9	3.761	206.187	413.070	0.00127	0.00136	161.968	151.159
34.5	0.615	33.691	137.069	0.00044	0.00048	76.168	70.437
34.5	1.244	68.196	171.584	0.00075	0.00082	90.717	82.746
34.5	1.872	102.590	205.907	0.00094	0.00106	108.602	96.827
20.7	0.613	33.599	95.552	0.00062	0.00069	53.868	48.635
20.7	0.866	47.493	109.537	0.00075	0.00084	63.492	56.533
20.7	1.119	61.346	123.294	0.00085	0.00096	72.547	64.089

Table 5.29 Typical resilient modulus test results (A-1BL, sample 2)

		Summary of Resilient Modulus Test Results					
		(152 mm diameter)					
Test Type:	**T292-91I**				**Soil Identification**		
Date:	03/25/1997				Lee County, Site #1B		
Sample:	#2				S.R. 884, Base		
Mold:	#1				Limerock		
Lab. Moisture:		15.20%			Opt. Moisture:		15.20%
Lab. Den.:	17.57 kN/m^3				Max. Dry Den.:		17.47 kN/m^3
Compaction Effect:		20 blows/layer (8 layers)					
					Conditioning Information		
					Load Type:		Dynamic
					Deviator Stress:		103.5 kPa
					Confining Pressure:		138 kPa
					Number of Repetition:		1000
Confining Pressure	Axial Load	Deviator Stress	Bulk Stress	Strain (152 mm)	Strain (305 mm)	Modulus (152 mm)	Modulus (305 mm)
kPa	kN	kPa	kPa			MPa	MPa
137.8	1.199	65.713	479.275	0.0001	0.0002	469.130	398.872
137.8	2.501	137.115	551.085	0.0004	0.0004	381.847	342.089
137.8	3.757	205.923	619.877	0.0007	0.0007	305.278	283.805
103.4	1.242	68.074	378.539	0.0002	0.0003	285.049	259.354
103.4	2.500	137.024	447.646	0.0005	0.0005	270.159	250.345
103.4	3.758	206.014	516.417	0.0008	0.0009	246.133	228.774
68.9	0.612	33.538	240.645	0.0001	0.0002	228.207	201.991
68.9	1.243	68.125	275.130	0.0004	0.0004	193.272	180.157
68.9	2.501	137.105	343.988	0.0007	0.0007	199.605	184.295
68.9	3.758	206.004	413.070	0.0011	0.0012	186.753	171.319
34.5	0.614	33.650	137.069	0.0003	0.0003	112.942	104.215
34.5	1.242	68.095	171.584	0.0006	0.0007	113.781	103.444
34.5	1.869	102.457	205.907	0.0008	0.0009	127.527	113.867
20.7	0.613	33.610	95.552	0.0004	0.0004	84.543	75.354
20.7	0.866	47.473	109.537	0.0005	0.0006	91.275	80.194
20.7	1.118	61.306	123.294	0.0006	0.0007	99.479	86.023

Table 5.30 Typical resilient modulus test results (A-1BL, average)

		Summary of Resilient Modulus Test Results					
		(152 mm diameter)					
Test Type: T292-91I					**Soil Identification**		
Date:	03/10/1997	02/25/1997			Lee County, Site #1B		
Sample:	#1	#2			S.R. 884, Base		
Mold:	#1	#1			Limerock		
Lab. Moisture:		15.10%			Opt. Moisture:		15.20%
Lab. Den.:		17.60 kN/m^3			Max. Dry Den.:		17.47 kN/m^3
Compaction Effect:		20 blows/layer (8 layers)					
					Conditioning Information		
					Load Type:		Dynamic
					Deviator Stress:		103.5 kPa
					Confining Pressure:		138 kPa
					Number of Repetition:		1000
Confining Pressure	Axial Load	Deviator Stress	Bulk Stress	Strain (152 mm)	Strain (305 mm)	Modulus (152 mm)	Modulus (305 mm)
kPa	kN	kPa	kPa			MPa	MPa
137.8	1.196	65.570	479.275	0.00010	0.00017	556.561	379.073
137.8	2.498	136.917	551.085	0.00034	0.00042	402.240	326.815
137.8	3.757	205.923	619.877	0.00068	0.00076	301.540	270.873
103.4	1.240	67.998	378.539	0.00023	0.00028	300.910	245.795
103.4	2.498	136.922	447.646	0.00051	0.00057	269.806	239.571
103.4	3.757	205.973	516.417	0.00088	0.00095	235.837	217.431
68.9	0.614	33.661	240.645	0.00014	0.00018	238.254	185.130
68.9	1.243	68.151	275.130	0.00037	0.00041	185.129	165.944
68.9	2.501	137.110	343.988	0.00073	0.00079	188.725	173.463
68.9	3.760	206.096	413.070	0.00119	0.00128	174.360	161.239
34.5	0.614	33.671	137.069	0.00037	0.00040	94.555	87.326
34.5	1.243	68.145	171.584	0.00068	0.00074	102.249	93.095
34.5	1.870	102.524	205.907	0.00087	0.00098	118.065	105.347
20.7	0.613	33.605	95.552	0.00051	0.00057	69.206	61.994
20.7	0.866	47.483	109.537	0.00063	0.00072	77.383	68.364
20.7	1.119	61.326	123.294	0.00073	0.00083	86.013	75.056

Table 5.31 Summary of laboratory resilient modulus test results based on $M_R = k_1 \theta^{k2}$ model (6 in. Dia. Specimens)

Location	Soil Type	Test #	M_R from 15.2-cm Measurements (MPa)	R^2	M_R from 30.5-cm Measurements (MPa)	R^2	Lab. Density (kN/m^3)	Lab. Moisture Content (%)
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	$MR = 1.07\theta^{0.9129}$	0.62	$MR = 1.12\theta^{0.8789}$	0.78	17.60	15.10
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	$MR = 4.64\theta^{0.7428}$	0.69	$MR = 4.47\theta^{0.7290}$	0.79	18.44	10.65
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	$MR = 15.75\theta^{0.5803}$	0.53	$MR = 8.71\theta^{0.6361}$	0.76	18.23	10.37
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	$MR = 13.38\theta^{0.5945}$	0.38	$MR = 7.00\theta^{0.6540}$	0.74	18.97	11.00
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	$MR = 4.06\theta^{0.7627}$	0.67	$MR = 3.75\theta^{0.7590}$	0.80	18.55	11.68
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	$MR = 2.70\theta^{0.8181}$	0.62	$MR = 2.89\theta^{0.7792}$	0.80	19.04	10.87
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	$MR = 3.21\theta^{0.8016}$	0.61	$MR = 2.62\theta^{0.7968}$	0.81	19.20	9.20
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	$MR = 8.32\theta^{0.6529}$	0.51	$MR = 5.26\theta^{0.6985}$	0.73	19.46	7.05
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	$MR = 6.34\theta^{0.7090}$	0.74	$MR = 5.58\theta^{0.7146}$	0.74	19.45	8.75
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	$MR = 14.92\theta^{0.5035}$	0.93	$MR = 10.89\theta^{0.5342}$	0.97	18.51	7.90
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	$MR = 14.20\theta^{0.5183}$	0.95	$MR = 7.12\theta^{0.6233}$	0.97	17.71	10.05

*M_R in unit of MPa and q in unit of kPa

Table 5.32 Summary of laboratory resilient modulus test results based on $M_R = k_3 \sigma_3^{k4}$ model (6 in. Dia. Specimens)

Locations	Soil Type	Test #	M_R from 15.2-cm Measurements (MPa)	R^2	M_R from 30.5-cm Measurements (MPa)	R^2	Lab. Density (kN/m^3)	Lab. Moisture Content (%)
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	$MR = 5.14\theta^{0.8708}$	0.97	$MR = 5.54\theta^{0.8154}$	0.99	17.60	15.10
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	$MR = 15.77\theta^{0.7206}$	0.98	$MR = 15.85\theta^{0.6904}$	0.99	18.44	10.65
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	$MR = 35.67\theta^{0.5995}$	0.98	$MR = 25.53\theta^{0.6100}$	0.99	18.23	10.37
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	$MR = 27.35\theta^{0.6483}$	0.97	$MR = 20.87\theta^{0.6306}$	0.99	18.97	11.00
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	$MR = 13.93\theta^{0.7464}$	0.99	$MR = 14.10\theta^{0.7274}$	1.00	18.55	11.68
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	$MR = 10.39\theta^{0.7945}$	0.97	$MR = 11.77\theta^{0.7256}$	0.99	19.04	10.87
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	$MR = 11.23\theta^{0.7885}$	0.98	$MR = 10.89\theta^{0.7453}$	0.99	19.20	9.20
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	$MR = 21.21q^{0.6705}$	0.97	$MR = 16.88\theta^{0.6739}$	0.99	19.46	7.05
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	$MR = 20.85\theta^{0.6825}$	0.99	$MR = 18.55\theta^{0.6873}$	0.99	19.45	8.75
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	$MR = 40.22\theta^{0.4335}$	1.00	$MR = 31.86\theta^{0.4537}$	1.00	18.51	7.90
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	$MR = 39.86\theta^{0.4434}$	0.99	$MR = 25.30\theta^{0.5257}$	1.00	17.71	10.05

*M_R in unit of MPa and s_3 in unit of kPa

Table 5.33 Summary of laboratory resilient modulus test results based on $M_R = k_1 \theta^{k2}$ model (4 in Dia. Specimens)

Location	Soil Type	Test #	M_R from 10.2-cm Measurements (MPa)	R^2	M_R from 20.3-cm Measurements (MPa)	R^2	Lab. Density (kN/m^3)	Lab. Moisture Content (%)
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	$M_R = 5.80\theta^{0.624}$	0.70	$M_R = 5.65\theta^{0.6104}$	0.75	17.53	15.3
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	$M_R = 6.36\theta^{0.6738}$	0.74	$M_R = 5.01\theta^{0.6828}$	0.78	18.82	10.4
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	$M_R = 28.97\theta^{0.4483}$	0.68	$M_R = 14.55\theta^{0.5257}$	0.76	18.21	10.4
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	$M_R = 16.75\theta^{0.5339}$	0.57	$M_R = 13.47\theta^{0.5418}$	0.71	18.86	11.0
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	$M_R = 7.79\theta^{0.6599}$	0.77	$M_R = 6.44\theta^{0.6627}$	0.80	18.62	11.5
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	$M_R = 4.77\theta^{0.6829}$	0.77	$M_R = 3.56\theta^{0.7256}$	0.80	19.03	10.8
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	$M_R = 10.61\theta^{0.5729}$	0.62	$M_R = 10.13\theta^{0.581}$	0.78	19.20	9.3
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	$M_R = 20.23\theta^{0.5157}$	0.62	$M_R = 15.87\theta^{0.5252}$	0.73	19.50	7.1
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	$M_R = 17.91\theta^{0.5371}$	0.73	$M_R = 12.94\theta^{0.5631}$	0.78	19.35	8.8
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	$M_R = 15.84\theta^{0.4736}$	0.96	$M_R = 9.86\theta^{0.5381}$	0.97	18.65	7.9
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	$M_R = 11.54\theta^{0.535}$	0.96	$M_R = 7.24\theta^{0.5998}$	0.98	17.60	10.1

*M_R in unit of MPa and q in unit of kPa

Table 5.34 Summary of laboratory resilient modulus test results based on $M_R = k_3 \sigma_3^{k4}$ model (4 in. Dia. Specimens)

Location	Soil Type	Test #	M_R from 10.2-cm Measurements (MPa)	R^2	M_R from 20.3-cm Measurements (MPa)	R^2	Lab. Density (kN/m^3)	Lab. Moisture Content (%)
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	$M_R = 16.21\sigma_3^{0.6061}$	0.98	$M_R = 15.89\sigma_3^{0.5855}$	0.99	17.53	15.3
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	$M_R = 20.08\sigma_3^{0.6446}$	0.98	$M_R = 16.37\sigma_3^{0.6481}$	0.99	18.82	10.4
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	$M_R = 58.68\sigma_3^{0.4433}$	0.98	$M_R = 35.10\sigma_3^{0.5063}$	0.99	18.21	10.4
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	$M_R = 36.68\sigma_3^{0.5429}$	0.98	$M_R = 32.39\sigma_3^{0.5294}$	0.99	18.86	11.0
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	$M_R = 24.17\sigma_3^{0.6290}$	0.99	$M_R = 20.34\sigma_3^{0.6281}$	0.99	18.62	11.5
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	$M_R = 16.25\sigma_3^{0.6375}$	0.99	$M_R = 13.18\sigma_3^{0.6754}$	0.99	19.03	10.8
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	$M_R = 29.33\sigma_3^{0.5808}$	0.97	$M_R = 26.58\sigma_3^{0.5620}$	0.99	19.20	9.3
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	$M_R = 44.54\sigma_3^{0.5159}$	0.98	$M_R = 37.28\sigma_3^{0.5125}$	0.99	19.50	7.1
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	$M_R = 43.66\sigma_3^{0.5201}$	0.98	$M_R = 33.80\sigma_3^{0.5387}$	0.98	19.35	8.8
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	$M_R = 40.74\sigma_3^{0.4039}$	0.99	$M_R = 29.04\sigma_3^{0.4570}$	0.99	18.65	7.9
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	$M_R = 33.92\sigma_3^{0.4535}$	0.99	$M_R = 24.44\sigma_3^{0.5062}$	0.99	17.60	10.1

*M_R in unit of MPa and s_3 in unit of kPa

Table 5.35 Summary of laboratory resilient modulus test results based on $M_R = k_5 \sigma_3^{k6} \sigma_d^{k7}$ model (4 in. Dia. Specimens)

Location	Soil Type	Test #	M_R from 102-mm Measurements (MPa)	R^2	M_R from 203-mm Measurements (MPa)	R^2
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	$MR = 1.370(\sigma_3)^{0.692}(\sigma_\delta)^{-0.164}$	0.976	$MR = 1.323(\sigma_3)^{0.652}(\sigma_\delta)^{-0.126}$	0.983
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	$MR = 1.370(\sigma_3)^{0.738}(\sigma_\delta)^{-0.116}$	0.980	$MR = 1.144(\sigma_3)^{0.731}(\sigma_\delta)^{-0.067}$	0.990
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	$MR = 1.926(\sigma_3)^{0.533}(\sigma_\delta)^{-0.165}$	0.973	$MR = 1.663(\sigma_3)^{0.573}(\sigma_\delta)^{-0.123}$	0.984
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	$MR = 1.822(\sigma_3)^{0.687}(\sigma_\delta)^{-0.269}$	0.975	$MR = 1.670(\sigma_3)^{0.620}(\sigma_\delta)^{-0.167}$	0.988
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	$MR = 1.476(\sigma_3)^{0.681}(\sigma_\delta)^{-0.097}$	0.977	$MR = 1.386(\sigma_3)^{0.672}(\sigma_\delta)^{-0.082}$	0.986
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	$MR = 1.286(\sigma_3)^{0.676}(\sigma_\delta)^{-0.075}$	0.959	$MR = 1.186(\sigma_3)^{0.710}(\sigma_\delta)^{-0.067}$	0.975
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	$MR = 1.670(\sigma_3)^{0.690}(\sigma_\delta)^{-0.208}$	0.970	$MR = 1.564(\sigma_3)^{0.638}(\sigma_\delta)^{-0.144}$	0.981
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	$MR = 1.861(\sigma_3)^{0.638}(\sigma_\delta)^{-0.225}$	0.973	$MR = 1.721(\sigma_3)^{0.599}(\sigma_\delta)^{-0.159}$	0.984
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	$MR = 1.773(\sigma_3)^{0.594}(\sigma_\delta)^{-0.139}$	0.973	$MR = 1.721(\sigma_3)^{0.599}(\sigma_\delta)^{-0.159}$	0.981
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	$MR = 1.609(\sigma_3)^{0.405}(\sigma_\delta)^{-0.002}$	0.988	$MR = 1.443(\sigma_3)^{0.450}(\sigma_\delta)^{-0.018}$	0.992
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	$MR = 1.507(\sigma_3)^{0.445}(\sigma_\delta)^{0.022}$	0.987	$MR = 1.340(\sigma_3)^{0.487}(\sigma_\delta)^{0.046}$	0.990

*M_R in unit of MPa. s_3 and s_d in unit of kPa

Table 5-36 Summary of laboratory resilient modulus test results based on $M_R = k_5 \sigma_3^{k6} \sigma_d^{k7}$ model (6 in. Dia. Specimens)

Location	Soil Type	Test #	M_R from 152-mm Measurements (MPa)	R^2	M_R from 305-mm Measurements (MPa)	R^2
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	$MR = 0.871(\sigma_3)^{0.946}(\sigma_\delta)^{-0.156}$	0.948	$MR = 0.799(\sigma_3)^{0.844}(\sigma_\delta)^{-0.057}$	0.975
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	$MR = 1.388(\sigma_3)^{0.825}(\sigma_\delta)^{-0.196}$	0.984	$MR = 1.305(\sigma_3)^{0.749}(\sigma_\delta)^{-0.109}$	0.991
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	$MR = 1.863(\sigma_3)^{0.773}(\sigma_\delta)^{-0.326}$	0.981	$MR = 1.534(\sigma_3)^{0.681}(\sigma_\delta)^{-0.133}$	0.990
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	$MR = 1.910(\sigma_3)^{0.907}(\sigma_\delta)^{-0.493}$	0.970	$MR = 1.470(\sigma_3)^{0.714}(\sigma_\delta)^{-0.157}$	0.990
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	$MR = 1.371(\sigma_3)^{0.871}(\sigma_\delta)^{-0.236}$	0.989	$MR = 1.255(\sigma_3)^{0.776}(\sigma_\delta)^{-0.110}$	0.992
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	$MR = 1.221(\sigma_3)^{0.894}(\sigma_\delta)^{-0.201}$	0.958	$MR = 1.127(\sigma_3)^{0.755}(\sigma_\delta)^{-0.057}$	0.977
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	$MR = 1.298(\sigma_3)^{0.913}(\sigma_\delta)^{-0.246}$	0.971	$MR = 1.109(\sigma_3)^{0.783}(\sigma_\delta)^{-0.073}$	0.987
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	$MR = 1.659(\sigma_3)^{0.851}(\sigma_\delta)^{-0.343}$	0.976	$MR = 1.386(\sigma_3)^{0.761}(\sigma_\delta)^{-0.165}$	0.987
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	$MR = 1.649(\sigma_3)^{0.766}(\sigma_\delta)^{-0.157}$	0.986	$MR = 1.420(\sigma_3)^{0.770}(\sigma_\delta)^{-0.157}$	0.989
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	$MR = 1.666(\sigma_3)^{0.459}(\sigma_\delta)^{-0.063}$	0.989	$MR = 1.503(\sigma_3)^{0.454}(\sigma_\delta)^{-0.001}$	0.997
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	$MR = 1.630(\sigma_3)^{0.456}(\sigma_\delta)^{-0.031}$	0.991	$MR = 1.373(\sigma_3)^{0.515}(\sigma_\delta)^{0.028}$	0.996

*M_R in unit of MPa. s_3 and s_d in unit of kPa

Table 5.37 Summary of k_1 and k_2 values (6 in. Dia. specimens)

Location	Soil Type	Laboratory Resilient Modulus Test Results ($^*M_R = k_1\theta^{k2}$)						
		Test #	k_1	k_2	R^2	k_1	k_2	R^2
			152-mm measurements			305-mm measurements		
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	1.07	0.9129	0.62	1.12	0.8789	0.78
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	4.64	0.7428	0.69	4.47	0.7290	0.79
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	15.75	0.5803	0.53	8.71	0.6361	0.76
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	13.38	0.5945	0.38	7.00	0.6540	0.74
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	4.06	0.7627	0.67	3.75	0.7590	0.80
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	2.70	0.8181	0.62	2.89	0.7792	0.80
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	3.21	0.8016	0.61	2.62	0.7968	0.81
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	8.32	0.6529	0.51	5.26	0.6985	0.73
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	6.34	0.7090	0.74	5.58	0.7146	0.74
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	14.92	0.5035	0.93	10.89	0.5342	0.97
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	14.20	0.5183	0.95	7.12	0.6233	0.97

Table 5.38 Summary of k_1 and k_2 values (4 in. Dia. specimens)

Location	Soil Type	Laboratory Resilient Modulus Test Results ($M_R = k_1\theta^{k2}$)						
		Test #	k_1	k_2	R^2	k_1	k_2	R^2
			102-mm measurements			203-mm measurements		
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	5.80	0.6240	0.70	5.65	0.6104	0.75
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	6.36	0.6738	0.74	5.01	0.6828	0.78
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	28.97	0.4483	0.68	14.55	0.5257	0.76
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	16.75	0.5339	0.57	13.47	0.5418	0.71
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	7.79	0.6599	0.77	6.44	0.6627	0.80
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	4.77	0.6829	0.77	3.56	0.7256	0.80
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	10.61	0.5729	0.62	10.13	0.5810	0.78
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	20.23	0.5157	0.62	15.87	0.5252	0.73
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	17.91	0.5371	0.73	12.94	0.5631	0.78
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	15.84	0.4736	0.96	9.86	0.5381	0.97
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	11.54	0.5350	0.96	7.24	0.5998	0.98

Table 5.39 Summary of k_3 and k_4 values (6 in. Dia. specimens)

Locations	Soil Type	Laboratory Resilient Modulus Test Results (*$M_R = k_3\sigma_3^{k4}$)						
		Test #	k_3	k_4	R^2	k_3	k_4	R^2
			152-mm measurements			305-mm measurements		
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	5.14	0.8708	0.97	5.54	0.8154	0.99
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	15.77	0.7206	0.98	15.85	0.6904	0.99
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	35.67	0.5995	0.98	25.53	0.6100	0.99
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	27.35	0.6483	0.97	20.87	0.6306	0.99
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	13.93	0.7464	0.99	14.10	0.7274	1.00
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	10.39	0.7945	0.97	11.77	0.7256	0.99
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	11.23	0.7885	0.98	10.89	0.7453	0.99
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	21.21	0.6705	0.97	16.88	0.6739	0.99
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	20.85	0.6825	0.99	18.55	0.6873	0.99
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	40.22	0.4335	1.00	31.86	0.4537	1.00
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	39.86	0.4434	0.99	25.30	0.5257	1.00

Table 5.40 Summary of k_3 and k_4 values (4 in. Dia. specimens)

Location	Soil Type	Laboratory Resilient Modulus Test Results ($M_R = k_3\sigma_3^{k4}$)						
		Test #	k_3	k_4	R^2	k_3	k_4	R^2
			102-mm measurements			203-mm measurements		
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	16.21	0.6061	0.98	15.89	0.5855	0.99
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	20.08	0.6446	0.98	16.37	0.6481	0.99
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	58.68	0.4433	0.98	35.10	0.5063	0.99
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	36.68	0.5429	0.98	32.39	0.5294	0.99
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	24.17	0.6290	0.99	20.34	0.6281	0.99
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	16.25	0.6375	0.99	13.18	0.6754	0.99
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	29.33	0.5808	0.97	26.58	0.5620	0.99
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	44.54	0.5159	0.98	37.28	0.5125	0.99
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	43.66	0.5201	0.98	33.80	0.5387	0.98
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	40.74	0.4039	0.99	29.04	0.4570	0.99
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	33.92	0.4535	0.99	24.44	0.5062	0.99

*M_R in unit of MPa and q in unit of kPa

Table 5.41 Summary of k_5, k_6 and k_7 values (6 in. Dia. specimens)

Location	Soil Type	Laboratory Resilient Modulus Test Results ($M_R = k_5 \sigma_3^{k6} \sigma_d^{k7}$)							
		Test #	k_5	k_6	k_7	R^2	k_5	k_6	k_7	R^2
			152-mm measurements				305-mm measurements			
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	0.871	0.946	-0.156	0.95	0.799	0.844	-0.057	0.98
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	1.388	0.825	-0.196	0.98	1.305	0.749	-0.109	0.99
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	1.863	0.773	-0.326	0.98	1.534	0.681	-0.133	0.99
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	1.910	0.907	-0.493	0.97	1.470	0.714	-0.157	0.99
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	1.371	0.871	-0.236	0.99	1.255	0.776	-0.110	0.99
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	1.221	0.894	-0.201	0.96	1.127	0.755	-0.057	0.98
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	1.298	0.913	-0.246	0.97	1.109	0.783	-0.073	0.99
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	1.659	0.851	-0.343	0.98	1.386	0.761	-0.165	0.99
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	1.649	0.766	-0.157	0.99	1.420	0.770	-0.157	0.99
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	1.666	0.459	-0.063	0.99	1.503	0.454	-0.001	1.00
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	1.630	0.456	-0.031	0.99	1.373	0.515	0.028	1.00

Table 5.42 Summary of k_5, k_6 and k_7 values (4 in. Dia. specimens)

Location	Soil Type	Laboratory Resilient Modulus Test Results ($M_R = k_5 \sigma_3^{k6} \sigma_6^{k7}$)							
		Test #	k_5	k_6	k_7	R^2	k_5	k_6	k_7	R^2
			102-mm measurements				203-mm measurements			
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	1.370	0.692	-0.164	0.98	1.323	0.652	-0.126	0.98
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	1.370	0.738	-0.116	0.98	1.144	0.731	-0.057	0.99
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	1.926	0.533	-0.165	0.97	1.663	0.573	-0.123	0.98
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	1.822	0.687	-0.269	0.98	1.670	0.620	-0.167	0.99
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	1.476	0.681	-0.097	0.98	1.386	0.672	-0.082	0.99
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	1.286	0.676	-0.075	0.96	1.186	0.710	-0.067	0.98
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	1.670	0.690	-0.208	0.97	1.564	0.638	-0.144	0.98
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	1.861	0.638	-0.225	0.97	1.721	0.599	-0.159	0.98
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	1.773	0.594	-0.139	0.97	1.721	0.599	-0.159	0.98
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	1.609	0.405	-0.002	0.99	1.443	0.450	-0.018	0.99
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	1.507	0.445	0.022	0.99	1.340	0.487	0.046	0.99

Table 5.43 Typcial resilient modulus test results for A-2-4 soil (A-1AS, sample 1)

		Summary of Resilient Modulus Test Results					
			(152 mm diameter)				
Test Type:	**T292-91I**				**Soil Identification**		
Date:	07/02/1997				Polk County, Site #1		
Sample:	#1				U.S. 17, Subgrade		
Mold:	#1				Silty Sand		
Lab. Moisture:		10.00%			Opt. Moisture:		10.00%
Lab. Den.:		17.74 kN/m^3			Max. Dry Den.:		17.47 kN/m^3
Compaction Effect:		18 blows/layer (8 layers)					
					Conditioning Information		
					Load Type:		Dynamic
					Deviator Stress:		103.5 kPa
					Confining Pressure:		138 kPa
					Number of Repetition:		1000
Confining Pressure	Axial Load	Deviator Stress	Bulk Stress	Strain (152 mm)	Strain (305 mm)	Modulus (152 mm)	Modulus (305 mm)
kPa	kN	kPa	kPa			MPa	MPa
103.4	0.867	47.514	357.728	0.00015	0.00017	315.328	281.059
103.4	1.242	68.074	378.350	0.00021	0.00024	321.414	283.708
103.4	1.868	102.396	412.717	0.00033	0.00036	308.514	285.182
68.9	0.613	33.610	240.424	0.00013	0.00015	256.306	218.675
68.9	0.865	47.402	254.201	0.00019	0.00022	254.195	218.313
68.9	1.242	68.064	274.756	0.00028	0.00031	239.938	220.599
68.9	1.869	102.478	309.384	0.00042	0.00045	244.496	227.273
34.5	0.360	19.726	123.187	0.00010	0.00013	189.092	155.494
34.5	0.611	33.508	136.948	0.00019	0.00023	179.412	147.499
34.5	0.865	47.422	150.842	0.00028	0.00032	169.887	149.524
34.5	1.240	67.983	171.398	0.00039	0.00043	174.713	156.809
13.8	0.357	19.584	61.066	0.00016	0.00021	120.021	93.660
13.8	0.610	33.416	74.852	0.00029	0.00035	114.327	96.579
13.8	0.863	47.310	88.726	0.00040	0.00047	118.644	100.847

Table 5.44 Typcial resilient modulus test results for A-2-4 soil (A-1AS, sample 2)

		Summary of Resilient Modulus Test Results					
			(152 mm diameter)				
Test Type:	**T292-91I**				**Soil Identification**		
Date:	07/04/1997				Polk County, Site #1		
Sample:	#2				U.S. 17, Subgrade		
Mold:	#3				Silty Sand		
Lab. Moisture:		10.10%			Opt. Moisture:		10.00%
Lab. Den.:		17.68 kN/m^3			Max. Dry Den.:		17.47 kN/m^3
Compaction Effect:		18 blows/layer (8 layers)					
					Conditioning Information		
					Load Type:		Dynamic
					Deviator Stress:		103.5 kPa
					Confining Pressure:		138 kPa
					Number of Repetition:		1000
Confining Pressure	Axial Load	Deviator Stress	Bulk Stress	Strain (152 mm)	Strain (305 mm)	Modulus (152 mm)	Modulus (305 mm)
kPa	kN	kPa	kPa			MPa	MPa
103.4	0.865	47.422	357.728	0.00014	0.00015	328.421	309.411
103.4	1.242	68.105	378.350	0.00021	0.00022	329.961	307.765
103.4	1.870	102.519	412.717	0.00032	0.00034	321.589	305.029
68.9	0.612	33.538	240.424	0.00013	0.00014	263.729	242.684
68.9	0.863	47.300	254.201	0.00018	0.00020	264.265	241.641
68.9	1.236	67.749	274.756	0.00025	0.00028	268.338	241.973
68.9	1.872	102.590	309.384	0.00040	0.00042	259.348	244.233
34.5	0.362	19.828	123.187	0.00010	0.00012	196.501	166.665
34.5	0.612	33.569	136.948	0.00018	0.00021	191.545	159.888
34.5	0.865	47.442	150.842	0.00024	0.00029	196.161	164.800
34.5	1.240	67.993	171.398	0.00037	0.00040	183.116	169.331
13.8	0.361	19.807	61.066	0.00014	0.00019	142.710	104.405
13.8	0.612	33.549	74.852	0.00022	0.00032	151.973	106.406
13.8	0.865	47.402	88.726	0.00035	0.00043	135.076	110.323

Table 5.45 Typcial resilient modulus test results for A-2-4 soil (A-1AS, average)

		Summary of Resilient Modulus Test Results					
			(152 mm diameter)				
Test Type:	**T292-91I**				**Soil Identification**		
Date:	07/02/1997	07/04/1997			Polk County, Site #1		
Sample:	#1	#2			U.S. 17, Subgrade		
Mold:	#1	#3			Silty Sand		
Lab. Moisture:		10.05%			Opt. Moisture:		10.00%
Lab. Den.:		17.71 kN/m^3			Max. Dry Den.:		17.47 kN/m^3
Compaction Effect:		18 blows/layer (8 layers)					
					Conditioning Information		
					Load Type:		Dynamic
					Deviator Stress:		103.5 kPa
					Confining Pressure:		138 kPa
					Number of Repetition:		1000
Confining Pressure	Axial Load	Deviator Stress	Bulk Stress	Strain (152 mm)	Strain (305 mm)	Modulus (152 mm)	Modulus (305 mm)
kPa	kN	kPa	kPa			MPa	MPa
103.4	0.866	47.468	357.728	0.00015	0.00016	321.874	295.235
103.4	1.242	68.090	378.350	0.00021	0.00023	325.687	295.737
103.4	1.869	102.457	412.717	0.00033	0.00035	315.052	295.105
68.9	0.612	33.574	240.424	0.00013	0.00015	260.017	230.680
68.9	0.864	47.351	254.201	0.00018	0.00021	259.230	229.977
68.9	1.239	67.906	274.756	0.00027	0.00029	254.138	231.286
68.9	1.870	102.534	309.384	0.00041	0.00044	251.922	235.753
34.5	0.361	19.777	123.187	0.00010	0.00012	192.796	161.079
34.5	0.612	33.538	136.948	0.00018	0.00022	185.478	153.694
34.5	0.865	47.432	150.842	0.00026	0.00030	183.024	157.162
34.5	1.240	67.988	171.398	0.00038	0.00042	178.915	163.070
13.8	0.359	19.696	61.066	0.00015	0.00020	131.366	99.033
13.8	0.611	33.482	74.852	0.00026	0.00033	133.150	101.493
13.8	0.864	47.356	88.726	0.00037	0.00045	126.860	105.585

Table 5.46 Summary of LBR Test Results

DISTRICT 1	LBR	Dry Density (pcf)	Moist. Content (%)	AASHTO Classification
Lee Co., Site #1B, S.R. 884				
Base (Limerock)	65	118.0	12.1	
Subgrade (Fine Sand)	43	104.1	12.0	A-3
EMB (Fine Sand)	19	107.9	10.8	A-3
Lee Co., Site #2B, S.R. 884				
Base (Limerock)	113	122.3	10.2	
Subgrade (Fine Sand)	49	105.7	10.8	A-3
EMB (Fine Sand)	33	105.0	13.3	A-3
Polk Co., Site #1A, U.S. 17				
Base (Limerock)	110	121.4	10.8	
Subgrade (Silty Sand)	47	116.5	10.1	A-2-4
EMB (Fine Sand)	16	108.7	12.4	A-3
Polk Co., Site #2A, U.S. 17				
Base (Limerock)	90	121.8	10.0	
Subgrade (Silty Sand)	64	119.0	10.5	A-2-4
EMB (Fine Sand)	30	110.2	10.8	A-3

DISTRICT 2	LBR	Dry Density (pcf)	Moist. Content (%)	AASHTO Classification
Clay Co, Site #5, U.S. 17				
Base (Limerock)	118	119.6	10.4	
Subgrade (Fine Sand)	38	100.5	13.5	A-3
EMB (Silty Sand)	29	104.7	12.8	A-2-4
Clay Co, Site #6, U.S. 17				
Base (Limerock)	90	117.1	11.8	
Subgrade (Fine Sand)	46	100.9	14.3	A-3
EMB (Fine Sand)	29	101.7	12.4	A-3
Alachua Co, Site #3, U.S. 301				
Base (Limerock)	126	121.4	10.8	
Subgrade (Fine Sand)	49	113.2	11.7	A-3
EMB (Fine Sand)	53	116.9	12.4	A-3
Alachua Co, Site #4, U.S. 301				
Base (Limerock)	132	121.8	10.3	
Subgrade (Silty Sand)	43	112.1	11.2	A-2-4
EMB (Clay)	68	124.6	11.7	A-6

Table 5.46 (Continued)

DISTRICT 3	LBR	Dry Density (pcf)	Moist. Content (%)	AASHTO Classification
Jefferson Co., Site #1A, U.S. 27				
Base (Limerock)	128	118.1	11.1	
Subgrade (Silty Clay)	69	126.3	9.4	A-4
EMB (Silty Clay)	61	131.1	8.6	A-2-6
Jefferson Co., Site #2A, U.S. 27				
Base (Limerock)	138	117.5	12.3	
Subgrade (Silty Clay)	116	130.2	7.4	A-4
EMB (Silty Sand)	87	131.1	8.3	A-2-4
Gadsden Co., Site #2B, U.S. 27				
Base (Limerock)	96	123.2	9.4	
Subgrade (Silty Sand)	145	128.6	6.9	A-2-4
EMB #1 (Silty Sand)	81	116.3	9.7	A-2-4
EMB #2 (Clay)	59	116.6	15.1	A-6
Gadsden Co., Site #3B, U.S. 27				
Base (Limerock)	84	121.0	10.1	
Subgrade (Fine Sand)	121	127.3	8.9	A-3
EMB (Clay)	54	112.9	11.3	A-6

DISTRICTS 4 & 6	LBR	Dry Density (pcf)	Moist. Content (%)	AASHTO Classification
Dade Co., Site #1, U.S. 41				
Base (Limerock)	128	130.8	7.3	
Subgrade (Limerock)	147	127.7	8.1	
EMB (Limerock)	172	131.2	7.0	
Dade Co., Site #2, U.S. 41				
Base (Limerock)	121	132.2	7.9	
Subgrade (Limerock)	125	132.5	7.4	
EMB (Limerock)	100	128.5	8.1	
Martin Co., Site #3, U.S. 1				
Base (Limerock)	191	132.8	7.1	
Subgrade (Fine Sand)	70	118.2	8.9	A-3
EMB #1 (Fine Sand)	21	106.3	9.6	A-3
Martin Co., Site #4, U.S. 1				
Base (Limerock)	122	130.5	7.1	
Subgrade (Silty Clay)	45	117.8	9.7	A-4
EMB (Fine Sand)	29	113.4	9.5	A-3

Table 5.46 (Continued)

DISTRICT 5	LBR	Dry Density (pcf)	Moist. Content (%)	AASHTO Classification
Seminole Co., Site #1, U.S. 414				
Base (Limerock)	109	124.1	9.5	
Subgrade (Silty Sand)	79	119.3	6.3	A-2-4
EMB (Silty Sand)	20	108.5	8.4	A-2-4
Seminole Co., Site #2, U.S. 414				
Base (Limerock)	112	123.1	11.2	
Subgrade (Silty Sand)	93	118.2	8.0	A-2-4
EMB (Fine Sand)	31	107.3	12.7	A-3
Osceola Co., Site #3, U.S. 441				
Base (Coquina)	146	131.6	7.8	
Subgrade (Fine Sand)	56	118.2	9.0	A-3
EMB (Fine Sand)	18	107.3	12.7	A-3
Osceola Co., Site #4, U.S. 441				
Base (Coquina)	211	131.9	6.0	
Subgrade (Fine Sand)	85	121.0	8.9	A-3
EMB (Fine Sand)	60	103.4	12.8	A-3

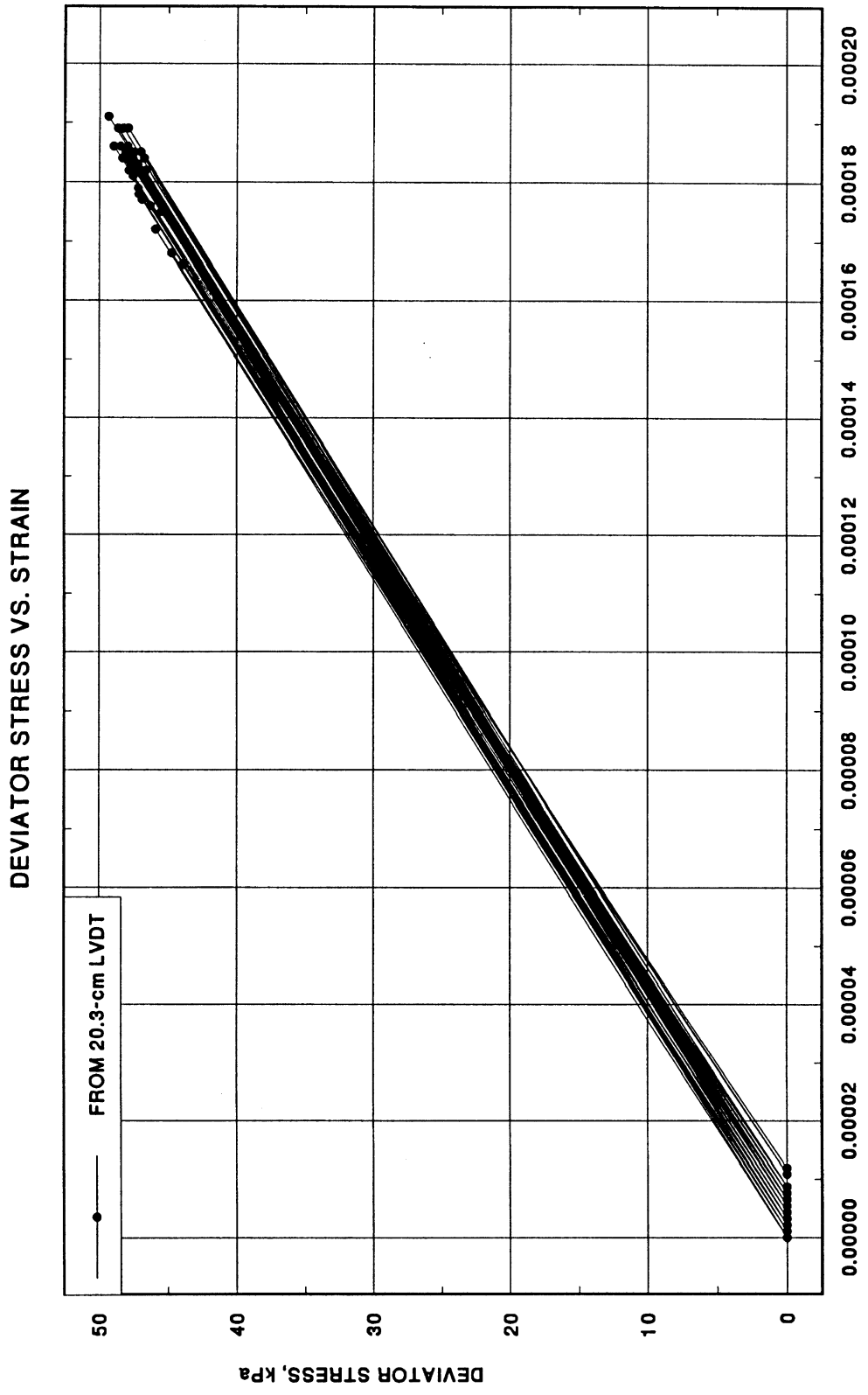


Figure 5.1 Typical deviator stress versus strain from a resilient modulus test

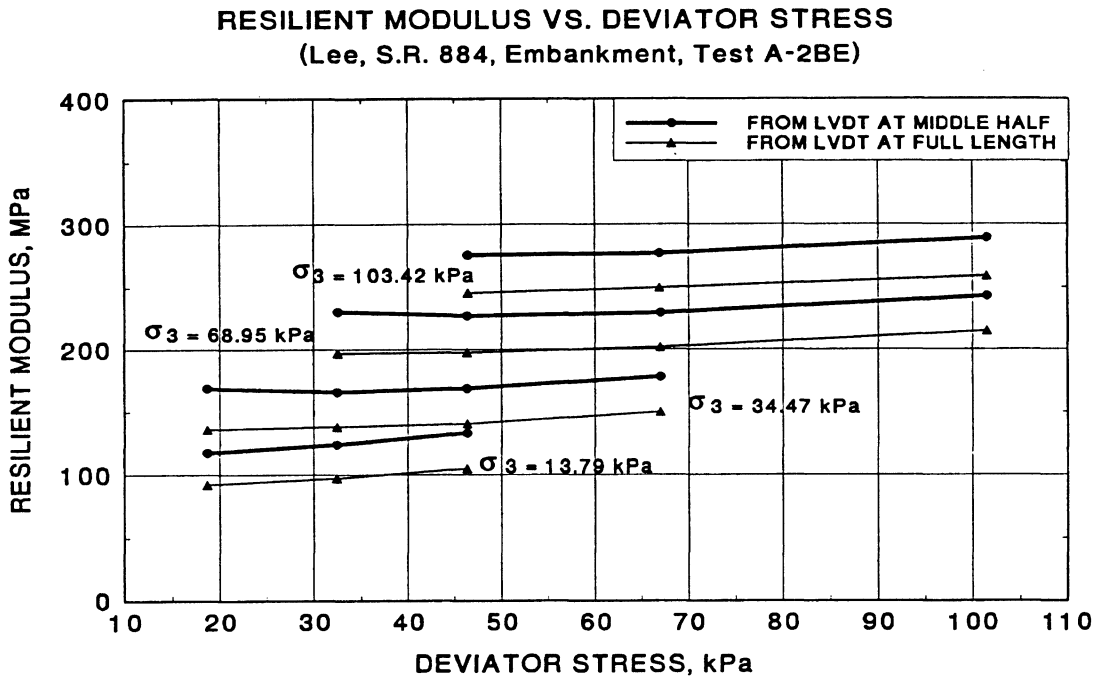


Figure 5.2 Typical resilient modulus versus deviator stress

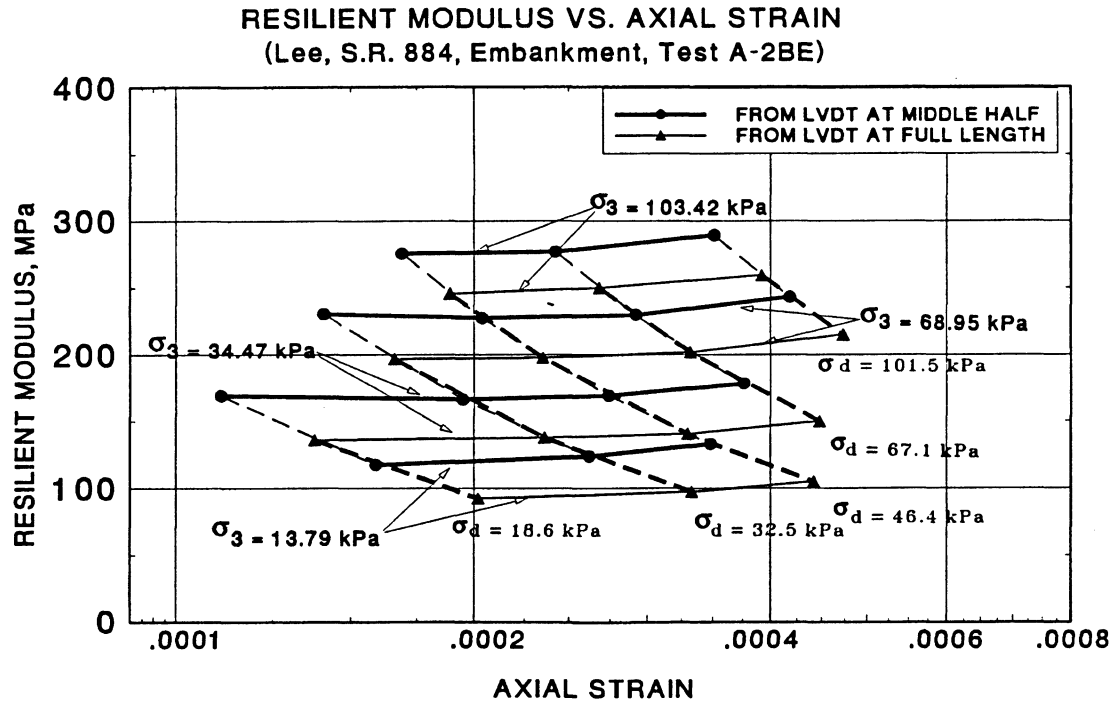


Figure 5.3 Typical resilient modulus versus axial strain

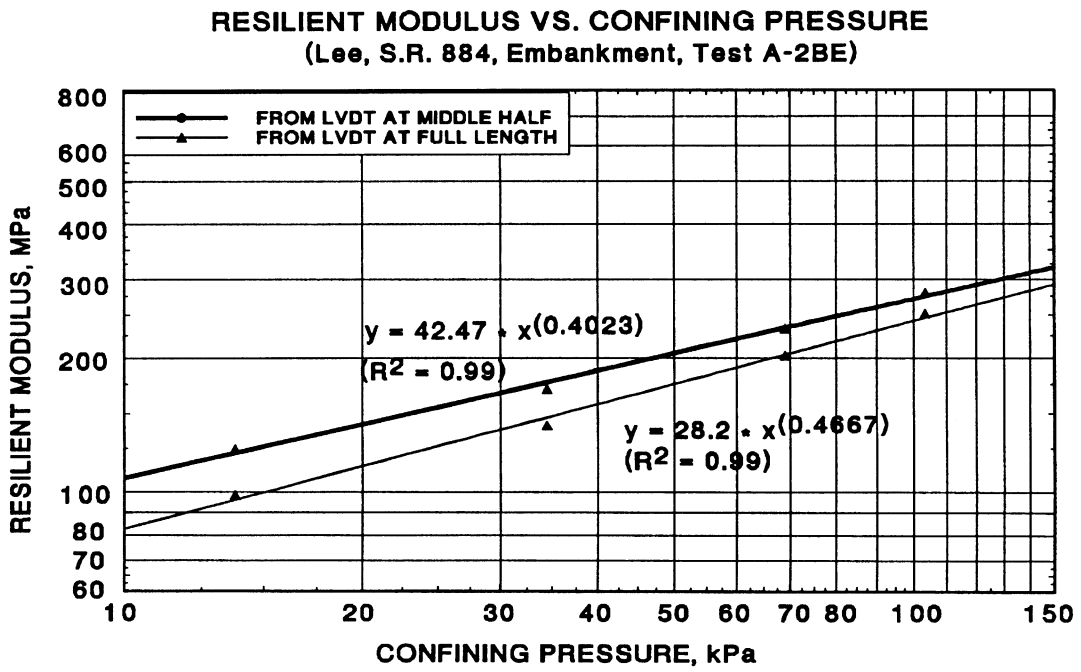


Figure 5.4 Typical resilient modulus versus confining pressure

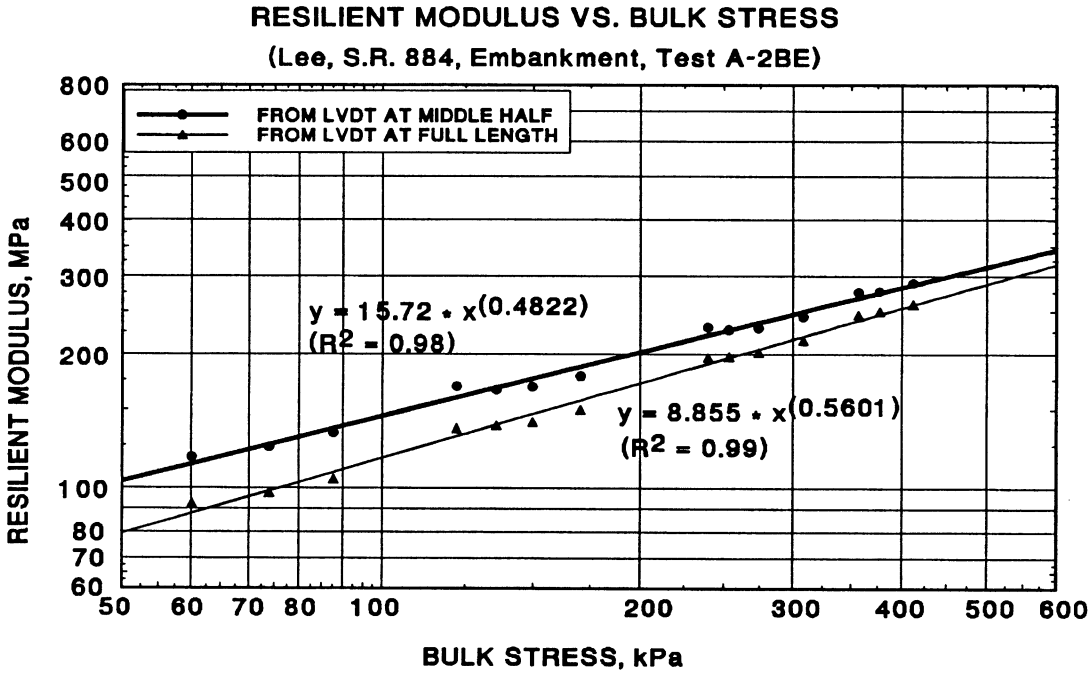


Figure 5.5 Typical resilient modulus versus bulk stress

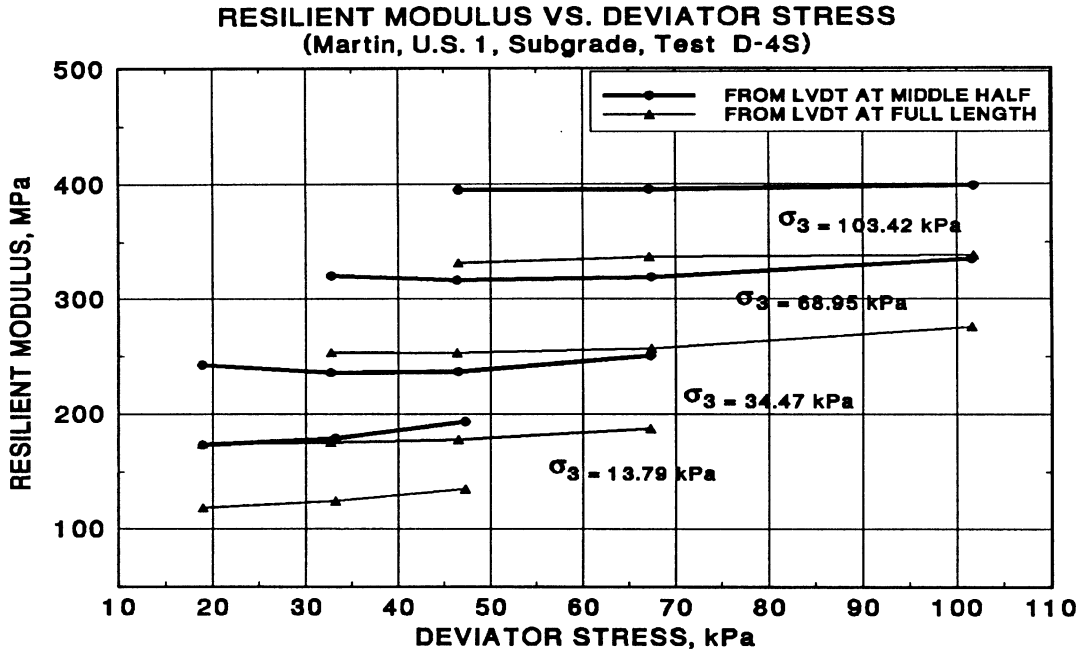


Figure 5.6 Typical resilient modulus versus deviator stress for A-4 soil

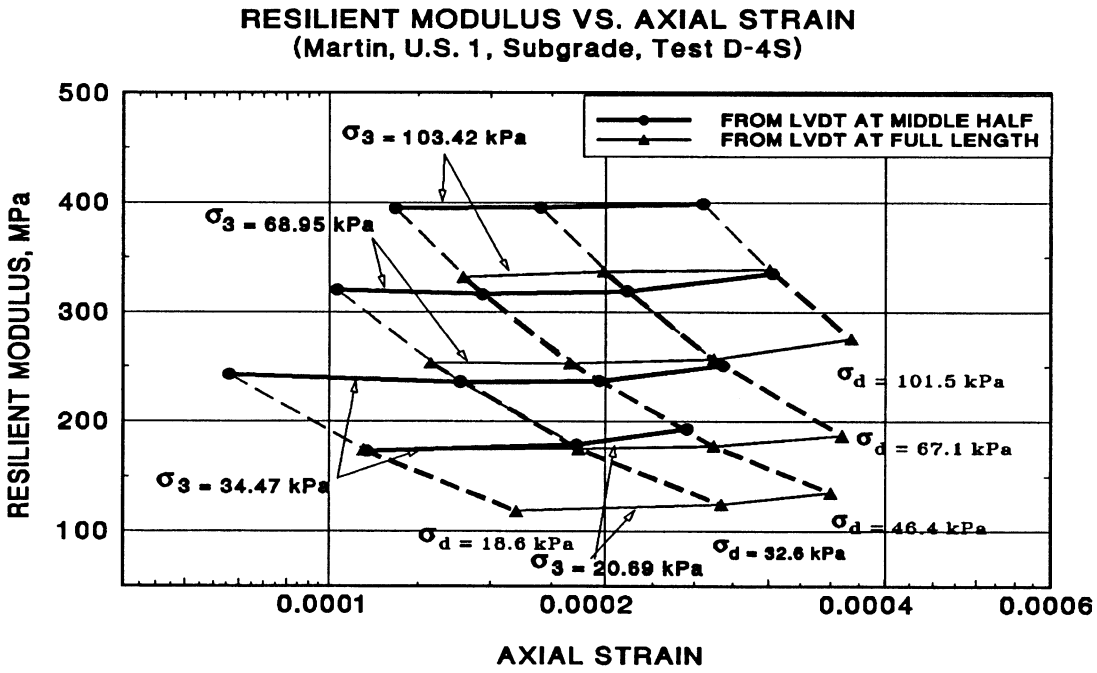


Figure 5.7 Typical resilient modulus versus axial strain for A-4 soil

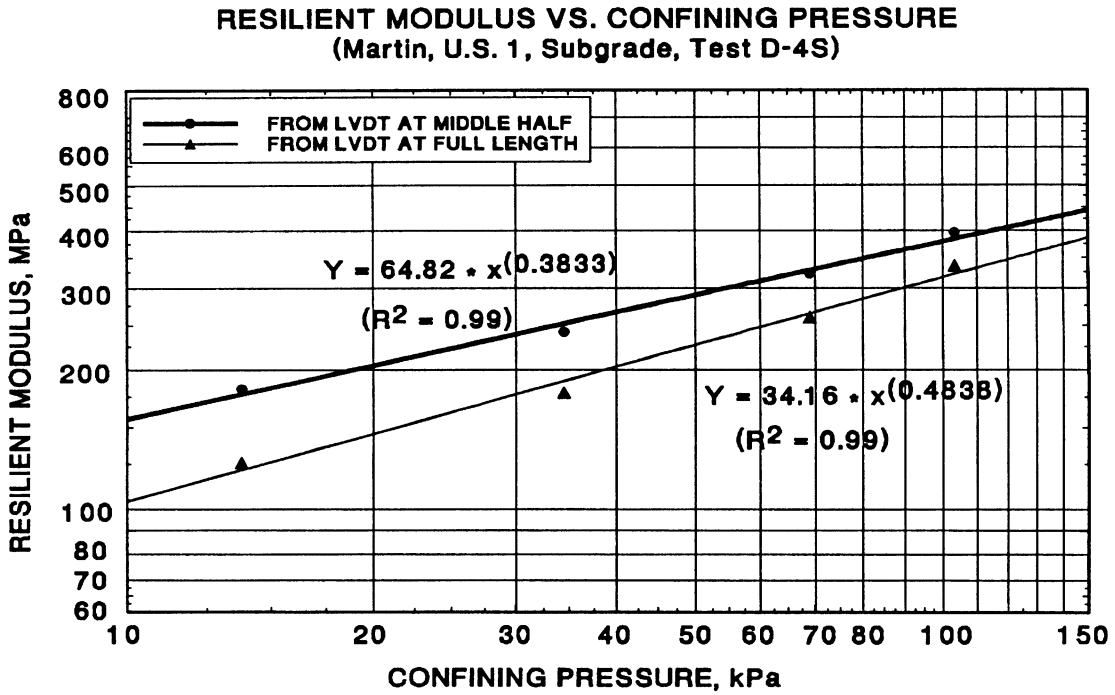


Figure 5.8 Typical resilient modulus versus confining pressure for A-4 soil

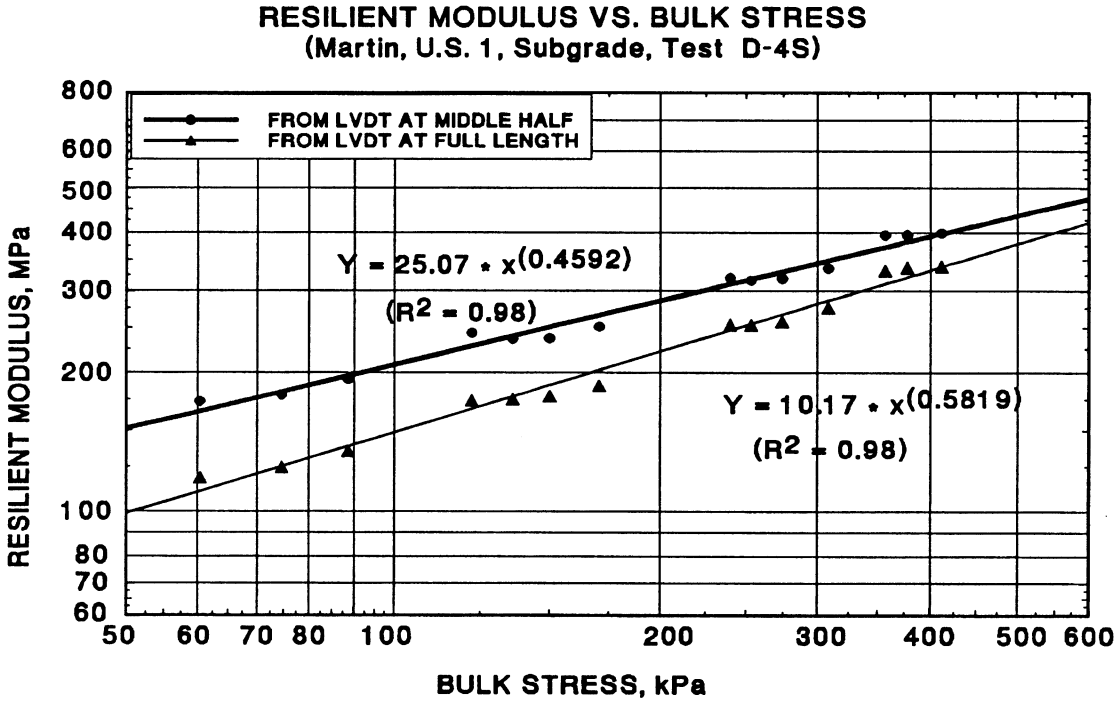


Figure 5.9 Typical resilient modulus versus bulk stress for A-4 soil

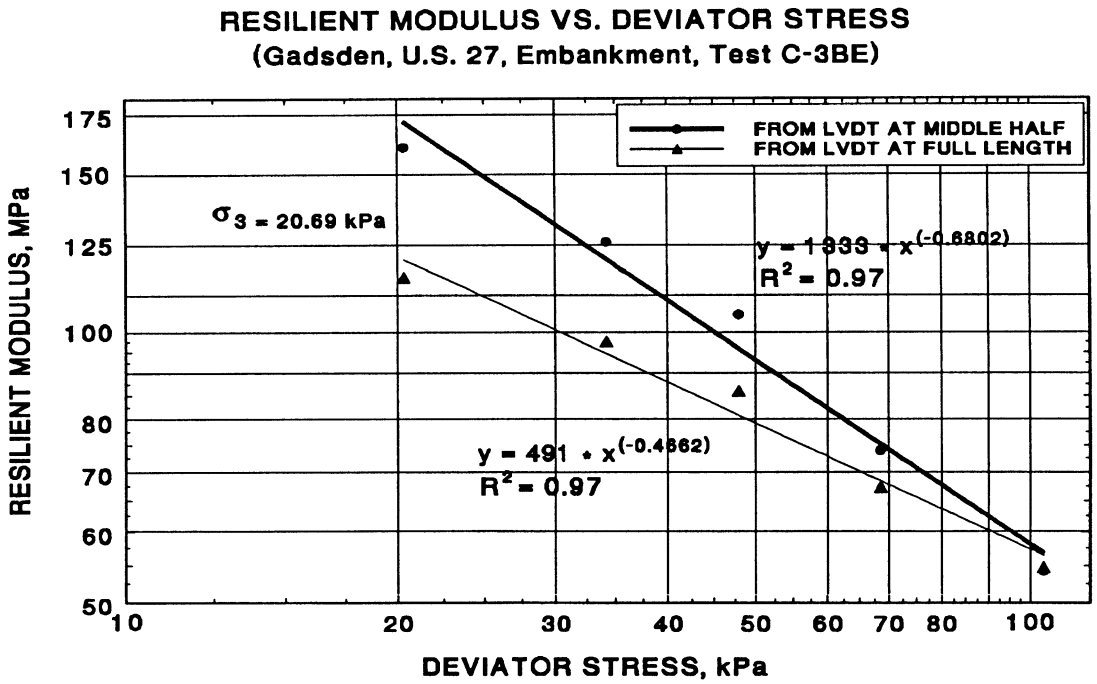


Figure 5.10 Typical resilient modulus versus deviator stress for A-6 soil

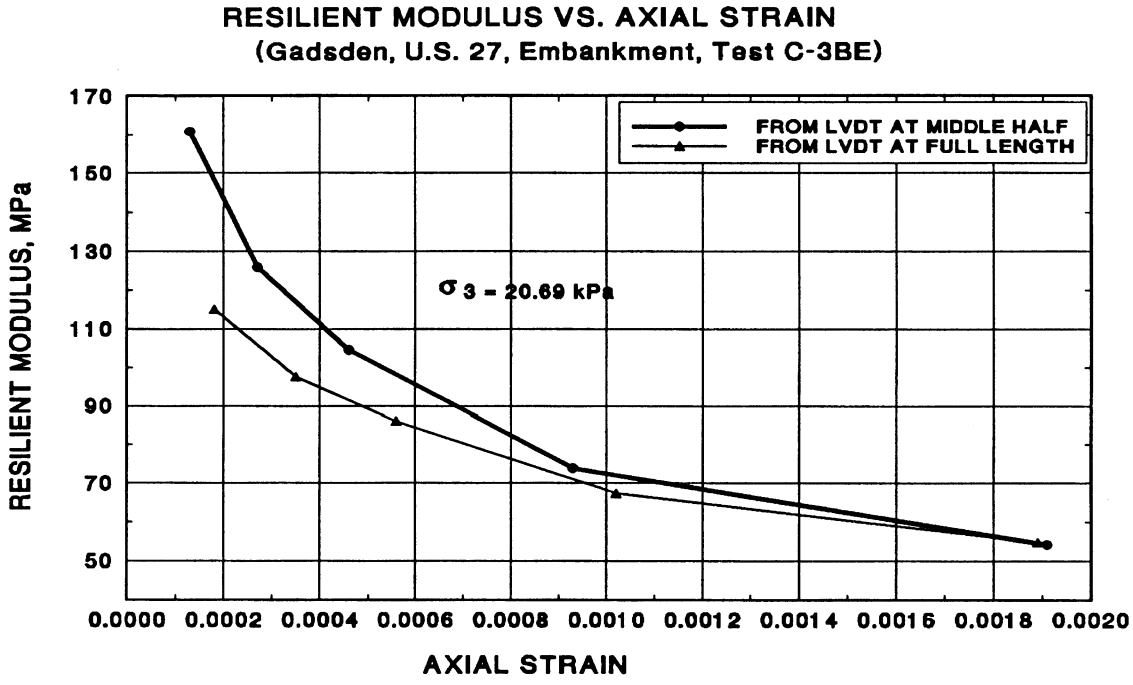


Figure 5.11 Typical resilient modulus versus axial strain for A-6 soil

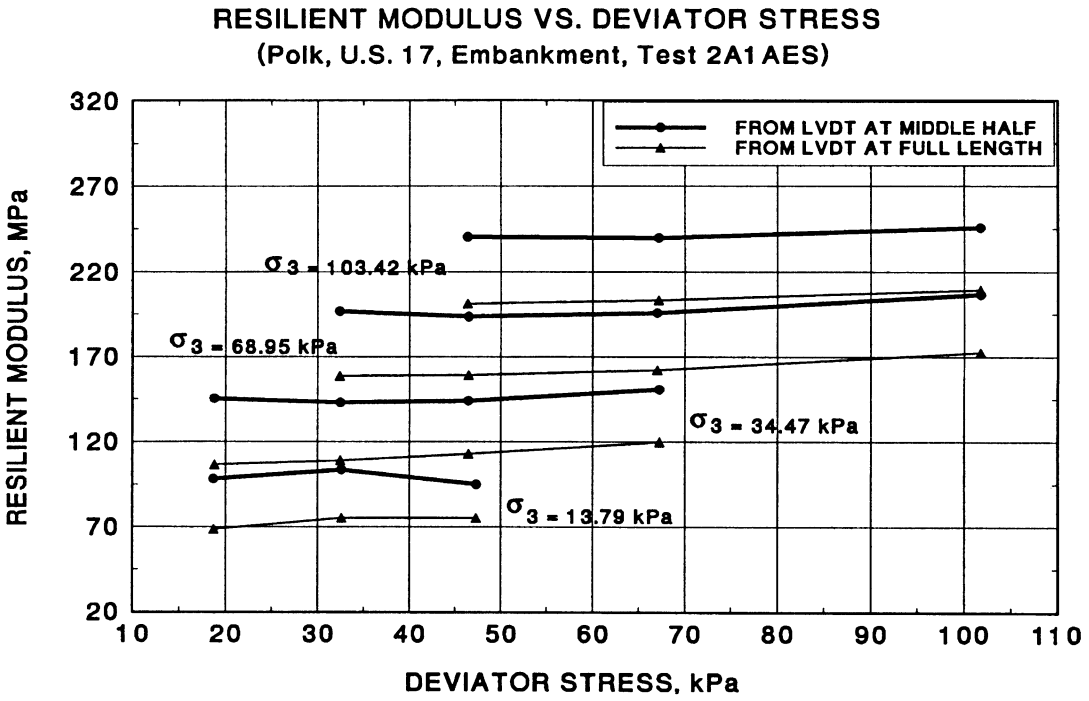


Figure 5.12 Resilient modulus versus deviator stress for yest 2A1 AES

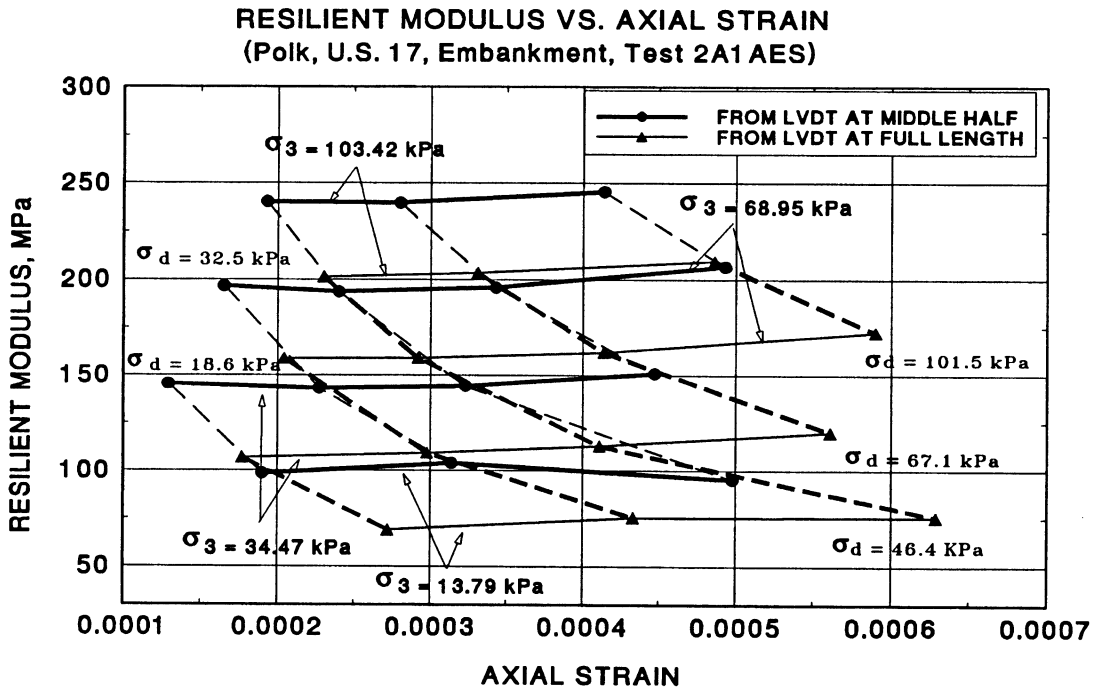


Figure 5.13 Resilient modulus versus axial strain for test 2A1 AES

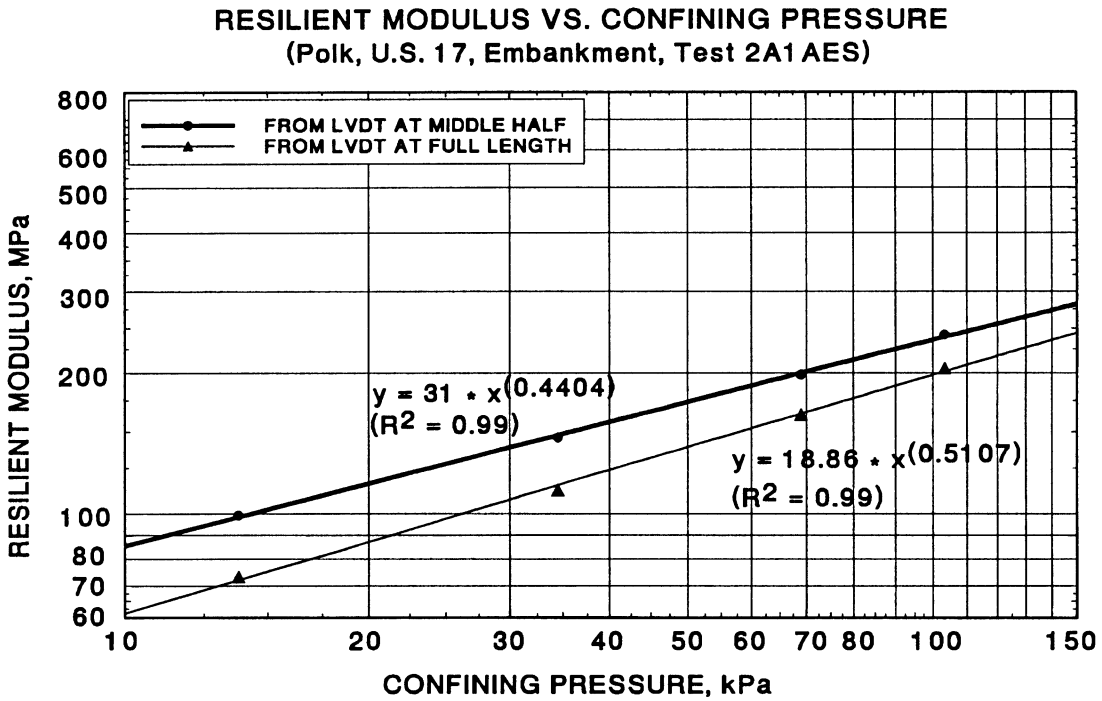


Figure 5.14 Resilient modulus versus confining pressure for test 2A1 AES

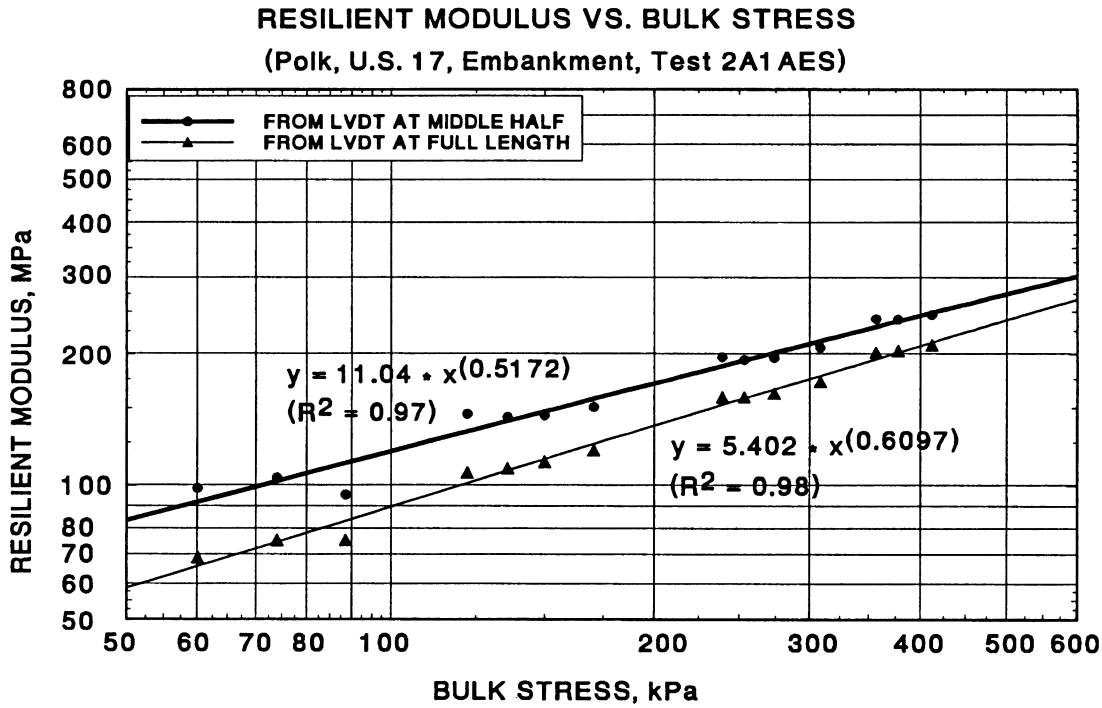


Figure 5.15 Resilient modulus versus bulk stress for test 2A1 AES

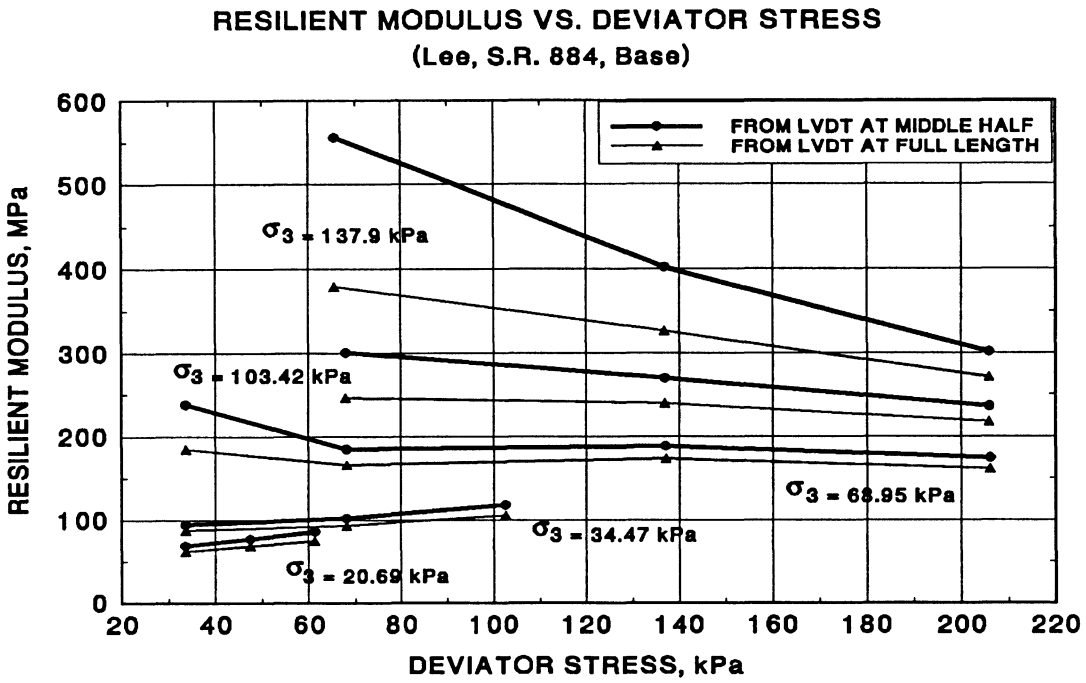


Figure 5.16 Typical resilient modulus versus deviator stress for limerock

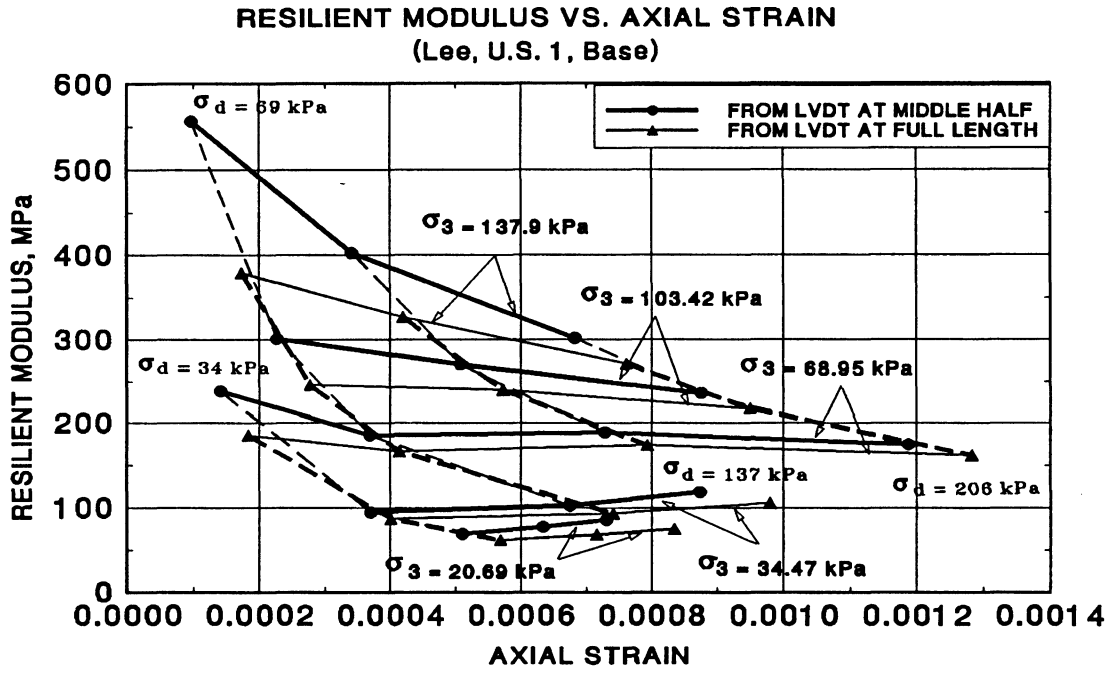


Figure 5.17 Typical resilient modulus versus axial strain for limerock

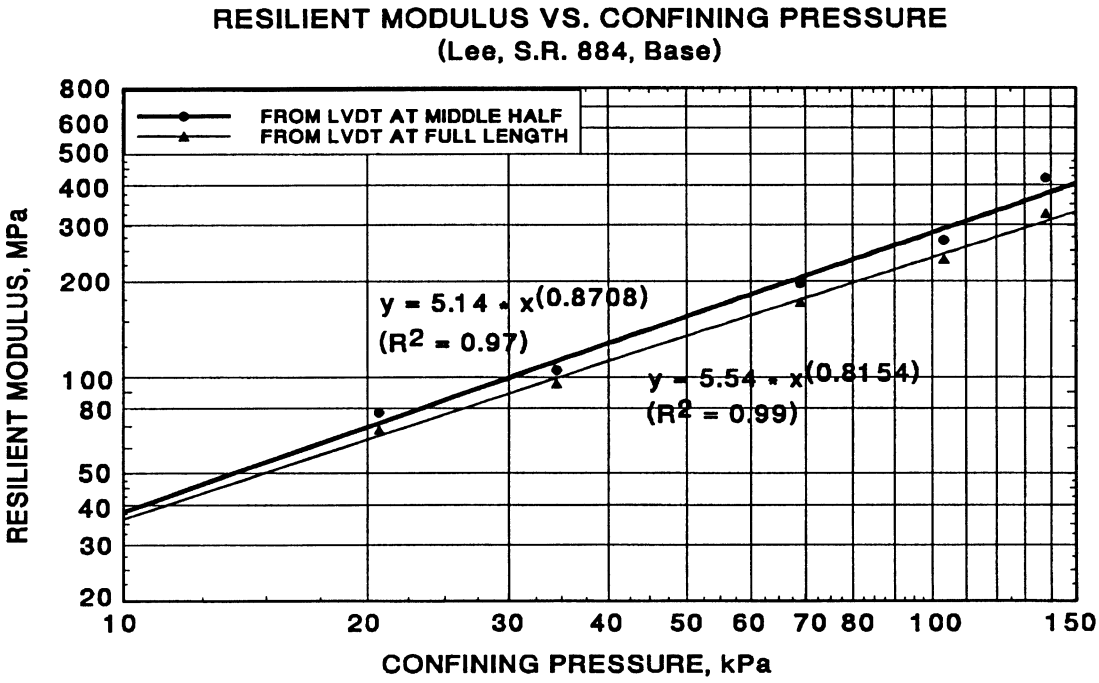


Figure 5.18 Resilient modulus versus confining pressure for limerock

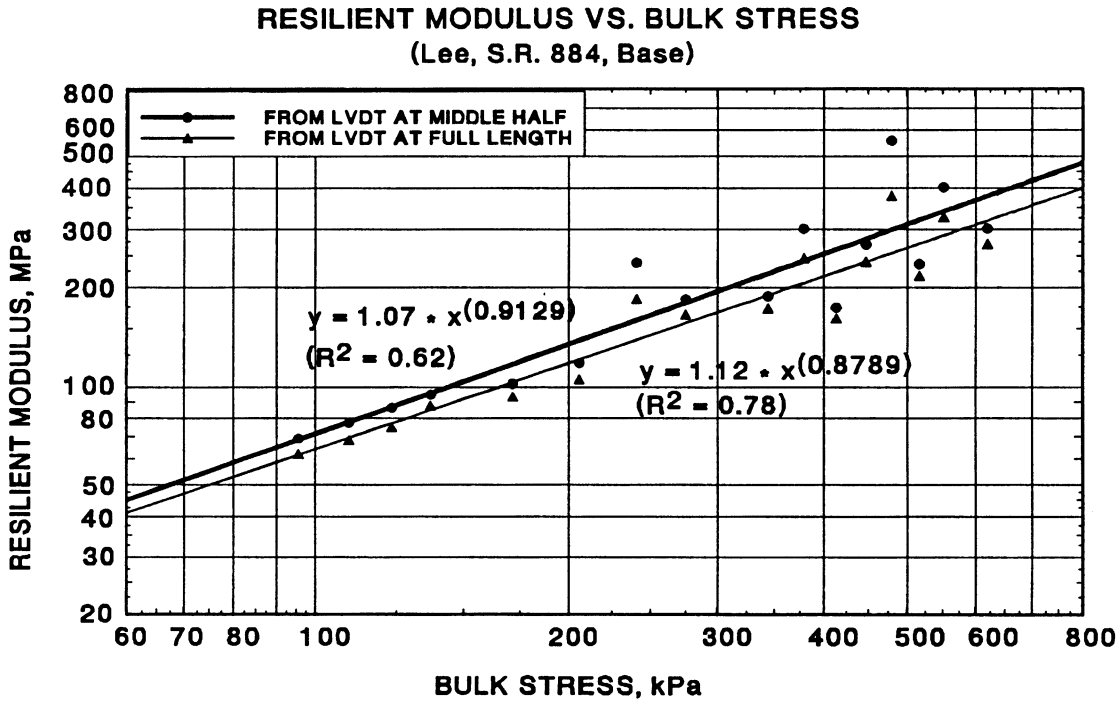


Figure 5.19 Resilient modulus versus bulk stress for limerock

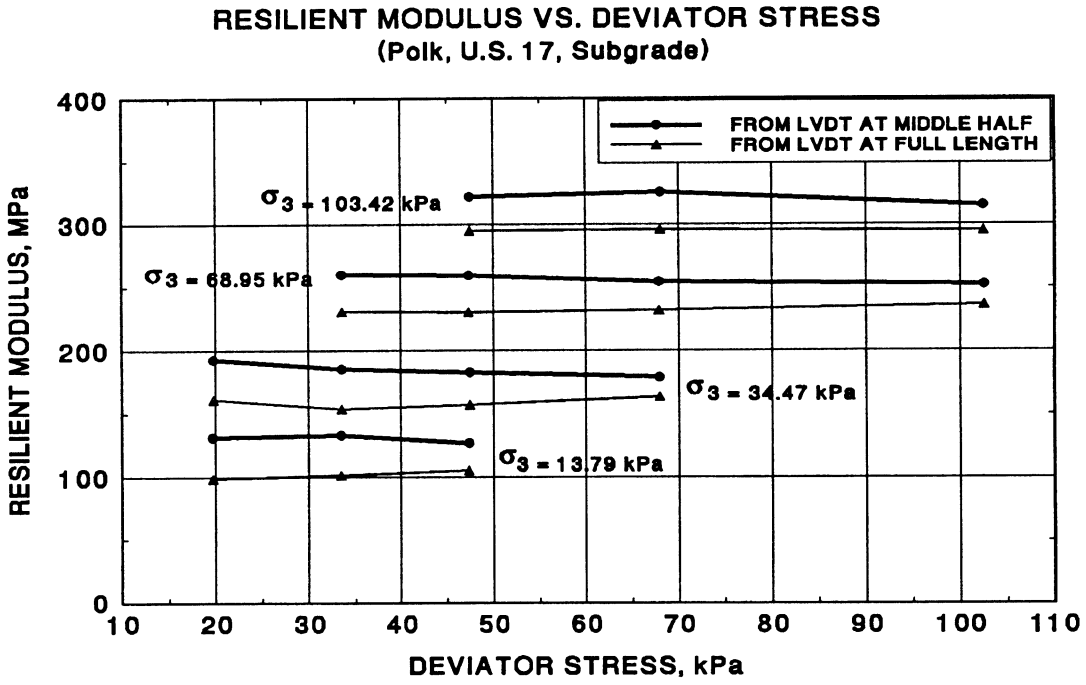


Figure 5.20 Resilient modulus versus deviator stress for A-2-4 soil

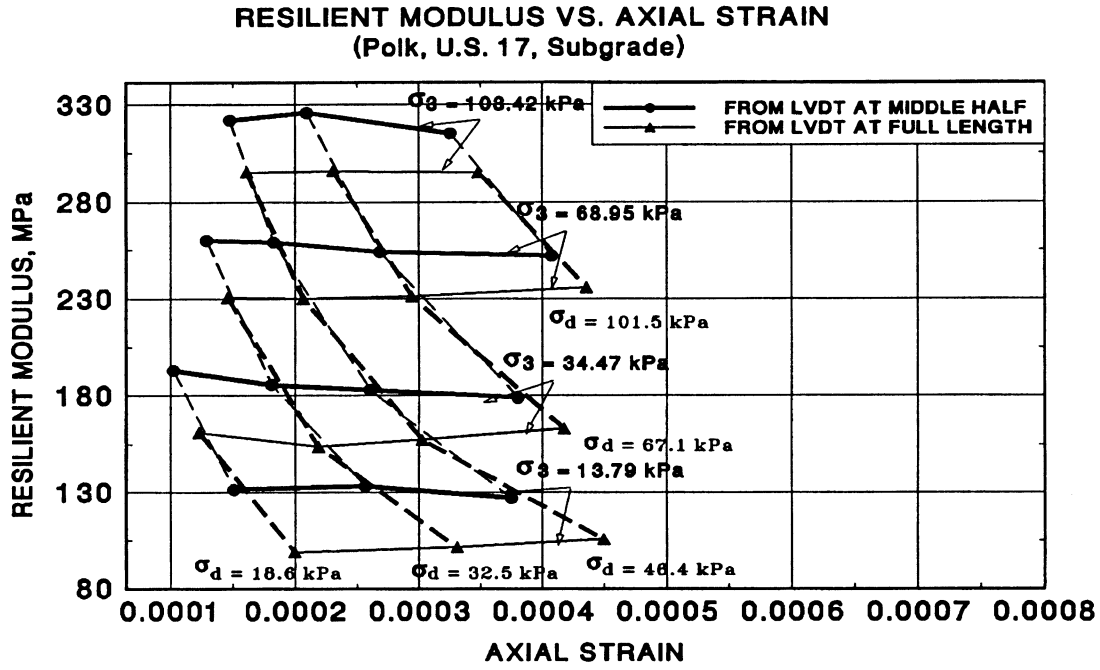


Figure 5.21 Resilient modulus versus axial strain for A-2-4 soil

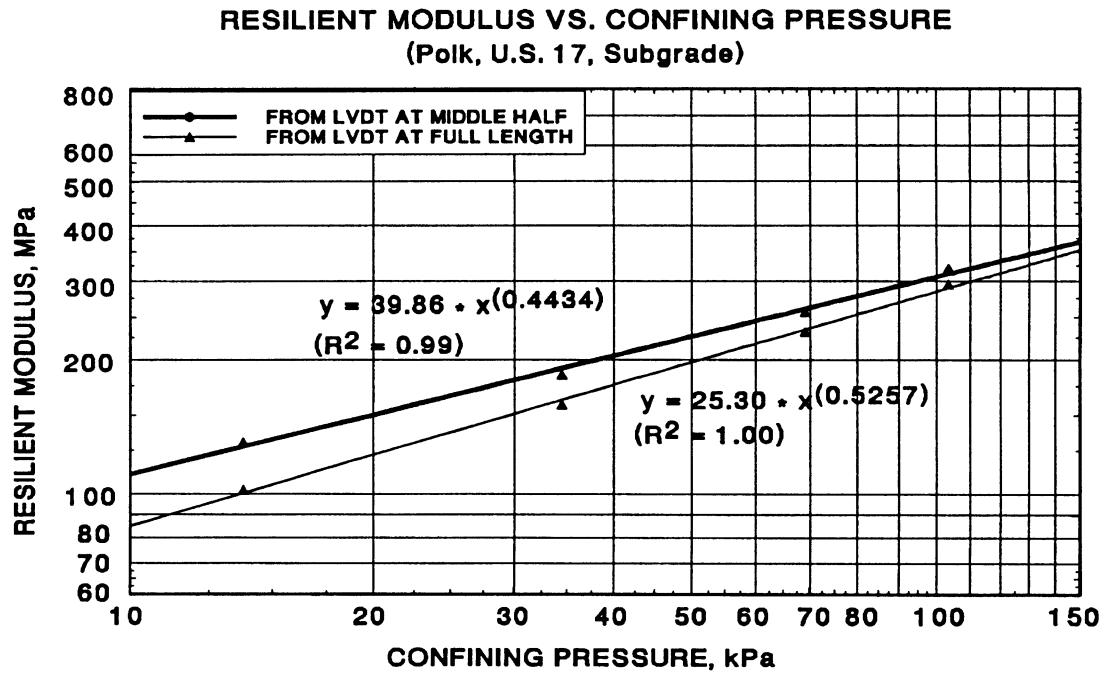


Figure 5.22 Resilient modulus versus confining pressure for A-2-4 soil

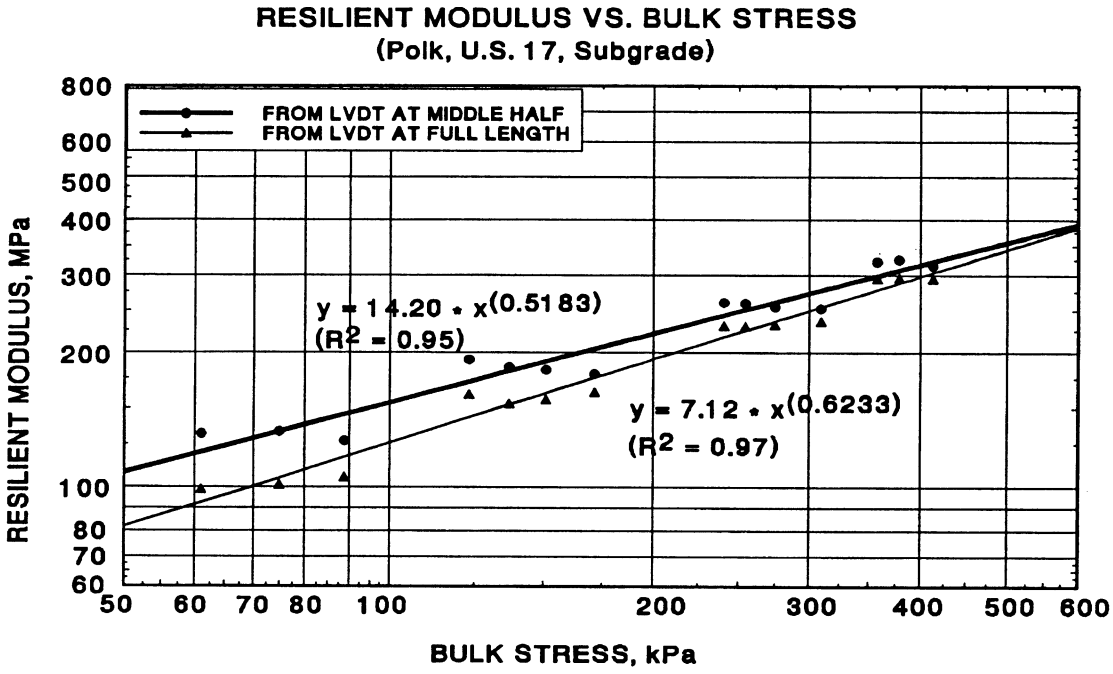
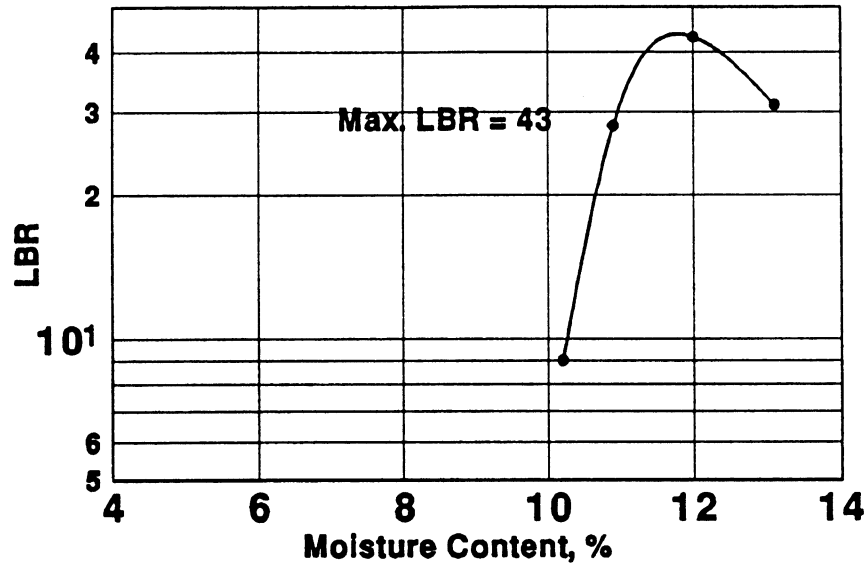
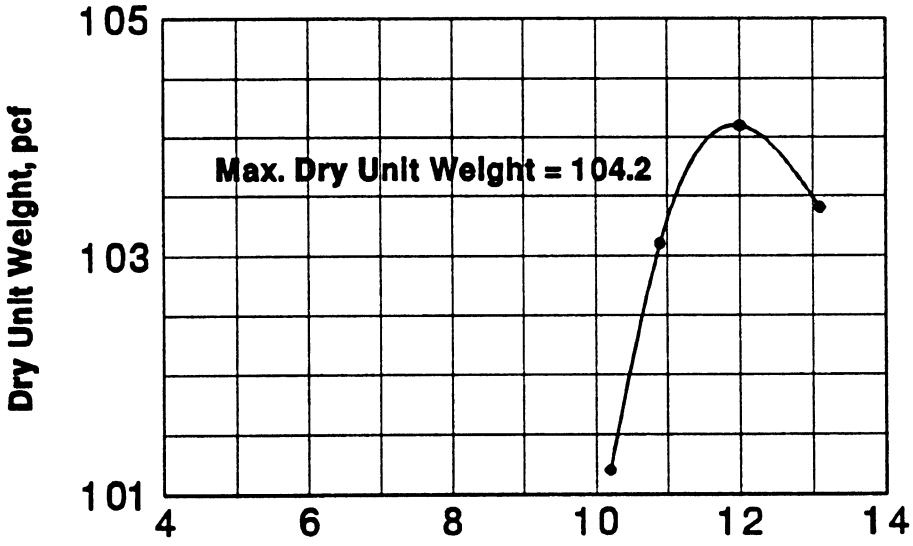


Figure 5.23 Resilient modulus versus bulk stress for A-2-4 soil



(a) Moisture Content vs. LBR



(b) Moisture Content vs. Dry Unit Weight

Figure 5.24 Typical LBR test results

CHAPTER 6

ANALYSIS OF FIELD TEST RESULTS

6.1 General

The results of the field experimental program are presented in Chapter 4. The field results obtained from the FWD test, plate bearing test, and Dynaflect test were further compared and analyzed. Correlation relationships between the field test results were established and are presented in this chapter.

6.2 Comparison of Plate Layer Moduli with FWD Back-calculated Moduli

The FWD backcalculated moduli and plate layer moduli are summarized in Table 6.1. The plate layer moduli were calculated using Burmister's equation and the FWD backcalculation procedure was presented in Chapter 4. Comparison of the plate layer moduli with the FWD back-calculated moduli is shown in Figure 6.1a for all three pavement layers, i.e., base, stabilized subgrade, and

embankment layers. As shown in the figure, the FWD backcalculated moduli were about 1.5 times higher than the plate layer moduli. The regression relationship is as follows:

$$M_{FWD} = 0.9681 M_{PLT} + 148.51 \quad (MPa) \quad (R^2 = 0.48) \quad \text{..... (6.1)}$$

For the trend line forced to intersect origin, the regression equation becomes:

$$M_{FWD} = 1.53 M_{PLT} \quad (R^2 = 0.24) \quad \text{..... (6.2)}$$

Among the plate layer modulus values, the one from Alachua County (site 4, subgrade) appears to be an outlier. The soil was A-2-4. However, the modulus value was 1350 MPa (196 ksi), which is approximately 5-10 times higher than similar subgrade modulus value. Since FWD data for Alachua County were not available, the plate layer moduli were not included for this comparison. However, as in other comparisons described later, this kind of outlier data were taken out of consideration.

As shown in Figure 6.1a, the base layers were stronger and had higher average moduli than the subgrade and embankment layers. Comparison of the plate layer moduli with the FWD back-calculated moduli is shown in Figures 6.1b, 6.1c, and 6.1d for the base, stabilized subgrade, and embankment layers, respectively. The data were very scattered. However, the FWD back-calculated moduli were higher than the plate layer moduli for the base, stabilized subgrade, and embankment layers.

Figures 6.2a through 6.2d show the comparison by the types of pavement materials. The limerock base materials had higher modulus values than the A-3 and A-2-4 sands. However, the A-3 sands had very similar modulus values as the A-2-4 sands. The major difference between the A-3 and A-2-4 in-situ soils was the degree of compaction and relative density of the sandy soils.

6.3 Comparison of Plate Layer Moduli with Dynaflect Results

The Dynaflect backcalculated results were not very reliable. The FDOT method which uses the fourth sensor deflection reading to correlate with plate layer modulus was adopted for comparison. The results are summarized in Table 6.2 and presented in Figure 6.3 for illustration. The plate

layer modulus increased with a decrease in the Dynaflect deflection sensor No.4 reading as shown in Figure 6.3a. This complied with the nature of the materials: a higher modulus value meant a stronger material and, thus, less deflection. In Figure 6.3a, the data point that stands out is from Dade County, site 1, with limerock material as embankment. If this data point is eliminated, as shown in Figure 6.3b, little relationship exists between the readings and the plate layer moduli. Similar correlations of the deflection readings for A-2-4 and A-3 sand embankment layers and the corresponding plate layer moduli are shown in Figure 6.3c and 6.3d. Many factors can influence the results, such as accuracy of sensor reading, difference in pavement structures, and variation of plate layer modulus.

6.4 Summary

From the comparison of the field test results, summaries are made as follows:

1. The FWD moduli were about 1.5 times greater than the plate layer moduli. The regression equation is: $M_{FWD} = 1.53 M_{PLT}$ (MPa);
2. For Dynaflect tests, since the backcalculation results were not available, only the relationships between the

Dynaflect deflection sensor No.4 readings and plate layer moduli were studied and the results were not very satisfying. The correlation shows that a material that has a higher plate layer modulus value yields a smaller deflection reading in Dynaflect test sensor No.4. However, within a certain type of material, such as A-3 sand, no clear trend may be found between the plate layer moduli and the Dynaflect sensor No.4 deflection readings.

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Table 6.1 Plate Layer Modulus vs FWD Modulus

SITES	PAVEMENT STRUCTURE	AASHTO CLASSIFICATION	PLM		FWD	
			MPa	ksi	MPa	ksi
Lee Co. SR884 Site 1B	Base	Limerock	171.01	24.82	335.10	48.60
	Subgrade	A-3	131.52	19.09	217.88	31.60
	Embankment	A-3	48.68	7.07	143.42	20.80
Lee Co. SR884 Site 2B	Base	Limerock	187.35	27.19		
	Subgrade	A-3	186.10	27.01		
	Embankment	A-3	103.18	14.98		
Polk Co. US17 Site 1A	Base	Limerock	261.54	37.96	416.46	60.40
	Subgrade	A-2-4	211.25	30.66	253.05	36.70
	Embankment	A-3	48.68	7.07	279.94	40.60
Polk Co. US17 Site 2A	Base	Limerock	286.69	41.61	439.90	63.80
	Subgrade	A-2-4	183.58	26.65	303.38	44.00
	Embankment	A-3	141.20	20.49	269.59	39.10
Alachua Co. US301 Site 3	Base	Limerock	518.06	75.19		
	Subgrade	A-3	268.16	38.92		
	Embankment	A-3	67.58	9.81		
Alachua Co. US301 Site 4	Base	Limerock	573.94	83.30		
	Subgrade	A-2-4	1350.44 *	196.00 *		
	Embankment	A-6	54.47	7.91		
Jefferson Co. US27 Site 1A	Base	Limerock	171.22	24.85	255.12	37.00
	Subgrade	A-4	131.19	19.04	208.23	30.20
	Embankment	A-2-6	82.33	11.95	188.23	27.30
Jefferson Co. US27 Site 2A	Base	Limerock	192.92	28.00		
	Subgrade	A-4	141.56	20.55		
	Embankment	A-2-4	115.06	16.70		
Gadsden Co. US27 Site 2B	Base	Limerock	219.45	31.85	226.85	32.90
	Subgrade	A-2-4	108.04	15.68	146.86	21.30
	Embankment	A-2-4	82.27	11.94	126.87	18.40
Gadsden Co. US27 Site 3B	Base	Limerock	212.21	30.80	219.26	31.80
	Subgrade	A-3	120.58	17.50	122.04	17.70
	Embankment	A-6	94.46	13.71	113.77	16.50
Dade Co. US41 Site 1	Base	Limerock	647.49	93.98	601.24	87.20
	Subgrade	Limerock	441.30	64.05	493.68	71.60
	Embankment	Limerock	421.79	61.22	483.34	70.10
Martin Co. US1 Site 3	Base	Limerock	245.97	35.70	511.61	74.20
	Subgrade	A-3	178.45	25.90	383.36	55.60
	Embankment	A-3	58.22	8.45	346.13	50.20
Martin Co. US1 Site 4	Base	Limerock	255.62	37.10	590.90	85.70
	Subgrade	A-4	125.40	18.20	457.14	66.30
	Embankment	A-3	90.42	13.12	262.70	38.10
Seminole Co. US414 Site 1	Base	Limerock	266.71	38.71	393.70	57.10
	Subgrade	A-2-4	110.58	16.05	367.50	53.30
	Embankment	A-2-4	109.91	15.95	214.43	31.10
Seminole Co. US414 Site 2	Base	Limerock	248.38	36.05	419.91	60.90
	Subgrade	A-2-4	99.11	14.39	300.62	43.60
	Embankment	A-3	94.99	13.79	164.10	23.80
Osceola Co. US441 Site 3	Base	Coquina	337.61	49.00	1003.91	145.60
	Subgrade	A3	114.79	16.66	346.82	50.30
	Embankment	A3	58.22	8.45	188.92	27.40
Osceola Co. US441 Site 4	Base	Coquina	295.17	42.84	489.55	71.00
	Subgrade	A3	111.89	16.24	206.85	30.00
	Embankment	A3	57.28	8.31	148.93	21.60

Table 6.2 Plate Layer Modulus vs Dynaflect Deflection Sensor No.4 Readings

SITES	PAVEMENT STRUCTURE	AASHTO CLASSIFICATION	PLM		DYN	
			MPa	ksi	(10^{-3}) mm	mils
Lee Co. SR884 Site 1B	Embankment	A-3	48.68	7.07	3.81	0.15
Lee Co. SR884 Site 2B	Embankment	A-3	103.18	14.98	3.30	0.13
Polk Co. US17 Site 1A	Embankment	A-3	48.68	7.07	4.57	0.18
Polk Co. US17 Site 2A	Embankment	A-3	141.20	20.49	4.06	0.16
Alachua Co. US301 Site 3	Embankment	A-3	67.58	9.81	4.06	0.16
Alachua Co. US301 Site 4	Embankment	A-6	54.47	7.91	3.30	0.13
Jefferson Co. US27 Site 1A	Embankment	A-2-6	82.33	11.95	2.79	0.11
Jefferson Co. US27 Site 2A	Embankment	A-2-4	115.06	16.70	3.05	0.12
Clay Co. US17 Site 5	Embankment	A-2-4	119.77	17.38	5.84	0.23
Clay Co. US17 Site 6	Embankment	A-3	110.10	15.98	5.59	0.22
Gadsden Co. US27 Site 2B	Embankment	A-2-4	82.27	11.94	2.54	0.10
Gadsden Co. US27 Site 3B	Embankment	A-6	94.46	13.71	2.29	0.09
Dade Co. US41 Site 1	Embankment	Limerock	421.79	61.22	1.02	0.04
Martin Co. US1 Site 3	Embankment	A-3	58.22	8.45	3.30	0.13
Martin Co. US1 Site 4	Embankment	A-3	90.42	13.12	5.08	0.20
Seminole Co. US414 Site 1	Embankment	A-2-4	109.91	15.95	4.83	0.19
Seminole Co. US414 Site 2	Embankment	A-3	94.99	13.79	4.32	0.17
Osceola Co. US441 Site 3	Embankment	A-3	58.22	8.45	5.08	0.20
Osceola Co. US441 Site 4	Embankment	A-3	57.28	8.31	4.57	0.18

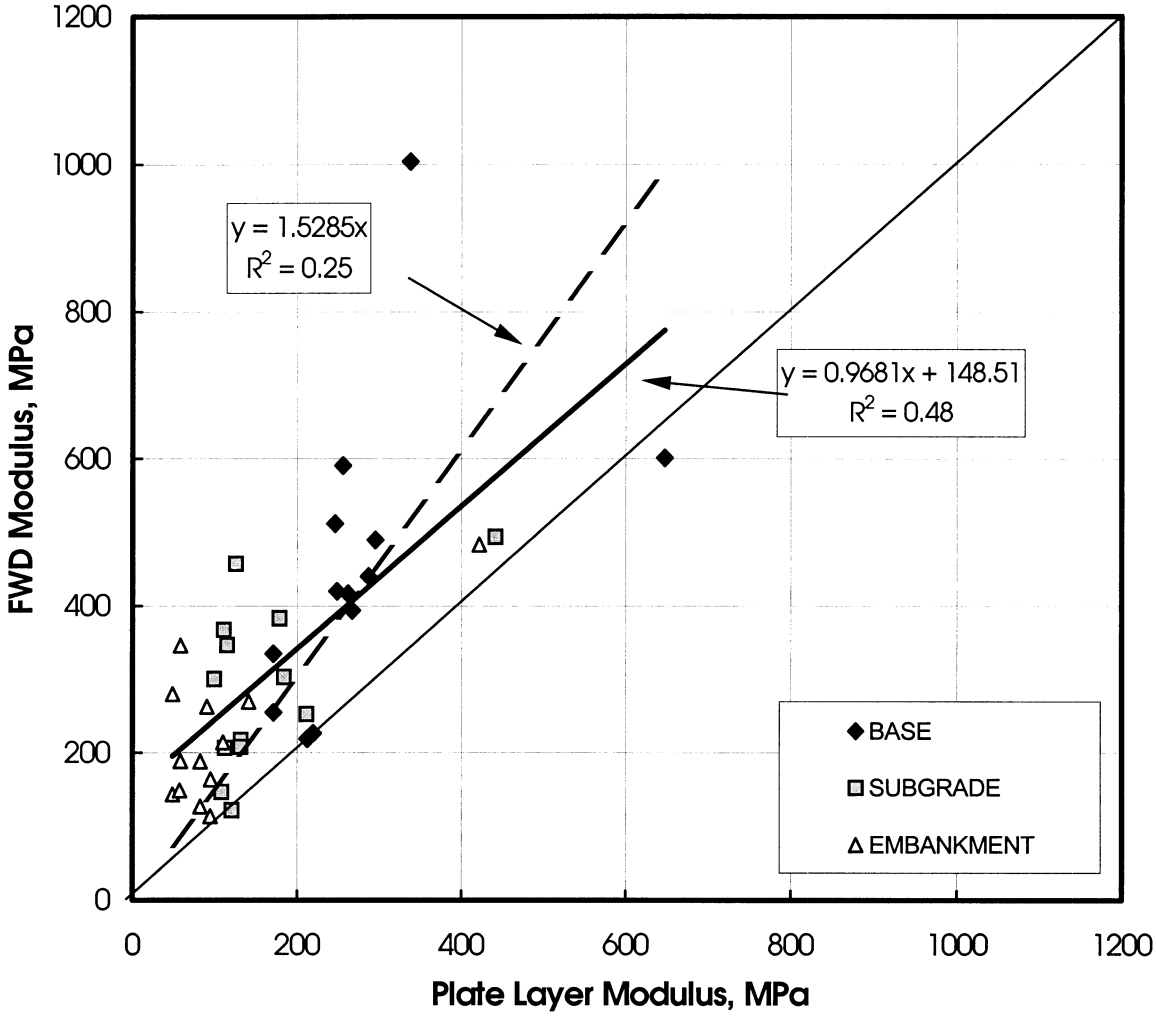


Figure 6.1a Comparison of plate layer moduli with FWD backcalculated moduli

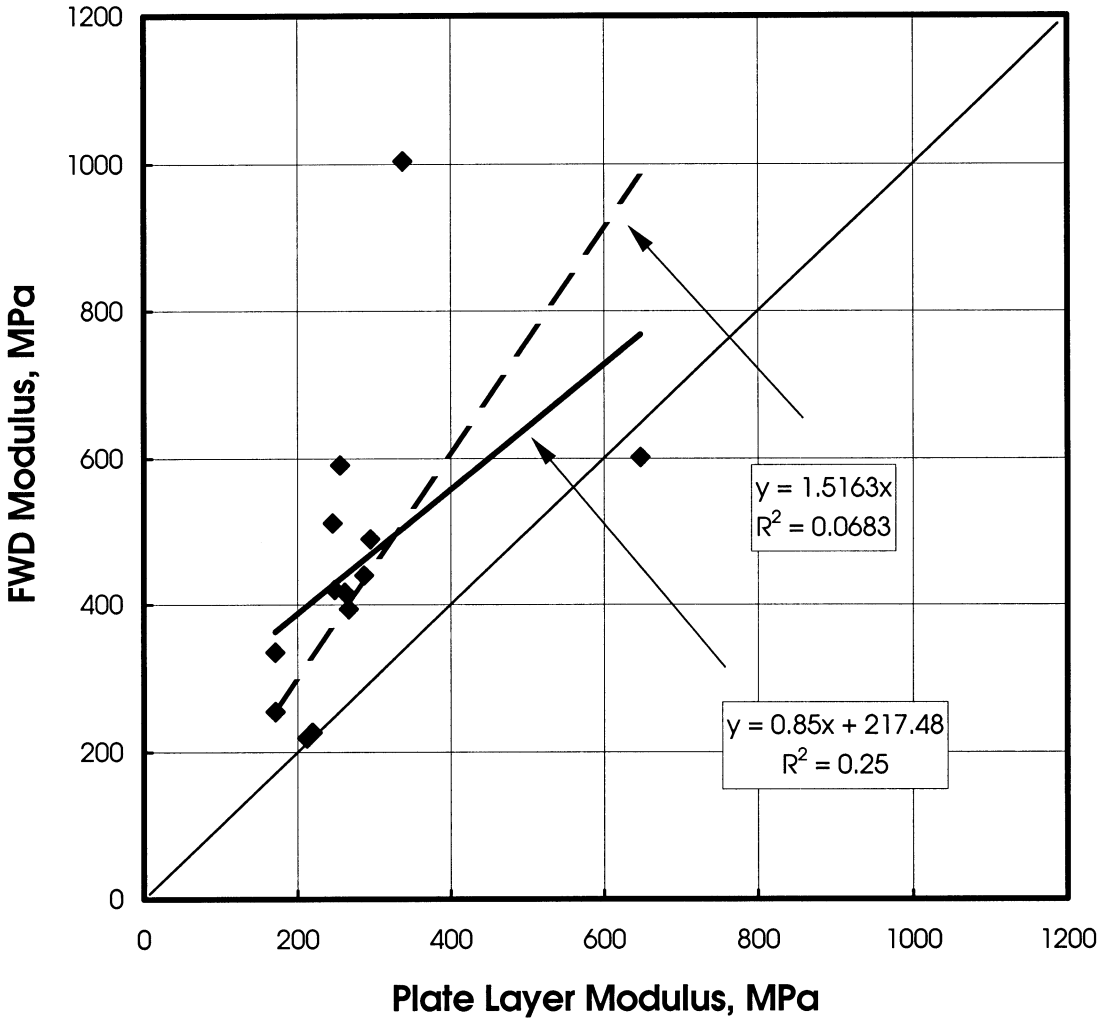


Figure 6.1b Comparison of plate layer moduli with FWD backcalculated moduli for base layers

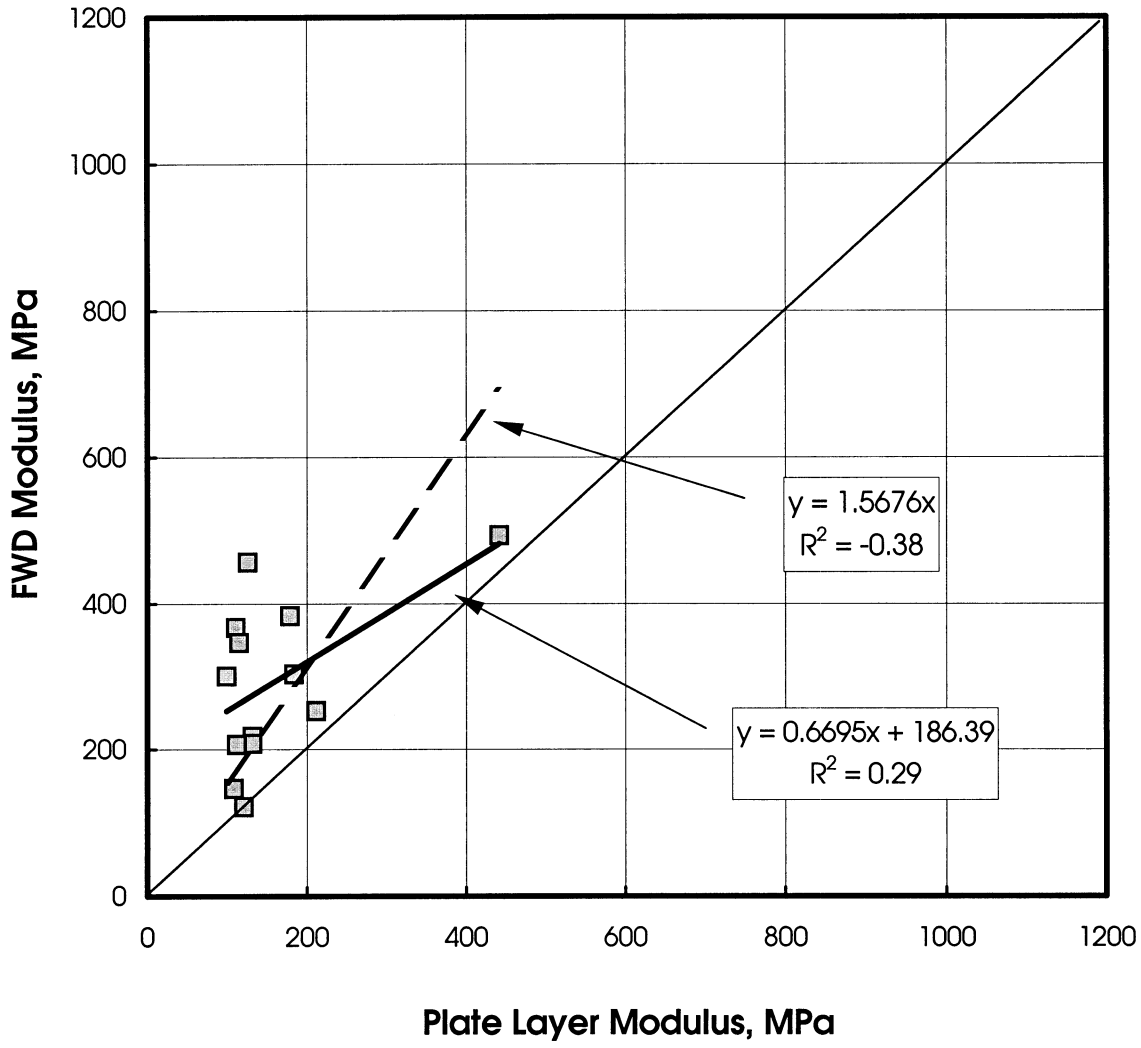


Figure 6.1c Comparison of plate layer moduli with FWD backcalculated moduli for subgrade layers

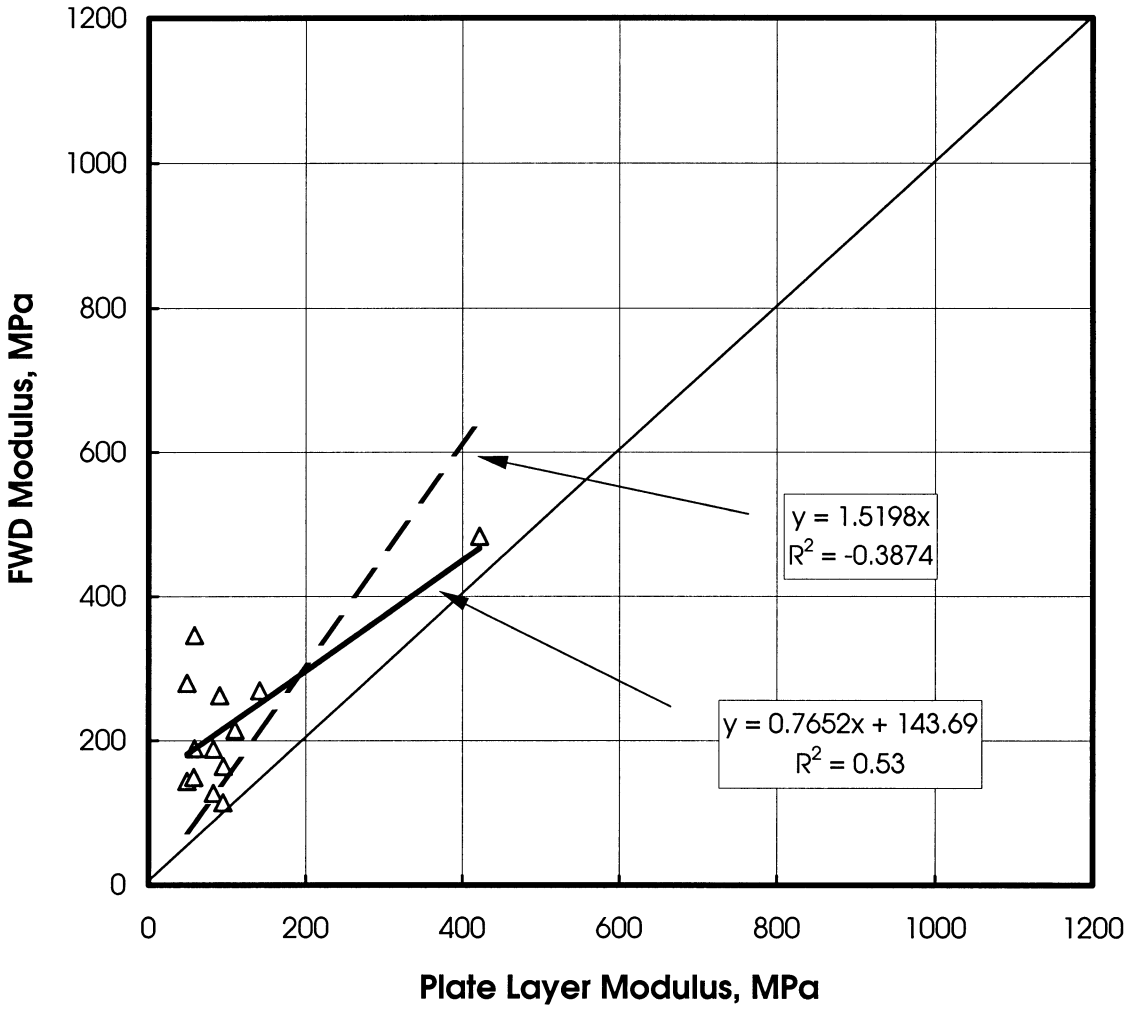


Figure 6.1d Comparison of plate layer moduli with FWD backcalculated moduli for embankment layers

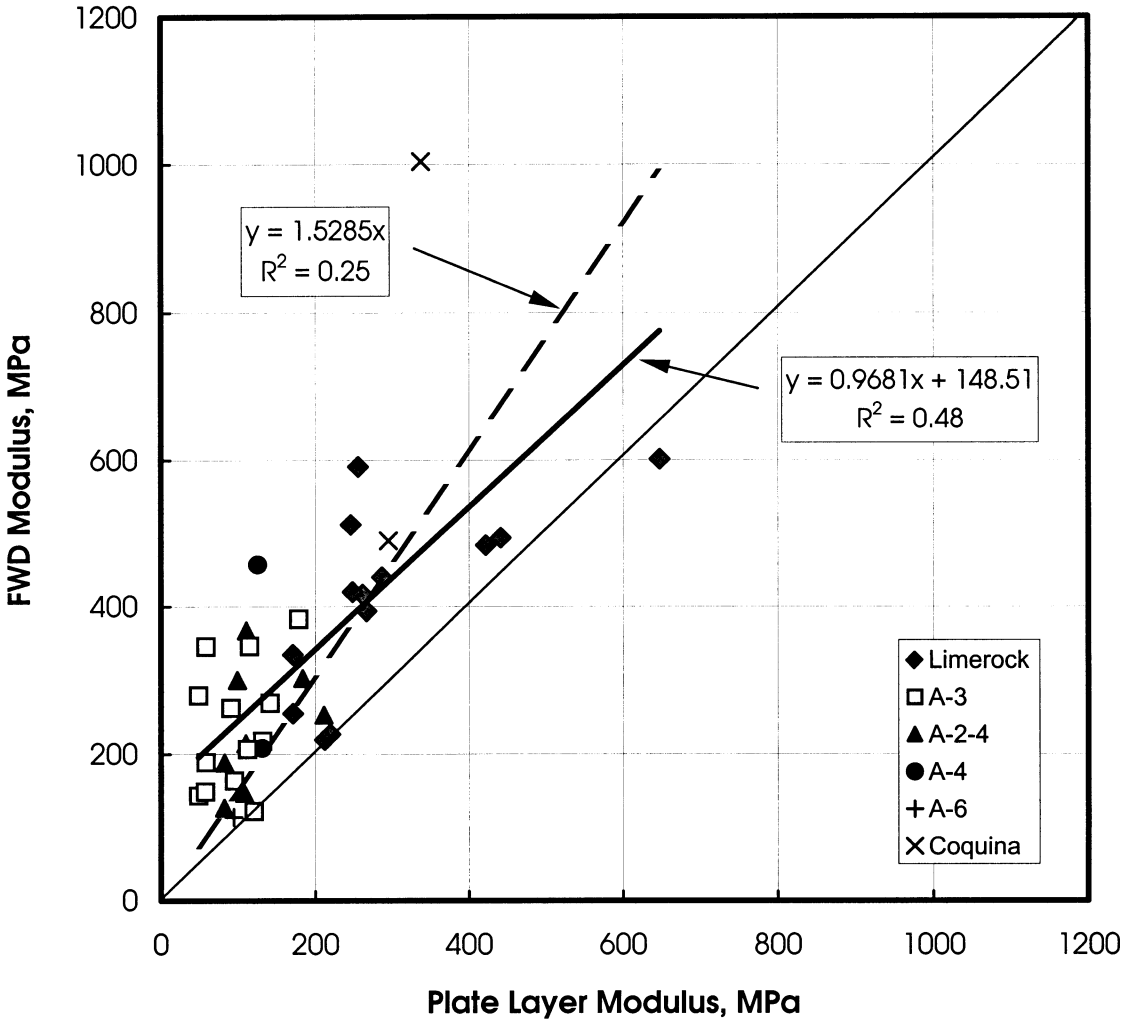


Figure 6.2a Comparison of plate layer moduli with FWD backcalculated moduli by pavement materials

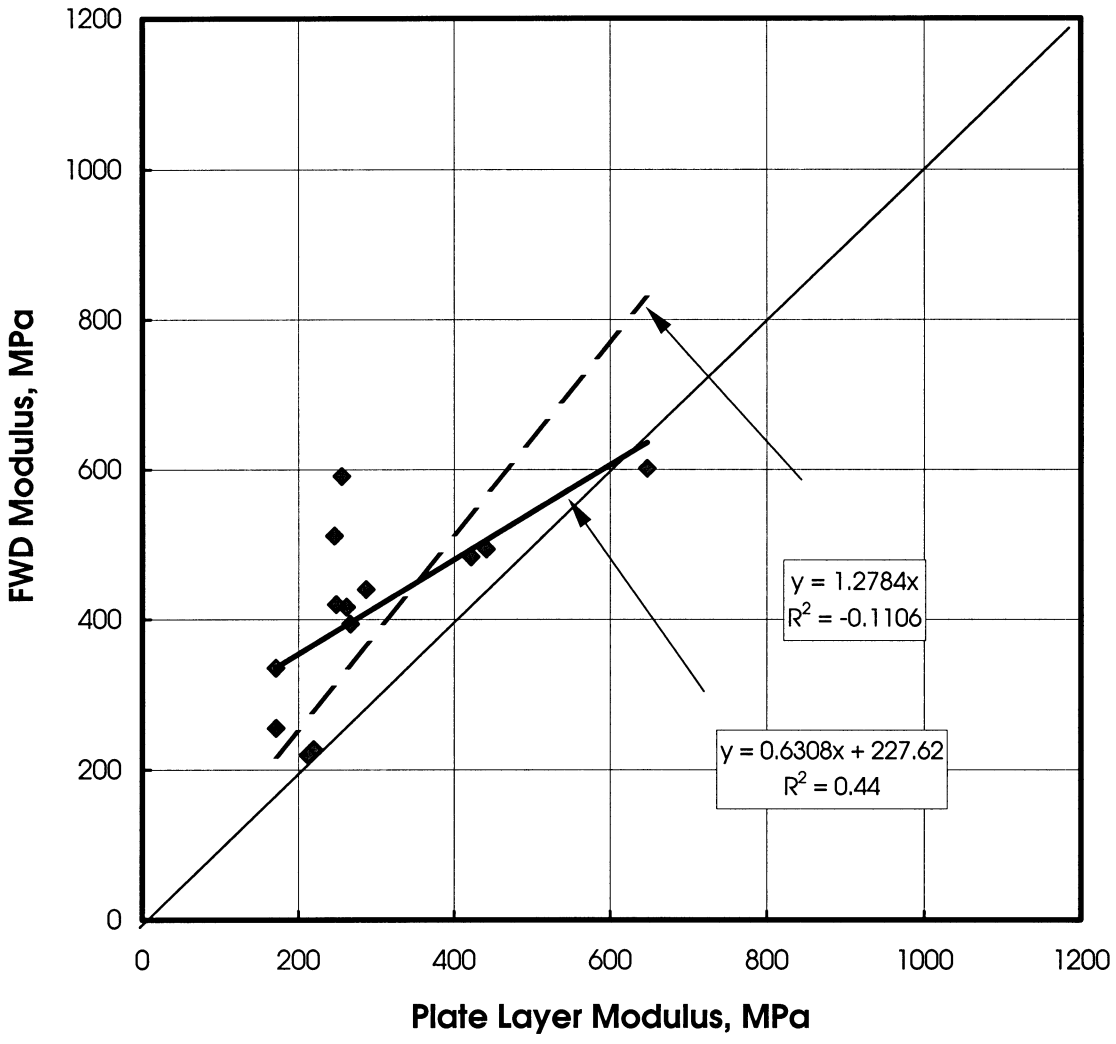


Figure 6.2b Comparison of plate layer moduli with FWD backcalculated moduli for limerock

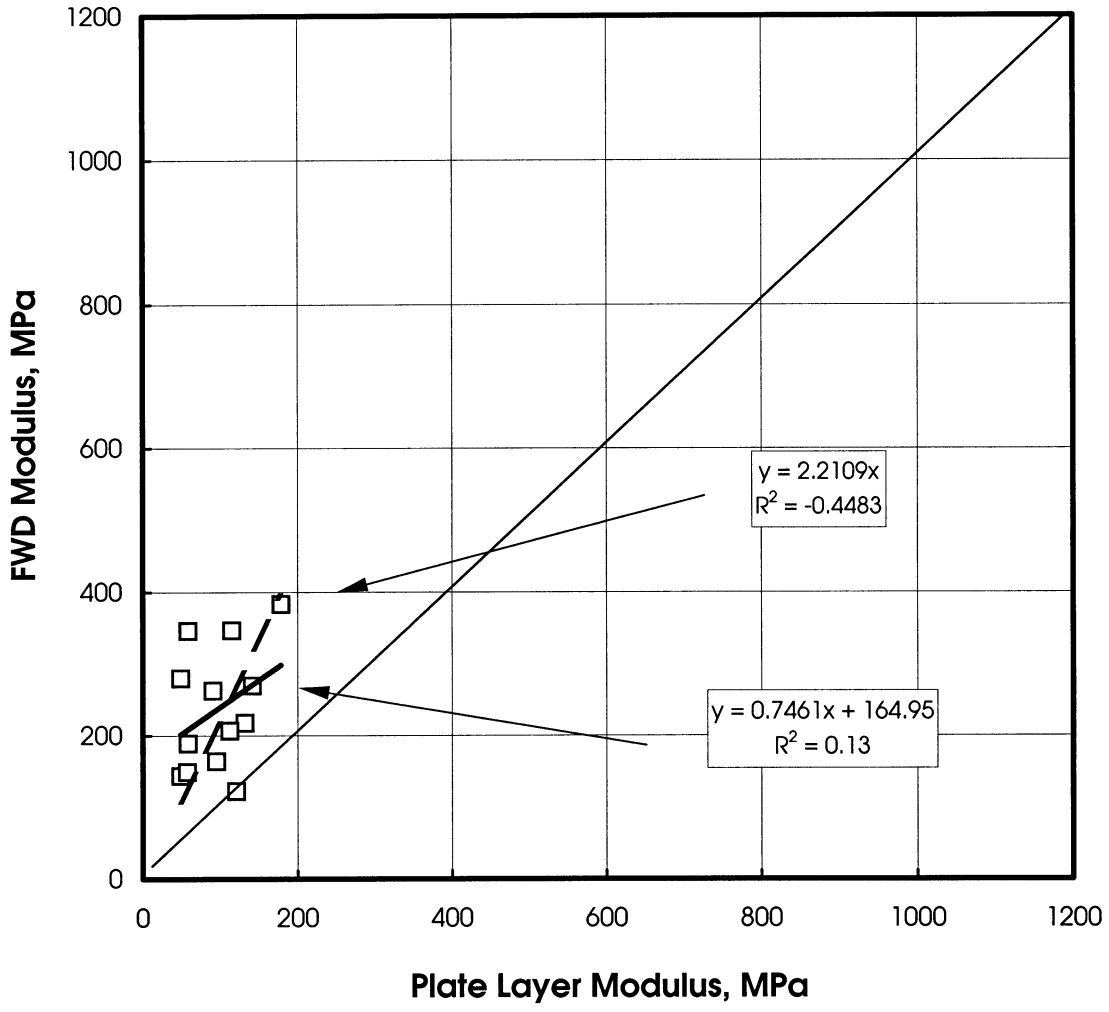


Figure 6.2c Comparison of plate layer moduli with FWD backcalculated moduli for A-3 soils

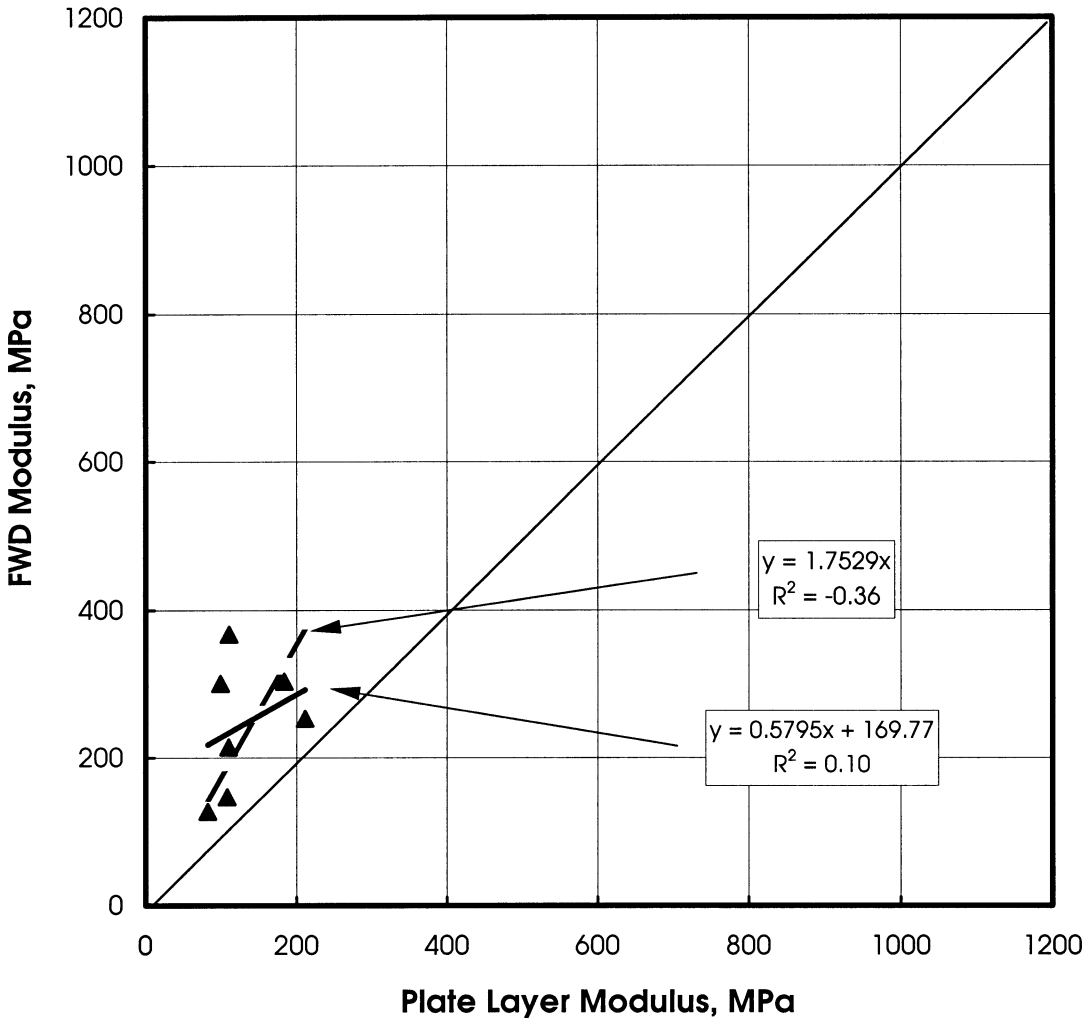


Figure 6.2d Comparison of plate layer moduli with FWD backcalculated moduli for A-2-4 soils

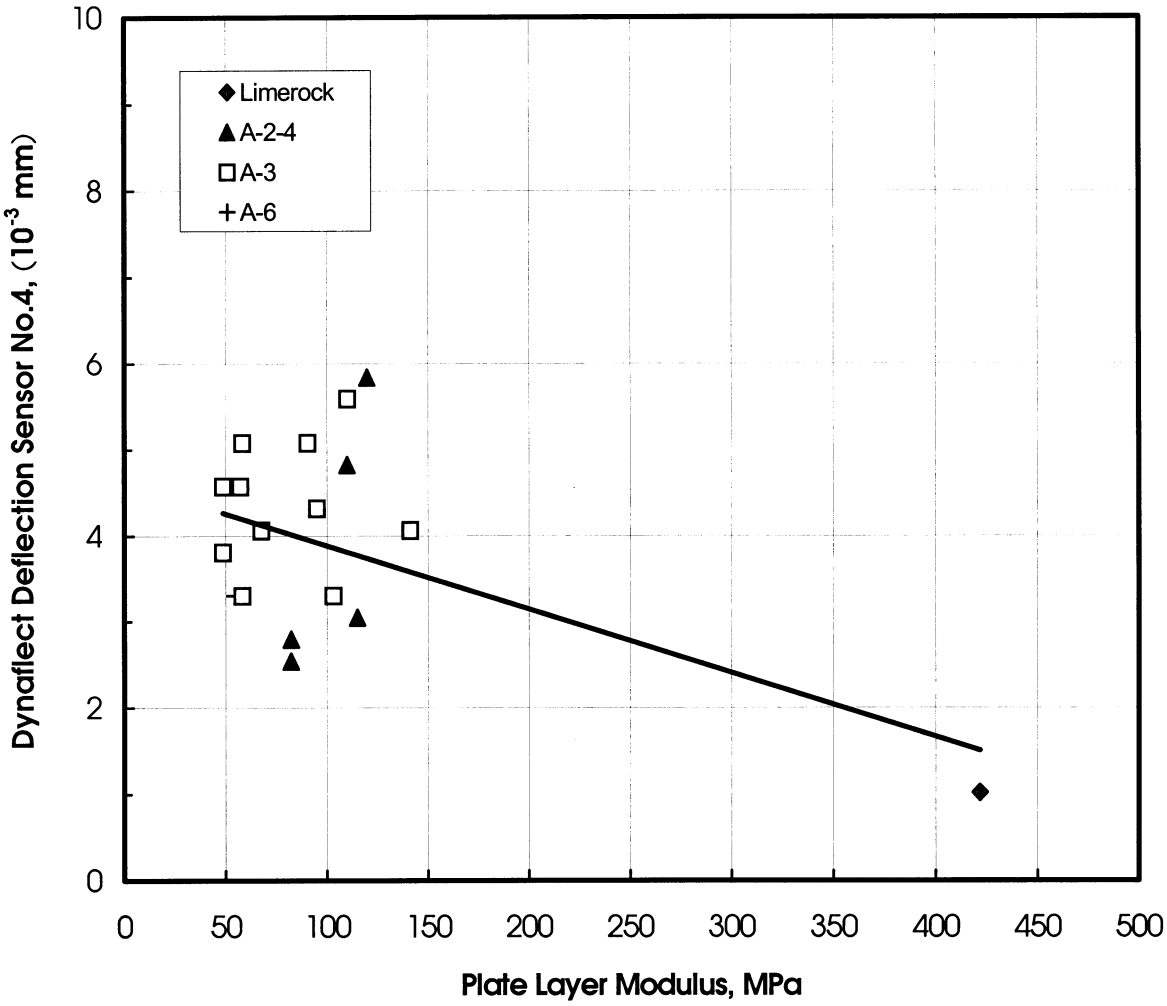


Figure 6.3a Plate layer moduli versus dynaflect deflection sensor No.4 readings for embankment layers (with data from limerock material)

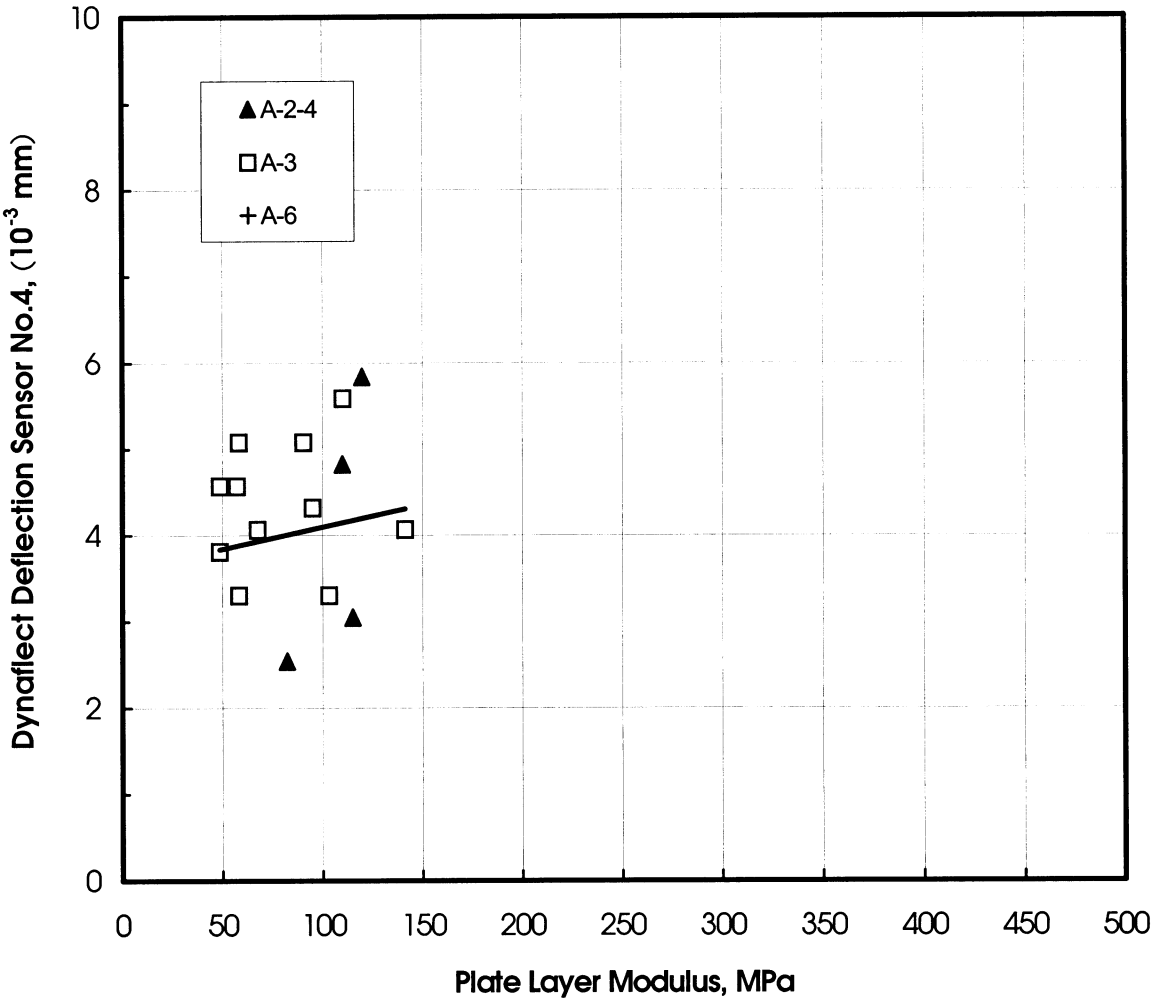


Figure 6.3b Plate layer moduli versus dynaflect deflection sensor No.4 readings for embankment layers (without data from limerock material)

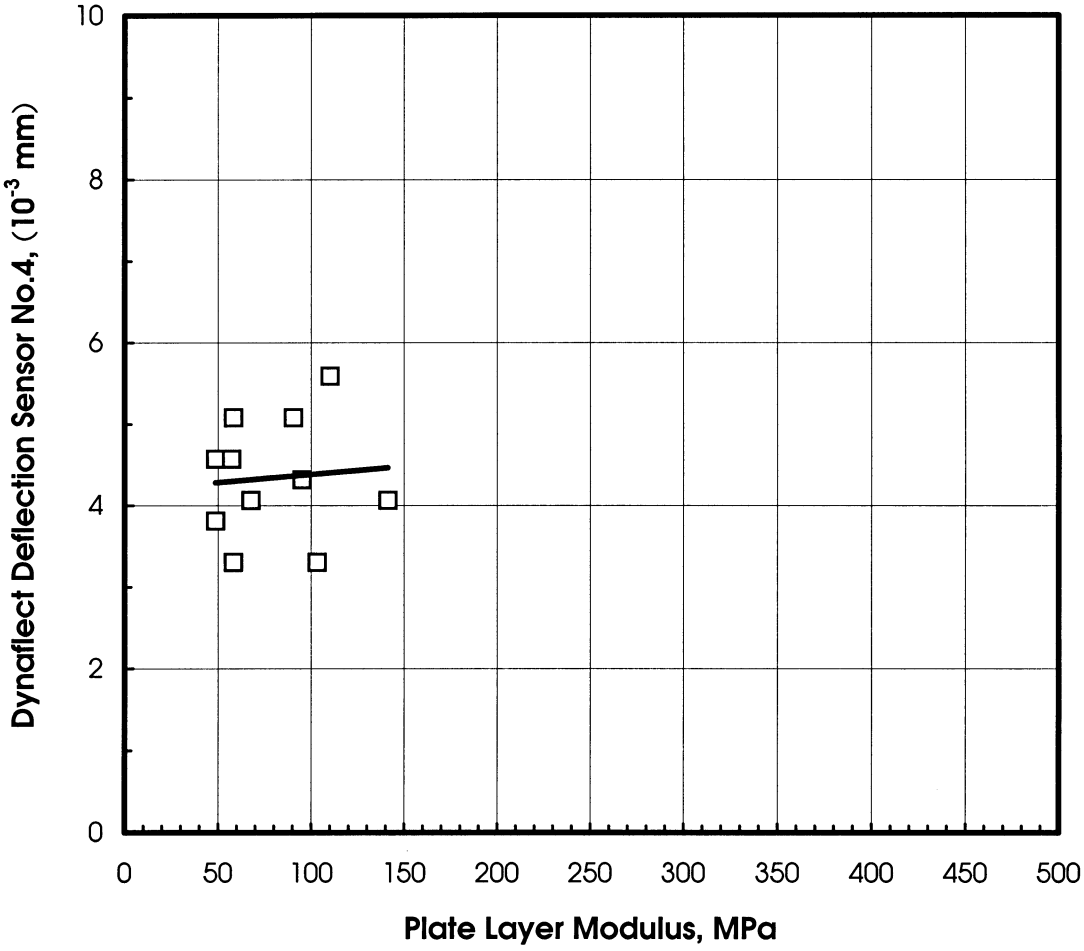


Figure 6.3c Plate layer moduli versus dynaflect deflection sensor No.4 readings for A-3 soils

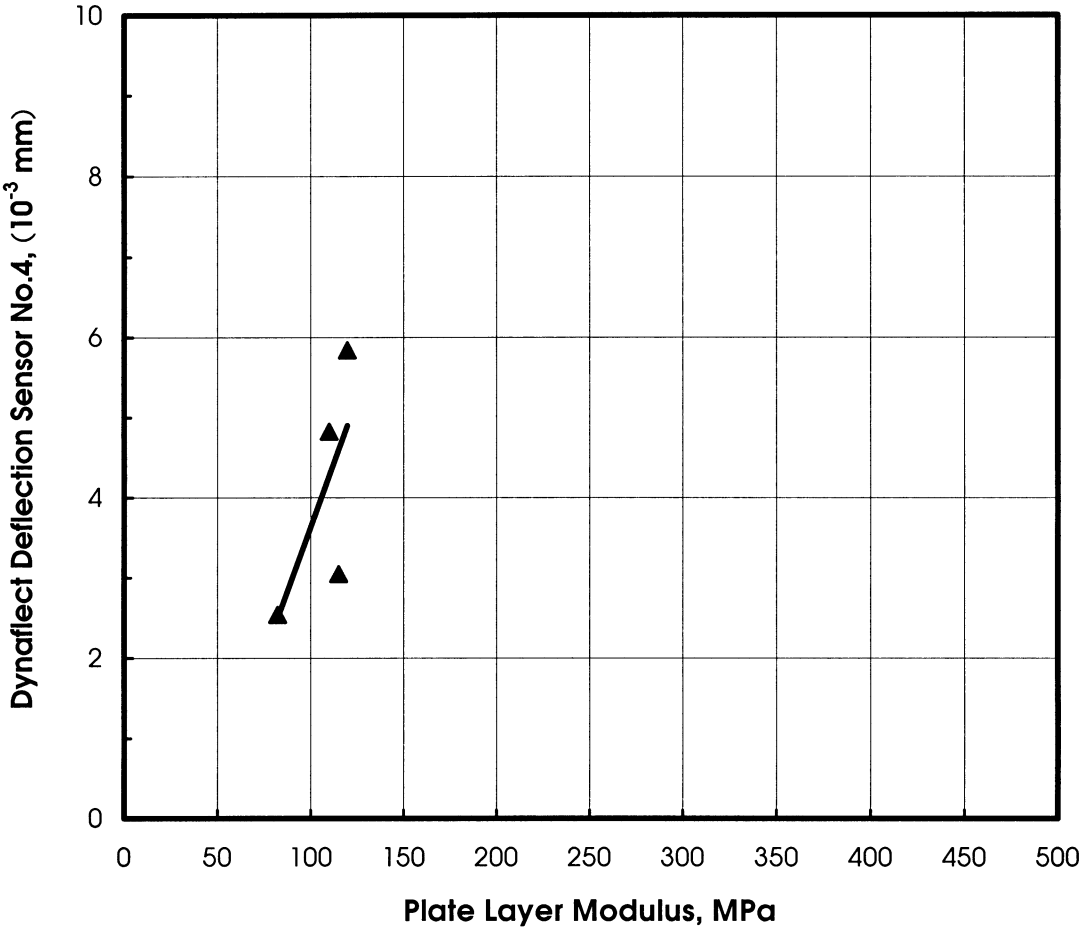


Figure 6.3d Plate layer moduli versus dynaflect deflection sensor No.4 readings for A-2-4 soils

CHAPTER 7

ANALYSIS OF LABORATORY TEST RESULTS

7.1 General

The laboratory experimental test results are summarized and presented in Chapter 5. The results are further analyzed in this chapter. Repeatability of the resilient modulus test, effect of specimen size, and the correlation relationships of resilient modulus values versus the bulk stress, confining pressure, deviator stress, and axial strain were investigated and are discussed. The *T 292-91I* and *T 294-92* test procedures were also compared in detail. The correlation relationships of resilient modulus values under optimum moisture content conditions and in-situ moisture content conditions versus LBR values were developed and are presented in this chapter.

7.2 Repeatability of Resilient Modulus Test

The primary purpose for conducting the resilient modulus test on two replicate soil specimens was to investigate the

repeatability of the test and to ensure validity of the resilient modulus test results. The repeatability of the resilient modulus test for each type of pavement soils is discussed in the following sections.

7.2.1 T 292-91I Method

A-3 soils. The repeatability of the resilient modulus test (*T 292-91I*) for A-3 soils is shown in Figure 7.1. The data were very close to the line of equality. The differences between the two tests were within about five percent; thus, the resilient modulus test was repeatable for A-3 soils for both 10.2-cm (4-in.) and 20.3-cm (8-in.) measurements.

A-2-4 soils. Figure 7.2 shows the comparison of resilient modulus values from Test 1 versus Test 2 (*T 292-91I*) for A-2-4 soils. Similar to A-3 soils, the resilient modulus test results from Test 1 and Test 2 were very close to each other (within about five percent) for both 10.2-cm and 20.3-cm measurements.

7.2.2 T 294-92 Method

A-4 soils. The comparison of the resilient modulus test results (*T 294-92*) from Test 1 and Test 2 for both 10.2-cm and 20.3-cm measurements is shown in Figure 7.3 for A-4

soils. All data points fell close to the line of equality, which indicated that the resilient modulus test is repeatable for A-4 soils.

A-2-4 soils. Figure 7.4 shows the comparison of resilient modulus values from Test 1 versus Test 2 (*T 294-92*) for A-2-4 soils. Similar to the *T 292-91I* test procedure, the resilient modulus test results from Test 1 and Test 2 are very close to each other (within about five percent) for both 10.2-cm and 20.3-cm measurements.

In summary, it is evident that all resilient modulus tests are repeatable. The differences between two replicate tests for A-2-4, A-3, and A-4 soils were very small (within about five percent). Since the resilient modulus test is repeatable, the following discussion sections are based on the average results of two replicate tests.

7.3 Resilient Moduli from 10.2-cm and 20.3-cm LVDT Measurements

There was a significant difference between the M_R values computed from the deformations measured by the 10.2-cm LVDT (measure the deformation of the half length of specimen) measurements and by the 20.3-cm LVDT (measure the deformation of the full length of specimen) measurements. In general, the

20.3-cm LVDT measurements, especially external measurements (mounted outside the triaxial cell), would induce significant errors to the measurements because of air gaps between the specimen and accessories such as porous stones and platens, and errors such as sample alignment and bedding problems. This is so called the end effect. The 10.2-cm LVDT measurements, though hard to install, provided results which are less influenced by the system compliance of triaxial cell accessories. In this study, both 10.2-cm and 20.3-cm LVDT measurements were used for the *T 292-91I* test procedure, and the 20.3-cm LVDT measurements were mounted inside the triaxial cell, which partially eliminated the end effects. However, in all cases, the results from the 10.2-cm measurements still resulted in higher resilient modulus values than those from the 20.3-cm measurements.

A number of tests were conducted with different positions of the middle LVDTs within the length of specimen as shown in Figure 7.5. Four replicate samples were tested for the four different positions of the middle LVDTs mounted from the bottom to the top of the test specimen.

Figure 7.6 shows that the variation of the resilient modulus of a subgrade sand at different positions of the middle LVDTs were very small. However, the differences were

significant when one of the LVDTs was positioned on the top platen (Place 4, Figure 7.5). The figure clearly demonstrates the influence of the end effect on the resilient modulus measurements.

7.4 Influence Factors on Resilient Modulus

Bulk stress, confining pressure, deviator stress, and axial strain have strong influences on the laboratory resilient modulus measurements. Those influence factors are discussed in the following sections.

7.4.1 Influence of Bulk Stress

7.4.1.1 Base Materials

The bulk stress had a significant influence on the resilient modulus of granular materials. A log-log plot of the average resilient modulus versus bulk stress for base materials (limerock and coquina) is shown in Figure 7.7. As illustrated in the figure, the resilient modulus values increased as the bulk stresses increased. Two regression lines were drawn to illustrate the linear relationships between the logarithm of the resilient modulus and the logarithm of the bulk stress. However, the data were relatively scattered with the R^2 = 0.75 and 0.80 for the

10.2-cm and 20.3-cm LVDT measurements, respectively. A correlation relationship definitely existed between the logarithm of the resilient modulus and the logarithm of the bulk stress, although the R^2 values were not exceptionally high.

7.4.1.2 A-3 and A-2-4 Soils

The logarithm of the average resilient modulus versus the logarithm of the average bulk stress for A-3 and A-2-4 soils are presented in Figures 7.8 and 7.9, respectively. All the data points were close to the linear regression lines. The range of the R^2 values was from 0.96 to 0.99. This indicated that there was a definite correlation relationship existing between the logarithm of the resilient modulus and the logarithm of the bulk stress for A-3 and A-2-4 soils. The bulk stress had a significant influence on the resilient modulus.

7.4.2 Influence of Confining Pressure

7.4.2.1 Base Materials

The confining pressure also had a remarkable influence on the resilient modulus of granular materials. Under the isotropic confining pressure condition, the resilient modulus

generally increased as the confining pressure increased. The influence of confining pressure on the resilient modulus of base materials is shown in Figure 7.10. A linear relationship existed between the resilient modulus and confining pressure.

It was observed that the differences of the resilient modulus values calculated from the 10.2-cm and 20.3-cm LVDT measurements increased as the confining pressure increased. However, the differences in percentage were slightly decreased as the confining pressure continued to increase.

7.4.2.2 A-3 and A-2-4 Soils

The influence of confining pressure on the resilient modulus for A-3 and A-2-4 soils is shown in Figures 7.11 and 7.12, respectively. Similar trends were observed in the figures for A-3 and A-2-4 soils. Again, the differences of resilient modulus values from the 10.2-cm and 20.3-cm measurements increased as the confining pressure increased, whereas the differences in percentage were slightly decreased as the confining pressure continued to increase for both A-3 and A-2-4 soils.

7.4.3 Influence of Deviatoric Stress

7.4.3.1 Base Materials

The resilient modulus values versus deviator stresses at various confining pressure levels are shown in Figure 7.13. In general, it is believed that the resilient modulus increases as the deviatoric stress increases for granular materials. This was correct for the confining pressure below 34.47 kPa from the test results. But the resilient moduli decreased as the deviator stresses increased at medium to high confining pressures (68.95 to 137.9 kPa). The resilient modulus values were higher at low deviator stresses for a given confining pressure. This was the stiffening effect of the materials. When higher deviator stresses were applied, the sample became stiffer due to more grain to grain contact resulting from the previous deviator stresses, or densification of the sample.

7.4.3.2 A-3 Soils and A-2-4 Soils

A-3 and A-2-4 soils were weaker as compared to the base materials. As can been seen from Figures 7.14 and 7.15, the resilient modulus increased slightly as the deviator stress increased. The stiffening effect of the materials is not significant at all.

7.4.4 Influence of Axial Strain

7.4.4.1 Base Materials

The influence of the axial strain on the resilient modulus is shown in Figure 7.16. The range of the axial strain of resilient modulus test on base materials was from $1x10^{-4}$ to $1x10^{-3}$. It is noted that, at a constant deviator stress, the resilient modulus decreased rapidly as the axial strain increased, as indicated by the dashed lines. The phenomenon was salient especially at a lower deviator stress level. It was also observed that, at a higher confining pressure level, the resilient modulus decreased as the deviator stress and axial strain increased. However, at a lower confining pressure level, the resilient modulus values remained about the same as the deviator stress and axial strain increased.

7.4.4.2 A-3 and A-2-4 Soils

The range of the axial strain for A-3 and A-2-4 soils during the resilient modulus test was from $1x10^{-4}$ to $6x10^{-4}$ (see Figures 7.17 and 7.18). Similar to the base materials, at a constant deviator stress, the resilient modulus decreased as the axial strain increased, as indicated by the dashed lines. It is noted that, different from the base

materials, the resilient modulus values increased slightly as the deviator stress and axial strain increased at all confining pressure levels as indicated by the solid lines.

7.5 Comparison of Test Procedures (T 292-91I vs. T 294-92)

The resilient modulus results from the two test procedure (AASHTO *T292-91I* and *T294-92*) were compared to investigate the effect of testing methods. The differences in the two test procedures due to various influence factors were compared in terms of the resilient response of soils from the *T 292-91I* procedure with those of the *T 294-92*. A discussion of the results follows.

7.5.1 Effect of Test Sequence

Figures 7.19 and 7.20 show the variations of resilient modulus on sand at a condition of confining pressure and deviator stress for the *T 292-91I* and *T 294-92* test procedures, respectively. As shown in Figure 7.21, the *T 292-91I* procedure began with high confining pressure and ended with low confining pressure whereas, in Figure 7.22, the *T 294-92* test procedure was conducted from low to high confining pressure. In the *T 292-91I* procedure, the resilient modulus values were a little unstable at high confining pressures, but were stable at low confining

pressures. Otherwise, the resilient modulus was unstable at the beginning of the testing sequence and became stable after a high number of load cycles. In the *T 294-92* procedure, the resilient modulus was stable at high confining pressures but varied a little at low confining pressures. This observation indicated that, after sequences of testing, the resilient modulus value reached a stable status as the result of a stiffening effect of the cyclic stress on the specimen.

7.5.2 Effect of Stress Path

The resilient modulus values obtained from the *T 292-91I* and the *T 294-92* under an identical state of stress for a subgrade soil were slightly different. There were many variable factors contributing to this difference. The significant differences between the two procedures were the stress path and the LVDTs' position.

Figures 7.21 and 7.22 present the different values of resilient modulus measured by the same procedure but with the reverse stress path in the *T 292-91I* and the *T 294-92* test procedures, respectively. In both procedures, for an identical sample, the resilient modulus values appeared to increase faster when the confining pressure progressed from low to high. The rate of increase also depended on the type

of soil. This indicated that the stiffening and strengthening effects on the specimen structure were attributed to the higher M_R values obtained from the *T 294-92* test procedure.

7.5.3 Effect of Conditioning

Controversy exists around the need to condition all samples at the full range of deviator stresses and confining pressures because the conditioning sequence takes as much, if not more, of the operator's attention and time as the test sequence itself. On the contrary, other researchers insist that the conditioning is needed to eliminate the imperfect contacts between end platens, to minimize disturbance effects caused by sampling or laboratory preparation, and to reduce the plastic strain development.

Figures 7.23 and 7.24 present the effect of conditioning and unconditioning on the resilient modulus results of a sand specimen versus bulk stress. Without conditioning the resilient modulus values were always lower than those with conditioning. The reasons may come from the end effects and the disturbance effects in the unconditioning test. Nazarian et al. (1995) experimented with the use of grout specimen ends. The authors stated that specimen conditioning may

affect the resilient modulus because they changed the stress history of the soil prior to testing.

The data indicated that the values of the resilient modulus with conditioning were always higher than those without conditioning. Observations show that the resilient modulus values calculated from the test with conditioning were more consistent than those from the test without conditioning. The imperfect contacts between specimen end platens may be eliminated by the conditioning (see Figures 7.25 and 7.26). The disturbance effects caused by sampling or laboratory preparation may be minimized, while the plastic strain development may also be reduced.

7.5.4 Effect of Different Positions of LVDT Measurements

Figure 7.6 shows that the variation of the resilient modulus of a subgrade sand at different positions of the middle LVDTs are very small. However, the differences are significant when the end effect is taken into consideration, i.e., the LVDTs were either positioned on the platen or mounted outside the triaxial cell. The effects of different positions of LVDT measurements for the *T 292-91I* and *T 294-92* procedures (Figure 7.27) were investigated and are described further in the following sections.

T 292-91I method. In this study, for the *T 292-91I* procedure, four LVDTs were mounted inside the triaxial cell as illustrated in Figure 7.27(a). The results from the 10.2-cm measurements (Position A in Figure 7.27 (a)) resulted in higher resilient modulus values than those from the 20.3-cm measurements (Position B in Figure 7.27(a)). A resilient modulus ratio is defined as the following:

$$M_R Ratio(A,B) = \frac{M_R(LVDTs\ at\ Position\ A)}{M_R(LVDTs\ at\ Position\ B)} \quad \text{..... (7.1)}$$

Figures 7.28 and 7.29 illustrate the resilient modulus ratio, M_R ratio (A,B), between the 10.2-cm and 20.3-cm measurements for A-3 and A-2-4 soils, respectively. The figures show that the resilient modulus ratios also depend on the type of soil. The average ratios of the resilient modulus values from the 10.2-cm and 20.3-cm measurements are summarized in Table 7.1.

The ratios also depend on the level of confining pressure. The ratios ranged from 1.35 to 1.30 at lower confining pressures and from 1.19 to 1.14 at higher confining

pressures for A-3 and A-2-4 soils, respectively. The lower ratios at the higher pressures were probably due to the near perfect contact between the end platen, the porous stone, and the specimen ends. This observation was consistent with the findings by other researchers (Mohammad and Puppala, 1994).

T 294-92 method. For the *T 294-92* procedure, two LVDTs were attached to the piston rod outside of the chamber instead of using the LVDTs for the 20.3-cm measurements (Figure 7.27(b)). The results from the externally-mounted LVDT measurements (Position 3 in Figure 7.27(b)) resulted in lower resilient modulus values than those from both the 10.2-cm (LVDT Position 1) and 20.3-cm (LVDT Position 2) measurements. Three resilient modulus ratios are defined as the following:

$$M_R Ratio\,(2,1) = \frac{M_R\,(LVDTs\ at\ Position\ 2)}{M_R\,(LVDTs\ at\ Position\ 1)} \qquad \text{(7.2)}$$

$$M_R\ Ratio\,(3,1) = \frac{M_R\,(LVDTs\ at\ Position\ 3)}{M_R\,(LVDTs\ at\ Position\ 1)} \qquad \text{(7.3)}$$

$$M_R Ratio\,(3,2) = \frac{M_R\,(LVDTs\ at\ Position\ 3)}{M_R\,(LVDTs\ at\ Position\ 2)} \quad \text{.....} \quad (7.4)$$

These average resilient modulus ratios are summarized in Table 7.2. The ratios are also presented in Figures 7.30 through 7.33. The average M_R ratio (3,1) ranged from 0.61 to 0.64 at lower confining pressures and from 0.54 to 0.55 at higher confining pressures for A-3 and A-2-4 soils, respectively. The average M_R ratio (2,1) ranged from 0.67 at lower confining pressure to 0.83 at higher confining pressure for A-3 soils. The average M_R ratio (3,2) ranged from 0.87 at lower confining pressure to 0.69 at higher confining pressure for A-3 soils. The results show that the resilient modulus results from the externally-mounted LVDT measurements (LVDT Position 3 in Figure 7.27(b)) were the lowest among the three different positions of LVDT measurements.

T 292-91I method versus T 294-92 method. Four different procedural ratios were investigated to compare the AASHTO *T*

292-91I and *T 294-92* test procedures (refer to Figure 7.27(a),(b)):

Procedural Ratio (1,A):

$$PR(1,A) = \frac{M_R(LVDTs\ at\ Position\ 1, T294)}{M_R(LVDTs\ at\ Position\ A, T292)} \quad \text{..... (7.5)}$$

Procedural Ratio (3,A):

$$PR(3,A) = \frac{M_R(LVDTs\ at\ Position\ 3, T294)}{M_R(LVDTs\ at\ Position\ A, T292)} \quad \text{..... (7.6)}$$

Procedural Ratio (1,B):

$$PR(1,B) = \frac{M_R(LVDTS\ at\ Position\ 1, T294)}{M_R(LVDTs\ at\ Position\ B, T292)} \quad \text{..... (7.7)}$$

Procedural Ratio (3,B):

$$PR(3,B) = \frac{M_R(LVDTS\ at\ Position\ 3, T294)}{M_R(LVDTs\ at\ Position\ B, T292)} \quad \text{..... (7.8)}$$

Procedural ratio, PR(1,A). As predicted, the average PR(1,A) values, which are always greater than one, show that the *T 294-92* procedure provided higher resilient modulus

values than the *T 292-91I* as seen in Figures 7.34 and 7.35. The PR(1,A) also increased from lower confining pressure to higher confining pressure as shown in Table 7.3.

This can be explained by the effects of the stress path. In the *T 294-92* procedure, the confining pressure increased from the 20.68 kPa (low) to 137.9 kPa (high) when in the *T 292-91I*, the confining pressure decreased from 103.42 kPa (high) to 13.79 kPa (low). The cyclic stress, which had a stiffening effect on the specimen structure because the stress application followed the low-to-high sequence, was attributed to the higher resilient modulus yielded by the *T 294-92*.

Procedural ratio, PR(3,A). The average ratios of PR(3,A) are summarized in Table 7.3 and presented in Figures 7.36 and 7.37 for A-3 and A-2-4 soils, respectively. The ratios ranged from 0.72 to 0.70 at lower confining pressures and from 0.72 to 0.67 at higher confining pressures for A-3 and A-2-4 soils, respectively.

Procedural ratio, PR(1,B). The average ratios of PR(1,B) are summarized in Table 7.3 and presented in Figures 7.38 and 7.39 for A-3 and A-2-4 soils, respectively. The

ratios ranged from 1.55 to 1.41 at lower confining pressures and from 1.41 to 1.32 at higher confining pressures for A-3 and A-2-4 soils, respectively.

Procedural ratio, PR(3,B). The ratios between the resilient modulus values measured from the external system of the *T 294-92* and those of the full length system of the *T 292-91I* were always smaller than one. Under the effect of stress path, the resilient modulus values from the *T 294-92* procedure were higher than those from the *T 292-91I*. The ratios are summarized in Table 7.3 and presented in Figures 7.40 and 7.41. For both types of soil, A-3 and A-2-4, the ratios were always smaller than one and decreased when confining pressure increased.

The compressibility of the test equipment and the delayed-elasticity of a soil specimen in response to a dynamic load can be used to explain this phenomenon. The dynamic load used in both test procedures has a loading period of 0.1 second and a relaxation period of 0.9 second (Figure 7.42). At the peak of the load, when the specimen was compressed, its length was shortened. During the relaxation period, the soil expanded but can not return to its former length. Thus, a small distance between the steel

ball and rammer resulted. For the next cycle, the loading rod moved an extra distance before it can come in contact with the steel ball. Because the external LVDTs were located on the piston rod, this added distance between the rammer and steel ball affected the strain measurement and caused a decrease in the resulting resilient modulus value.

7.6 Effect of Specimen Size

Differences exist in resilient modulus values between the test results from 6-inch diameter specimens and those from 4-inch diameter specimens. Comparison of the test results is discussed in the following sections.

7.6.1 Resilient Modulus Values

The resilient moduli from both 6-inch diameter specimens and 4-inch diameter specimens are summarized in Tables 5.31 through 5.36. For ease of comparison, M_R values from both sizes of specimens are illustrated in the same figure for each type of soils. Typical relationships are shown in Figures 7.43 through 7.48.

Limerock. Figures 7.43 and 7.44 show the differences of resilient modulus values for base material from Seminole County, site #1. Basically, the M_R values for both sizes of specimens were not much different. The largest difference

was within 20 percent (at 20 kPa confining pressure). At the other confining pressures the differences were much smaller.

As specified in T 292-91I, the confining pressure varied from 3 psi (20.7 kPa) to 20 psi (137.8 kPa). Considering the deviator stress, the bulk stress varied from 14 psi (96.5 kPa) to 100 psi (689 kPa). Therefore, the M_R values were predicted over the range from 10 kPa to 150 kPa and from 60 kPa to 800 kPa for confining pressure and bulk stress, respectively. As shown in Table 7.4, in most cases the average M_R ratios of the 4-in. vs. 6-in. diameter specimens were close to 1.0.

A-3 and A-2-4 materials. Figures 7.45 and 7.46 show the differences of resilient modulus values for A-3 material from Gadsden County, site #3B. Figures 7.46 and 7.48 show the differences of resilient modulus values for A-2-4 material from Polk County, site #1A. For both materials, the M_R values were very close from one size of specimens to the other.

7.6.2 R^2 values

R^2 values of resilient modulus for both sizes of specimens and both the middle half measurement and full

length measurement can be found in Tables 5.35 through 5.40. These values are further summarized in Tables 7.5 through 7.7.

Limerock. R^2 is an important coefficient reflecting the fitness of regression. For both sizes of specimens the R^2 values of the middle half measurements were smaller than that of the full length measurements.

$M_R = k_1\theta^{k2}$ is the only model recommended by the *AASHTO Design Guide* (1993). For the middle half measurements, 6-inch diameter specimens gave R^2 values generally varying from 0.53 to 0.74 with an average value of 0.60. The wide range of R^2 values indicated significant variation. 4-inch diameter specimens gave R^2 values varying from 0.57 to 0.77 with an average value of 0.69. R^2 values of the full length measurements were obviously better than those of the middle half measurements. For 6-inch diameter specimens, R^2 values varied from 0.73 to 0.81. For 4-inch diameter specimens, R^2 values varied from 0.71 to 0.80. The average R^2 value for both sizes of specimens was 0.77.

Based on above discussion, for the middle half measurements, the 4-inch specimens gave less variation than the 6-inch specimens. For the full length measurements there was not remarkable difference between them.

For R^2 values based on $M_R = k_3\sigma_3^{k4}$ model, there was not much difference between them. The middle half measurements for both sizes of specimens gave R^2 ranging from 0.97 to 0.99 with an average value of 0.98. Almost all of the full length measurements gave R^2 = 0.99 (except one 0.98 and one 1.00). The overall average R^2 value was 0.99.

$M_R = k_5\sigma_3^{k6}\sigma_d^{k7}$ model gave good regression for both sizes of specimens. For the middle half measurements, the average R^2 values are 0.97 for both sizes of specimens. For the full length measurements, the 6-inch specimens gives R^2 = 0.99, while the 4-inch specimens gave R^2 = 0.98.

A-3 and A-2-4 materials. For both regression models all measurements showed a strong relationship between the resilient modulus and confining pressure or bulk stress. As shown in Tables 7.5 and 7.6, the least R^2 value was 0.93 for $M_R = k_1\theta^{k2}$ model. The R^2 values of the full length measurements were better than those of the middle half measurements, and the 4-inch specimens gave higher R^2 values than that of the 6-inch specimens. However, for $M_R = k_3\sigma_3^{k4}$ and $M_R = k_5\sigma_3^{k6}\sigma_d^{k7}$ models there were hardly any differences of R^2 values between the two sizes of specimens for both measurements.

7.6.3 Regression Coefficients

To compare the regression coefficients, k_1 through k_7 for both sizes of specimens, the data were statistically analyzed. The results are summarized in Table 7.8.

The test results of both middle half measurements and full length measurements were analyzed using normal distribution for all k values. The analysis was based on 95% confidence level. The corresponding Z value is 1.86. Referring to Table 7.8, the absolute value of the test statistics of all regression coefficients were larger than 1.86, except k_5 of the middle half measurements and k_7 of the full length measurements. Thus, the k values of the two sizes of sample were different. An explanation follows.

- **k_1 and k_2 Values**

The k_1 and k_2 values for both sizes of specimens and both measurements are illustrated in Figures 7.49 through 7.52.

Limerock. For all limerock materials, k_1 values of 6-inch specimens were always smaller than that of 4-inch specimens, while k_2 values of 6-inch specimens were always larger than that of 4-inch specimens. This explains the phenomenon that at low bulk stress the M_R values of 6-in.

diameter specimens were smaller than that of 4-in. diameter specimens.

A-3 and A-2-4 materials. No significant difference existed between the k_1 and k_2 values from both sizes of specimens.

- **k_3 and k_4 Values**

The k_3 and k_4 values for both sizes of specimens and both measurements are illustrated in Figures 7.53 through 7.56.

Limerock. Similarly, for all limerock materials, the k_3 values of 6-inch specimens were always smaller than that of 4-inch specimens, while the k_4 values of 6-inch specimens were always smaller than that of 4-inch specimens. Typically at low confining pressure the M_R values of 6-inch diameter specimens were smaller than that of 4-inch diameter specimens.

A-3 and A-2-4 materials. No significant difference was found between the k_3 and k_4 values from both sizes of specimens.

- **k_5, k_6, and k_7 Values**

Limerock. Normally the k_5 and k_7 values of 6-inch specimens were smaller than that of 4-inch specimens. In all cases, the k_6 values of 6-inch specimens were larger than

that of 4-inch specimens. For limerock materials confining pressure had more influence at 6-inch diameter specimens than at 4-inch diameter specimens.

A-3 and A-2-4 materials. Again, the k_6 values of 6-inch specimens were larger than that of 4-inch specimens. However, no distinct relationship was found between the k_5, and k_7 values.

7.7 Comparison of Laboratory Test Results

The laboratory resilient modulus test results were further compared with the LBR values. The comparison between the laboratory resilient modulus test results under optimum moisture content (OMC) and that under in-situ moisture content will be presented in Chapter 8. The theory relating the laboratory resilient modulus to that obtained from the field under the identical state of stress and at 2 psi confining pressure will be also described in Chapter 8.

7.7.1 Laboratory Resilient Modulus under OMC versus LBR Values

The test results of laboratory resilient modulus and LBR values are summarized in Tables 7.9 and 7.10. Comparison of the LBR values with the laboratory resilient modulus values at OMC condition and under confining pressure 2 psi

is shown in Figure 7.57 for the subgrade and embankment layers. The data are scattered. No relationship existed between the laboratory MR and LBR values. At optimum moisture content compacted condition, only the subgrade and embankment materials were tested for the laboratory resilient modulus in this study.

The primary subgrade soils were A-3 and A-2-4 sands for this study. The comparison in terms of the types of pavement materials is shown in Figure 7.58. Figure 7.58b shows that no relationship existed between the laboratory MR and LBR values for the A-3 sand. However, a reasonable correlation existed between the laboratory MR and LBR values for the A-2-4 sands (Figure 7.58c). The A-2-4 sands contained a certain amount of #200 fines and behaved more like fine grain soils.

Comparison of the LBR values with the laboratory MR values at OMC condition and under the identical state of stresses caused by traffic is shown in Figures 7.59 and 7.60 for the pavement layers and in terms of the type of pavement materials, respectively. Similar results existed as for under confining pressure 2 psi. Again, no relationship exists between the laboratory MR at OMC and LBR values. However, as shown in Figure 7.60c, a good correlation (with

R^2 = 0.75) existed between the laboratory MR and LBR values for the A-2-4 sands.

The correlation relationship is as follows:

$$MR_{lab(OMC)} = 0.6247(LBR) + 112.59 \quad (MPa) \quad (R^2 = 0.75) \quad \text{..... (7.9)}$$

for A-2-4 sand.

The lack of correlation may be due to the fact that the two methods reflect totally different behaviors of the characteristics of pavement materials. As the LBR mainly exhibited the static bearing strength of the materials, the resilient modulus showed the dynamic response of pavement materials to real traffic loadings. Thus, some materials may have very high LBR values but will yield relatively low resilient modulus values, and vice versa. Researchers in other states have also received the similar results that hardly any relationship exists between CBR (CBR = 0.8 LBR) and laboratory resilient modulus values.

7.7.2 Laboratory MR under in-situ MC versus LBR Values

The test results of LBR and laboratory resilient modulus values under in-situ moisture condition are summarized in Table 7.11. The relationships of LBR versus laboratory resilient modulus values at in-situ moisture condition are shown in Figure 7.61 (for different pavement

layers), and Figure 7.62 (for different pavement materials). The data were scattered. The correlation relationship is as follows,

$$MR_{Lab(In-situ)} = 0.7729(LBR) + 112.57 \quad (MPa) \quad (R^2=0.31) \quad \text{..... (7.10)}$$

The results were similar to the results of laboratory resilient modulus under OMC condition versus LBR values. However, the A-2-4 soils did not show a strong correlation between the laboratory MR and LBR values under in-situ conditions (Figure 7.62d).

7.8 Summary

The following summaries are made from the analyses of laboratory test results:

1. The resilient modulus measured from the middle LVDTs was significantly different from that determined from the full length LVDTs because of the end effects and system compliance. For the T 292-91I test procedure, the average ratios of the resilient modulus values between the 20.3-cm and 10.2-cm LVDT measurements ranged from about 0.75 at lower

confining pressures to about 0.85 at higher confining pressures.

2. The significant differences between the T 292-91I and T 294-92 were attributed to the stress history and the LVDTs' positions. The effect of stress history was evaluated for each procedure by testing at the same LVDT position. The T294-92 yielded slightly higher values than those of the T 292-91I. However, the resilient modulus values measured from the external measurements of T 294-92 were lower than that of the internal full length measurements of T 292-91I because of the system compliance.

3. The conditioning partially eliminated the imperfect contacts between end platens and minimized disturbance effects caused by laboratory preparation. Nevertheless, the conditioning changes the stress history of the specimens prior to testing by stiffening the specimens.

4. Based on the comparison of the two test methods, the effect of stress history resulted in only about 15 to 20% difference in resilient modulus, while the difference due to LVDT positions may be 25 to 30%.

5. The resilient moduli measured from the 6-in. diameter specimen and 4-in. diameter specimen were not significantly different for the limerock and granular pavement materials.

6. The comparison of LBR and laboratory resilient modulus values under optimum moisture conditions did not appear to have a clear correlation between them. However, it seems that a good correlation existed between the laboratory MR and LBR values for the A-2-4 soils.

   The correlation relationship is as follows:

   $MR_{lab(OMC)} = 0.6247(LBR) + 112.59 \quad (MPa)$ (R^2 = 0.75) for A-2-4 sand.

7. The correlation relationship between LBR and laboratory resilient modulus values under in-situ moisture conditions is as follows:

   $MR_{Lab(In-situ)} = 0.77(LBR) + 112.57 \quad (MPa)$ (R^2 = 0.31).

   The A-2-4 soils did not show a strong correlation between the laboratory MR and LBR values under in-situ conditions.

Table 7.1 Average Resilient Modulus Ratios, M_R (A,B), from the 10.2-cm and 20.3-cm LVDT Measurements (T 292-91I Method) (Refer to Figures 7.30 and 7.31)

Confining Pressure (kPa)	Type of Soil	
	A-3	A-2-4
13.79	1.35	1.30
34.47	1.30	1.25
68.97	1.23	1.18
103.42	1.19	1.14

Table 7.2 Average Resilient Modulus Ratios, M_R (3,1), MR (2,1), and MR (3,2) from the 10.2-cm and 20.3-cm (internal and external) LVDT Measurements (T 294-92 Method) (Refer to Figure 7.32, 7.33, 7.34, and 7.35)

Confining Pressure (kPa)	M_R Ratio (3,1)		M_R Ratio (2,1)	M_R Ratio (3,2)
	A-3 Soils	A-2-4 Soils	A-3 Soils	A-3 Soils
20.68	0.61	0.64	0.67	0.87
34.47	0.60	0.63	0.70	0.84
68.42	0.59	0.61	0.76	0.78
103.42	0.55	0.57	0.79	0.73
137.9	0.54	0.55	0.83	0.69

Table 7.3 Average Procedural Ratios, PR (1,A), PR (3,A), PR (1,B), and PR (3,B) from the 10.2-cm and 20.3-cm (internal and external) LVDT Measurements (T 292 versus T294) (Refer to Figures 7.36 through 7.43)

Confining Pressure (kPa)	PR (1,A)		PR (3,A)		PR (1,B)		PR (3,B)	
	A-3	A-2-4	A-3	A-2-4	A-3	A-2-4	A-3	A-2-4
13.79/20.68	1.16	1.08	0.72	0.70	1.55	1.41	0.96	0.91
34.47	1.14	1.09	0.72	0.69	1.47	1.36	0.91	0.95
68.95	1.18	1.15	0.73	0.70	1.43	1.34	0.88	0.82
103.42	1.19	1.16	0.72	0.67	1.41	1.32	0.85	0.76

Table 7.4(a) Comparison of Resilient Modulus of Limerock

Test	Confining Pressure	Deviator Stress	Resilient Modulus					
			Middle Half Measurements			Full Length Measurements		
			4"	6"	4"/6"	4"	6"	4"/6"
	kPa	kPa	MPa	MPa	MPa	MPa	MPa	MPa
#1	138.00	65.570	401.377	556.561	0.721	339.081	379.073	0.894
	138.00	136.917	345.090	402.240	0.858	302.220	326.815	0.925
	138.00	205.923	285.188	301.540	0.946	257.577	270.873	0.951
	103.5	67.998	282.783	300.910	0.940	250.692	245.795	1.020
	103.5	136.922	256.797	269.806	0.952	232.694	239.571	0.971
	103.5	205.973	236.514	235.837	1.003	216.647	217.431	0.996
	69	33.661	245.367	238.254	1.030	210.521	185.130	1.137
	69	68.151	199.719	185.129	1.079	182.588	165.944	1.100
	69	137.110	195.418	188.725	1.035	180.062	173.463	1.038
	69	206.096	177.481	174.360	1.018	165.311	161.239	1.025
	34.5	33.671	140.119	94.555	1.482	126.989	87.326	1.454
	34.5	68.145	123.982	102.249	1.213	115.516	93.095	1.241
	34.5	102.524	130.525	118.065	1.106	120.435	105.347	1.143
	20.7	33.605	106.432	69.206	1.538	97.284	61.994	1.569
	20.7	47.483	105.921	77.383	1.369	96.707	68.364	1.415
	20.7	61.326	110.113	86.013	1.280	99.827	75.056	1.330
Average					1.098			1.138
#2	138.00	65.448	600.024	694.983	0.863	481.939	555.834	0.867
	138.00	136.963	516.578	577.096	0.895	426.292	497.517	0.857
	138.00	205.811	440.862	479.592	0.919	369.285	432.053	0.855
	103.5	67.947	403.062	449.641	0.896	334.996	394.458	0.849
	103.5	136.754	376.480	408.725	0.921	317.774	371.628	0.855
	103.5	205.846	360.297	391.125	0.921	304.301	359.396	0.847
	69	33.513	351.965	431.586	0.816	278.789	332.760	0.838
	69	67.891	284.055	320.496	0.886	238.023	284.951	0.835
	69	136.988	285.848	301.311	0.949	239.751	281.933	0.850
	69	205.892	276.153	296.609	0.931	233.075	276.868	0.842
	34.5	33.411	192.770	216.229	0.892	158.530	188.593	0.841
	34.5	67.820	172.060	179.213	0.960	145.007	167.295	0.867
	34.5	102.427	186.378	187.655	0.993	154.114	176.138	0.875
	20.7	33.391	148.865	147.049	1.012	122.933	133.769	0.919
	20.7	47.351	148.956	142.162	1.048	122.459	128.990	0.949
	20.7	61.036	156.083	145.603	1.072	126.661	132.813	0.954
Average					0.936			0.869

Table 7.4(a) Comparison of Resilient Modulus of Limerock(continued)

Test	Confining Pressure	Deviator Stress	Resilient Modulus					
			Middle Half Measurements			Full Length Measurements		
			4"	6"	4"/6"	4"	6"	4"/6"
	kPa	kPa	MPa	MPa	MPa	MPa	MPa	MPa
#3	138.00	65.647	632.512	919.068	0.688	498.676	609.262	0.818
	138.00	136.902	542.447	697.231	0.778	441.342	532.644	0.829
	138.00	206.055	480.570	572.007	0.840	393.319	471.352	0.834
	103.5	68.028	474.010	657.977	0.720	380.667	447.167	0.851
	103.5	136.886	428.912	510.033	0.841	351.246	410.696	0.855
	103.5	205.816	414.772	472.596	0.878	340.345	396.190	0.859
	69	33.457	458.908	622.720	0.737	338.304	390.162	0.867
	69	68.018	364.820	436.051	0.837	287.165	324.425	0.885
	69	136.912	347.316	371.191	0.936	279.687	314.814	0.888
	69	205.750	345.201	361.117	0.956	277.030	312.111	0.888
	34.5	33.533	297.498	340.054	0.875	216.186	230.853	0.936
	34.5	68.059	251.619	252.441	0.997	191.074	202.974	0.941
	34.5	102.305	255.463	250.379	1.020	195.607	208.203	0.939
	20.7	33.370	247.952	261.869	0.947	175.765	172.735	1.018
	20.7	47.173	229.695	225.732	1.018	167.306	164.295	1.018
	20.7	61.066	229.150	206.634	1.109	166.832	165.033	1.011
Average					0.886			0.902
#4	138.00	65.738	694.437	945.909	0.734	525.643	555.543	0.946
	138.00	136.886	534.530	714.071	0.749	447.494	477.067	0.938
	138.00	205.979	466.294	489.160	0.953	402.948	425.037	0.948
	103.5	68.054	488.703	670.675	0.729	396.045	415.151	0.954
	103.5	137.039	403.570	463.215	0.871	353.289	366.197	0.965
	103.5	206.325	385.749	393.093	0.981	340.774	351.422	0.970
	69	33.477	506.910	703.925	0.720	367.245	358.960	1.023
	69	68.145	354.026	435.064	0.814	301.091	289.452	1.040
	69	137.009	313.793	306.103	1.025	276.965	273.725	1.012
	69	205.989	312.104	307.819	1.014	276.326	274.208	1.008
	34.5	33.681	274.743	342.802	0.801	223.238	203.653	1.096
	34.5	67.962	217.322	208.078	1.044	190.843	175.835	1.085
	34.5	102.564	217.756	206.421	1.055	191.887	181.421	1.058
	20.7	33.711	212.038	242.881	0.873	174.464	151.413	1.152
	20.7	47.396	194.366	181.282	1.072	164.067	143.190	1.146
	20.7	61.178	190.188	193.695	0.982	162.757	144.155	1.129
Average					0.901			1.029

Table 7.4(a) Comparison of Resilient Modulus of Limerock(continued)

Test	Confining Pressure	Deviator Stress	Resilient Modulus					
			Middle Half Measurements			Full Length Measurements		
			4"	6"	4"/6"	4"	6"	4"/6"
	kPa	kPa	MPa	MPa	MPa	MPa	MPa	MPa
#5	138.00	65.743	646.452	684.007	0.945	520.594	550.632	0.945
	138.00	136.993	571.431	562.253	1.016	470.939	508.715	0.926
	138.00	205.867	493.167	476.014	1.036	415.343	443.031	0.938
	103.5	68.130	451.520	480.620	0.939	383.720	408.561	0.939
	103.5	136.948	429.616	404.964	1.061	364.406	380.199	0.958
	103.5	205.994	407.494	385.689	1.057	346.531	359.976	0.963
	69	33.620	386.192	445.162	0.868	318.889	334.447	0.953
	69	68.079	330.554	309.410	1.068	278.984	284.083	0.982
	69	137.136	327.486	296.547	1.104	279.065	280.846	0.994
	69	206.009	316.520	279.359	1.133	270.500	269.338	1.004
	34.5	33.696	220.173	214.060	1.029	186.283	180.671	1.031
	34.5	68.090	199.256	172.642	1.154	172.196	163.579	1.053
	34.5	102.676	213.360	176.784	1.207	180.805	172.208	1.050
	20.7	33.661	168.047	144.223	1.165	139.182	128.103	1.086
	20.7	47.371	169.747	134.514	1.262	140.423	125.741	1.117
	20.7	61.265	178.409	135.025	1.321	147.075	130.502	1.127
Average					1.085			1.004
#6	138.00	65.275	467.171	747.270	0.625	439.588	500.746	0.878
	138.00	137.085	388.679	556.275	0.699	379.603	448.396	0.847
	138.00	205.877	331.869	421.084	0.788	328.372	383.056	0.857
	103.5	68.039	323.999	432.896	0.748	314.579	349.735	0.899
	103.5	137.146	312.137	385.240	0.810	302.689	340.420	0.889
	103.5	205.917	282.235	338.705	0.833	277.625	312.196	0.889
	69	33.645	259.928	366.894	0.708	243.982	261.760	0.932
	69	68.130	228.392	280.061	0.816	219.102	240.239	0.912
	69	136.988	236.586	275.827	0.858	227.097	250.928	0.905
	69	206.070	220.424	247.142	0.892	212.677	229.005	0.929
	34.5	33.569	136.930	160.111	0.855	131.193	138.605	0.947
	34.5	68.084	137.756	151.021	0.912	130.189	140.714	0.925
	34.5	102.407	155.469	167.481	0.928	143.380	154.954	0.925
	20.7	33.452	110.216	116.647	0.945	101.200	104.866	0.965
	20.7	47.437	119.207	123.602	0.964	106.820	111.801	0.955
	20.7	61.194	130.792	134.500	0.972	115.644	121.035	0.955
Average					0.835			0.913

Table 7.4(a) Comparison of Resilient Modulus of Limerock(continued)

Test	Confining Pressure	Deviator Stress	Resilient Modulus					
			Middle Half Measurements			Full Length Measurements		
			4"	6"	4"/6"	4"	6"	4"/6"
	kPa	kPa	MPa	MPa	MPa	MPa	MPa	MPa
#7	138.00	66.049	678.394	772.175	0.879	519.215	504.201	1.030
	138.00	136.927	537.788	561.841	0.957	442.144	453.631	0.975
	138.00	205.877	449.719	446.430	1.007	383.405	389.293	0.985
	103.5	67.866	455.624	471.214	0.967	374.893	354.788	1.057
	103.5	136.917	400.863	393.033	1.020	344.427	337.819	1.020
	103.5	205.968	373.705	357.807	1.044	323.910	318.723	1.016
	69	33.666	420.623	418.250	1.006	326.982	270.690	1.208
	69	68.140	321.611	288.755	1.114	276.108	242.249	1.140
	69	137.085	306.278	280.737	1.091	265.380	247.449	1.072
	69	205.963	291.903	262.351	1.113	255.509	238.240	1.072
	34.5	33.671	238.267	182.430	1.306	196.965	144.920	1.359
	34.5	68.079	200.233	160.305	1.249	175.847	139.493	1.261
	34.5	102.656	208.369	171.861	1.212	181.515	151.368	1.199
	20.7	33.574	186.511	130.560	1.429	155.973	106.534	1.464
	20.7	47.310	177.926	127.125	1.400	150.882	107.440	1.404
	20.7	61.311	179.559	133.465	1.345	153.028	113.325	1.350
Average					1.134			1.163
#8	138.00	65.860	699.338	824.669	0.848	550.967	579.728	0.950
	138.00	137.070	577.930	576.242	1.003	478.508	487.049	0.982
	138.00	205.984	516.005	480.169	1.075	432.779	420.486	1.029
	103.5	68.024	510.426	522.776	0.976	421.790	399.645	1.055
	103.5	136.933	440.376	401.613	1.097	377.441	356.245	1.059
	103.5	205.943	432.507	376.870	1.148	368.654	342.435	1.077
	69	33.536	531.616	527.820	1.007	385.026	347.293	1.109
	69	68.054	372.572	341.779	1.090	315.786	279.354	1.130
	69	137.044	343.513	297.657	1.154	294.437	266.423	1.105
	69	205.887	350.154	296.737	1.180	297.584	266.187	1.118
	34.5	33.439	303.750	268.407	1.132	242.991	192.293	1.264
	34.5	67.896	241.207	192.882	1.251	203.897	164.801	1.237
	34.5	102.455	243.004	194.450	1.250	205.507	170.256	1.207
	20.7	33.490	237.983	185.033	1.286	194.341	141.317	1.375
	20.7	47.293	215.310	161.625	1.332	181.006	132.459	1.367
	20.7	61.127	212.376	158.580	1.339	177.264	133.265	1.330
Average					1.135			1.150

Table 7.4(a) Comparison of Resilient Modulus of Limerock(continued)

Test	Confining Pressure	Deviator Stress	Resilient Modulus					
			Middle Half Measurements			Full Length Measurements		
			4"	6"	4"/6"	4"	6"	4"/6"
	kPa	kPa	MPa	MPa	MPa	MPa	MPa	MPa
#9	138.00	66.151	700.377	749.477	0.934	576.238	674.410	0.854
	138.00	136.948	586.910	625.410	0.938	498.763	570.232	0.875
	138.00	205.917	534.077	550.544	0.970	455.133	491.587	0.926
	103.5	68.079	505.916	524.990	0.964	427.313	467.430	0.914
	103.5	137.131	449.947	455.665	0.987	390.430	420.735	0.928
	103.5	206.131	450.065	439.919	1.023	383.273	402.041	0.953
	69	33.625	430.581	410.873	1.048	343.099	399.279	0.859
	69	68.039	369.482	358.304	1.031	315.592	326.881	0.965
	69	136.932	352.454	340.482	1.035	300.739	312.250	0.963
	69	205.917	363.592	338.890	1.073	307.843	309.198	0.996
	34.5	33.477	296.120	259.535	1.141	241.610	221.094	1.093
	34.5	67.947	246.228	206.103	1.195	207.082	193.451	1.070
	34.5	102.320	249.433	218.559	1.141	209.546	197.965	1.058
	20.7	33.528	232.344	178.395	1.302	187.480	159.427	1.176
	20.7	47.213	216.826	166.623	1.301	177.708	151.130	1.176
	20.7	61.204	217.300	167.867	1.294	178.140	152.409	1.169
Average					1.086			0.999

Table 7.4(b) Comparison of Resilient Modulus of Limerock(summary)

Test	Ratio of 4"/6"	
	Middle Half Measurements	Full Length Measurements
#1	1.098	1.138
#2	0.936	0.869
#3	0.886	0.902
#4	0.901	1.029
#5	1.085	1.004
#6	0.835	0.913
#7	1.134	1.163
#8	1.135	1.150
#9	1.086	0.999

Table 7.5 Summary of R^2 values for $MR = k_1\theta^{k2}$ model

Location	Soil Type	Test #	Middle Half Measurements		Full Length Measurements	
			6 in. dia.	4 in. dia.	6 in. dia.	4 in. dia.
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	0.62	0.70	0.78	0.75
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	0.69	0.74	0.79	0.78
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	0.53	0.68	0.76	0.76
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	0.38	0.57	0.74	0.71
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	0.67	0.77	0.80	0.80
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	0.62	0.77	0.80	0.80
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	0.61	0.62	0.81	0.78
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	0.51	0.62	0.73	0.73
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	0.74	0.73	0.74	0.78
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	0.93	0.96	0.97	0.97
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	0.95	0.96	0.97	0.98

Table 7.6 Summary of R^2 values for $MR = k_3\sigma_3^{k4}$ model

Location	Soil Type	Test #	Middle Half Measurements		Full Length Measurements	
			6 in. dia.	4 in. dia.	6 in. dia.	4 in. dia.
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	0.97	0.98	0.99	0.99
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	0.98	0.98	0.99	0.99
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	0.98	0.98	0.99	0.99
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	0.97	0.98	0.99	0.99
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	0.99	0.99	1.00	0.99
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	0.97	0.99	0.99	0.99
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	0.98	0.97	0.99	0.99
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	0.97	0.98	0.99	0.99
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	0.99	0.98	0.99	0.98
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	1.00	0.99	1.00	0.99
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	0.99	0.99	1.00	0.99

Table 7.7 Summary of R^2 values for $MR = k_5\sigma_3^{k6}\sigma_d^{k7}$ model

Location	Soil Type	Test #	Middle Half Measurements		Full Length Measurements	
			6 in. dia.	4 in. dia.	6 in. dia.	4 in. dia.
Lee Co., Site #1B, S.R. 884	Lime rock	A-1BL	0.95	0.98	0.98	0.98
Alachua Co., Site #4, U.S. 301	Lime rock	B-4L	0.98	0.98	0.99	0.99
Clay Co., Site #5, U.S. 17	Lime rock	B-5L	0.98	0.97	0.99	0.98
Clay Co., Site #6, U.S. 17	Lime rock	B-6L	0.97	0.98	0.99	0.99
Jefferson Co., Site #2A, U.S. 27	Lime rock	C-2AL	0.99	0.98	0.99	0.99
Gadsden Co., Site #2B, U.S. 27	Lime rock	C-2BL	0.96	0.96	0.98	0.98
Dade Co., Site #1, U.S. 41	Lime rock	F-1E	0.97	0.97	0.99	0.98
Martin Co., Site #4, U.S. 1	Lime rock	D-4L	0.98	0.97	0.99	0.98
Seminole Co., Site #1A, U.S. 414	Lime rock	E-1L	0.99	0.97	0.99	0.98
Gadsden Co., Site #3B, U.S. 27	A-3	C-3BS	0.99	0.99	1.00	0.99
Polk Co., Site #1A, U.S. 17	A-2-4	A-1AS	0.99	0.99	1.00	0.99

Table 7.8 Comparison of Regression Coefficients

	Regression Coefficient	Dia. (in.)	Number of Soils	Mean	s	$\mu_6-\mu_4$	$\sigma_{(6-4)}$	$(\mu_6-\mu_4)/\sigma_{(6-4)}$	Confidence Level	Z value
Middle Half Measurements	k1	6	9	6.61	5.00	-6.63	3.24	-2.05	95%	1.86
		4		13.24	8.32					
	k2	6		0.73	0.11	0.15	0.05	3.25		
		4		0.58	0.08					
	k3	6		17.95	9.41	-14.23	5.82	-2.44		
		4		32.18	14.72					
	k4	6		0.72	0.08	0.16	0.04	4.30		
		4		0.57	0.07					
	k5	6		1.47	0.33	-0.15	0.14	-1.07		
		4		1.62	0.24					
	k6	6		0.86	0.06	0.20	0.03	6.90		
		4		0.66	0.06					
	k7	6		-0.26	0.11	-0.10	0.04	-2.37		
		4		-0.16	0.06					
	Regression Coefficient	Dia. (in.)	Number of Soils	Mean	s	$\mu_6-\mu_4$	$\sigma_{(6-4)}$	$(\mu_6-\mu_4)/\sigma_{(6-4)}$	Confidence level	Z value
Full Length Measurements	k1	6	9	4.60	2.34	-5.14	1.73	-2.96	95%	1.86
		4		9.74	4.65					
	k2	6		0.74	0.08	0.14	0.03	3.90		
		4		0.60	0.07					
	k3	6		15.55	5.89	-10.11	3.69	-2.74		
		4		25.66	9.37					
	k4	6		0.70	0.06	0.12	0.03	4.27		
		4		0.58	0.06					
	k5	6		1.27	0.23	-0.22	0.11	-2.03		
		4		1.49	0.23					
	k6	6		0.76	0.05	0.12	0.02	4.97		
		4		0.64	0.05					
	k7	6		-0.11	0.04	0.01	0.02	0.43		
		4		-0.12	0.04					

Table 7.9 Laboratory Modulus at OMC and 2psi Confining Pressure versus LBR Values

SITES	STRUCTURE ELEMENT	AASHTO CLASSIFICATION	LBR	M_R (σ_3=2psi)		OMC
				ksi	MPa	%
Lee Co.	Subgrade	A-3	43	20.8	143.3	12.0
SR884 Site 1B	EMB	A-3	19	23.3	160.8	10.8
Lee Co.	Subgrade	A-3	49	21.2	146.3	10.8
SR884 Site 2B	EMB	A-3	33	19.3	133.4	13.3
Polk Co.	Subgrade	A-2-4	47	18.4	126.8	10.1
US17 Site 1A	EMB	A-3	16	14.3	98.5	12.4
Polk Co.	Subgrade	A-2-4	64	20.5	141.5	10.5
US17 Site 2A	EMB	A-3	30	21.7	149.4	10.8
Clay Co.	Subgrade	A-3	38	13.7	94.4	13.5
US17 Site 5	EMB	A-2-4	29	16.7	115.3	12.8
Clay Co.	Subgrade	A-3	46	13.1	90.2	14.3
US17 Site 6	EMB	A-3	29	17.0	117.4	12.4
Alachua Co.	Subgrade	A-3	49	16.7	114.9	11.7
US301 Site 3	EMB	A-2-4	53			
Alachua Co.	Subgrade	A-2-4		18.5	127.5	11.2
US301 Site 4	EMB	A-6	68			
Jefferson Co.	Subgrade	A-4	69			9.4
US27 Site 1A	EMB	A-2-6	61			8.6
Jefferson Co.	Subgrade	A-4	116			7.4
US27 Site 2A	EMB	A-2-4	87			8.3
Gadsden Co.	Subgrade	A-2-4	145	26.5	182.9	6.9
US27 Site 2B	EMB	A-2-4	59	20.3	139.7	9.7
Gadsden Co.	Subgrade	A-3	121	18.8	129.4	8.9
US27 Site 3B	EMB	A-6	54			
Martin Co.	Subgrade	A-3	70	30.2	208.4	8.9
US1 Site 3	EMB	A-3	21	21.8	150.4	9.6
Martin Co.	Subgrade	A-4	45	28.3	195.3	9.5
US1 Site 4	EMB	A-3	29	30.8	212.4	9.5
Seminole Co.	Subgrade	A-2-4	79	26.0	179.4	6.3
US414 Site 1	EMB	A-2-4	20	20.9	143.9	8.4
Seminole Co.	Subgrade	A-2-4	93	24.6	169.5	8
US414 Site 2	EMB	A-3	31	24.2	167.2	12.7
Osceola Co.	Subgrade	A-3	56	32.9	226.9	9.0
US441 Site 3	EMB	A-3	18	21.8	150.5	12.7
Osceola Co.	Subgrade	A-3	85	29.2	201.2	8.9
US441 Site 4	EMB	A-3	60	14.2	97.6	12.8

Table 7.10 Lab Modulus at OMC and State of Stress Caused by Traffic versus LBR Values

SITES	STRUCTURE ELEMENT	AASHTO CLASSIFICATION	LBR	LAB MODULUS (BULK)		OMC
				ksi	MPa	%
Lee Co.	Subgrade	A-3	43	24.47	168.73	12.0
SR884 Site 1B	EMB	A-3	19	22.58	155.75	10.8
Lee Co.	Subgrade	A-3	49			10.8
SR884 Site 2B	EMB	A-3	33			13.3
Polk Co.	Subgrade	A-2-4	47	20.22	139.43	10.1
US17 Site 1A	EMB	A-3	16	14.00	96.56	12.4
Polk Co.	Subgrade	A-2-4	64	24.46	168.71	10.5
US17 Site 2A	EMB	A-3	30	21.19	146.12	10.8
Clay Co.	Subgrade	A-3	38	15.77	108.79	13.5
US17 Site 5	EMB	A-2-4	29	15.75	108.61	12.8
Clay Co.	Subgrade	A-3	46	14.05	96.88	14.3
US17 Site 6	EMB	A-3	29	16.50	113.81	12.4
Alachua Co.	Subgrade	A-3	49	18.49	127.51	11.7
US301 Site 3	EMB	A-2-4	53			
Alachua Co.	Subgrade	A-2-4		27.49	189.58	11.2
US301 Site 4	EMB	A-6	68			
Jefferson Co.	Subgrade	A-4	69			9.4
US27 Site 1A	EMB	A-2-6	61			8.6
Jefferson Co.	Subgrade	A-4	116			7.4
US27 Site 2A	EMB	A-2-4	87			8.3
Gadsden Co.	Subgrade	A-2-4	145	27.86	192.17	6.9
US27 Site 2B	EMB	A-2-4	59	20.06	138.32	9.7
Gadsden Co.	Subgrade	A-3	121	19.77	136.32	8.9
US27 Site 3B	EMB	A-6	54			
Martin Co.	Subgrade	A-3	70	29.27	201.84	8.9
US1 Site 3	EMB	A-3	21	22.18	152.94	9.6
Martin Co.	Subgrade	A-4	45	30.47	210.13	9.5
US1 Site 4	EMB	A-3	29	31.23	215.36	9.5
Seminole Co.	Subgrade	A-2-4	79	26.32	181.54	6.3
US414 Site 1	EMB	A-2-4	20	19.32	133.21	8.4
Seminole Co.	Subgrade	A-2-4	93	25.16	173.52	8
US414 Site 2	EMB	A-3	31	23.24	160.29	12.7
Osceola Co.	Subgrade	A-3	56	36.36	250.74	9.0
US441 Site 3	EMB	A-3	18	20.29	139.93	12.7
Osceola Co.	Subgrade	A-3	85	30.86	212.81	8.9
US441 Site 4	EMB	A-3	60	13.50	93.11	12.8

Table 7.11 Lab Modulus at In-situ MC and Bulk Stress versus LBR Values

SITES	PAVEMENT STRUCTURE	AASHTO CLASSIFICATION	M_R		LBR
			MPa	ksi	
Lee Co. SR884 Site 1B	Base	Limerock	181.71	26.35	65
	Subgrade	A-3	156.13	22.64	43
	Embankment	A-3	117.32	17.01	19
Lee Co. SR884 Site 2B	Base	Limerock			113
	Subgrade	A-3			49
	Embankment	A-3			33
Polk Co. US17 Site 1A	Base	Limerock	181.22	26.28	110
	Subgrade	A-2-4	123.50	17.91	47
	Embankment	A-3	97.11	14.08	16
Polk Co. US17 Site 2A	Base	Limerock			90
	Subgrade	A-2-4	161.86	23.47	64
	Embankment	A-3	160.07	23.21	30
Alachua Co. US301 Site 3	Base	Limerock	249.21	36.14	126
	Subgrade	A-3	107.08	15.53	49
	Embankment	A-3			53
Alachua Co. US301 Site 4	Base	Limerock	237.42	34.43	132
	Subgrade	A-2-4	153.33	22.23	
	Embankment	A-6			68
Clay Co. US17 Site 5	Base	Limerock	312.02	45.24	118
	Subgrade	A-3	116.77	16.93	38
	Embankment	A-2-4	97.75	14.17	29
Clay Co. US17 Site 6	Base	Limerock	277.47	40.23	90
	Subgrade	A-3	107.04	15.52	46
	Embankment	A-3	110.59	16.04	29
Jefferson Co. US27 Site 1A	Base	Limerock	289.93	42.04	128
	Subgrade	A-4	185.61	26.91	69
	Embankment	A-2-6			61
Jefferson Co. US27 Site 2A	Base	Limerock	240.74	34.91	138
	Subgrade	A-4			116
	Embankment	A-2-4	77.86	11.29	87
Gadsden Co. US27 Site 2B	Base	Limerock	214.63	31.12	96
	Subgrade	A-2-4	104.49	15.15	145
	Embankment	A-2-4	92.80	13.46	59
Gadsden Co. US27 Site 3B	Base	Limerock	210.59	30.54	84
	Subgrade	A-3	124.19	18.01	121
	Embankment	A-6	111.43	16.16	54
Dade Co. US41 Site 1	Base	Limerock			128
	Subgrade	Limerock	226.62	32.86	147
	Embankment	Limerock	121.35	17.60	172
Dade Co. US41 Site 2	Base	Limerock			121
	Subgrade	Limerock			125
	Embankment	Limerock			100

Table 7.11 Lab Modulus at In-situ MC and Bulk Stress versus LBR Values (continued)

SITES	PAVEMENT STRUCTURE	AASHTO CLASSIFICATION	M_R		LBR
			MPa	ksi	
Martin Co. US1 Site 3	Base	Limerock			191
	Subgrade	A-3	164.80	23.90	70
	Embankment	A-3	146.04	21.18	21
Martin Co. US1 Site 4	Base	Limerock	323.96	46.97	122
	Subgrade	A-4	190.04	27.56	45
	Embankment	A-3	182.52	26.46	29
Seminole Co. US414 Site 1	Base	Limerock	235.11	34.09	109
	Subgrade	A-2-4	140.19	20.33	79
	Embankment	A-2-4	143.29	20.78	20
Seminole Co. US414 Site 2	Base	Limerock	160.64	23.29	112
	Subgrade	A-2-4	136.09	19.73	93
	Embankment	A-3	141.56	20.53	31
Osceola Co. US441 Site 3	Base	Coquina	323.67	46.93	146
	Subgrade	A3	226.90	32.90	56
	Embankment	A3	128.72	18.66	18
Osceola Co. US441 Site 4	Base	Coquina	245.53	35.60	211
	Subgrade	A3	195.40	28.33	85
	Embankment	A3	126.52	18.35	60

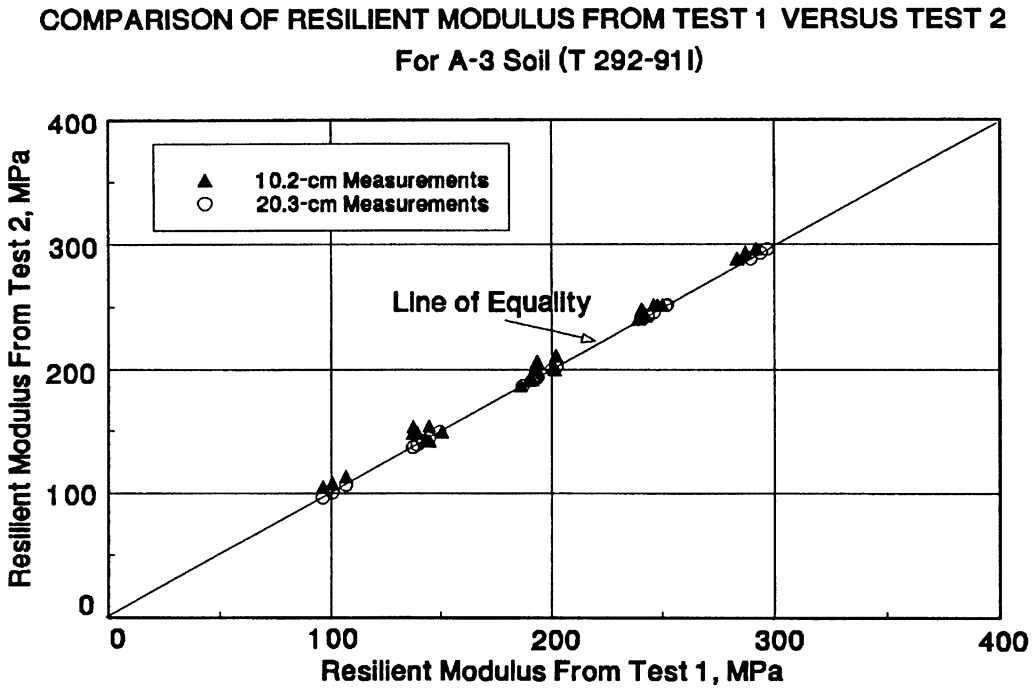


Figure 7.1 Comparison of resilient modulus from test 1 versus test2 for A-3 soil (T292-91I)

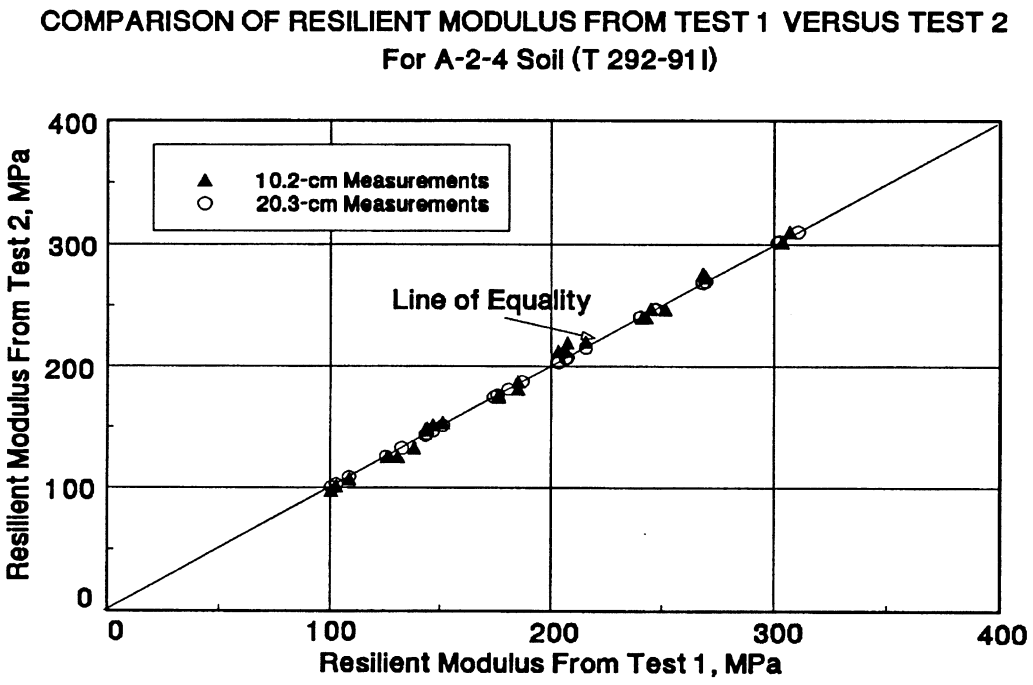


Figure 7.2 Comparison of resilient modulus from test 1 versus test2 for A-2-4 soil (T292-91I)

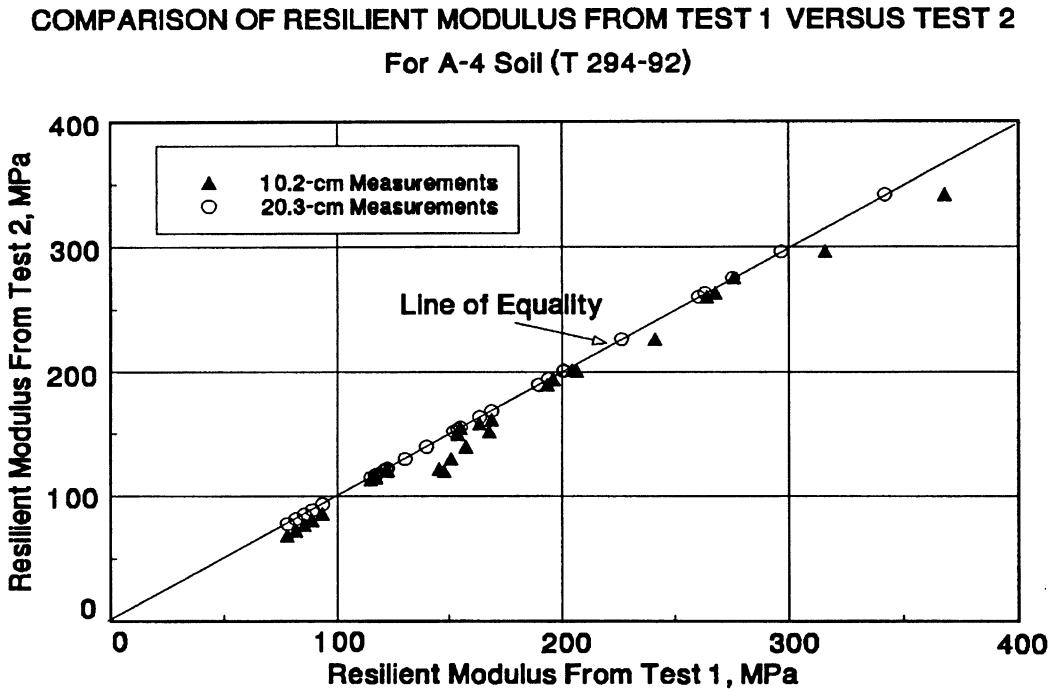


Figure 7.3 Comparison of resilient modulus from test 1 versus test2 for A-4 soil (T294-92)

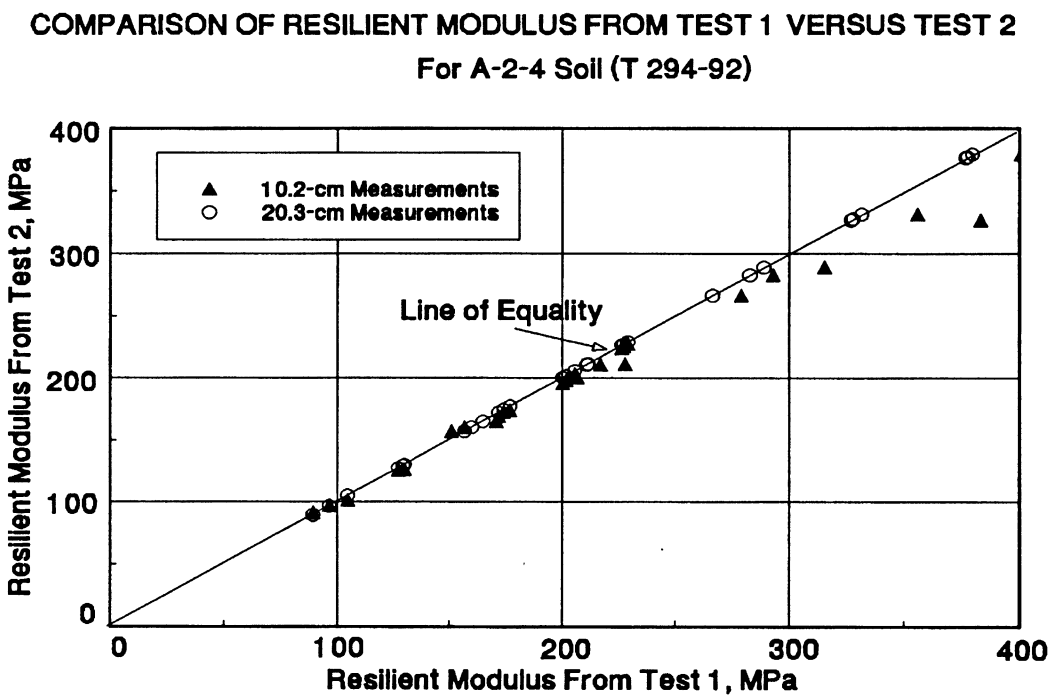


Figure 7.4 Comparison of resilient modulus from test 1 versus test2 for A-2-4 soil (T294-92)

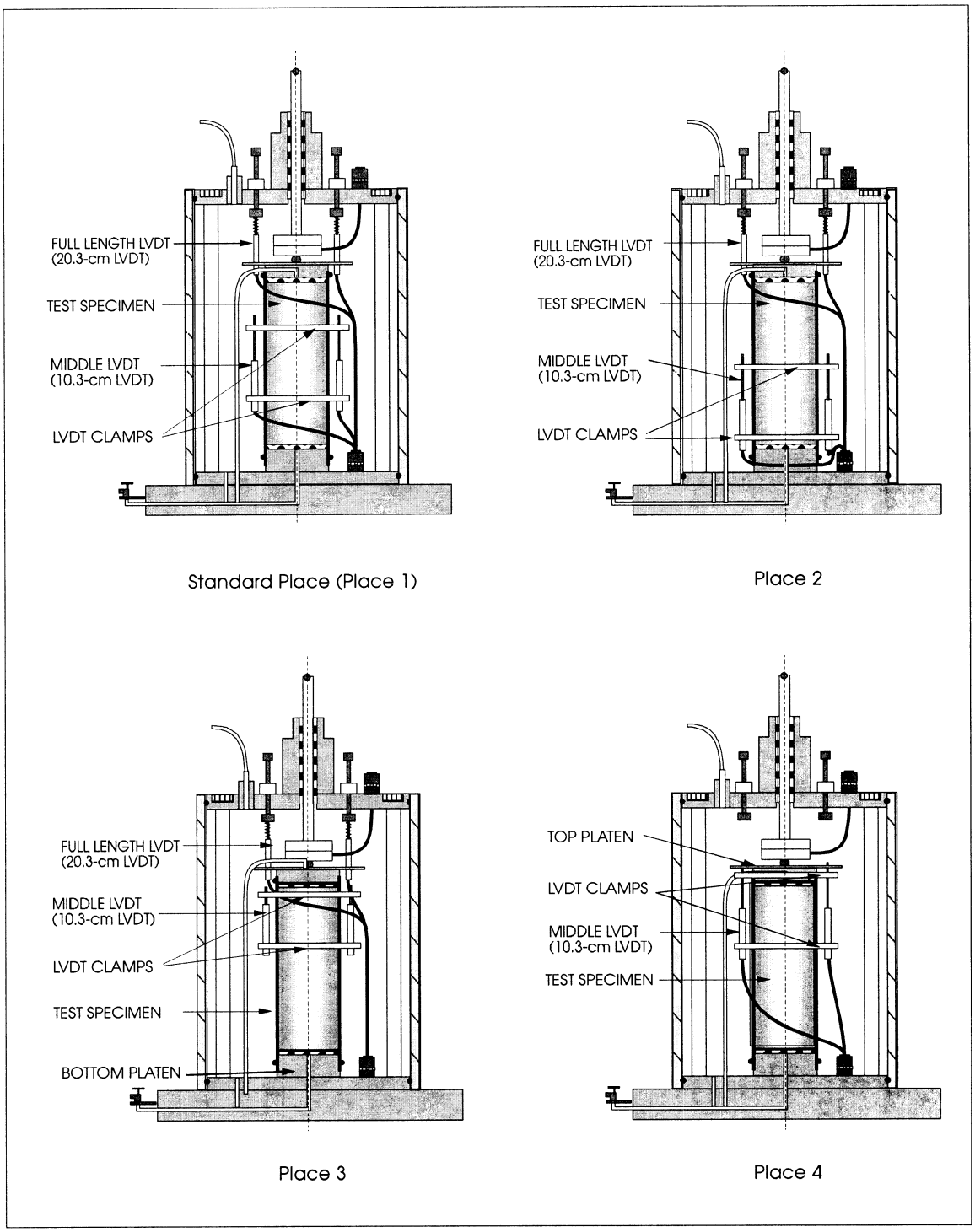


Figure 7.5 Different positions of the middle LVDTs

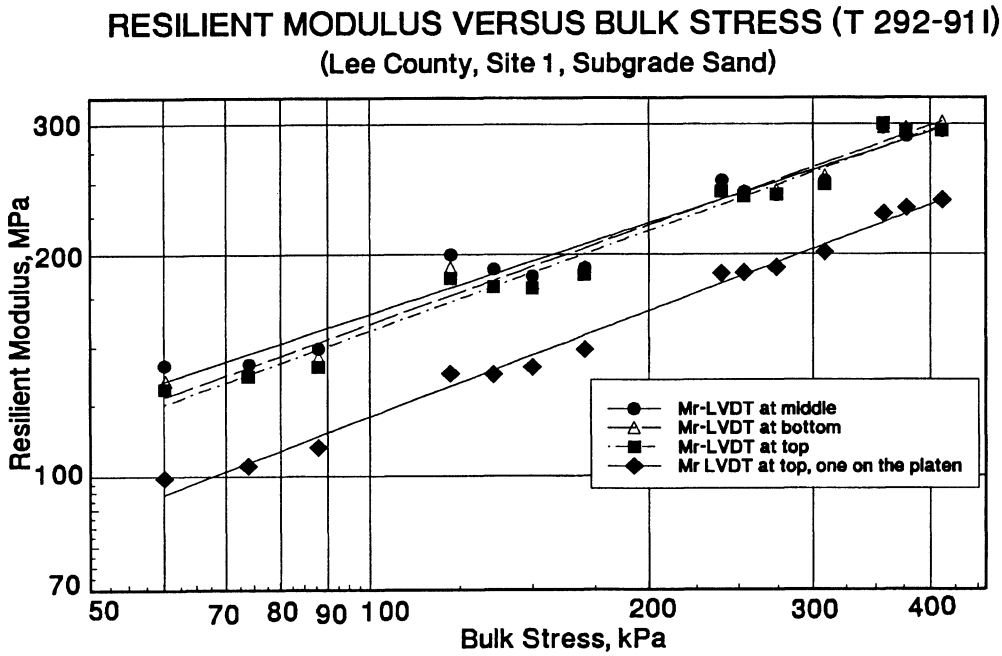


Figure 7.6 Resilient modulus versus bulk stress at different LVDTs' positions for a subgrade sand, T292-91I

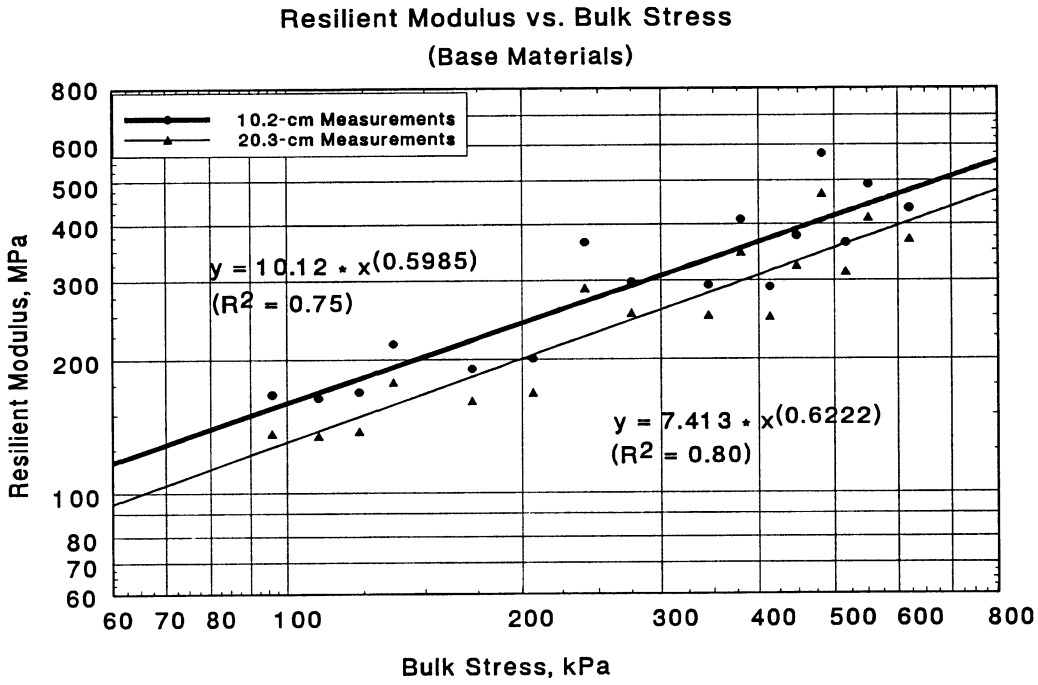


Figure 7.7 Resilient modulus versus bulk stress for base materials

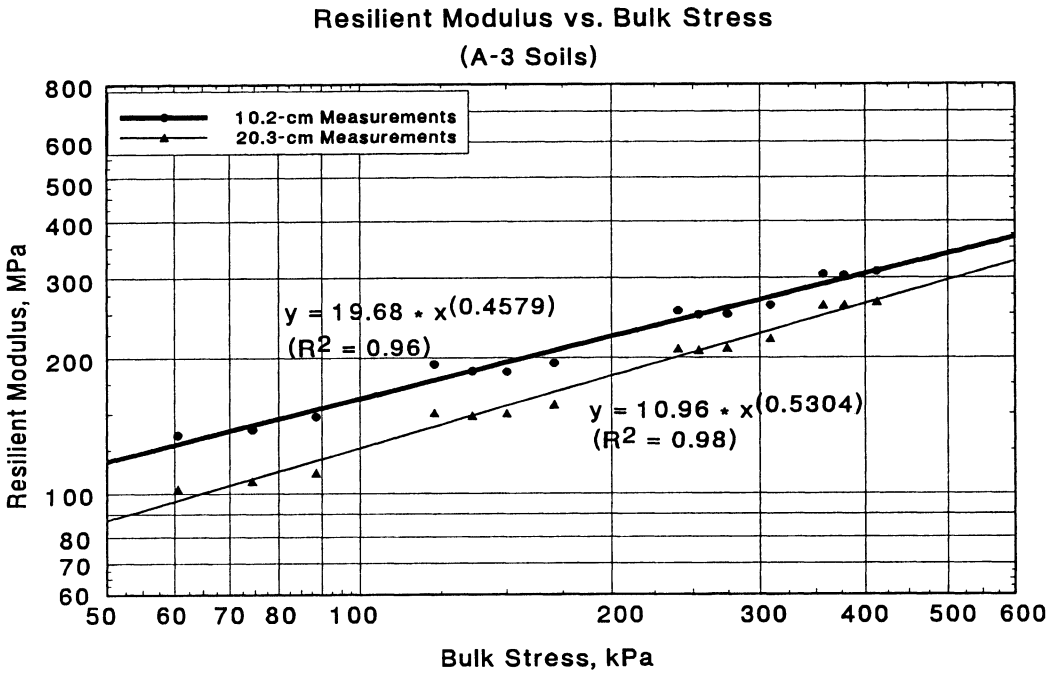


Figure 7.8 Resilient modulus versus bulk stress for A-3 soils

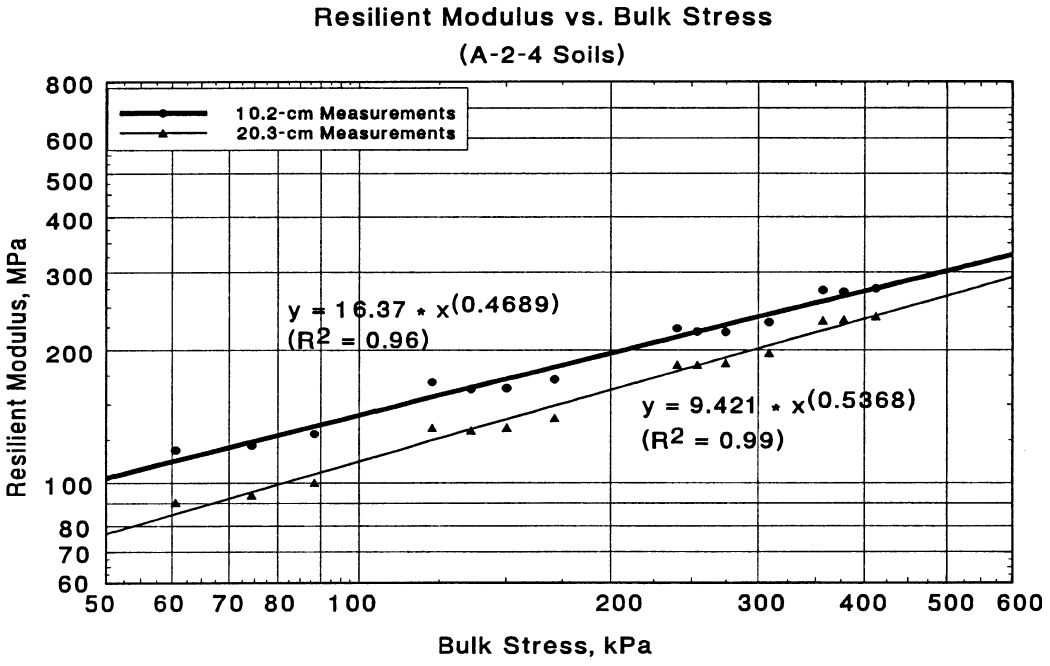


Figure 7.9 Resilient modulus versus bulk stress for A-2-4 soils

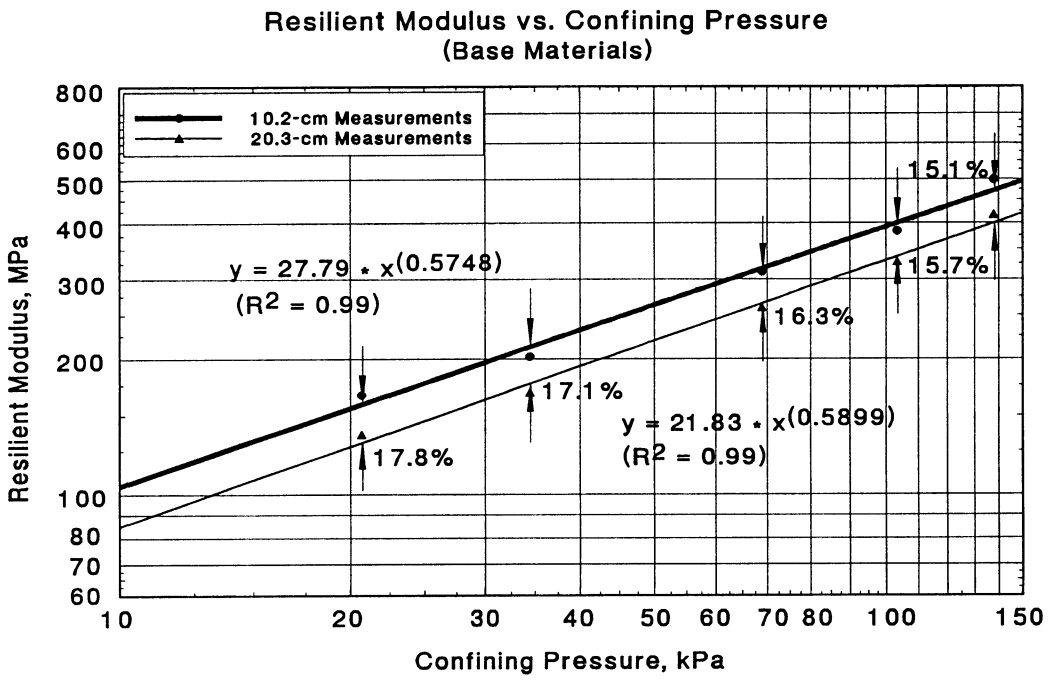


Figure 7.10 Resilient modulus versus confining pressure for base materials

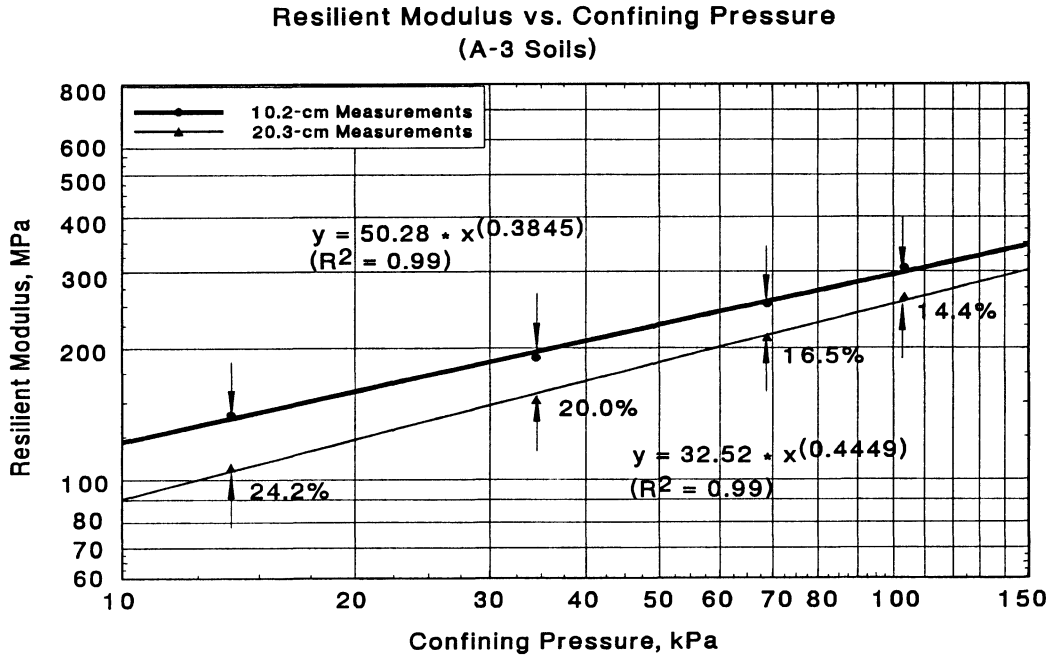


Figure 7.11 Resilient modulus versus confining pressure for A-3 soils

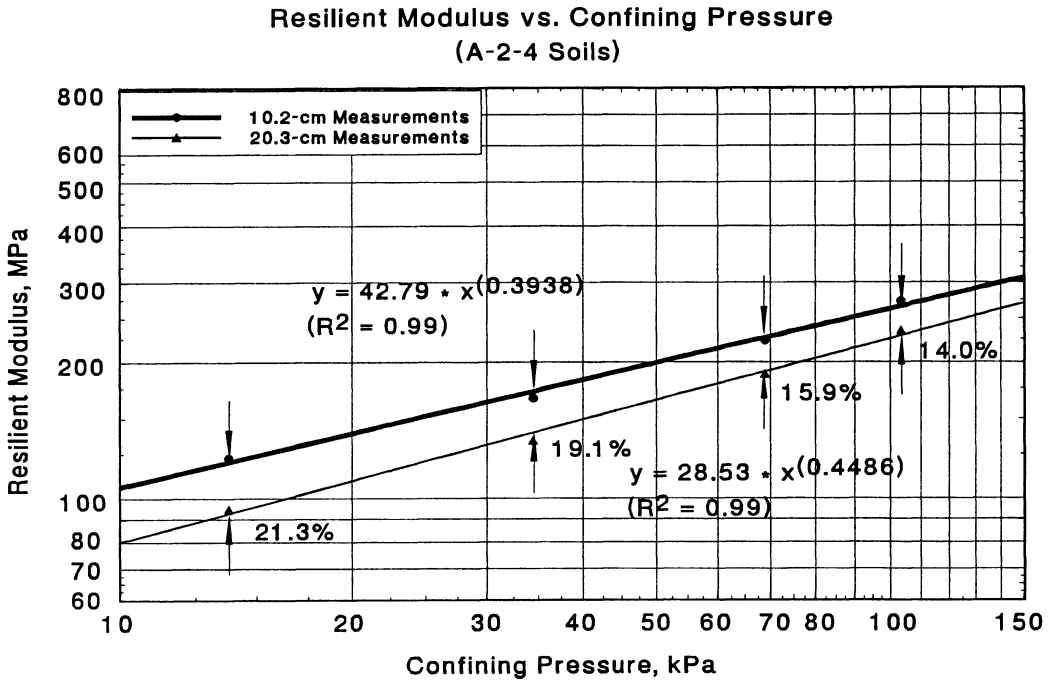


Figure 7.12 Resilient modulus versus confining pressure for A-2-4 soils

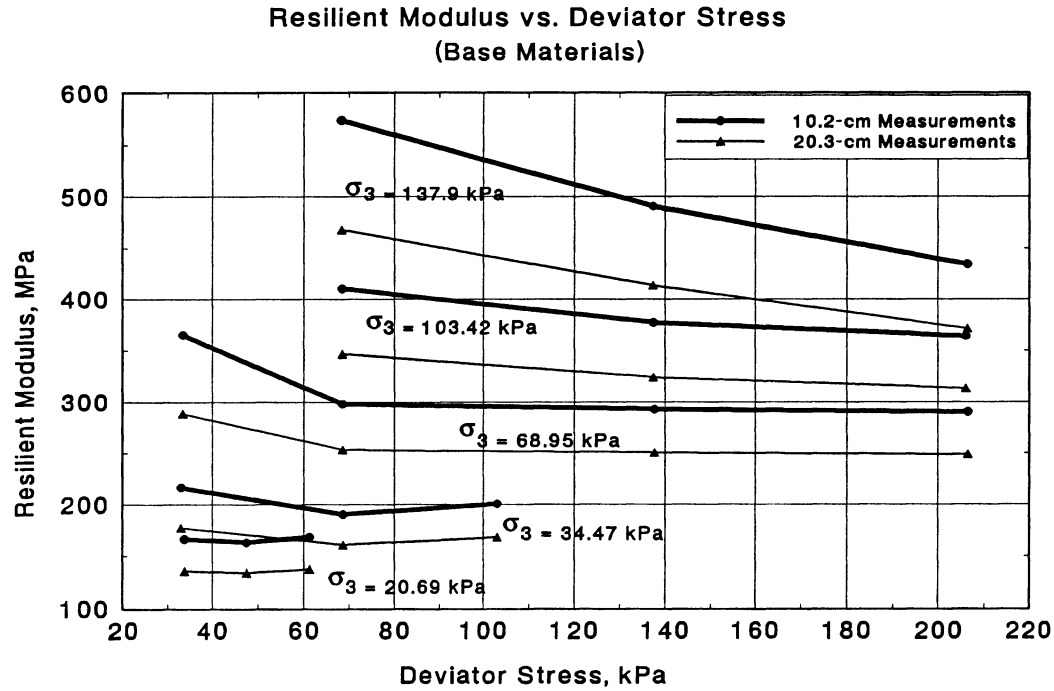


Figure 7.13 Resilient modulus versus deviator stress for base materials

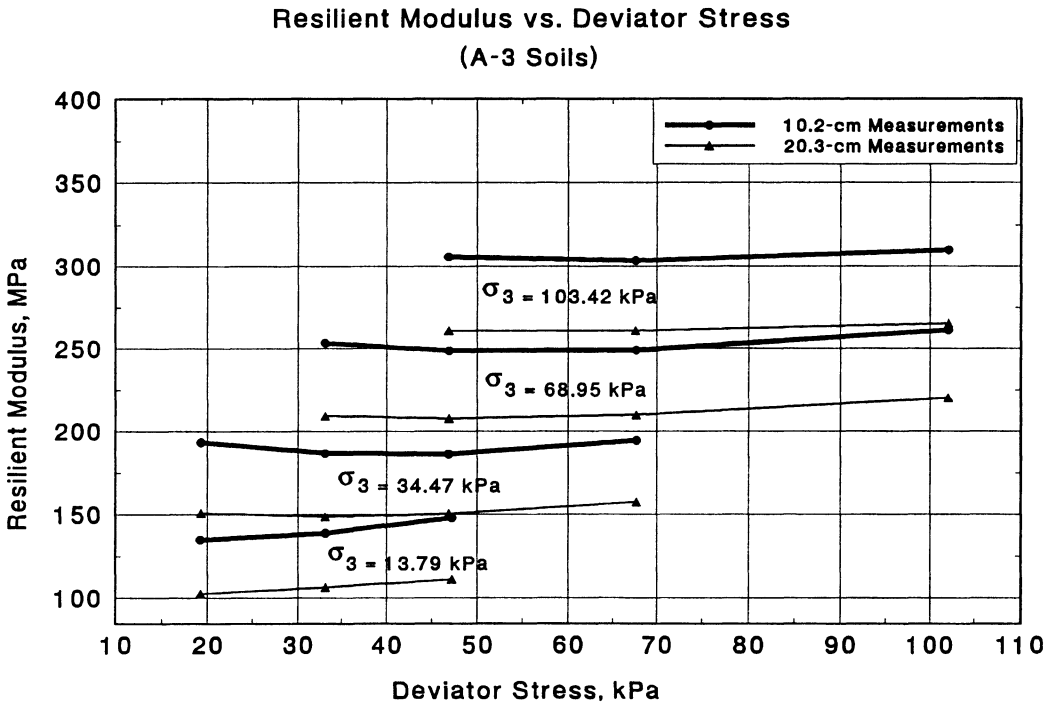


Figure 7.14 Resilient modulus versus deviator stress for A-3 soils

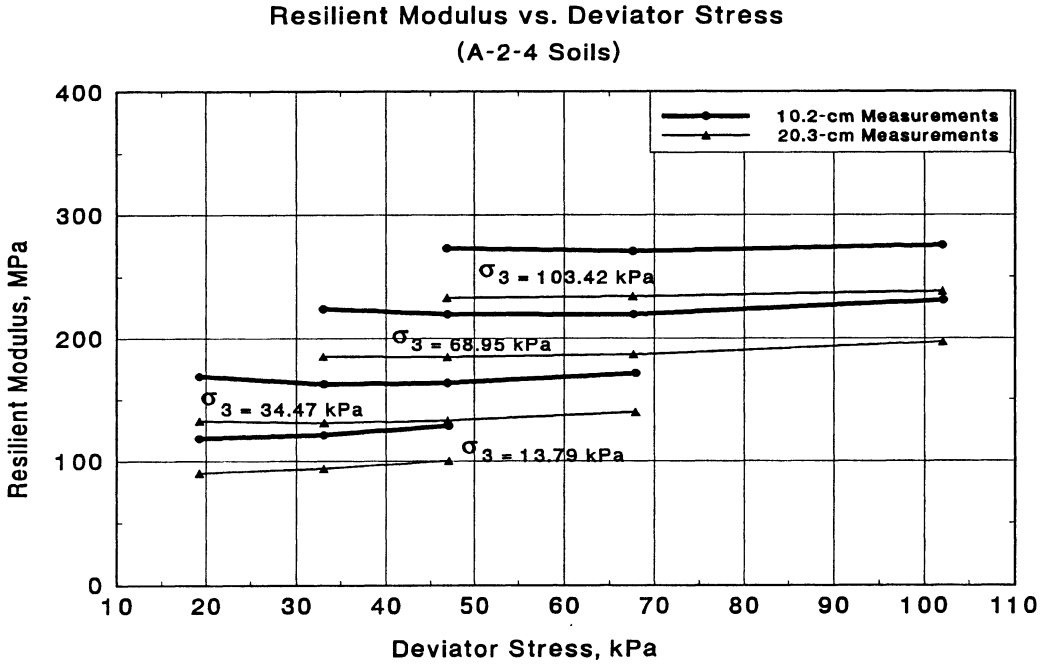


Figure 7.15 Resilient modulus versus deviator stress for A-2-4 soils

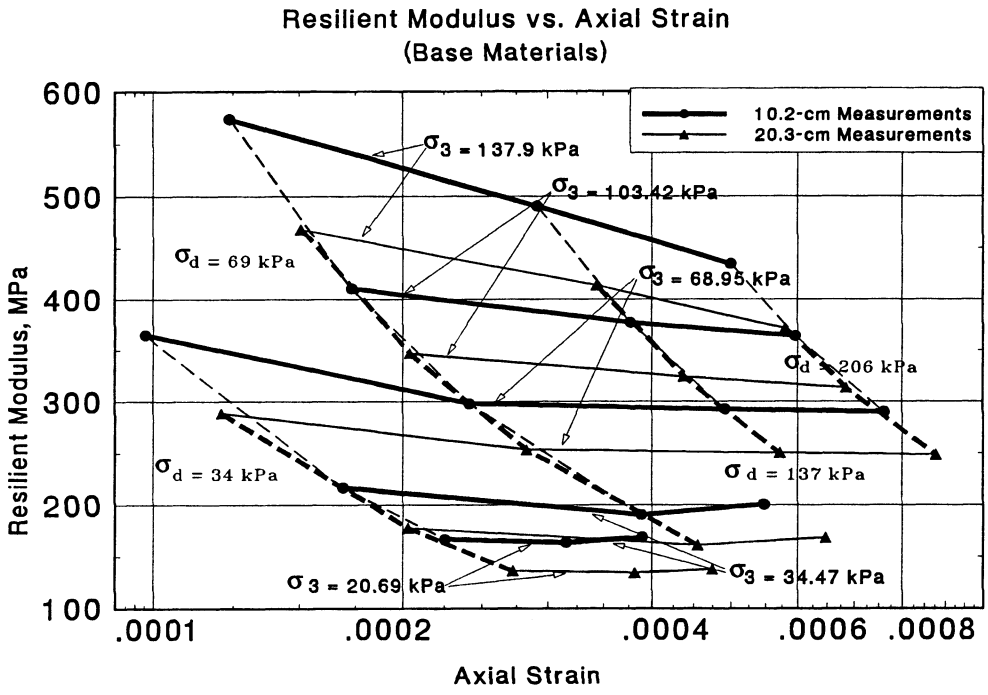


Figure 7.16 Resilient modulus versus axial strain for base materials

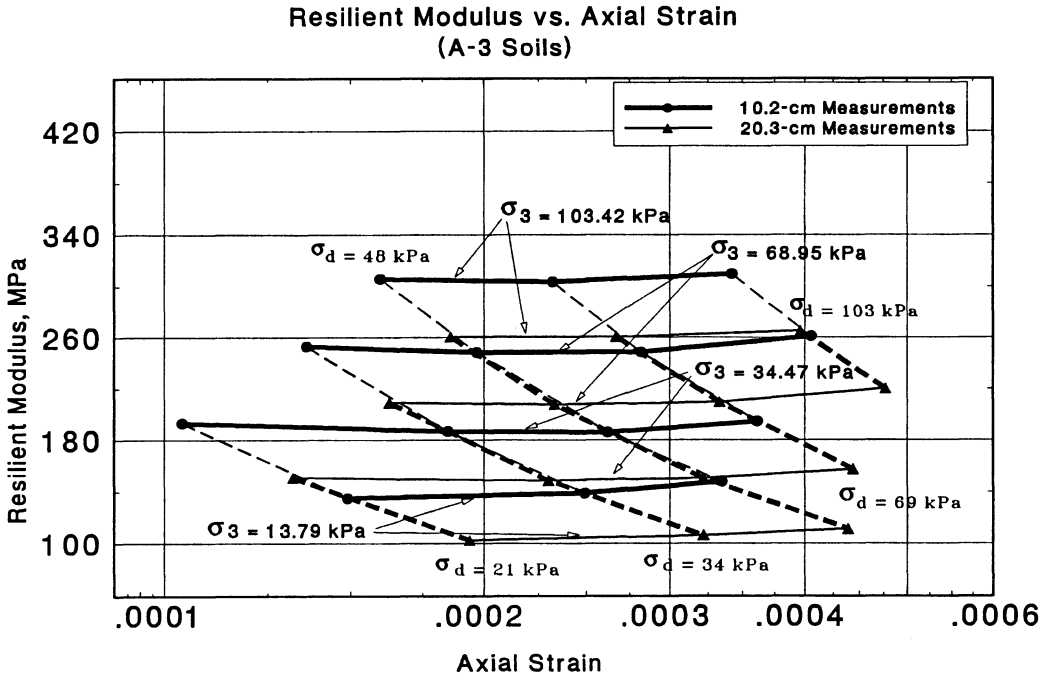


Figure 7.17 Resilient modulus versus axial strain for A-3 soils

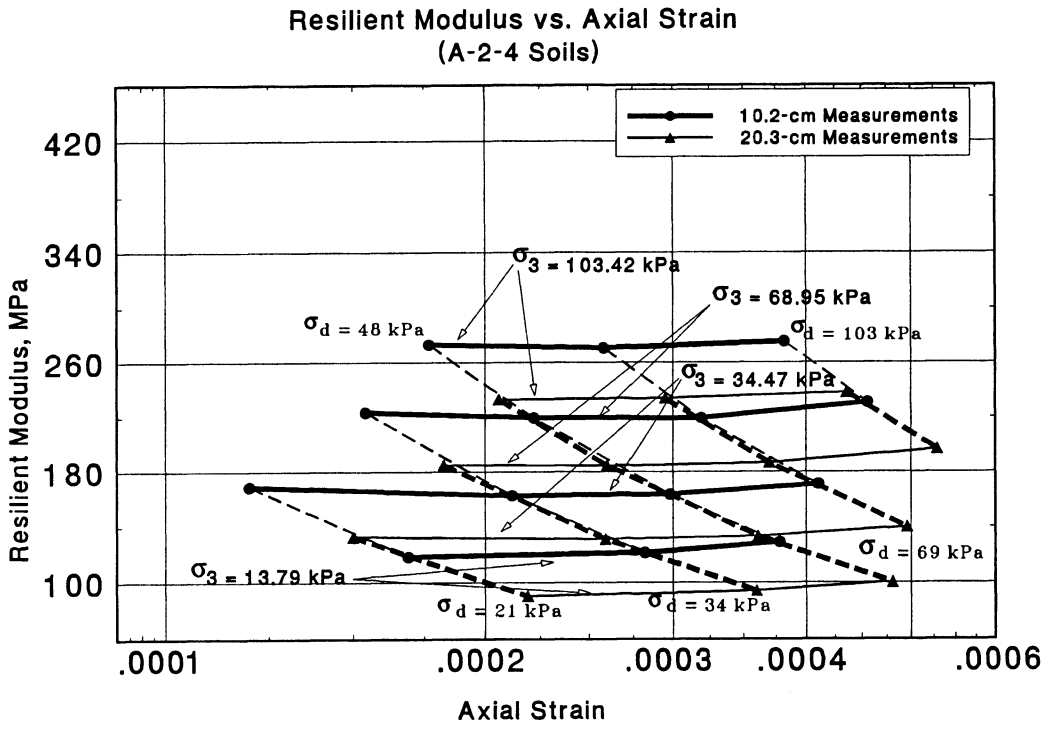


Figure 7.18 Resilient modulus versus axial strain for A-2-4 soils

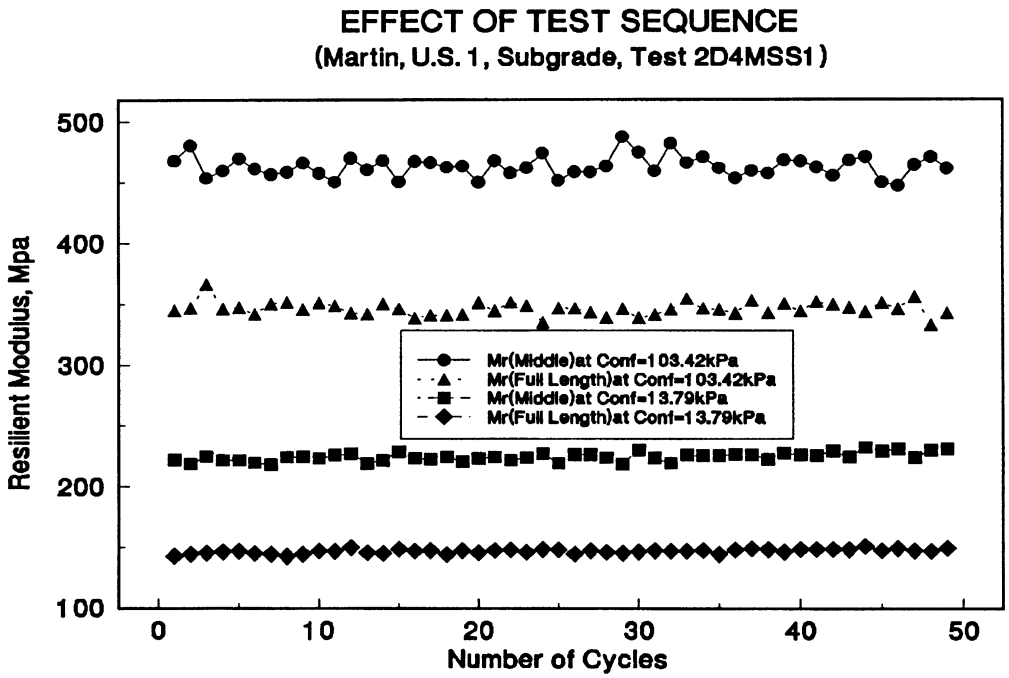


Figure 7.19 Stability of resilient modulus versus number of load cycles for A-3 soils (T292-91I, case1)

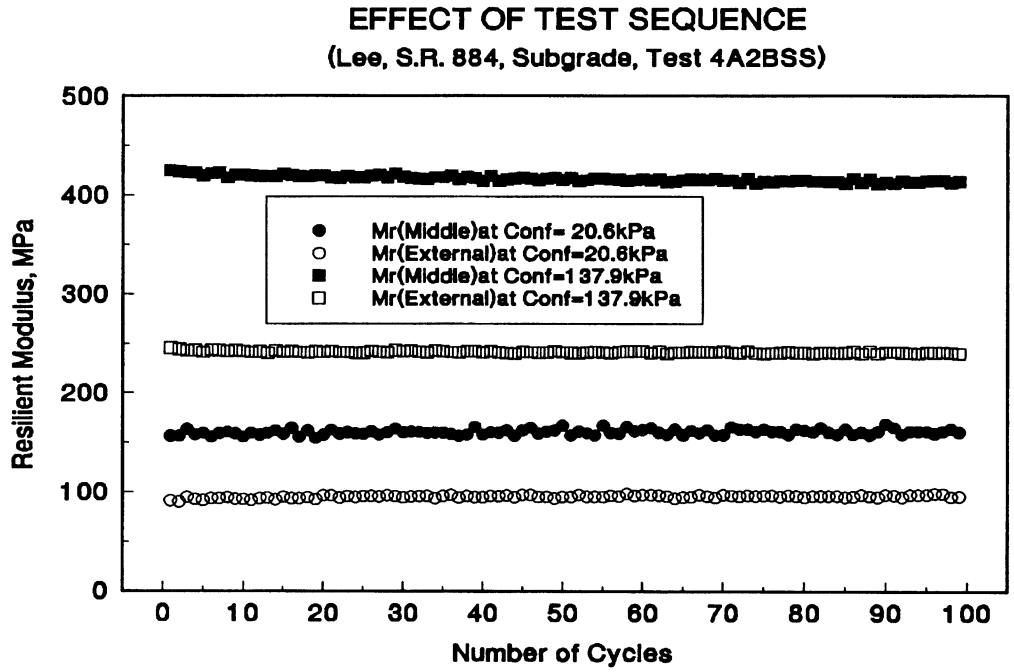


Figure 7.20 Stability of resilient modulus versus number of load cycles for A-3 soils (T294-92, case2)

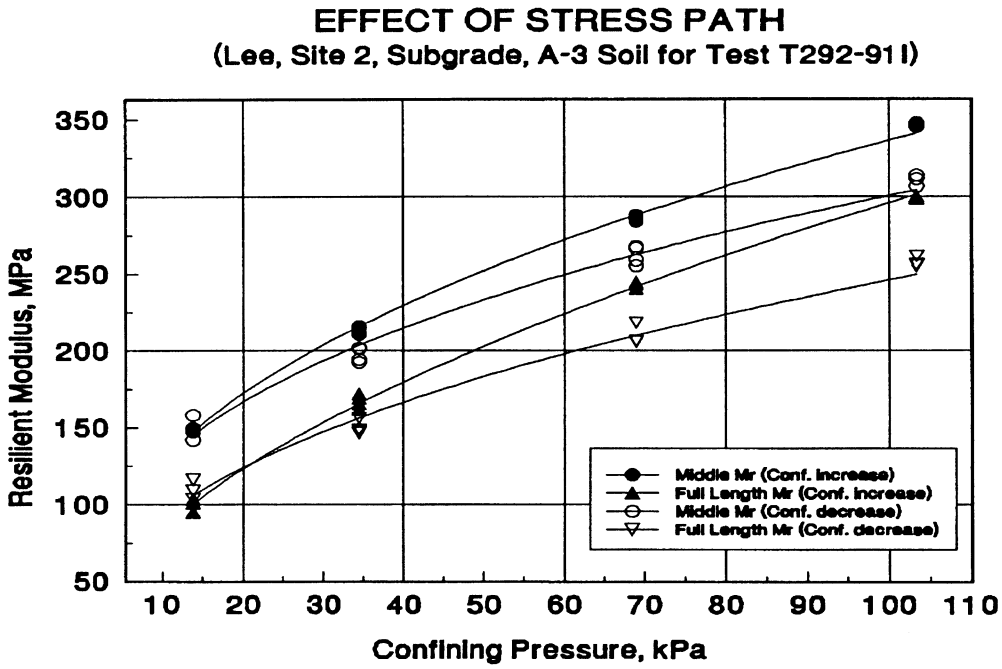


Figure 7.21 Effect of stress paths on resilient modulus versus confining pressure (T292-91I)

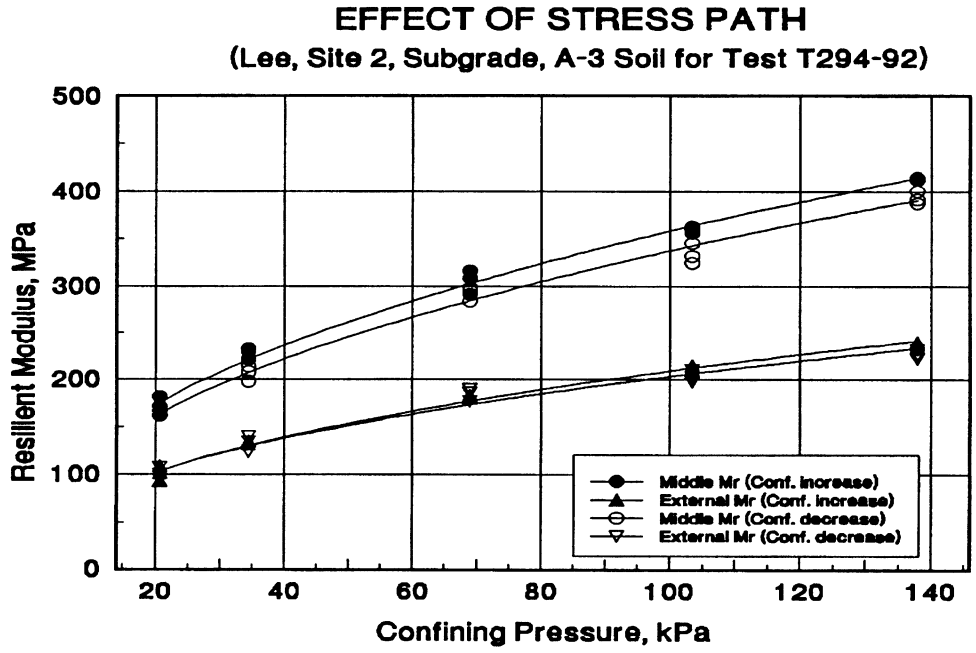


Figure 7.22 Effect of stress paths on resilient modulus versus confining pressure (T294-92)

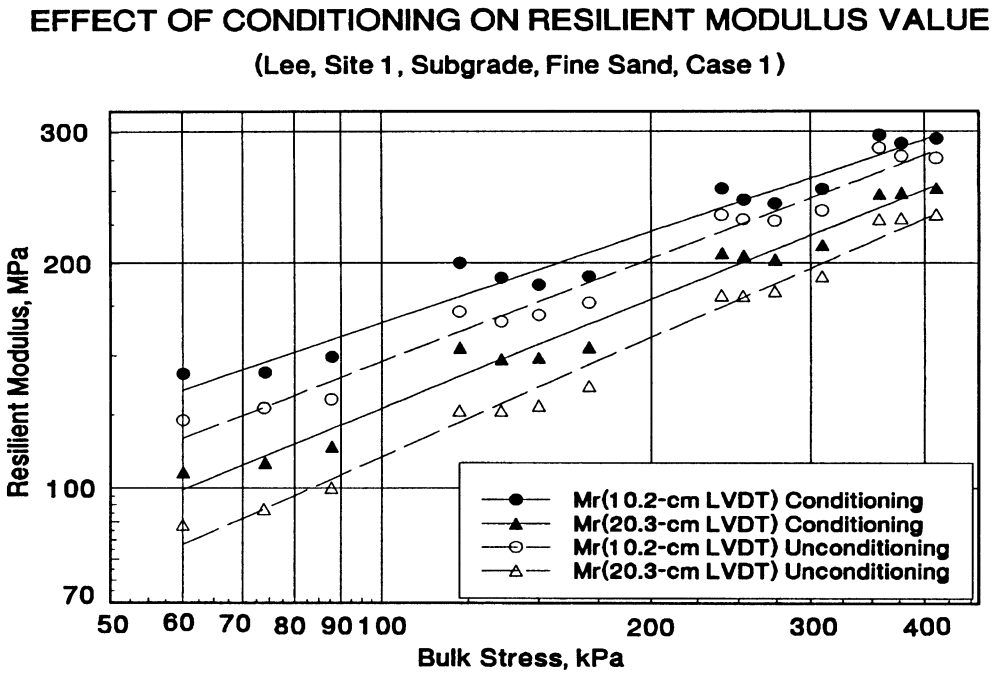


Figure 7.23 Effect of conditioning on resilient modulus values (T 292-91I, case 1)

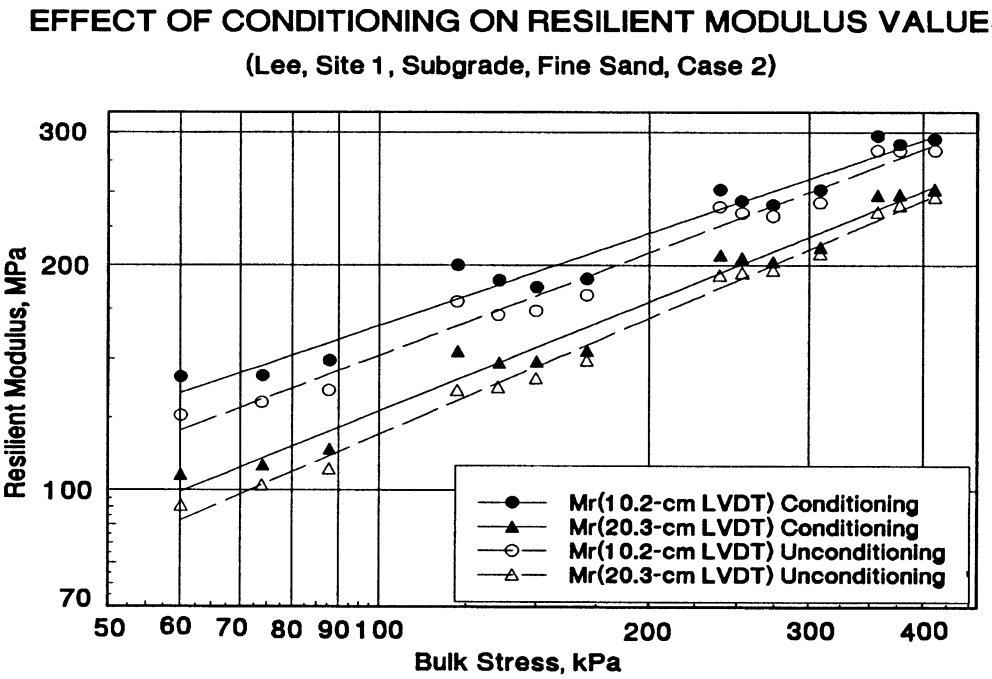


Figure 7.24 Effect of conditioning on resilient modulus values (T292-91I, case 2)

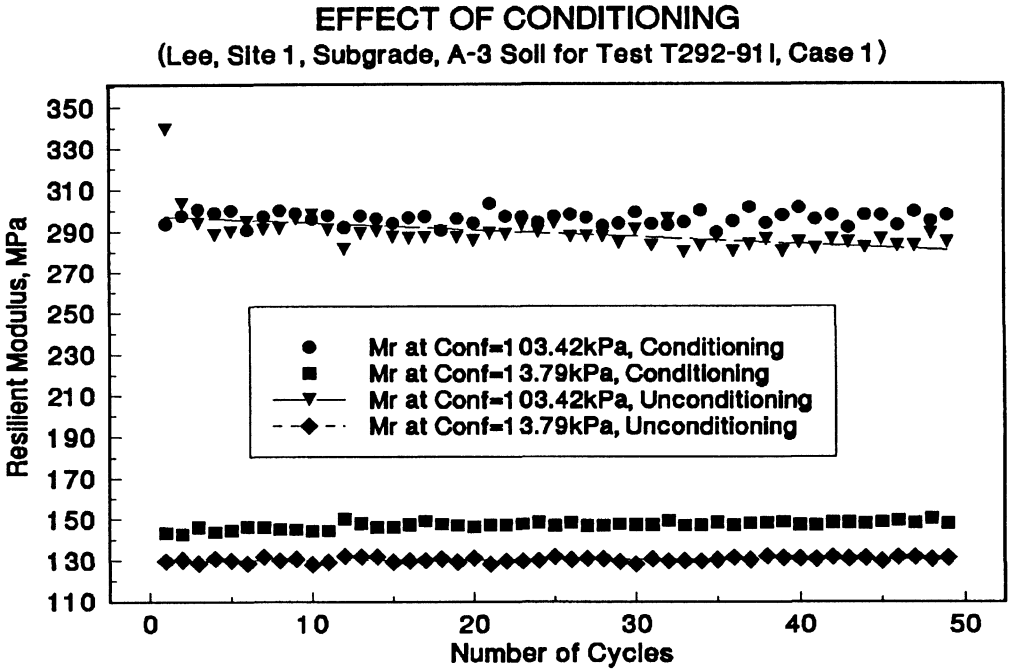


Figure 7.25 Effect of conditioning on stability of resilient modulus (T 292-91I, case 1)

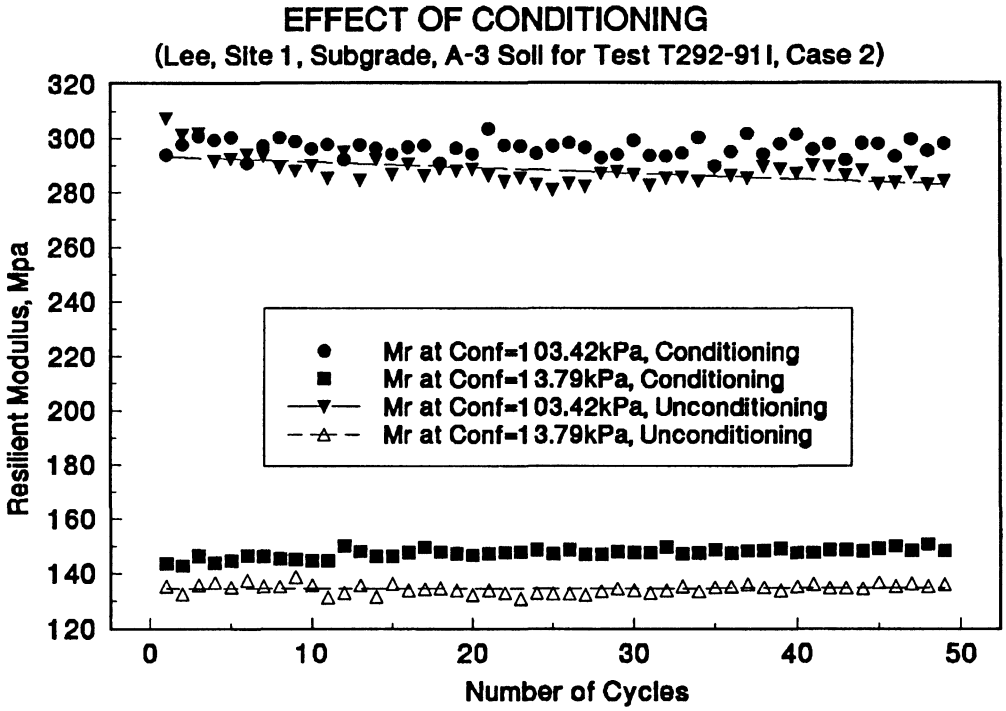
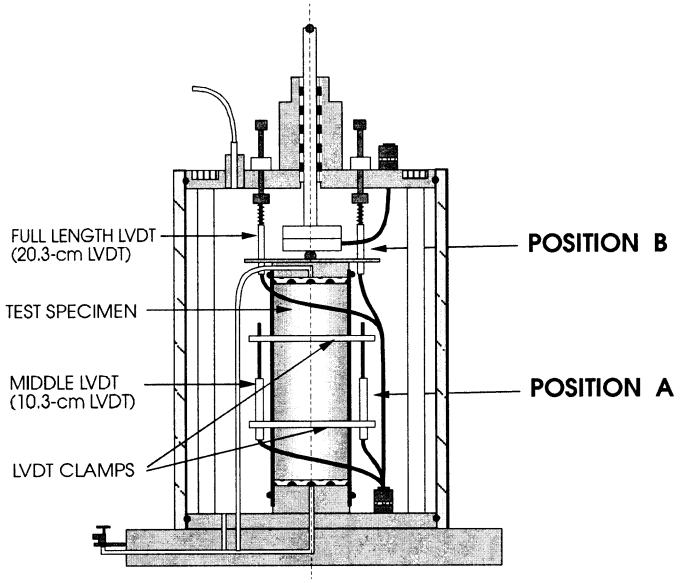
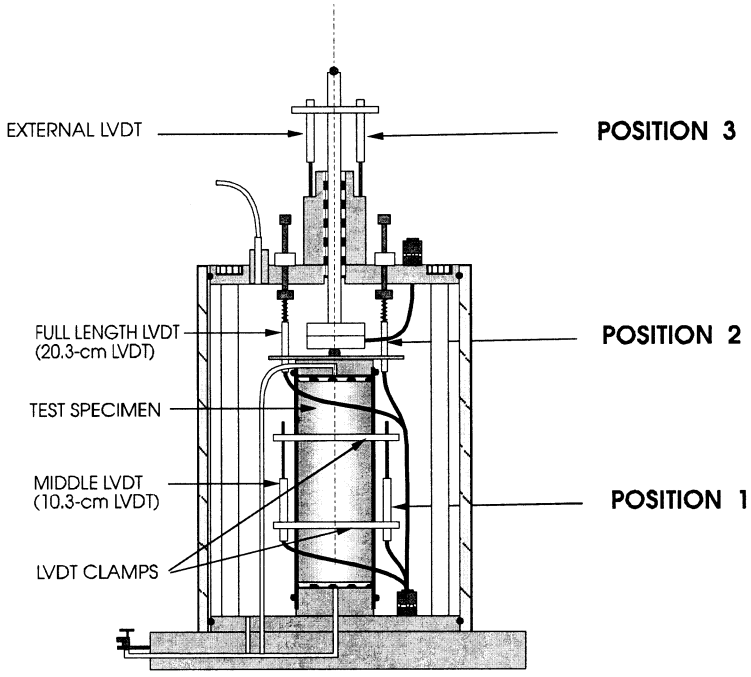


Figure 7.26 Effect of conditioning on stability of resilient modulus (T 292-91I, case 2)



(a) T 292-91I



(b) T294-92

Figure 7.27 Different positions of LVDTs, T292-91I and T294-92

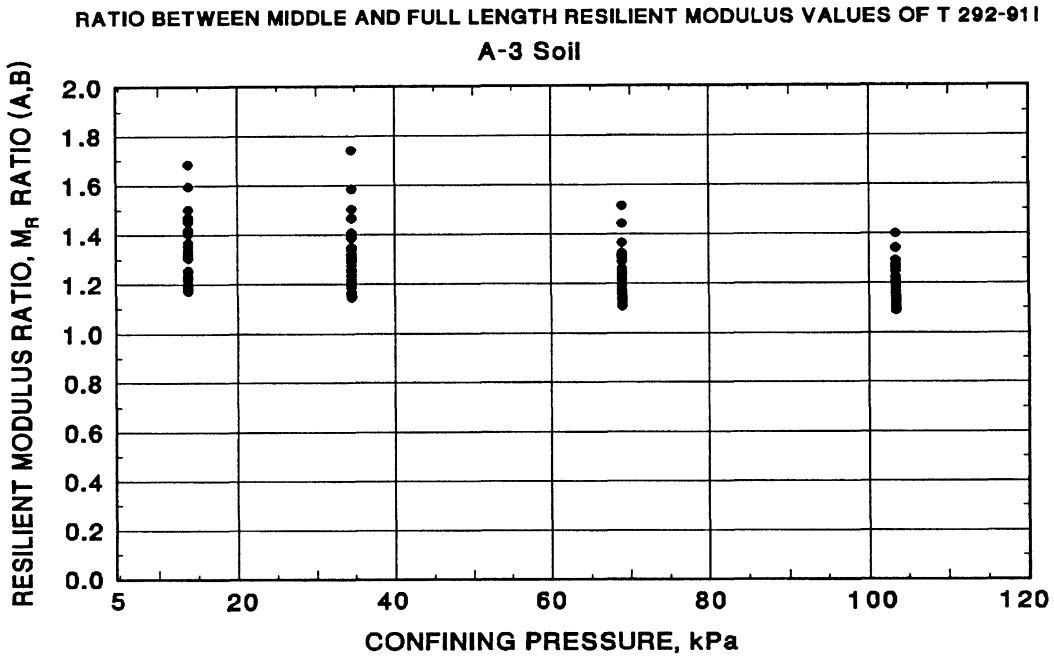


Figure 7.28 Ratio between middle and full length resilient modulus values of T 292-91I for A-3 soil

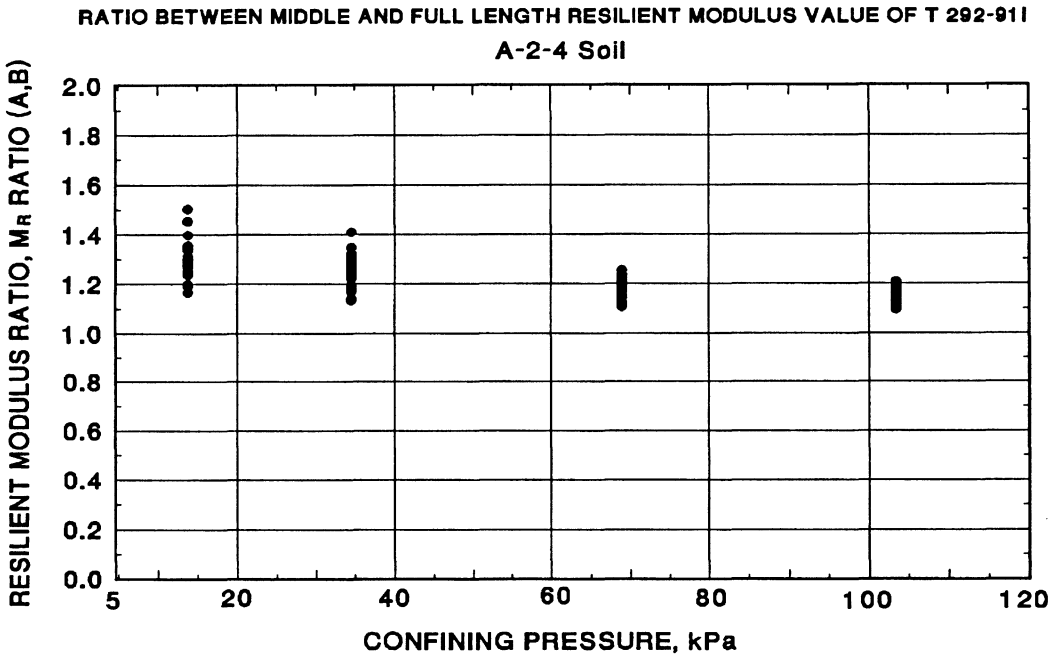


Figure 7.29 Ratio between middle and full length resilient modulus values of T 292-91I for A-2-4 soil

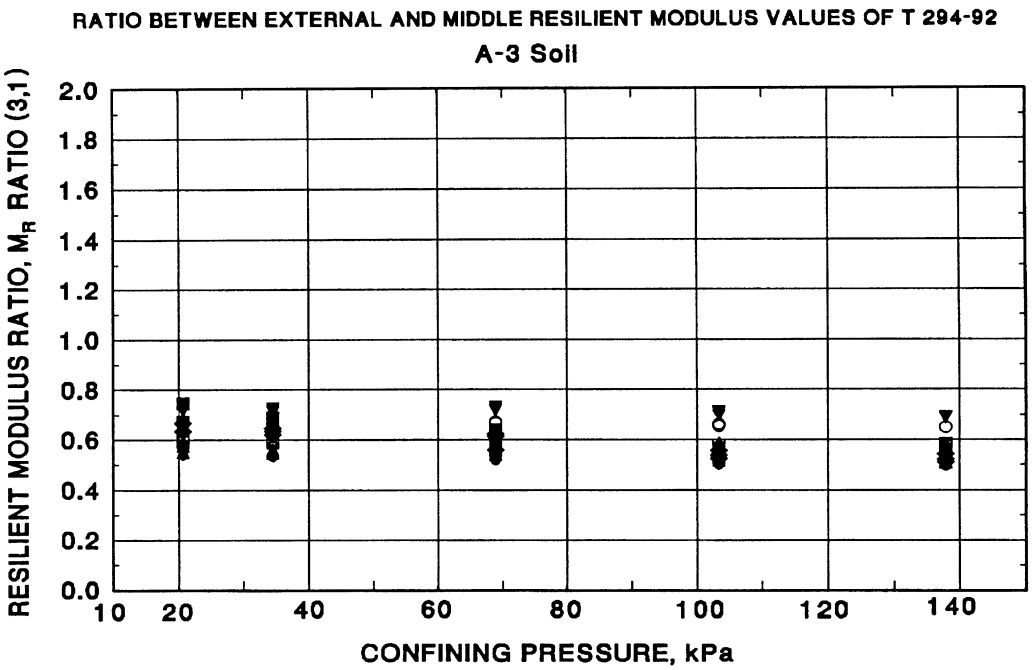


Figure 7.30 Ratio between external and middle resilient modulus values of T 294-92 for A-3 soil

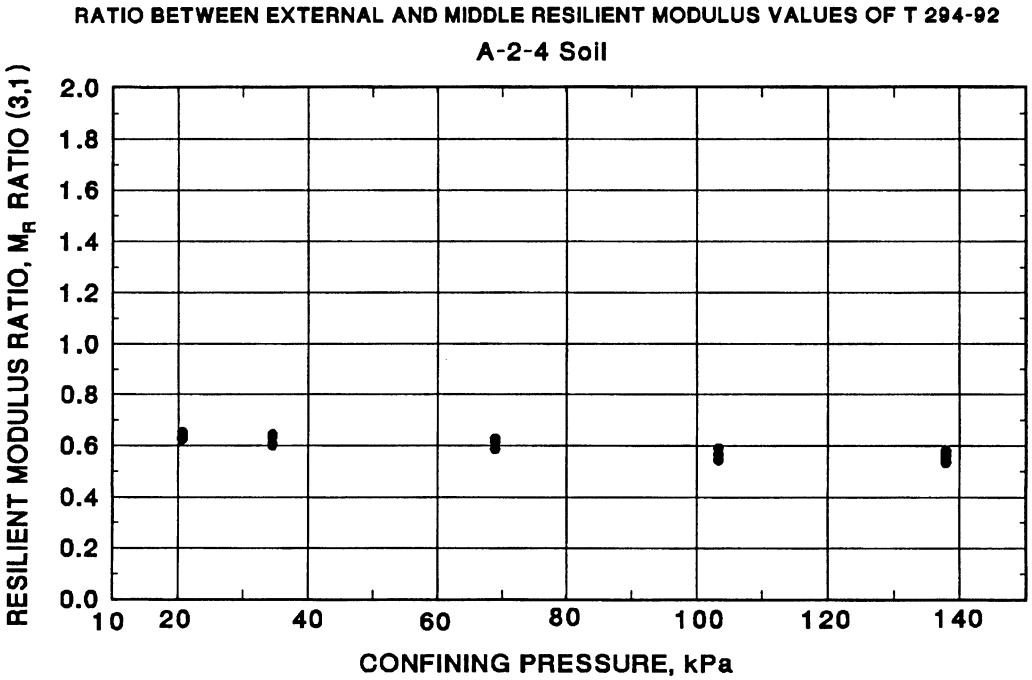


Figure 7.31 Ratio between external and middle resilient modulus values of T 294-92 for A-2-4 soil

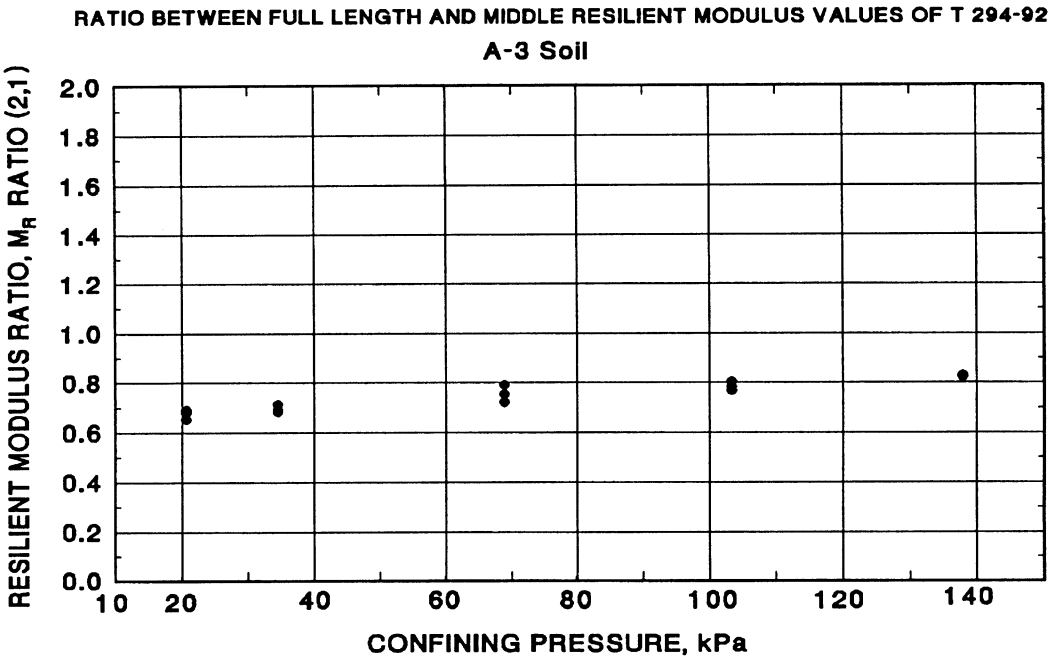


Figure 7.32 Ratio between full length and middle resilient modulus values of T 294-92 for A-3 soil

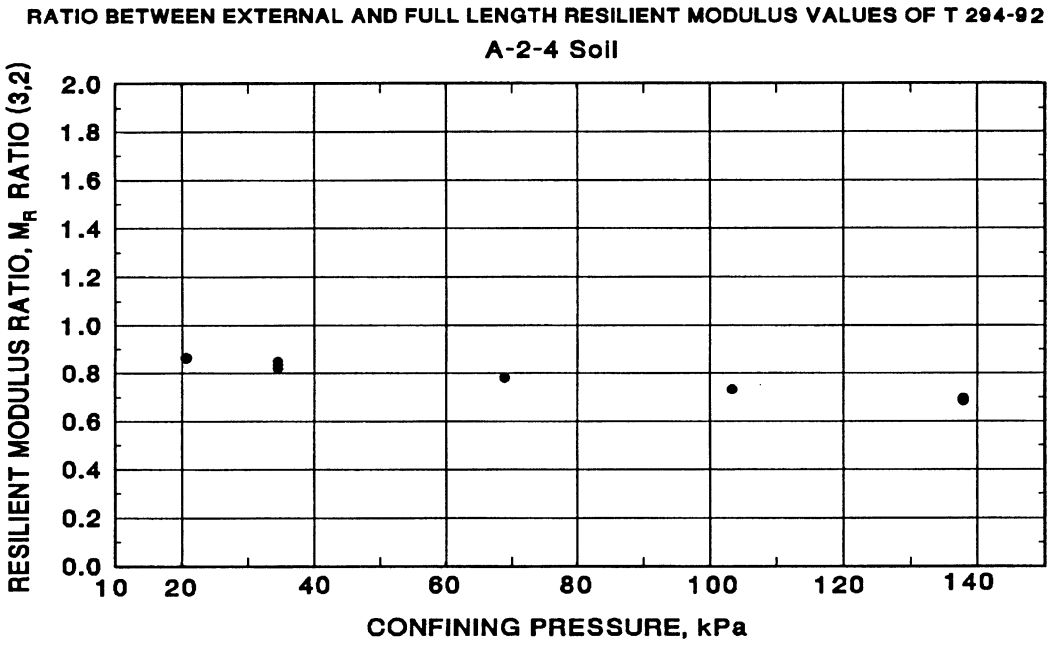


Figure 7.33 Ratio between external and full length resilient modulus values of T 294-92 for A-2-4 soil

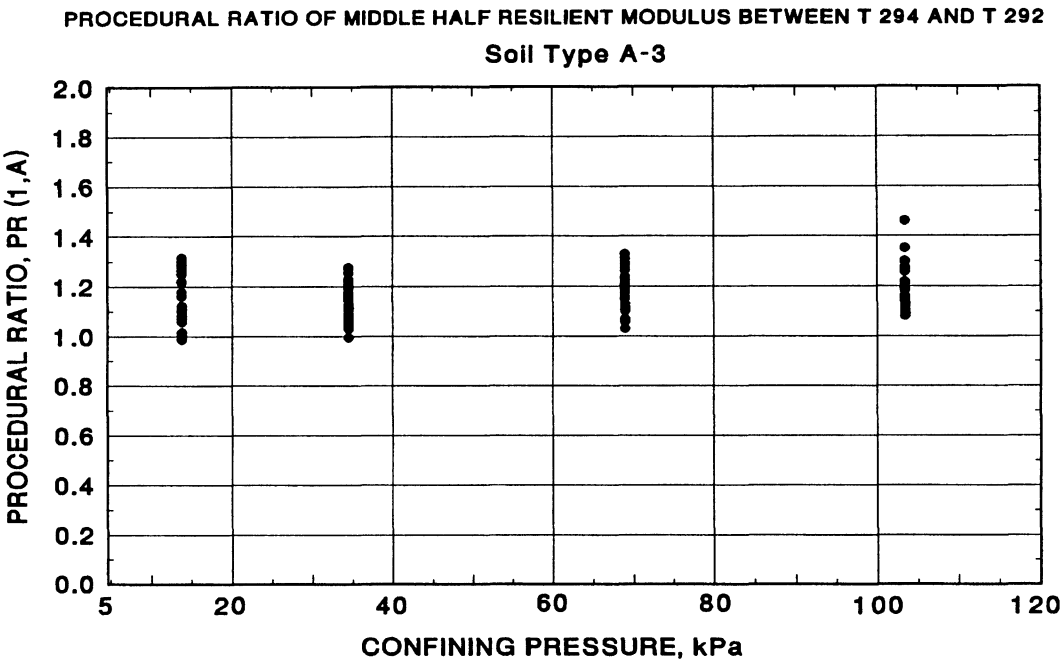


Figure 7.34 Procedural ratio of middle half resilient modulus values for A-3 soil

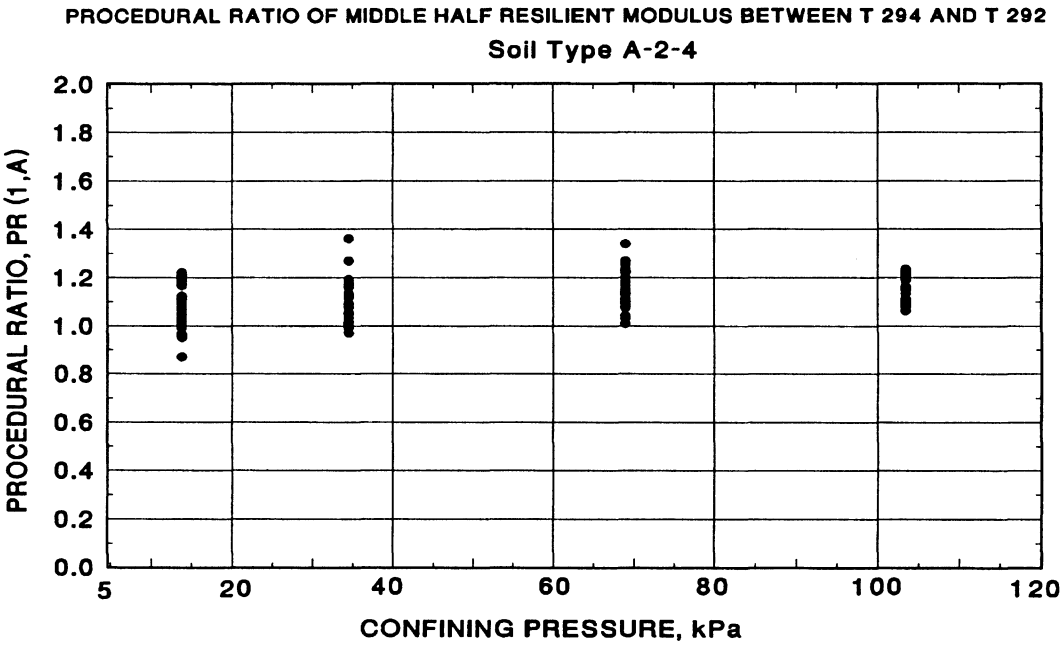


Figure 7.35 Procedural ratio of middle half resilient modulus values for A-2-4 soil

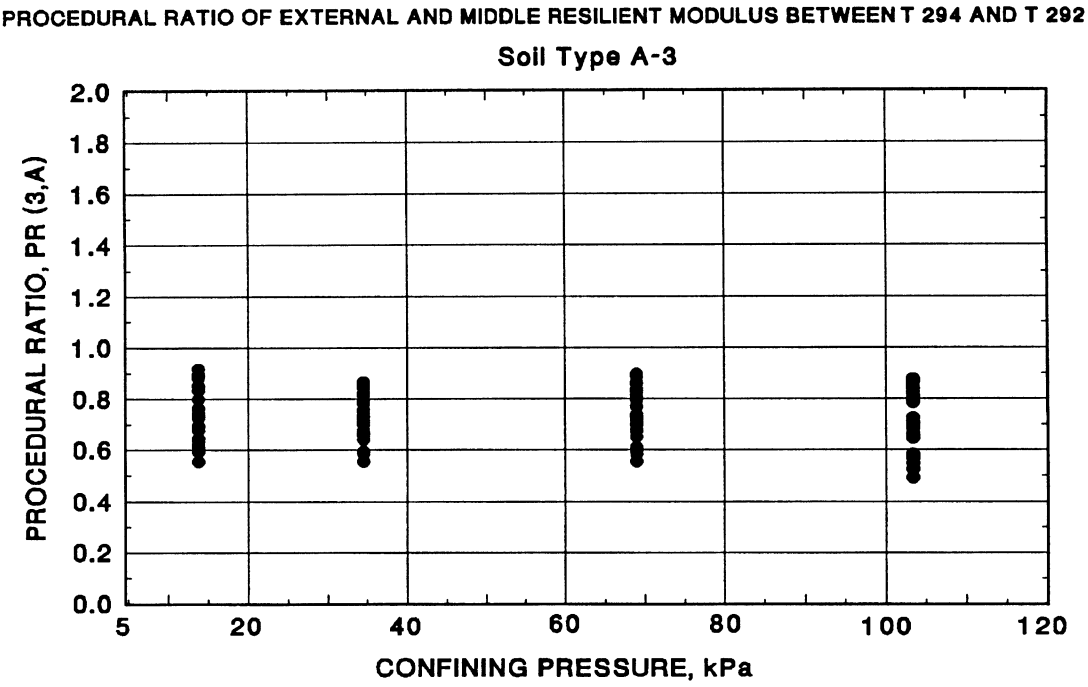


Figure 7.36 Procedural ratio of external and middle resilient modulus values for A-3 soil

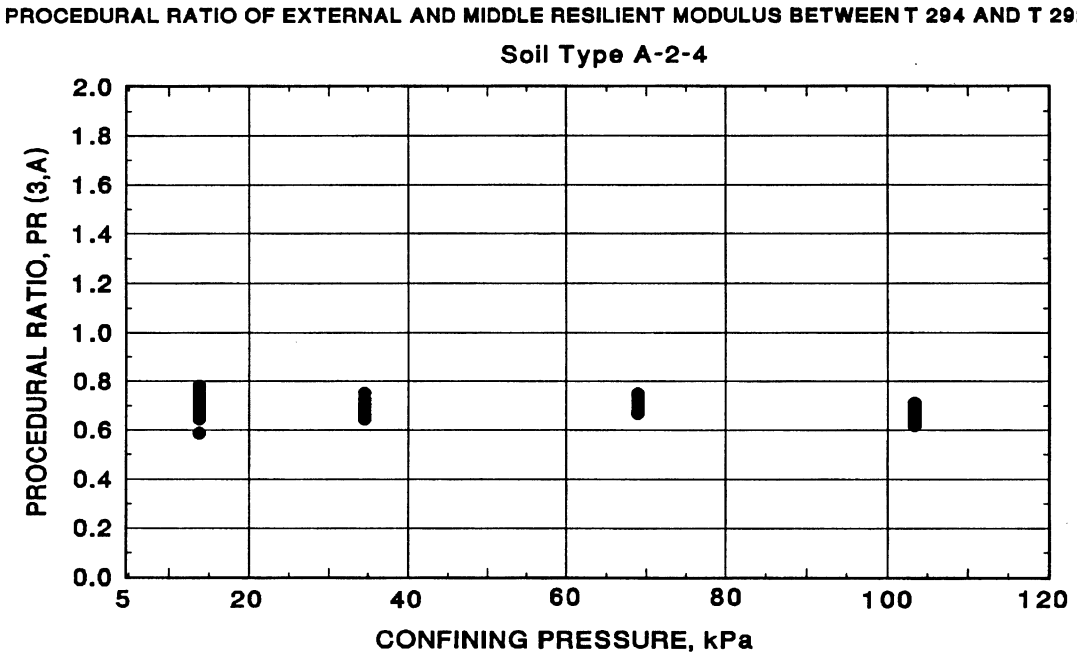


Figure 7.37 Procedural ratio of external and middle resilient modulus values for A-2-4 soil

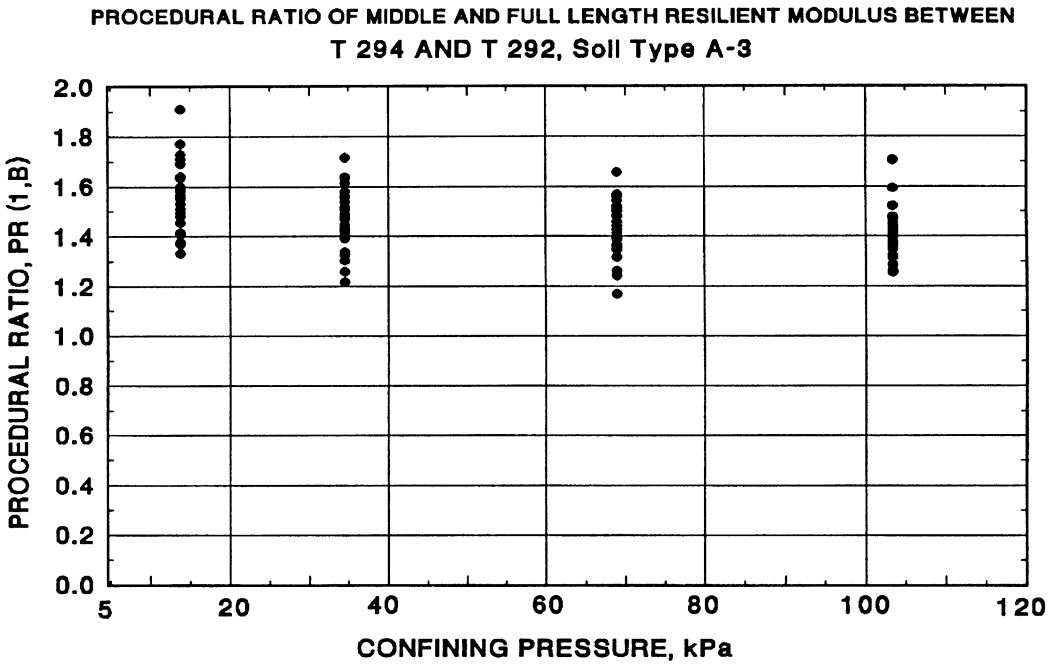


Figure 7.38 Procedural ratio of middle and full length resilient modulus values for A-3 soil

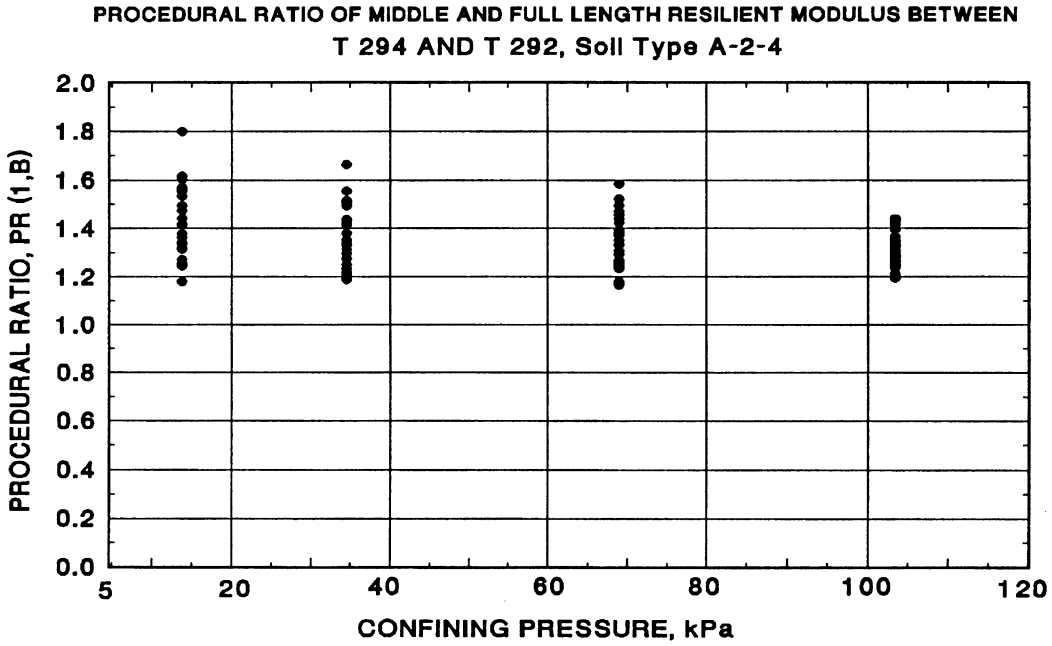


Figure 7.39 Procedural ratio of middle and full length resilient modulus values for A-2-4 soil

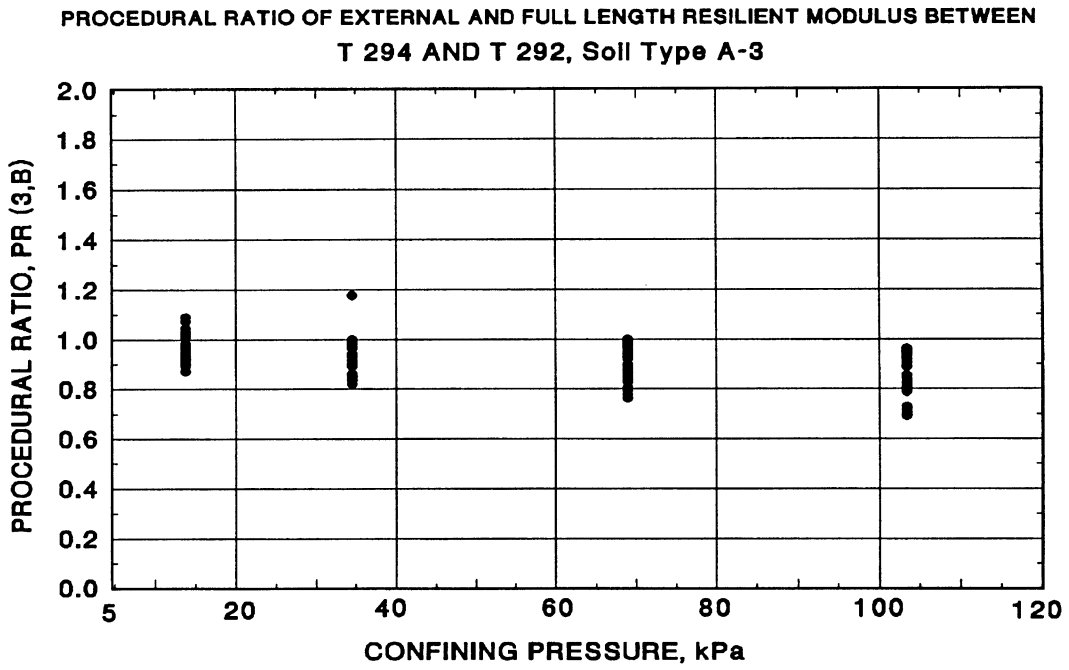


Figure 7.40 Procedural ratio of external and full length resilient modulus values for A-3 soil

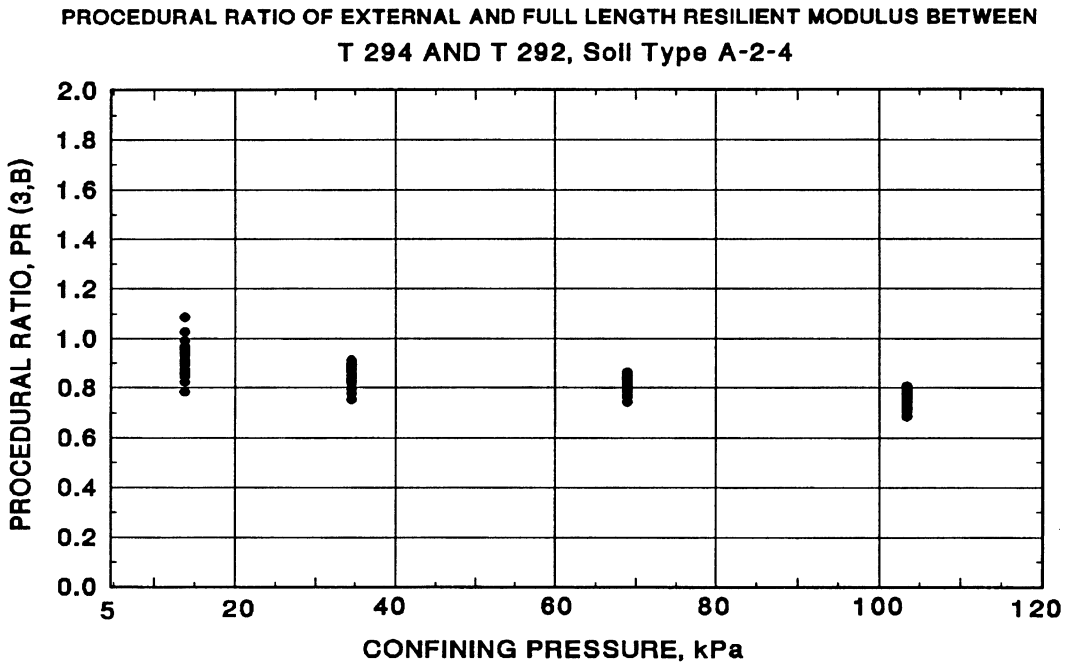


Figure 7.41 Procedural ratio of external and full length resilient modulus values for A-2-4 soil

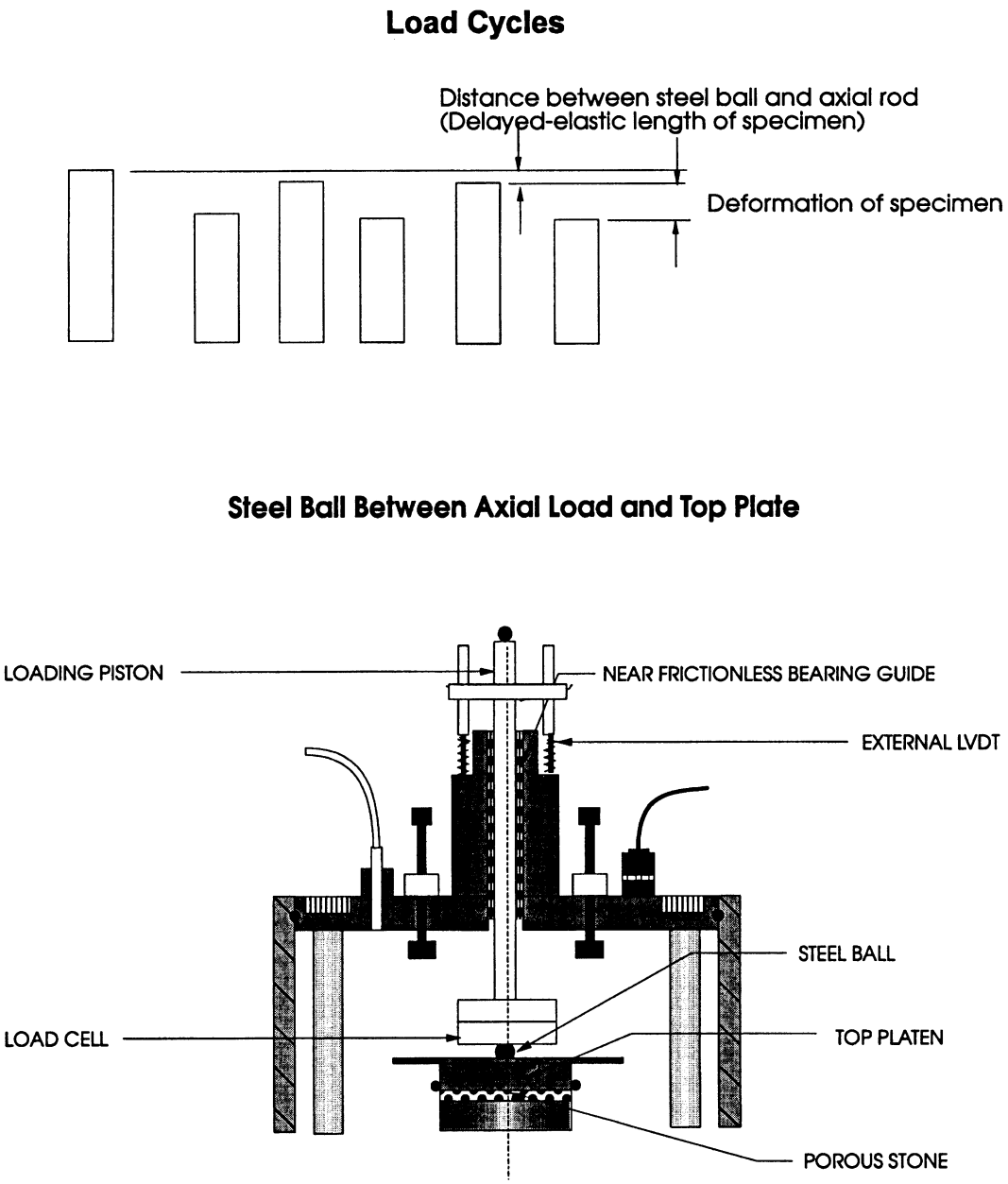


Figure 7.42 Error of apparatus in external LVDTs

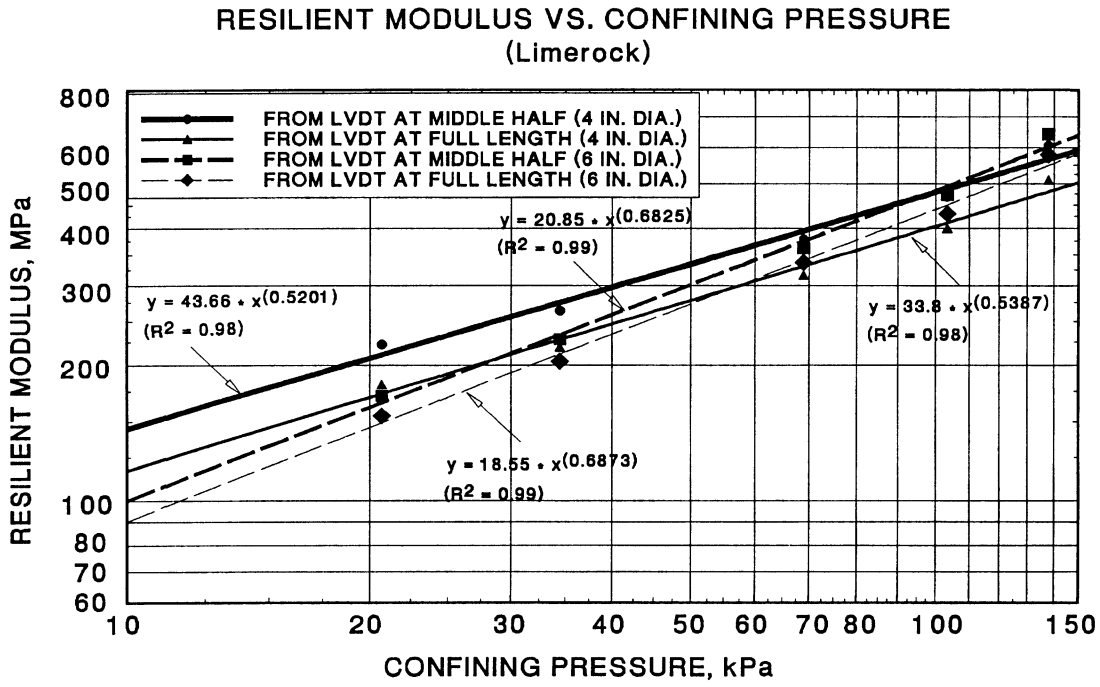


Figure 7.43 Resilient modulus versus confining pressure (4 in. versus 6 in.)

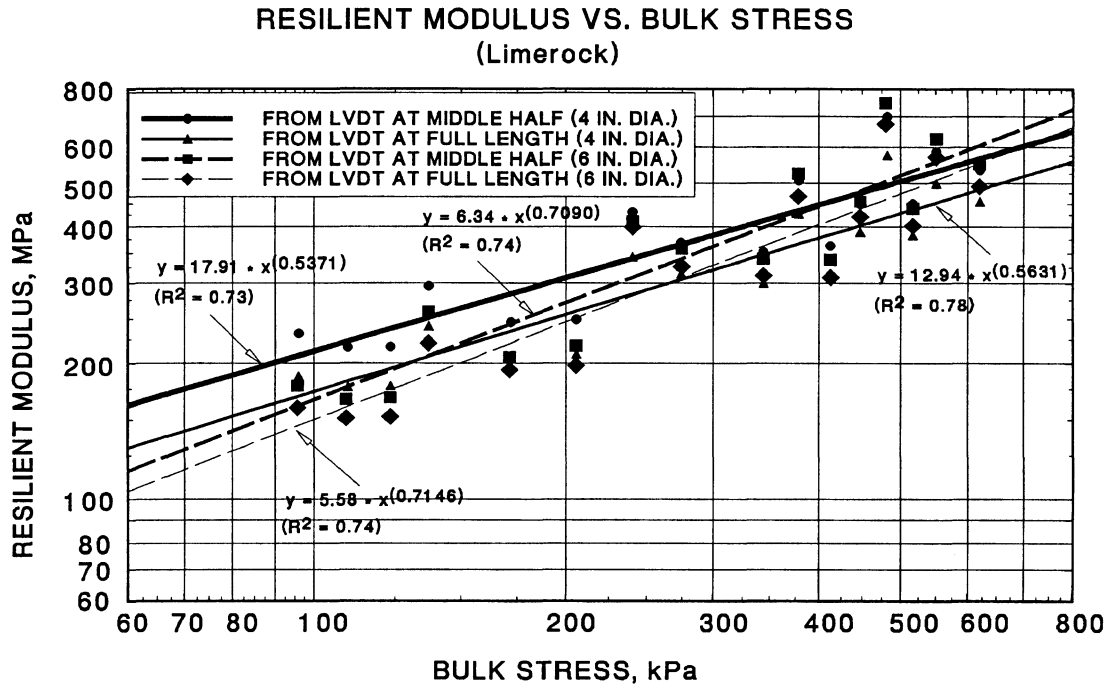


Figure 7.44 Resilient modulus versus bulk stress (4 in. versus 6 in.)

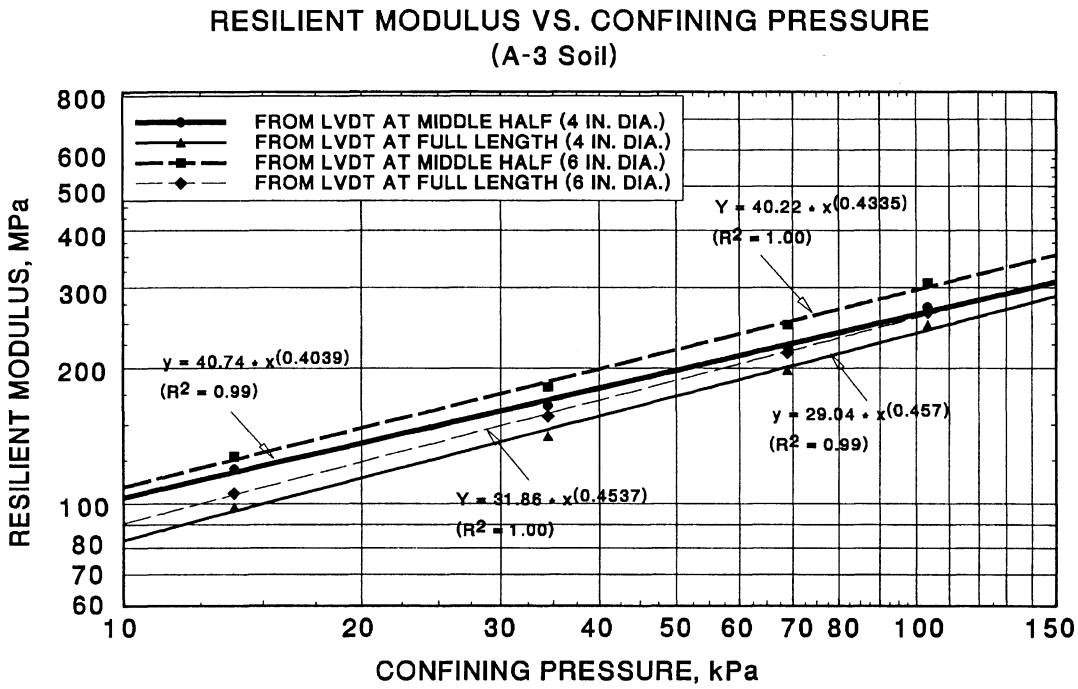


Figure 7.45 Resilient modulus versus confining pressure (4 in. versus 6 in.)

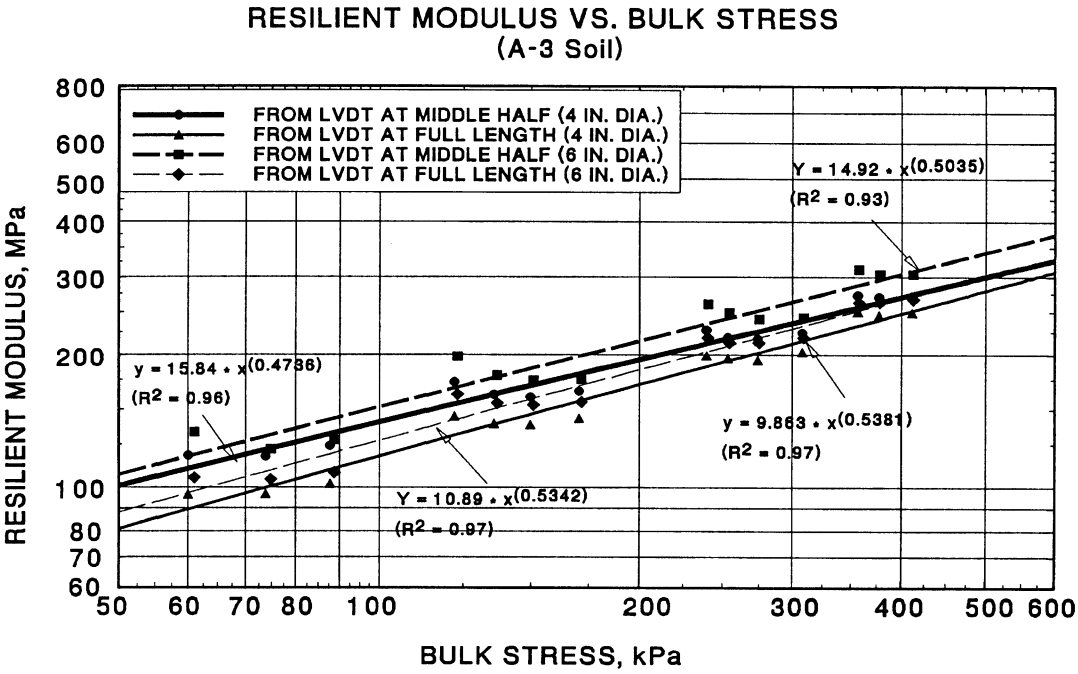


Figure 7.46 Resilient modulus versus bulk stress (4 in. versus 6 in.)

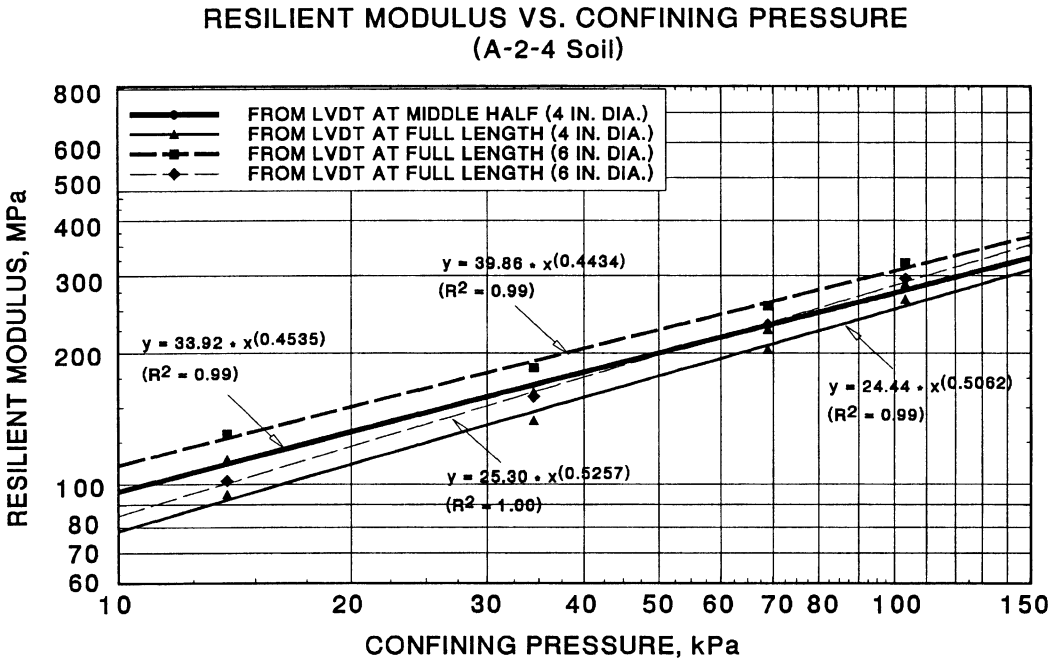


Figure 7.47 Resilient modulus versus confining pressure (4 in. versus 6 in.)

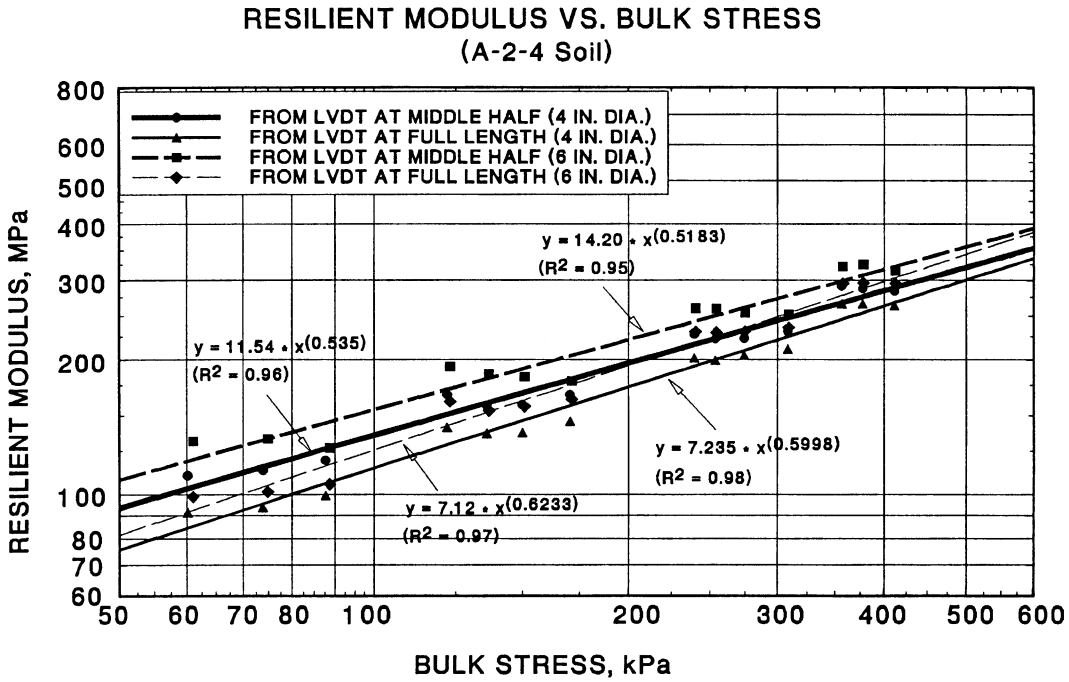


Figure 7.48 Resilient modulus versus bulk stress (4 in. versus 6 in.)

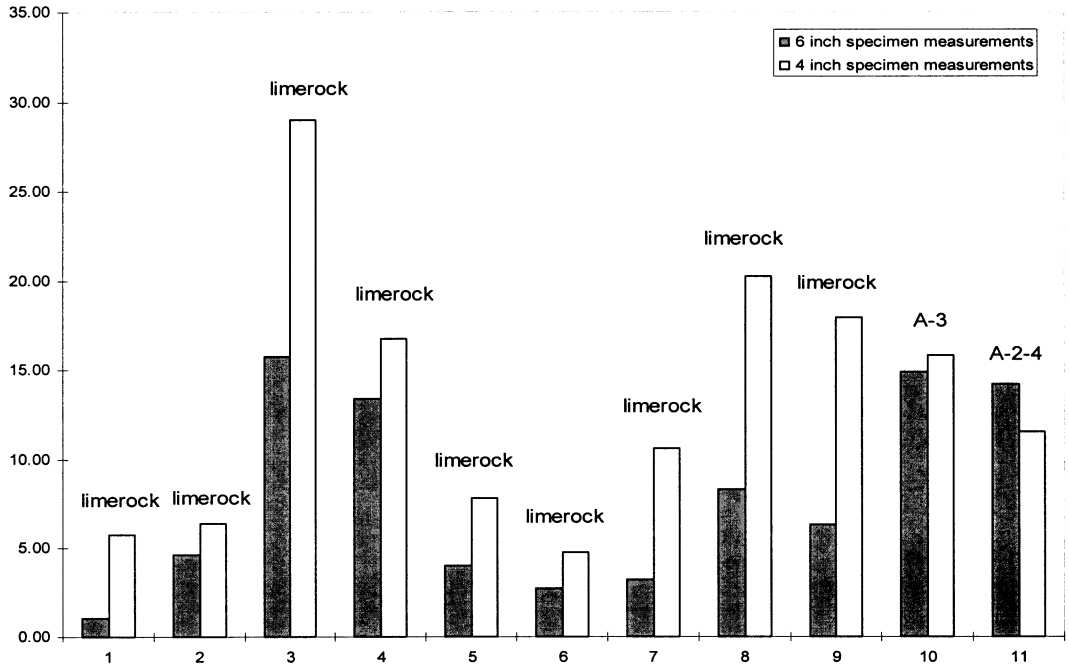


Figure 7.49 Comparison of k_1 values from middle half measurements

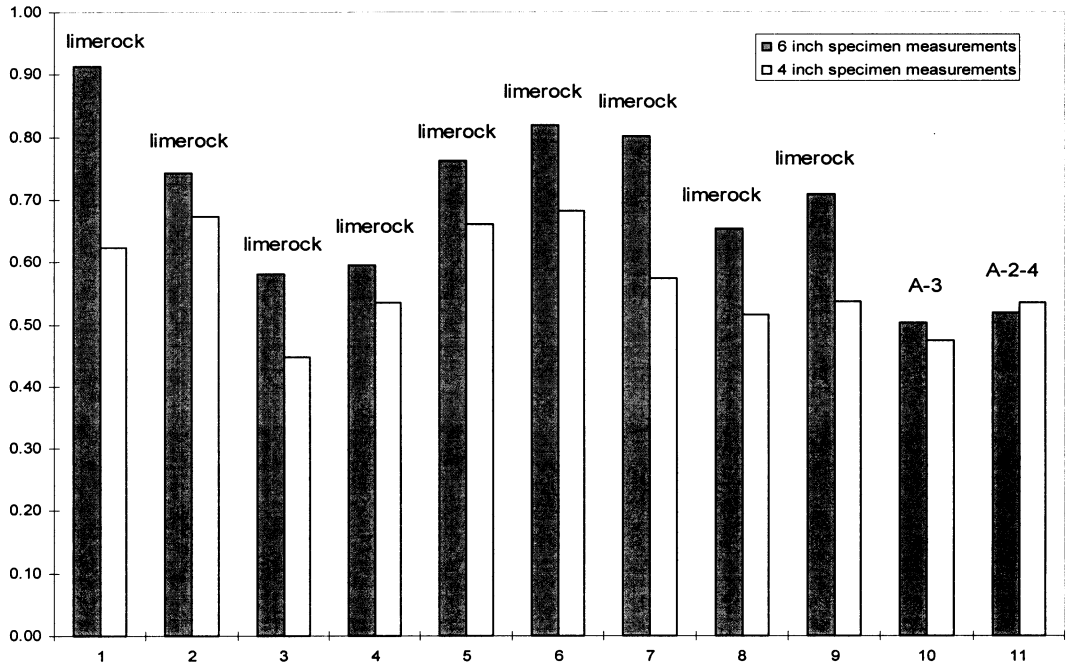


Figure 7.50 Comparison of k_2 values from middle half measurements

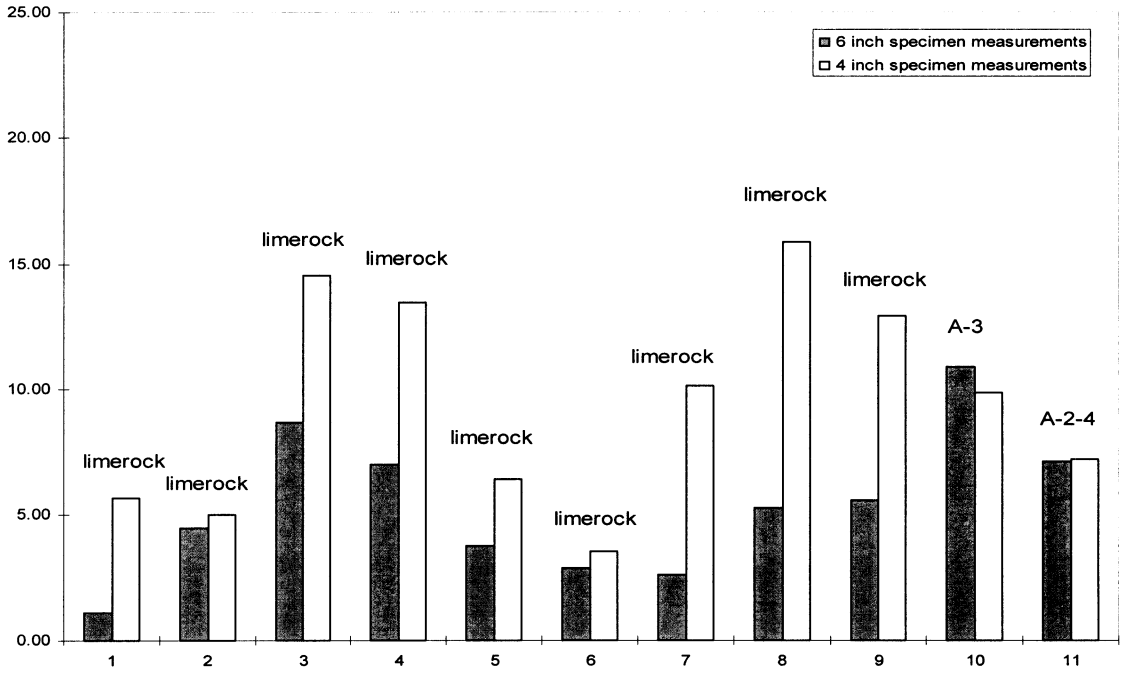


Figure 7.51 Comparison of k_1 values from full length measurements

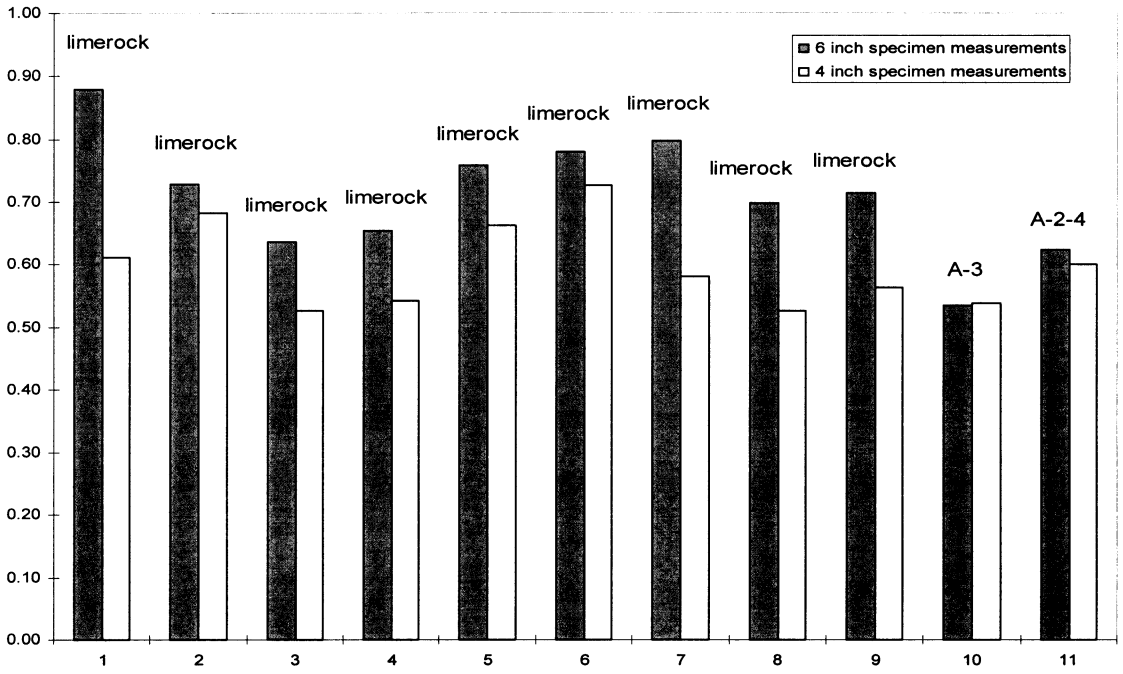


Figure 7.52 Comparison of k_2 values from full length measurements

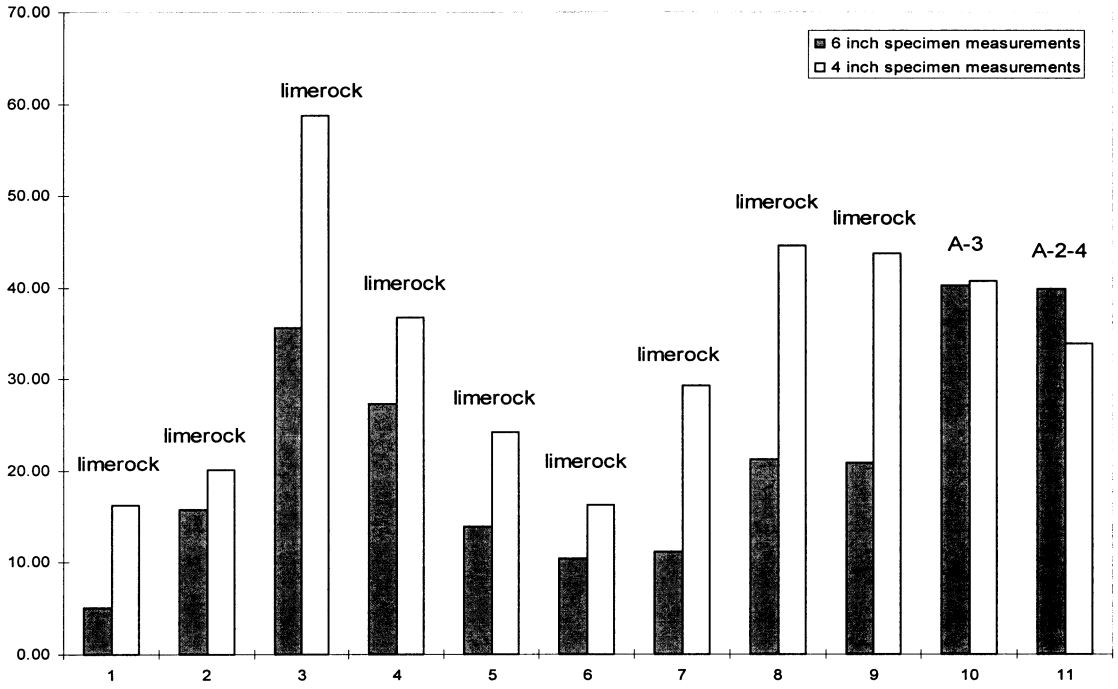


Figure 7.53 Comparison of k_3 values from middle half measurements

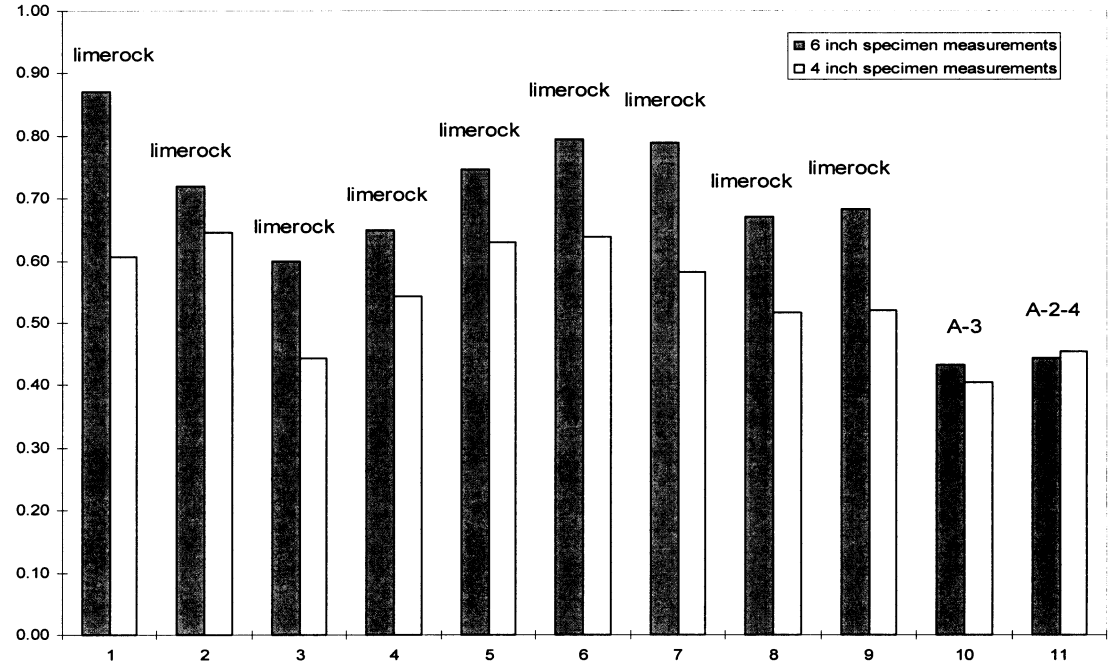


Figure 7.54 Comparison of k_4 values from middle half measurements

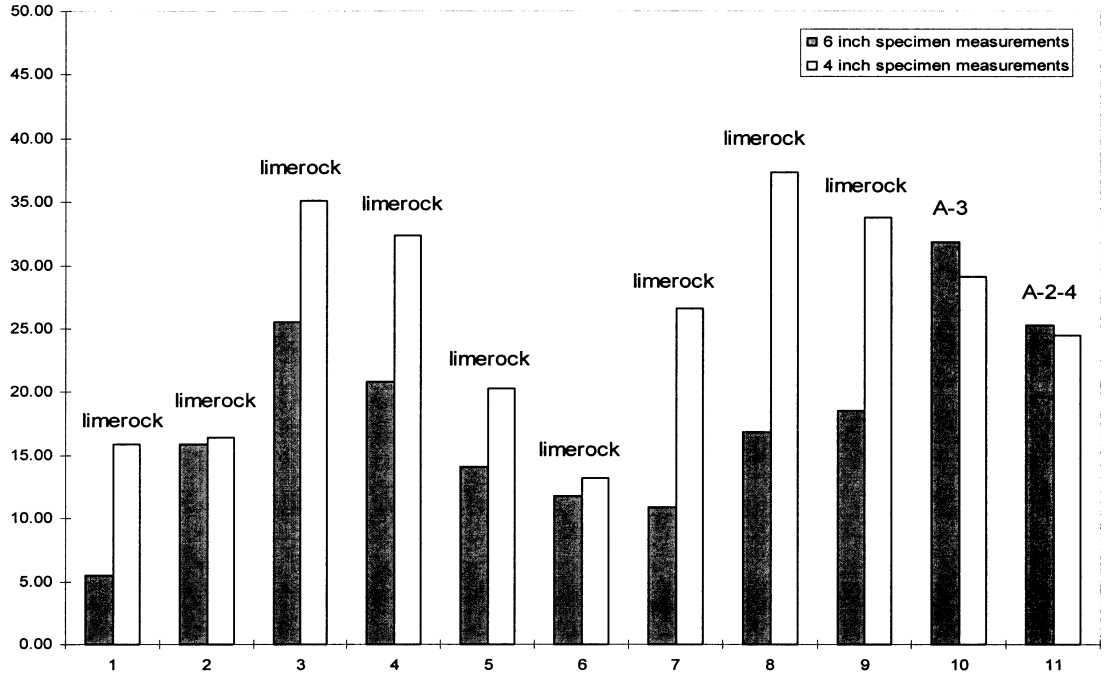


Figure 7.55 Comparison of k_3 values from full length measurements

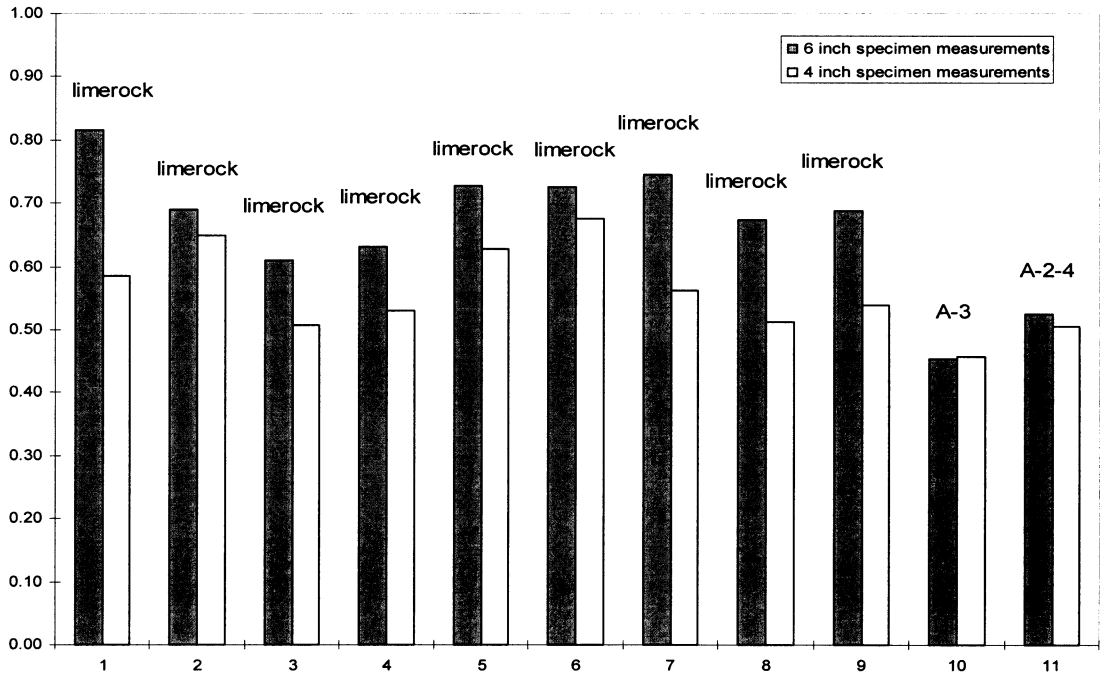


Figure 7.56 Comparison of k_4 values from full length measurements

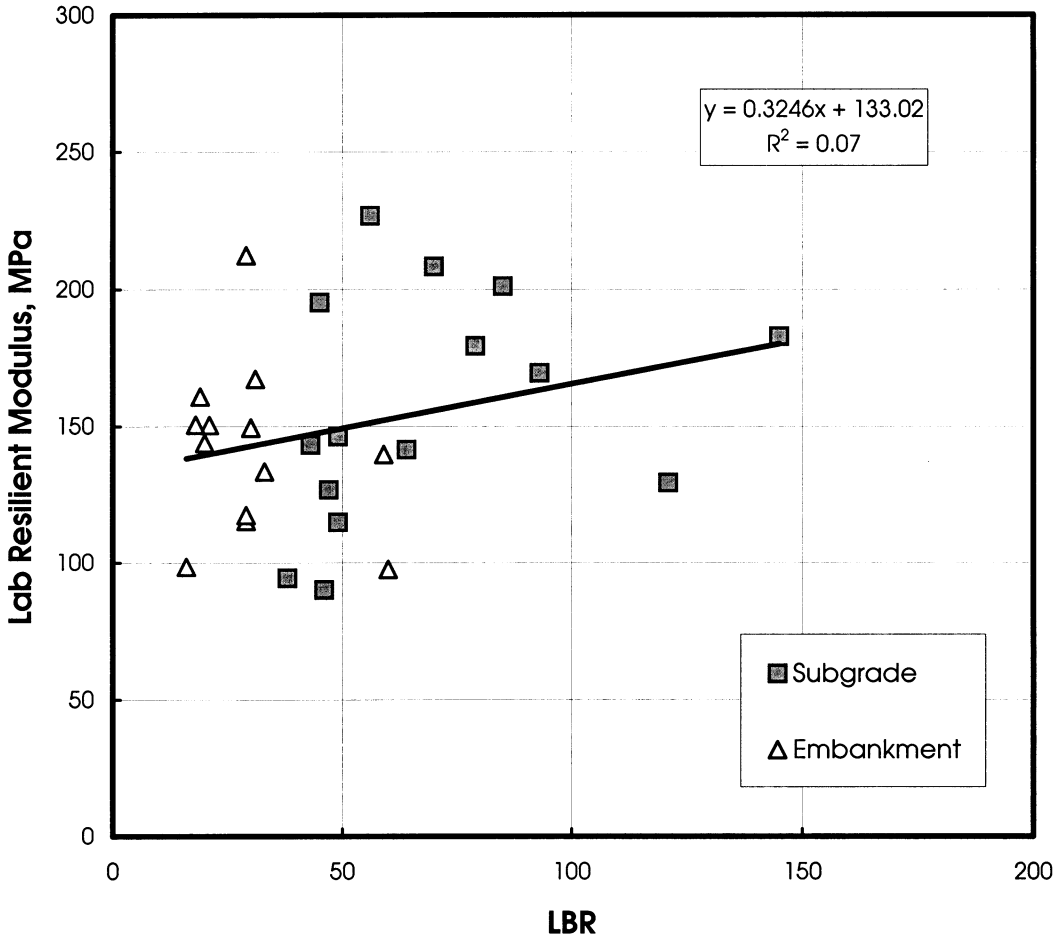


Figure 7.57a Comparison of LBR with laboratory resilient modulus at OMC, confining pressure 2 psi

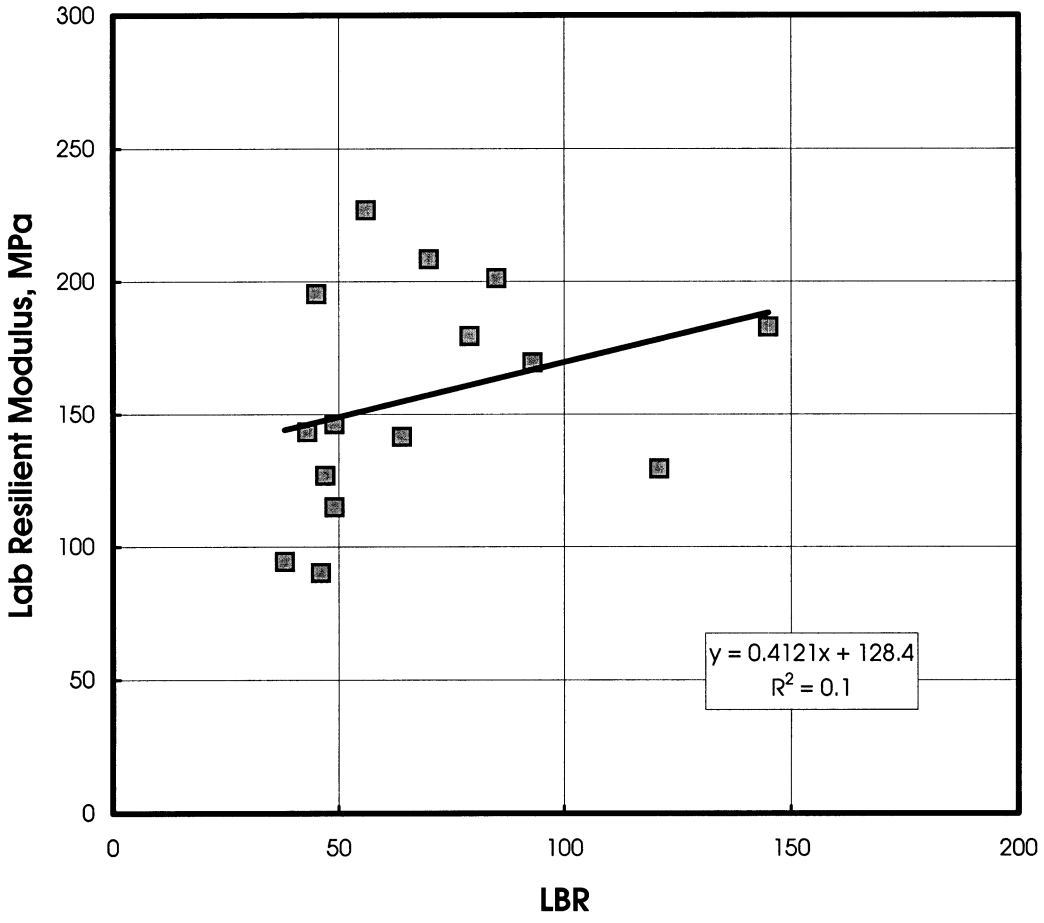


Figure 7.57b Comparison of LBR with laboratory resilient modulus at OMC, confining pressure 2 psi (Subgrade)

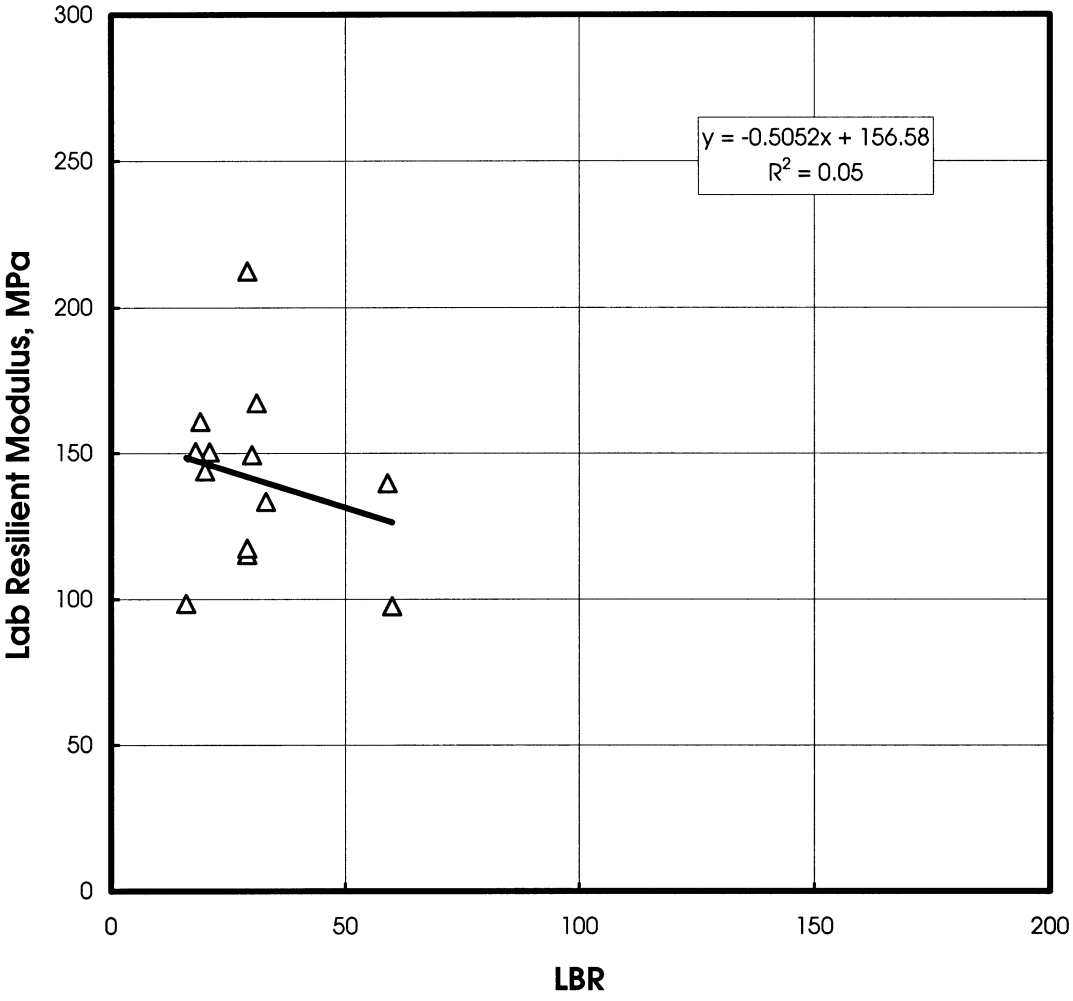


Figure 7.57c Comparison of LBR with laboratory resilient modulus at OMC, confining pressure 2 psi (Embankment)

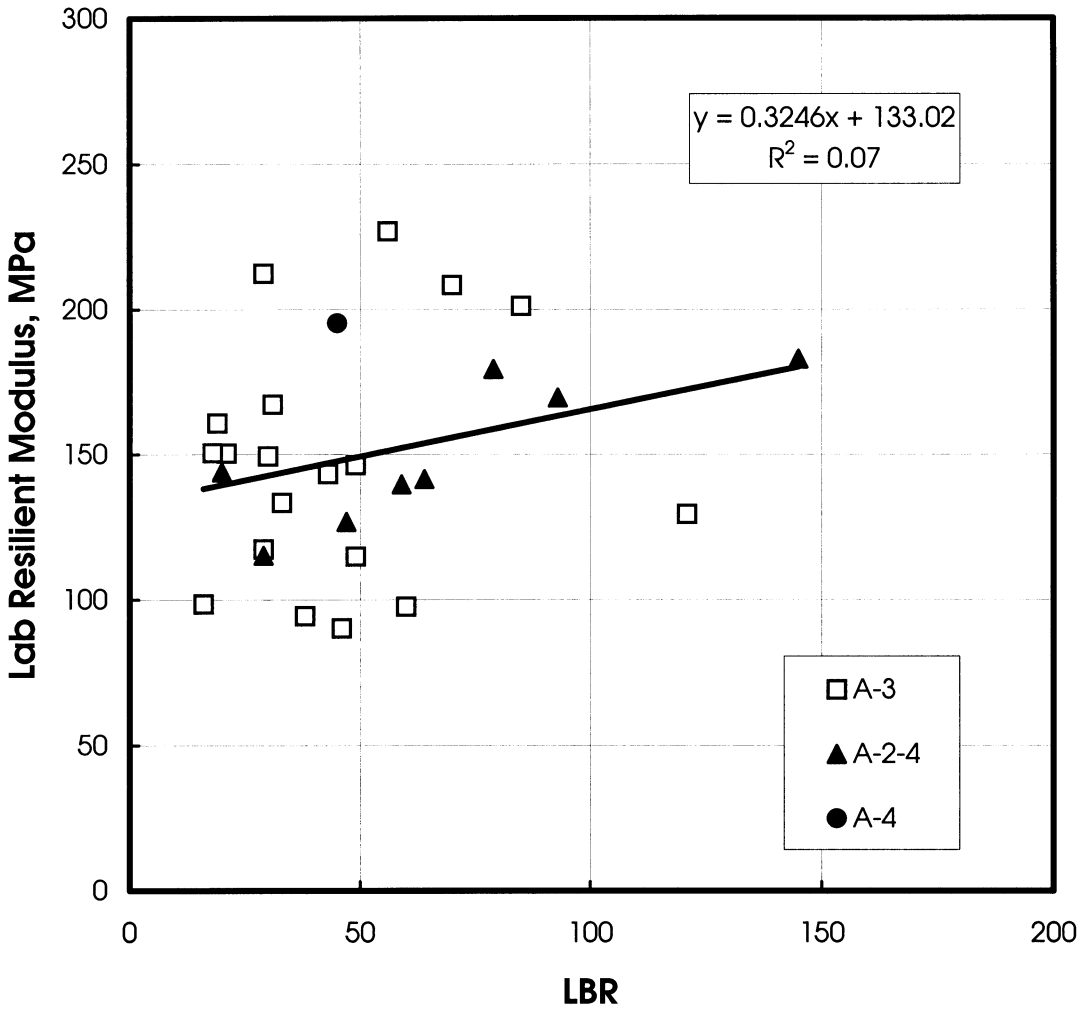


Figure 7.58a Comparison of LBR with laboratory resilient modulus at OMC, confining pressure 2 psi (by pavement materials)

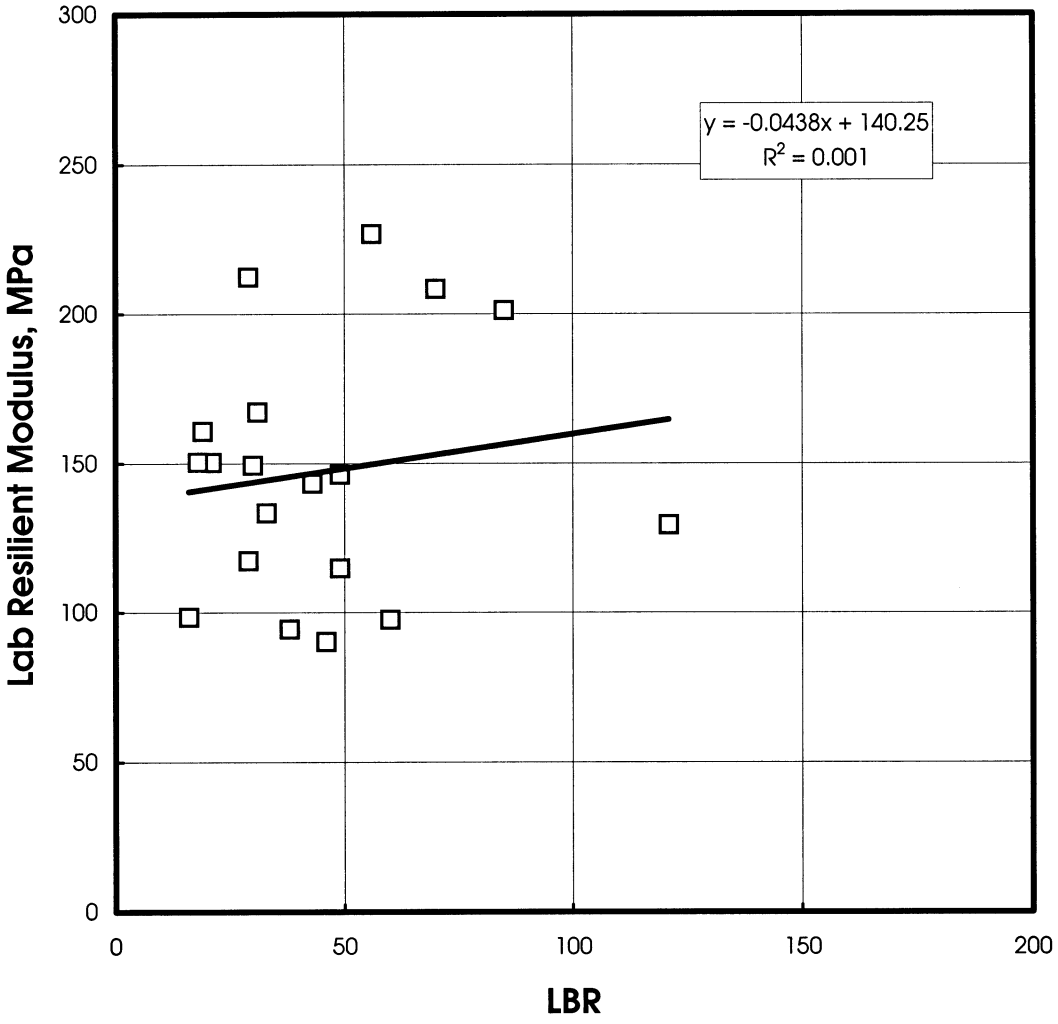


Figure 7.58b Comparison of LBR with laboratory resilient modulus at OMC, confining pressure 2 psi (A-3)

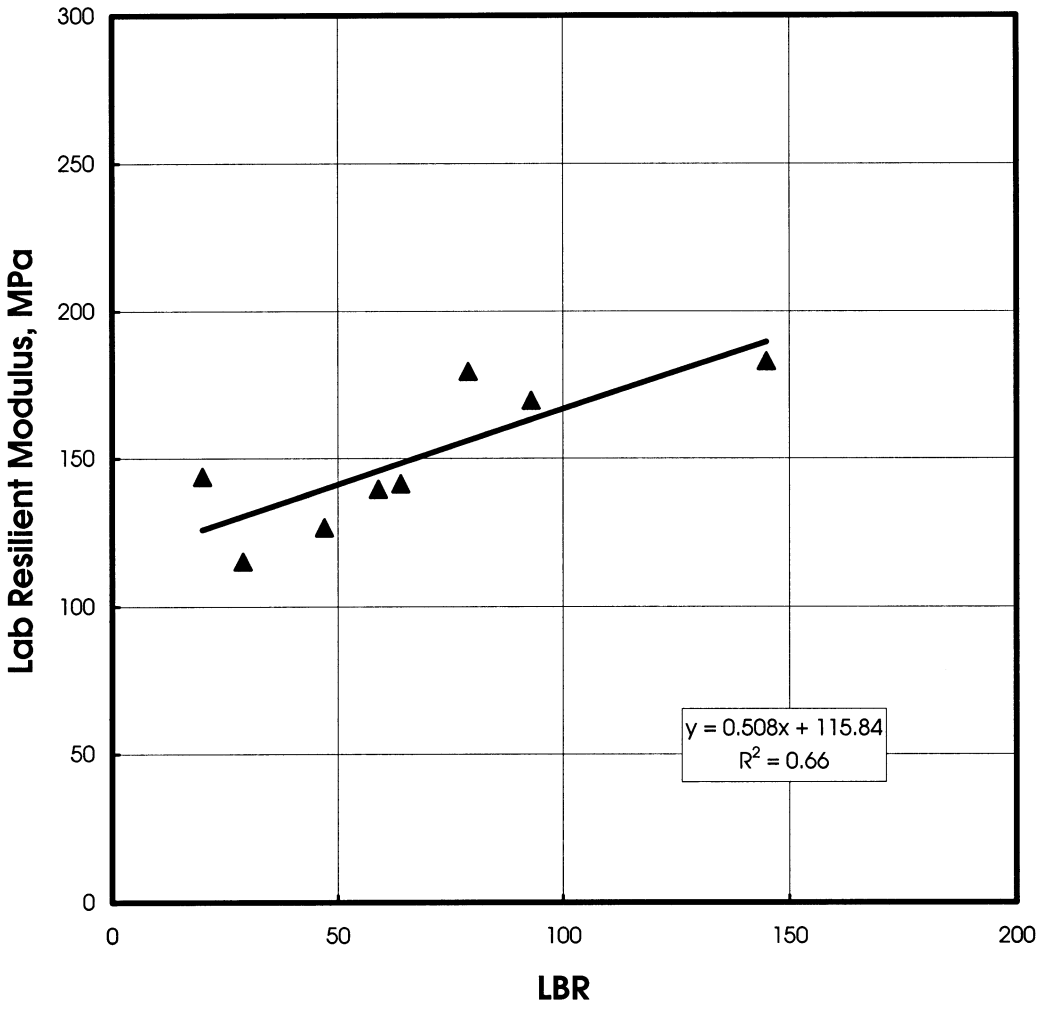


Figure 7.58c Comparison of LBR with laboratory resilient modulus at OMC, confining pressure 2 psi (A-2-4)

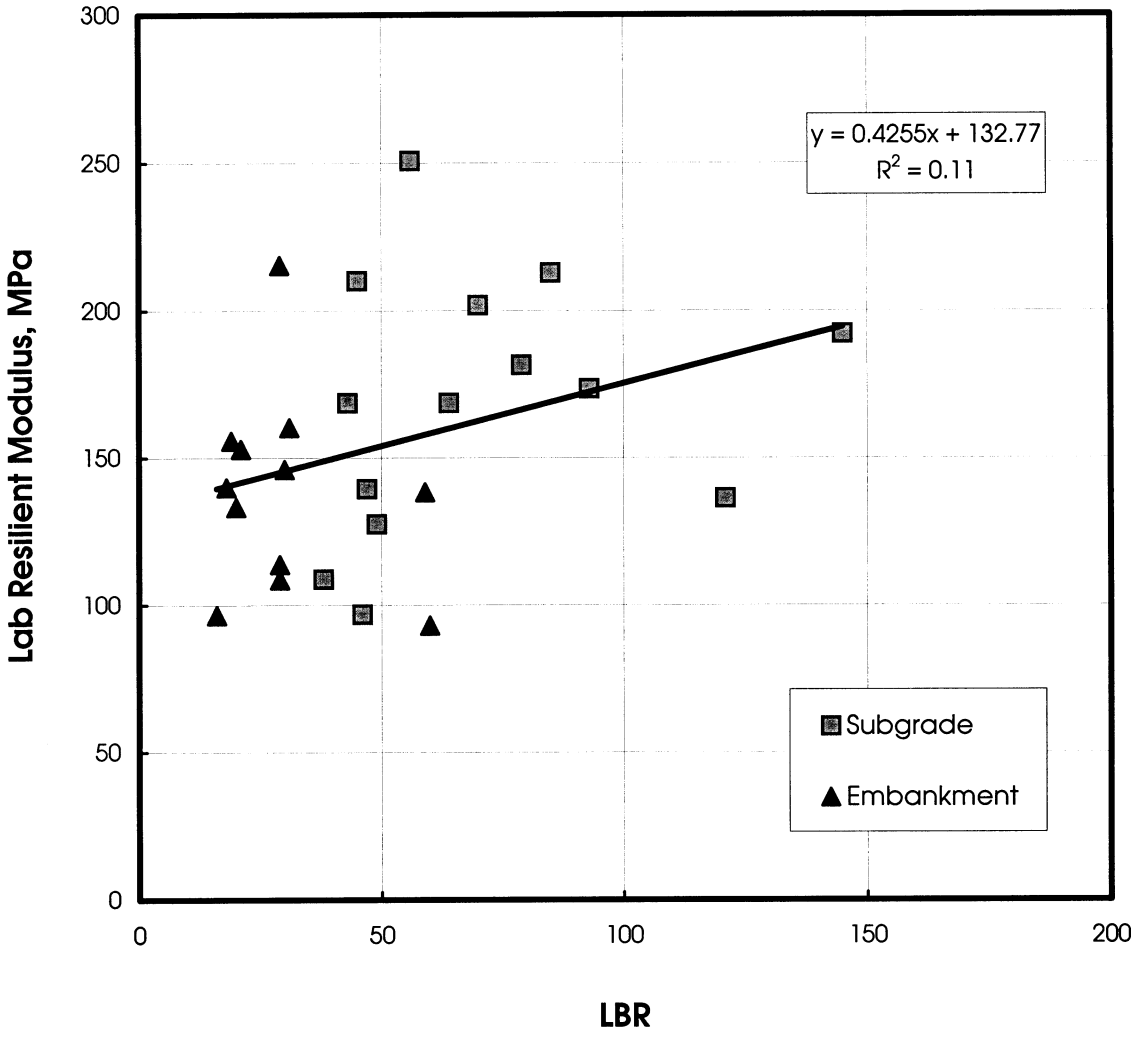


Figure 7.59a Comparison of LBR with laboratory resilient modulus at OMC, state of stresses caused by traffic

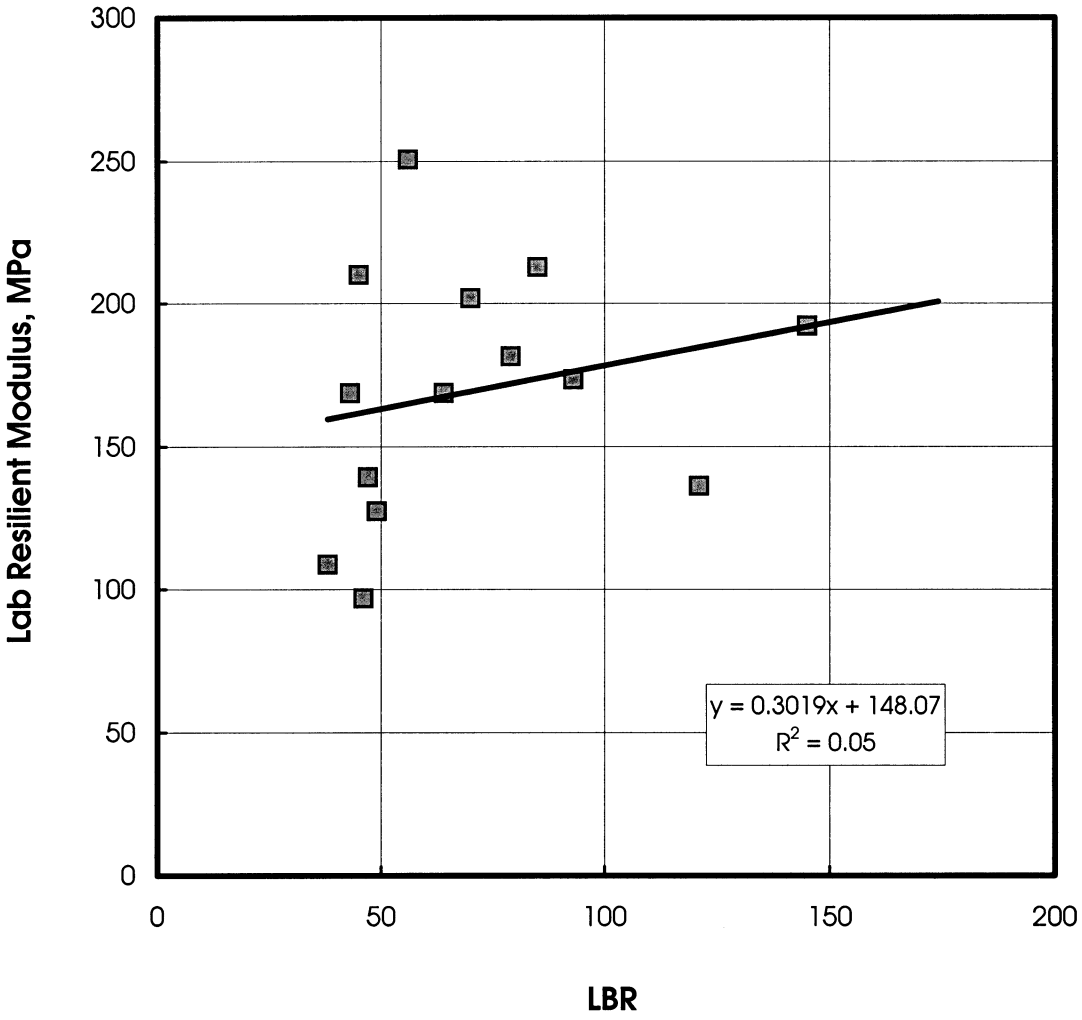


Figure 7.59b Comparison of LBR with laboratory resilient modulus at OMC, state of stresses caused by traffic (Subgrade)

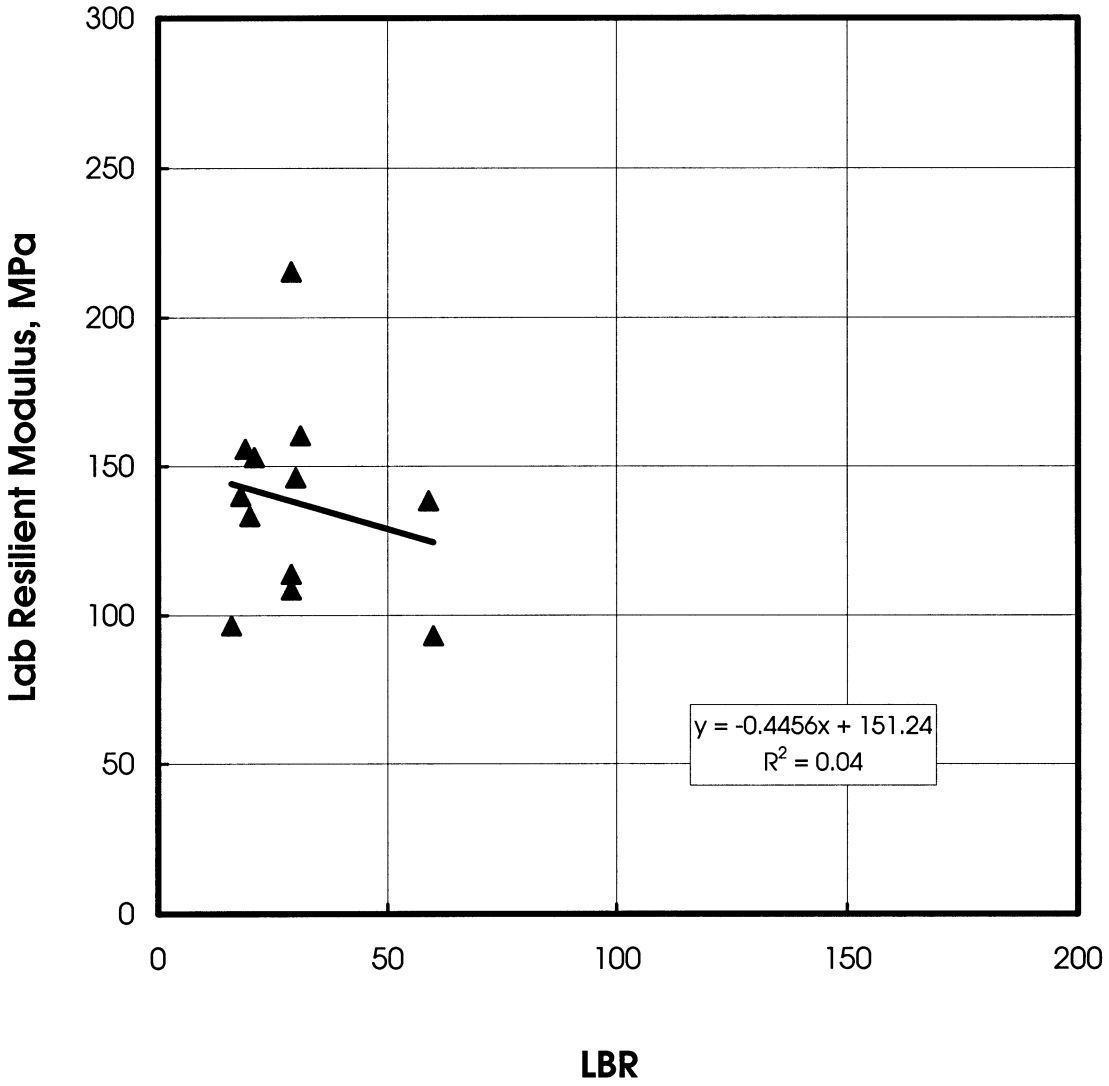


Figure 7.59c Comparison of LBR with laboratory resilient modulus at OMC, state of stresses caused by traffic (Embankment)

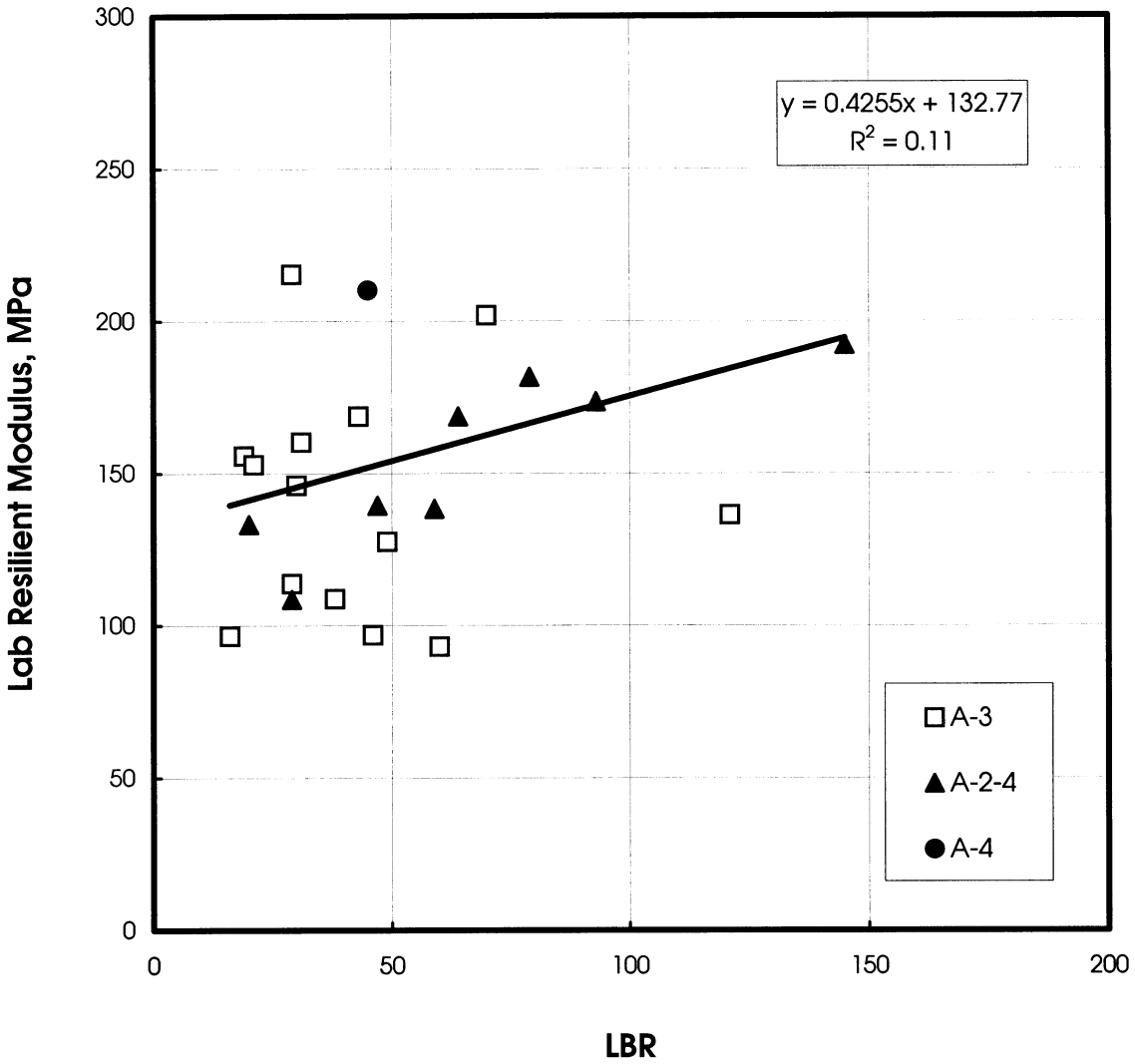


Figure 7.60a Comparison of LBR with laboratory resilient modulus at OMC, state of stresses caused by traffic (by pavement materials)

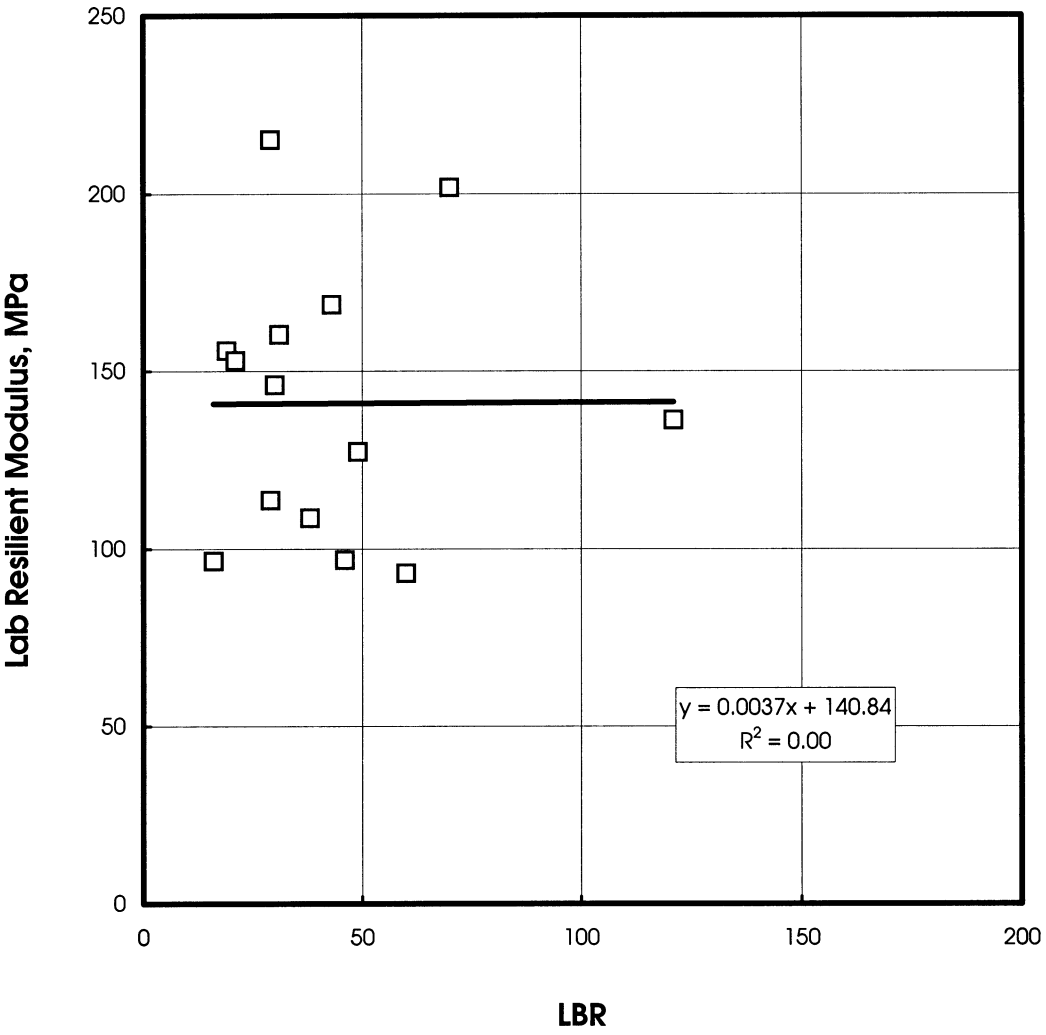


Figure 7.60b Comparison of LBR with laboratory resilient modulus at OMC, state of stresses caused by traffic (A-3)

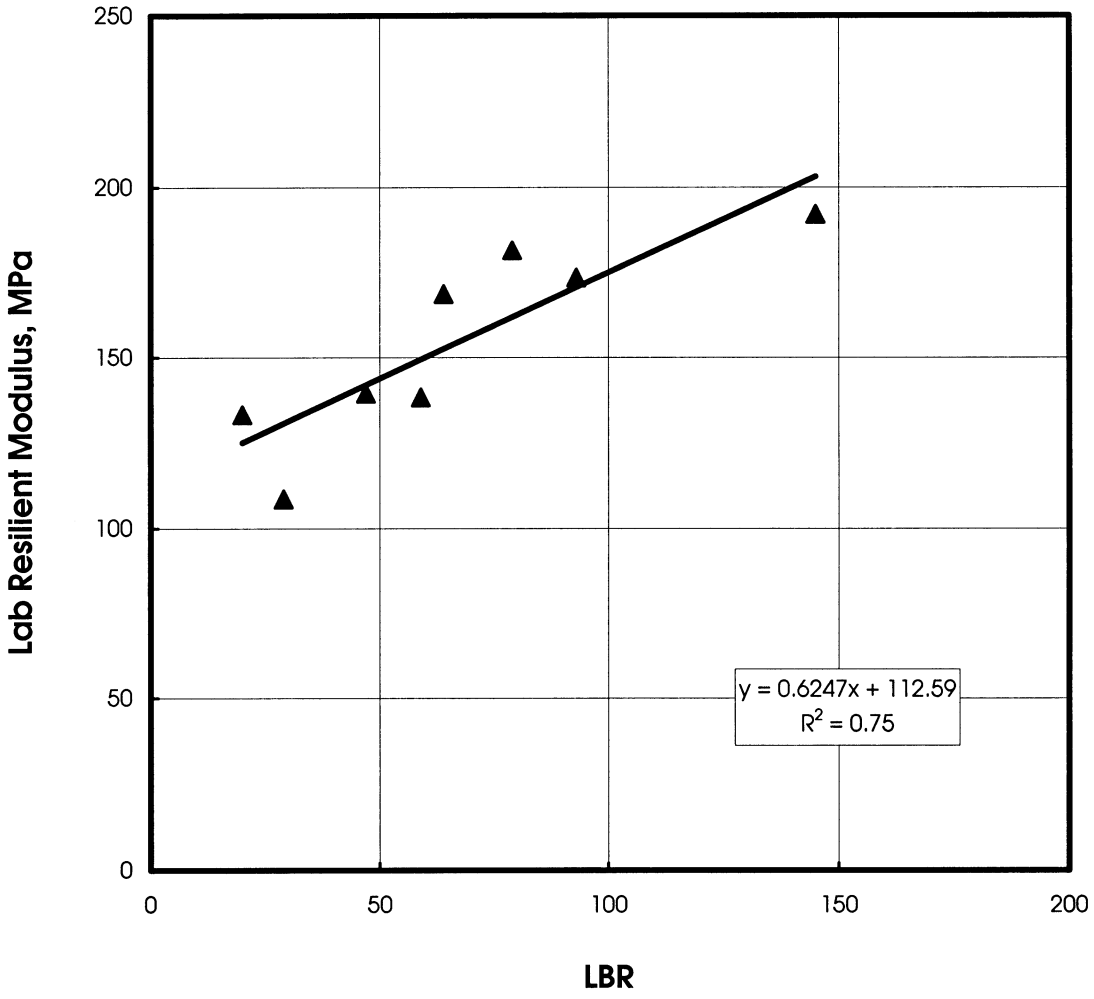


Figure 7.60b Comparison of LBR with laboratory resilient modulus at OMC, state of stresses caused by traffic (A-2-4)

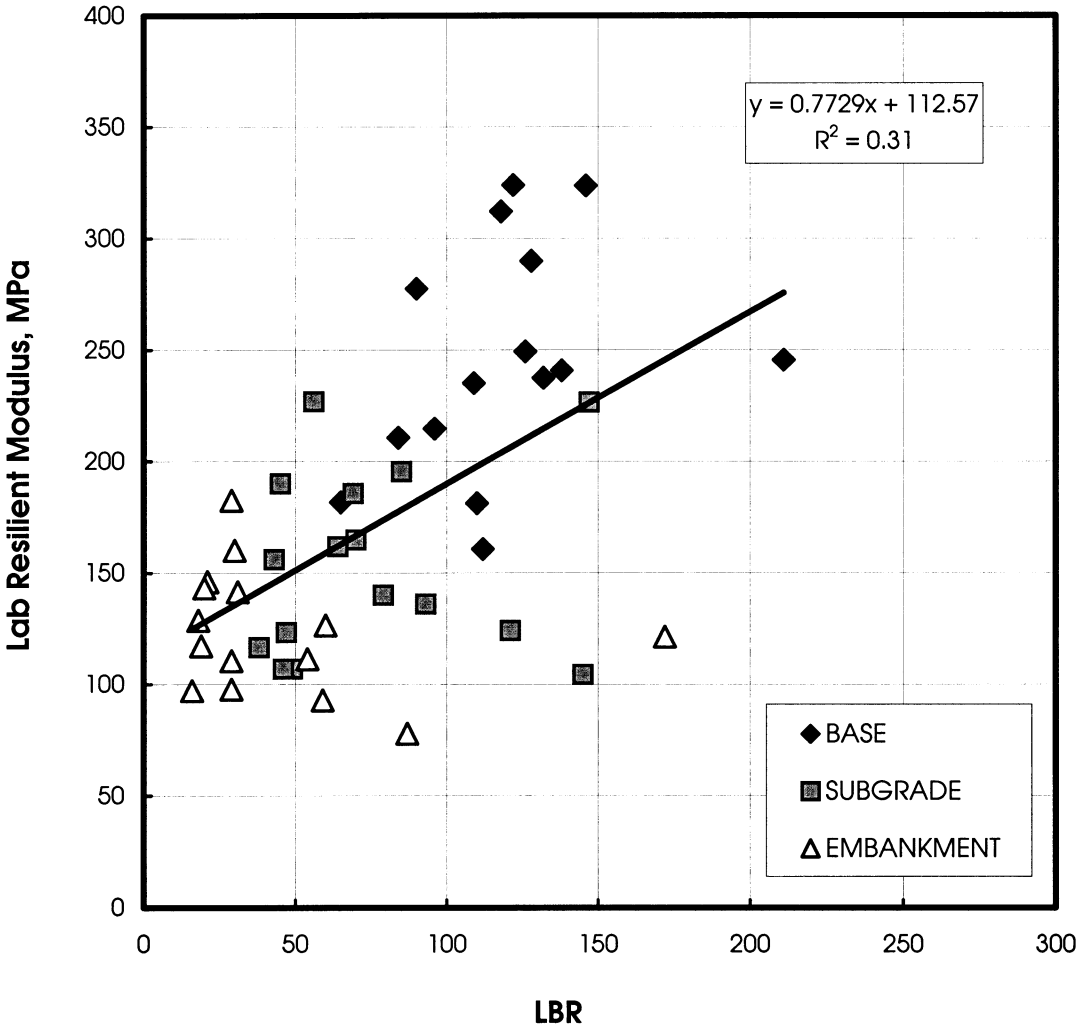


Figure 7.61a Comparison of LBR with laboratory resilient modulus at in-situ MC, state of stresses caused by traffic

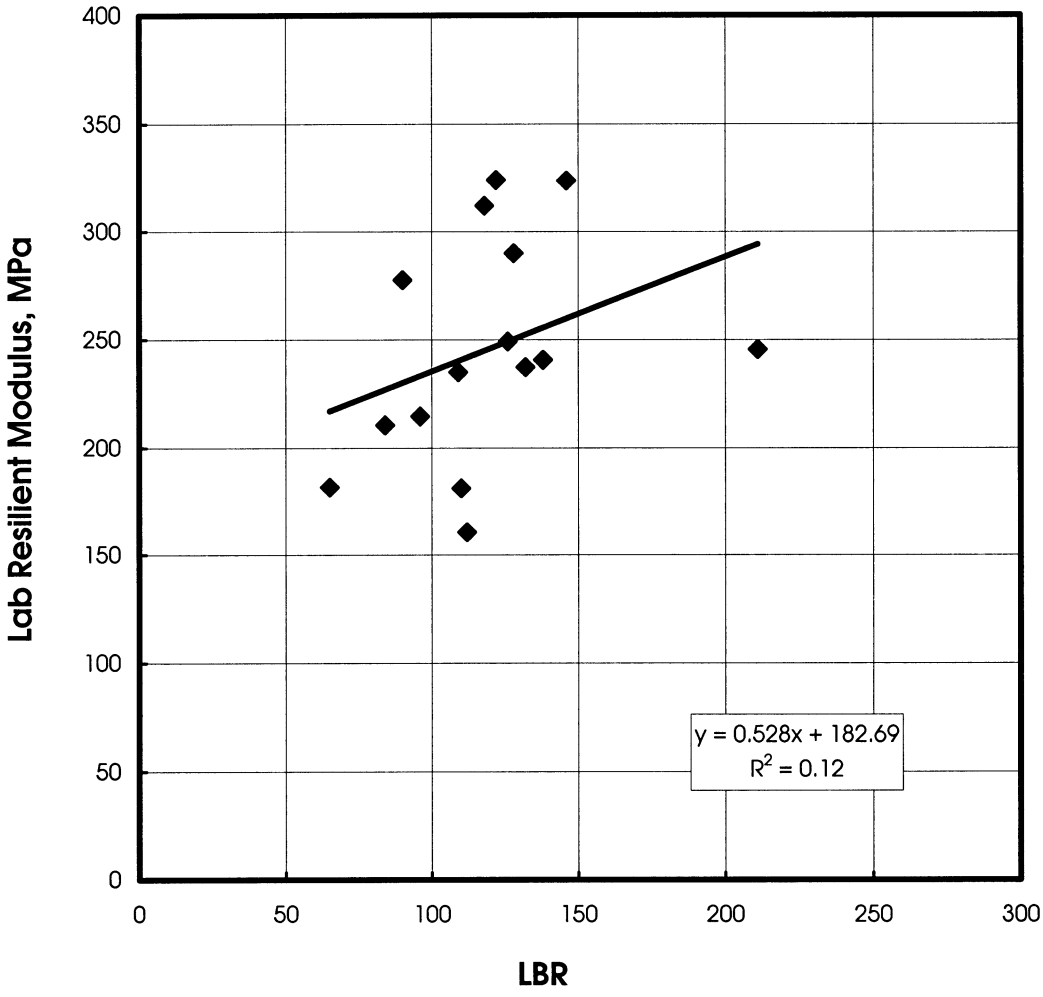


Figure 7.61b Comparison of LBR with laboratory resilient modulus at in-situ MC, state of stresses caused by traffic (Base)

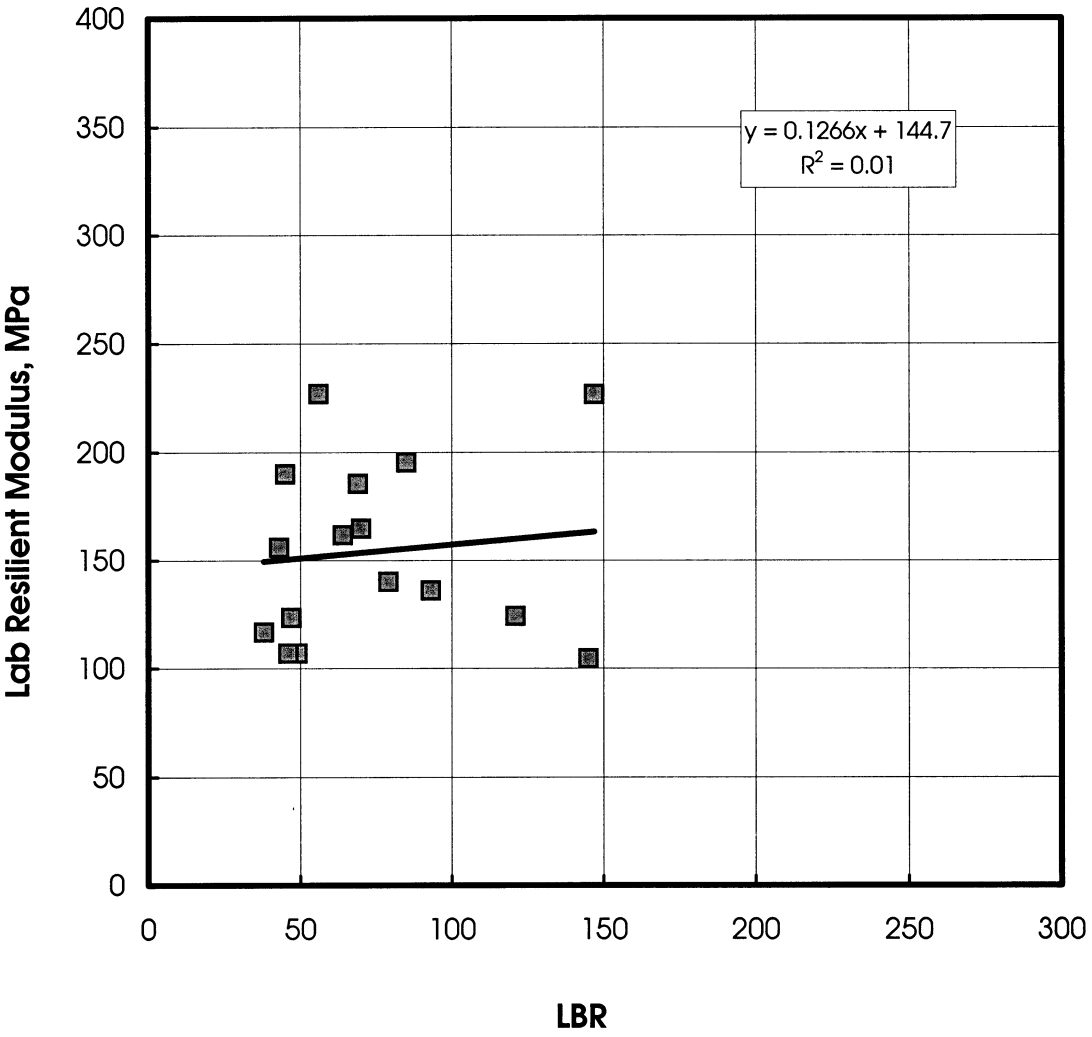


Figure 7.61c Comparison of LBR with laboratory resilient modulus at in-situ MC, state of stresses caused by traffic (Subgrade)

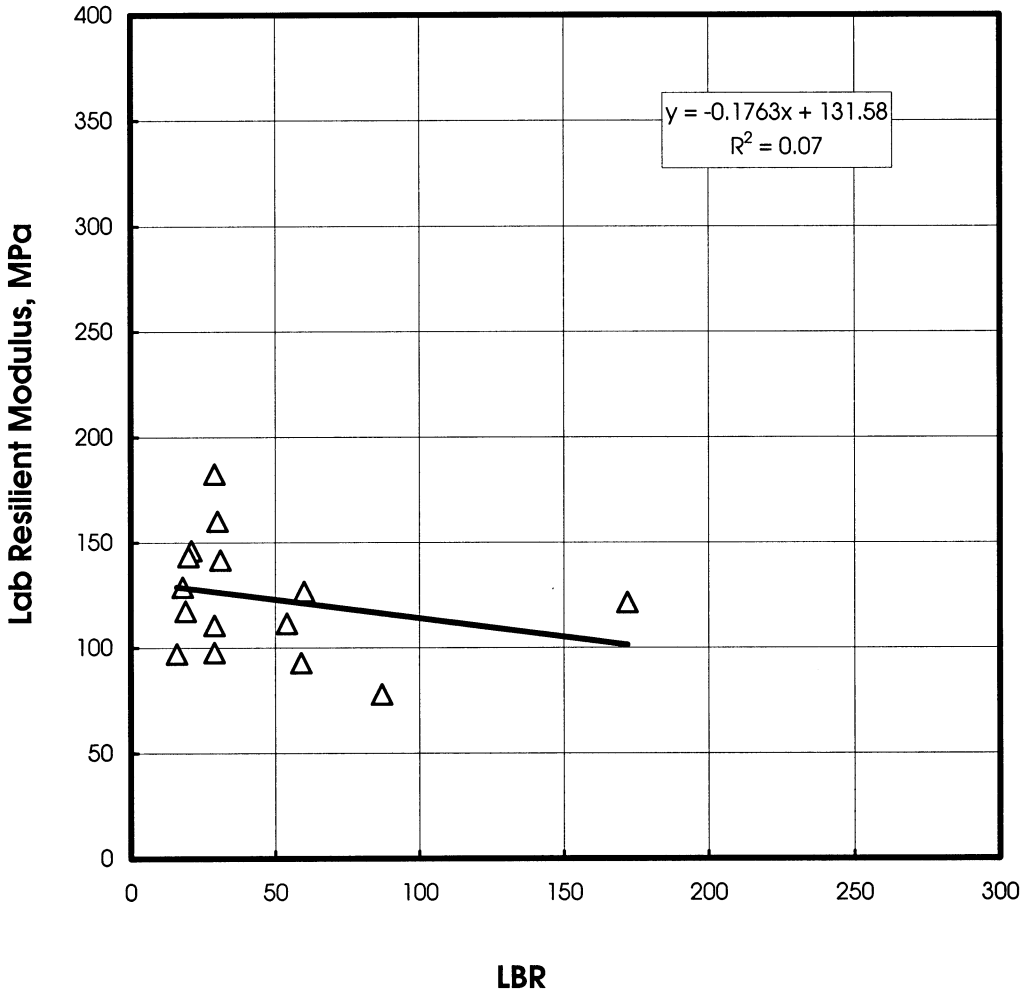


Figure 7.61d Comparison of LBR with laboratory resilient modulus at in-situ MC, state of stresses caused by traffic (Embankment)

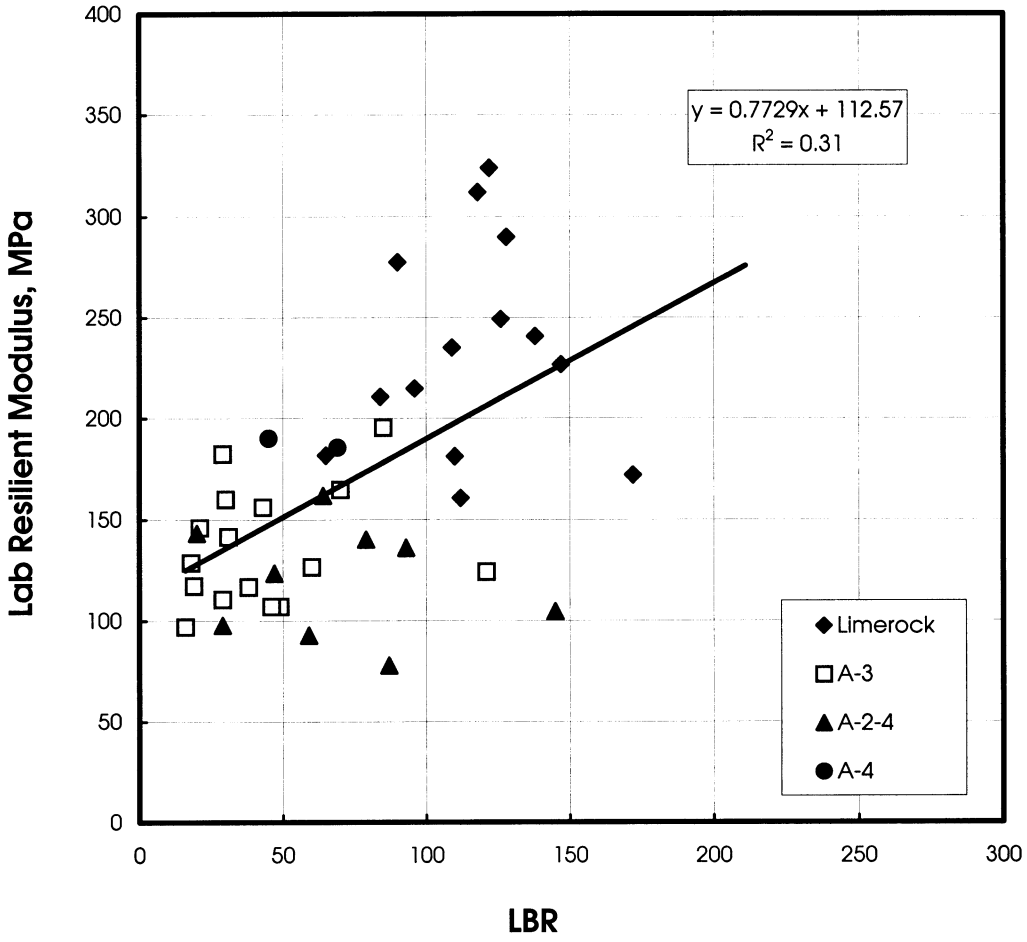


Figure 7.62a Comparison of LBR with laboratory resilient modulus at in-situ MC, state of stresses caused by traffic (by pavement materials)

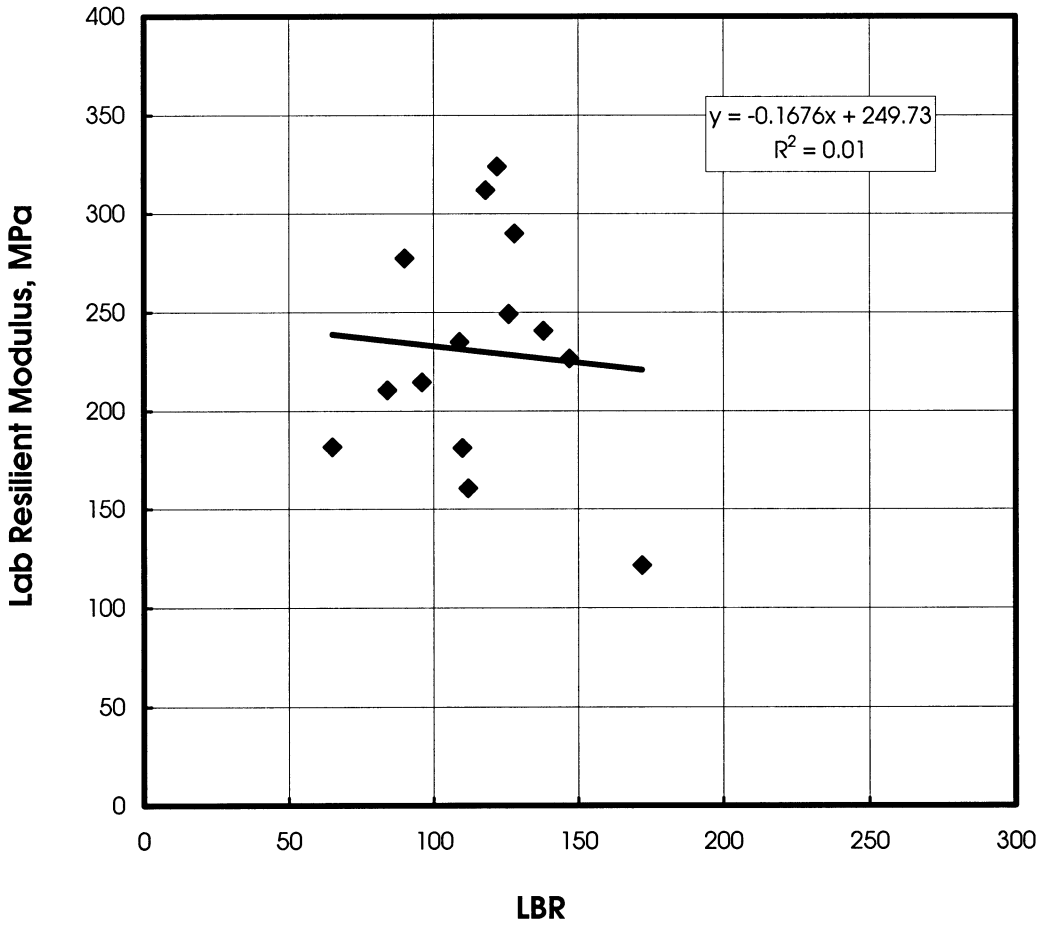


Figure 7.62b Comparison of LBR with laboratory resilient modulus at in-situ MC, state of stresses caused by traffic (Limerock)

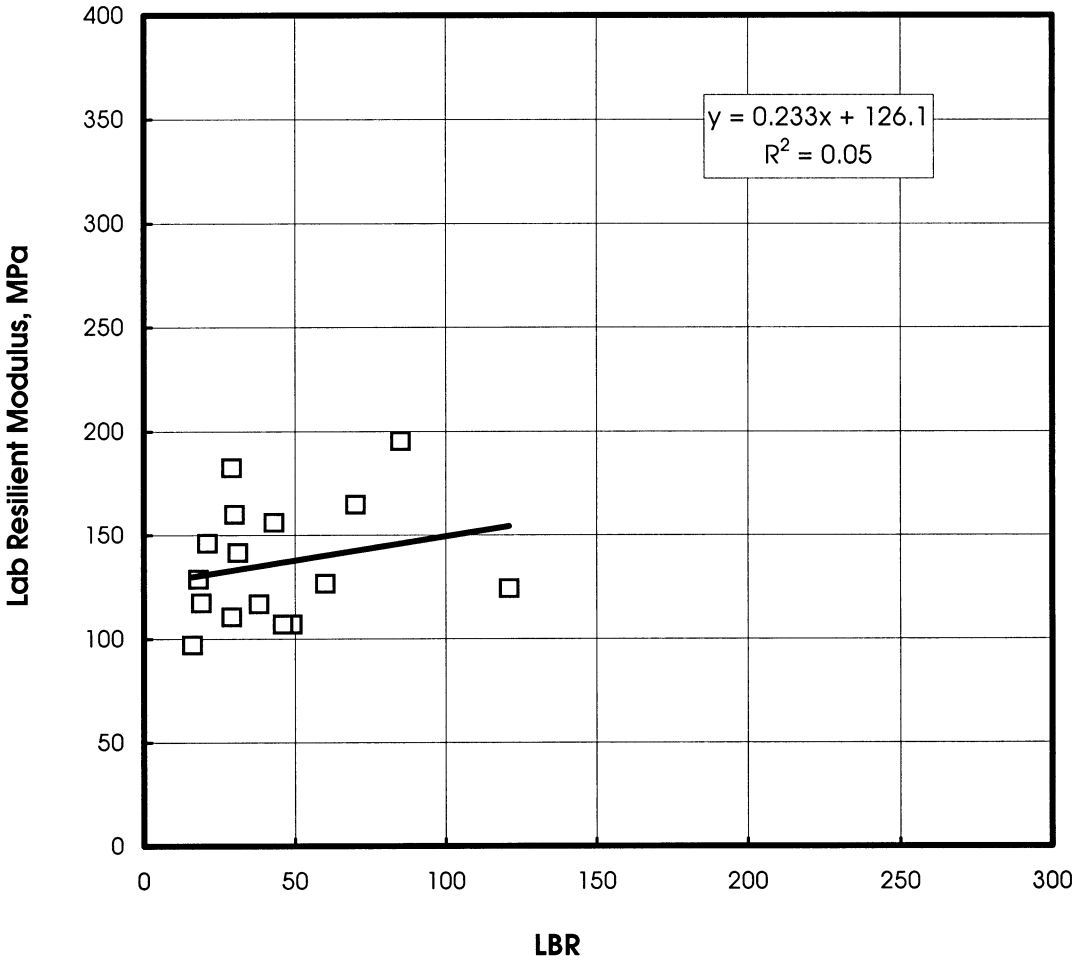


Figure 7.62c Comparison of LBR with laboratory resilient modulus at in-situ MC, state of stresses caused by traffic (A-3)

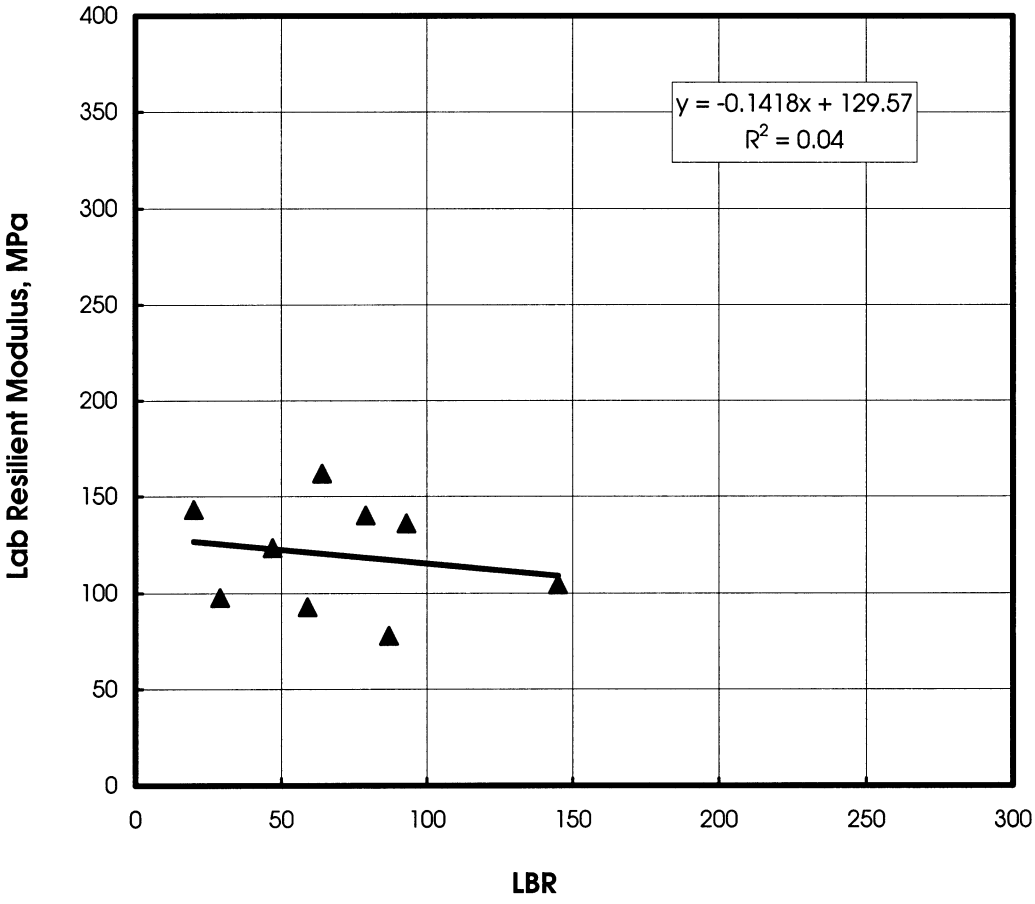


Figure 7.62d Comparison of LBR with laboratory resilient modulus at in-situ MC, state of stresses caused by traffic (A-2-4)

CHAPTER 8

DEVELOPMENT OF CORRELATIONS FROM FIELD AND LABORATORY EXPERIMENTAL RESULTS

8.1 General

Further analyses of correlation relationships between the field and laboratory experimental results are presented in this chapter. Five more comparisons are reported in this chapter. Some of them showed very strong correlations that may be used in future studies for implementing resilient modulus methods in new pavement design and maintenance. Others showed unsatisfactory correlations that may not be very useful. The determination of the confining pressure and state of stresses for the basis of comparison of resilient modulus is also discussed in this chapter.

8.2 Determination of State of Stresses under Traffic Load

The laboratory resilient modulus tests were conducted to determine the resilient characteristics of pavement

materials. The field tests were utilized to evaluate the bearing characteristics of in-service pavement materials. Both the laboratory and the field tests measured the fundamental engineering properties of pavement soils; it was therefore desirable to compare them. However, the resilient modulus values from the laboratory tests were stress dependent whereas the field modulus tests were conducted under in-situ stress conditions. Therefore, in order to compare these two different types of test, the state of stress in the field must be known so that the laboratory resilient modulus values can be compared with the field test results under identical state of stresses. The theory relating the laboratory resilient modulus results to those obtained from the field tests is described as follows.

8.2.1 State of Stresses

As described in Chapter 7, the resilient moduli of base, subgrade, and embankment soils are dependent on the state of stresses. For granular materials, the resilient modulus can be related to the bulk stress or confining pressure. In the field test, the in-situ lateral pressure, when added to the horizontal stress induced by the applied

vertical load, was considered to be the controlling stress in defining the resilient modulus test. The vertical stress was considered to be the deviatoric stress in the resilient modulus test. Layer theory was employed for the analysis and computer program ELSYM5 was used for computing the stresses.

8.2.2 Determination of Confining Pressure

The confining pressure was intended to simulate the confinement that the pavement would experience under the real traffic conditions. A number of computations were done to determine the correct value of confining pressure. Dual tires that transfer load to pavement were converted to an equivalent area of contact radius to suit the requirement of layer theory. The detail of conversion is shown in Figure 8.1. The standard load for highway pavement design is 18kp per tandem. That is 9kp for one equivalent tire shown in Figure 8.1. To calculate the horizontal stress in the pavement structure, the computer program ELSYM5 was used. To consider the influence of nearby tires, the state of stresses in the pavement under the two loads were also computed.

The ELSYM5 program considers the pavement layers weightless. However, the weight of pavement structures also generates horizontal stresses. For horizontal stress caused by pavements' self-weight, the following equation was used:

$$\sigma_h' = k_0 \cdot \sigma_v = k_0 \cdot \gamma \cdot d \quad \text{..... (8.1)}$$

where: σ_h' = horizontal stress caused by weight of soils

k_0 = coefficient of earth pressure at rest (use 0.5)

γ = unit weight of pavement materials (use 120 lb/ft^3)

d = depth of pavement structure

The results of total confining pressure under one load are summarized in Table 8.1 and illustrated in Figure 8.2. The results of total confining pressure under two loads are summarized in Table 8.2 and illustrated in Figure 8.3.

The distribution of the horizontal stress through the pavement is shown in Figures 8.2 and 8.3. The resilient modulus value needed for pavement design was the value of subgrade/embankment soil and a typical subgrade/embankment layer was placed at the depth of approximately 15 inches down from the surface of the pavement. Observations showed that from the depth of 10 inches down the total confining

pressures were less than stresses are around 14kPa (2 psi). Chen's literature (1999) also supports the result.

For design purposes, the confining pressure value was chosen as 14 kPa (2 psi) in order to be conservative.

8.2.3 Determination of State of Stresses

The vertical normal stresses were computed along a vertical line under the center of the load. The lateral confining pressure caused by the weight of the material above a particular point can be determined by assuming that it is equal to the lateral earth pressure at rest and, in the case of granular materials, the coefficient of earth pressure at rest, K_0, was assumed to be 0.5. This stress, when added to the lateral stress induced by the applied load, was considered to be the controlling stress in defining the resilient modulus of the granular material at this point.

Poisson's ratio was assumed as 0.35 for limerock, 0.4 for silty clay, and 0.35 for fine sand.

The vertical stress caused by the weight of the material above a particular point can be calculated by,

$$\sigma_v' = \gamma \cdot d \qquad \text{.....} \qquad (8.2)$$

where: σ_v' = vertical stress caused by weight of soil

γ = unit weight of pavement material

d = depth of pavement structure

The computational procedures are presented in Table 8.3. Then resilient modulus values were calculated by using formulas listed in Chapter 4 and Chapter 5 which were based on $M_R = k_1 \theta^{k_2}$ model.

8.3 FWD Backcalculated Moduli versus Laboratory Resilient Moduli

A Falling Weight Deflectometer (FWD) test is a nondestructive test (NDT). It is easy to conduct and the test data processing is relatively simple. It can be done as many times as needed within a relatively short period of time. The primary purpose of establishing the correlation relationship of FWD back-calculated moduli and laboratory measured moduli is to use the correlation in the rehabilitation for design of in-service pavement. Different from a Dynaflect test, which generated lower state stresses, the FWD test simulated the state of stresses under real traffic load. Therefore, FWD backcalculated modulus was expected to be more comparable with the

laboratory resilient modulus. When doing backcalculation, how to set the seed modulus of each pavement layer is the key for obtaining reasonable, reliable results. A different value or range of seed modulus will generate different calculated layer modulus. The program operator should have rich knowledge of typical modulus values of certain types of pavement materials. Controlling the Absolute Error within 3.0 and obtaining a large set of FWD data for one site will help in obtaining reasonable and reliable computation results.

Four different correlations were attempted in this research for comparisons of the FWD moduli with the laboratory resilient moduli. The four cases were compared on the basis of the following conditions:

Case I: In-situ condition with identical state of stresses

Case II: In-situ condition with confining pressure 2 psi

Case III: Optimum compacted condition with identical state of stresses

Case IV: Optimum compacted condition with confining pressure 2 psi

8.3.1 Case I - In-situ Condition with Identical State of Stresses

The results from FWD backcalculated modulus and laboratory resilient modulus under in-situ conditions with identical state of stresses are summarized in Table 8.4. Comparisons are shown in Figure 8.4 in terms of pavement layers and in Figure 8.5 in terms of pavement materials. From Figure 8.4a, a reasonable correlation relationship existed between the FWD backcalculated moduli and the laboratory resilient moduli based on in-situ conditions with identical state of stresses. The moduli obtained from FWD backcalculation were about 1.8 times greater than the laboratory measured moduli. The regression equation is as follows:

$$M_{FWD} = 1.8115 MR_{lab} \quad (MPa) \qquad \text{..... (8.3)}$$

with R^2 = 0.45

The comparisons are shown in Figure 8.4b, 8.4c, and 8.4d for the base, stabilized subgrade, and embankment layers, respectively. The ratios between the FWD backcalculated moduli and laboratory measured moduli were 1.86 for the base layer, 1.78 for the stabilized subgrade, and 1.55 for the embankment. The primary soils were

limerock, A-3, and A-2-4 sands. The comparisons are shown in Figure 8.5b, 8.5c, and 8.5d for the limerock, A-3, and A-2-4 sands, respectively. Figures 8.5b and 8.5c show that no strong correlation relationships existed for the limerock and A-3 materials. However, a reasonable correlation relationship existed between the FWD backcalculated moduli and the laboratory measured moduli under Case I conditions for the A-2-4 soils (Figure 8.5d).

The regression equation is as follows:

$$M_{FWD} = 1.927 MR_{lab} \quad (MPa) \qquad \text{(8.4)}$$

for A-2-4 soils with R^2 = 0.55

From the above comparisons, the FWD backcalculated moduli were about 1.5 to 1.9 times higher than the laboratory resilient moduli. These ratios are in general agreement with the suggestion by AASHTO Design Guide that the FWD backcalculated moduli are approximately two to three times higher than the laboratory determined moduli. In addition, observations showed that the FWD tests were performed under in-situ soil conditions and the laboratory resilient moduli were obtained from the reconstituted soil samples to simulate the in-situ moisture and density conditions and under identical in-situ state of stresses.

Thus, the comparison between the FWD moduli and laboratory moduli under the in-situ condition with identical state of stresses (Case I) was a straight, one to one direct comparison between the two tests.

8.3.2 Case II - In-situ Condition with Confining Pressure 2 psi

The results from FWD backcalculated modulus and laboratory resilient modulus under in-situ conditions with confining pressure 2 psi are summarized in Table 8.5. Comparisons are shown in Figure 8.6 in terms of different pavement layers, and in Figure 8.7 in terms of various pavement materials.

The regression equation is as follows:

$$M_{FWD} = 1.7615 MR_{lab} \quad (MPa) \qquad \text{..... (8.5)}$$

with R^2 = 0.27

The ratios between the FWD backcalculated moduli and laboratory measured moduli were 1.94 (R^2 = 0.38) for the stabilized subgrade layers (Figure 8.6b), 1.46 (R^2 = 0.40) for the embankment layers (Figure 8.6c), 1.58 (R^2 = 0.23) for A-3 sands (Figure 8.7b), and 1.99 (R^2 = 0.39) for A-2-4 soils (Figure 8.7c).

The correlation relationships under Case II were not as strong as those under Case I. However, the Case II conditions seemed to be applicable for the embankment layers based on the reasonable agreement between the FWD backcalculated moduli and laboratory determined moduli under confining pressure 2 psi.

8.3.3 Case III - Optimum Compacted Condition with Identical State of Stresses

The results from FWD backcalculated modulus and laboratory resilient modulus under an optimum compacted condition (OMC) with an identical state of stress are summarized in Table 8.6.

Comparisons are shown in Figure 8.8 for different pavement layers, and in Figure 8.9 in terms of various pavement materials.

The regression equation is as follows:

$$M_{FWD} = 1.495 MR_{lab} \quad (MPa) \qquad (8.6)$$

with R^2 = 0.20

The correlations shown in Figure 8.8 and 8.9 were not as strong as that for the Cases I and II under in-situ conditions. The major reason may be due to the fact that FWD

tests were performed under in-situ conditions. Thus, the FWD backcalculated moduli were not in agreement with the resilient modulus determined from the optimum compacted laboratory specimens.

8.3.4 Case IV - Optimum Compacted Condition with Confining Pressure 2 psi

The results from FWD backcalculated modulus versus laboratory resilient modulus under an optimum compacted condition with confining pressure 2 psi are summarized in Table 8.7. The data were plotted in Figure 8.10 for different pavement layers, and in Figure 8.11 in terms of various pavement materials.

The regression equation is as follows:

$$M_{FWD} = 1.5381 MR_{lab} \quad (MPa) \qquad \text{.....} \quad (8.7)$$

with R^2 = 0.17

The correlations shown in Figures 8.10 and 8.11 were not as strong as that for the Cases I and II because FWD tests were performed under in-situ conditions. In addition, the granular materials were sensitive to the change of confining pressure in the laboratory resilient modulus test. Therefore, a major lack of correlation existed under

Case IV conditions between the FWD test and the laboratory resilient modulus test.

8.4 Plate Layer Moduli versus Laboratory Resilient Moduli under Case I Condition

The results of plate layer modulus and laboratory resilient modulus under an in-situ condition with identical states of stresses (Case I) are summarized in Table 8.8.

Comparisons between plate layer moduli and laboratory resilient moduli are shown in Figure 8.12a for different pavement layers, Figure 8.12b for base layers, Figure 8.12c for subgrade layers, and Figure 8.12d for embankment layers. Although the data were relatively scattered, the trend of increasing laboratory resilient modulus with an increase in plate layer modulus was apparent.

The regression equation is as follows:

$$M_{PLT} = 0.9667 MR_{Lab(In-situMC)} \quad (MPa) \qquad (8.8)$$

with R^2=0.22.

The same data are plotted in Figure 8.13a for different pavement materials, Figure 8.13b for limerock materials, Figure 8.13c for A-3 soils, and Figure 8.13d for A-2-4 soils. The laboratory resilient moduli were 1.03 times

higher than the plate layer moduli for all the tested materials (Figures 8.12a and 8.13a). This may imply that the laboratory resilient moduli were equivalent to the plate layer moduli. However, in subgroups, the base data were scattered around the line of equality, the subgrade data showed an unsatisfactory correlation surrounding the line of equality, and the embankment data showed that the laboratory resilient moduli were generally greater than the plate layer moduli. Apparently, the correlation relationship depended upon the type of material. For limerock and A-3 soils, the correlations were poor as shown in Figure 8.13b and 8.13c. However, for A-2-4 soils, the correlation was fair (Figure 8.13d).

In this research, the relationships between the laboratory resilient moduli under optimum compacted condition and the plate layer moduli were not very satisfactory. It seems that the laboratory resilient moduli under optimum compacted condition did not represent the actual field condition, and thus, the results could not be compared with the moduli from field measurements.

8.5 Laboratory Resilient Moduli under Optimum Compacted Condition versus Laboratory Resilient Moduli under In-situ Condition

The laboratory resilient modulus test under an optimum compacted condition intended to simulate pavement materials immediately after construction. During the construction stage, pavement materials were typically compacted to over 95% of optimum densities. However, the moisture and densities of pavement structure will be changed with time due to environmental and traffic factors. Therefore, the laboratory resilient modulus test under an in-situ condition reflected the actual field condition of the pavement materials. Comparisons were made between laboratory resilient modulus tests at an optimum compacted condition and laboratory resilient modulus tests at an in-situ condition based on the same state of stresses and confining pressure at 2 psi.

8.5.1 Comparison under Same State of Stresses

The results of the laboratory resilient moduli under optimum compacted and in-situ conditions, in response to the same state of stresses, are summarized in Table 8.9. The data are plotted in Figure 8.14 for comparison. As shown in

Figure 8.14a, a good correlation existed. Most data points were above the line of equality.

The regression equation is as follows:

$$MR_{Lab(OMC)} = 1.117 MR_{Lab(In-situMC)} \quad (MPa) \quad \text{..... (8.9)}$$

with R^2 = 0.659

If one outstanding data point (Gadsden County, Site 2B, subgrade) was eliminated as shown in Figure 8.14b, c, d, then the trend becomes:

$$MR_{Lab(OMC)} = 1.1024 MR_{Lab(In-situMc)} \quad (MPa) \quad \text{..... (8.10)}$$

with R^2 = 0.78

Observations tend to show that the laboratory resilient moduli at an optimum compacted condition were 1.1 times higher than the laboratory resilient moduli at an in-situ condition. The comparison is again shown in Figure 8.15a, b, c, d in terms of various pavement materials. The correlations were also very reasonable for the A-3 and A-2-4 soils (Figure 8.15c, d).

8.5.2 Comparison under Confining Pressure 2 psi

The results of the laboratory resilient moduli under optimum compacted and in-situ conditions at confining pressure 2 psi are summarized in Table 8.10. The data are

shown in Figure 8.16 (a, b, c, d) for comparison. Most data points were above the line of equality (Figure 8.16a). If two outstanding data points were removed as shown in Figure 8.16b, the regression equation is as follows:

$$MR_{Lab(OMC)} = 1.1027 MR_{Lab(In-situMC)} \quad (MPa) \qquad \text{(8.11)}$$

with R^2 = 0.79

Again, the laboratory resilient moduli at OMC were 1.1 times higher than the laboratory resilient moduli at in-situ MC. This may due to the fact that the average density at OMC was higher than that at in-situ MC, thus, resulting in higher resilient modulus.

The comparison is shown in Figure 8.17a, b, c, d in terms of various pavement materials. The correlations are fair for the A-3 and A-2-4 soils.

8.6 Plate Layer Modulus versus LBR

The results of the plate layer moduli and LBR values are summarized in Table 8.11. Figure 8.18a shows the comparison of data from the experimental results.

The regression equation is as follows:

$$M_{PLT} = 2.7761(LBR) + 32.426 \quad (MPa) \qquad \text{(8.12)}$$

with R^2 = 0.41

Generally, the plate layer modulus increased with an increase in LBR value. As can be seen from Figure 8.18b, c, d, different structural subgroups showed different results. The base materials, mostly limerock, exhibited little correlation between the LBR and plate layer modulus (R^2 = 0.04). However, the embankment materials had a better correlation (R^2 = 0.64).

It seemed that the LBR was dependent upon the type of material tested for comparison (Figure 8.19). In general, the limerock materials exhibited higher LBR values (Figure 8.19b) whereas the embankment materials obtained lower LBR values (Figure 8.19c, d).

8.7 FWD Modulus versus LBR

The results of the FWD backcalculated moduli and LBR values are summarized in Table 8.12. Correlation relationship between the FWD backcalculated modulus and LBR is shown in Figure 8.20a.

The regression equation is as follows:

$$M_{FWD} = 1.8706(LBR) + 169.97 \quad (MPa) \qquad (8.13)$$

with R^2 = 0.28

Figure 8.20b, c, d show correlations of the subgroup of pavement layers. The correlation was not as strong as the correlation between the LBR and plate layer modulus. The correlation of LBR with plate layer modulus may be used for transferring LBR data to the resilient modulus. However, the LBR was dependent upon the type of material (Figure 8.21a, b, c, d). The correlation should be used with caution.

8.8 Summary of Comparisons

The basis of the comparisons made in this study are grouped into two areas: moisture content and state of stresses. The moisture content was a major factor that influenced the resilient modulus of pavement materials. Two different moisture content conditions were considered: optimum compacted and in-situ moisture content conditions. The optimum compacted condition was used for the design of new pavement construction whereas the in-situ moisture content condition presented the moisture state of the current in-place pavement in service.

State of stresses is another important factor for determining resilient modulus of pavement materials. This study demonstrates through rigorous analyses that the 14 kPa (2 psi) confining pressure reflected the actual state of

confinement that the subgrade and embankment may experience under traffic loadings. Bulk stress of each pavement layer was calculated according to the pavement profile and layer system theory.

The following summaries were made from the comparisons of field and laboratory results:

1. FWD backcalculated moduli were generally 1.5-1.9 times greater than laboratory resilient moduli. This is in agreement with the AASHTO guide which suggests that the FWD backcalculated moduli are approximately two to three times higher than the laboratory determined moduli.

2. Laboratory resilient moduli under in-situ moisture conditions were 1.03 times greater than plate layer moduli. This may imply that plate layer moduli were approximately equivalent to laboratory resilient moduli. However, the correlation relationship depended upon the type of soil.

3. Laboratory resilient modulus under optimum moisture content was 1.1 times higher than the laboratory resilient modulus under an in-situ moisture content. This shows that after construction the resilient modulus of the pavement materials tended to

decrease due to the effects of many influencing factors.

4. Plate layer moduli (in MPa) were about 2.8 times to LBR values. The regression equation is:

$M_{PLT} = 2.7761(LBR) + 32.426 \quad (MPa)$ (R^2=0.41, within the range of LBR values from 16 to 211).

5. The correlation relationship between FWD back-calculated moduli and LBR values was not very high. The regression equation is:

$M_{FWD} = 1.8706(LBR) + 169.97 \quad (MPa)$ (R^2=0.28, within the range of LBR values from 16 to 211).

Table 8.1 Confining Pressure under One Load and Soil Selfweight

Depth, in	Confining pressure due to load, psi	Vertical effective stress, psf	Horizontal stress, psi	Total confining pressure, psi
0.5	58.74	5	0.017	58.757
3.5	18.60	35	0.122	18.722
5.5	7.32	55	0.191	7.511
7.5	2.70	75	0.260	2.960
9.5	0.86	95	0.330	1.190
11.5	0.12	115	0.399	0.519
14.0	-0.20	140	0.486	0.286
17.0	-0.30	170	0.590	0.290
20.0	-0.30	200	0.694	0.394
23.0	-0.26	230	0.799	0.539

Table 8.2 Confining Pressure under Two Loads and Soil Selfweight

Depth, in	Confining Pressure due to load, psi	Vertical effective stress, psf	Horizontal stress, psi	Total confining pressure, psi
1.0	50.19	10	0.035	50.225
4.0	14.91	40	0.139	15.049
7.0	3.56	70	0.243	3.803
10.0	0.67	100	0.347	1.017
13.0	-0.64	130	0.451	-0.189
16.0	-0.24	160	0.556	0.316
19.0	-0.26	190	0.660	0.400
22.0	-0.24	220	0.764	0.524
25.0	-0.21	250	0.868	0.658
28.0	-0.18	280	0.972	0.792

Table 8.3 Computational Procedures for Determination of State of Stresses Based on Applied Traffic Load

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa
Lee Co., Site #1B, S.R.884	Base(Limerock)	17.02	1.70	3.40	13.01	216.84	220.25	14.71	249.66
	Subgrade(Fine Sand)	44.45	4.45	8.89	17.69	50.24	59.13	22.14	103.40
	Embankment(Fine Sand)	133.99	13.40	26.80	1.60	7.99	34.79	15.00	64.78
Lee Co., Site #2B, S.R.884	Base(Limerock)								
	Subgrade(Fine Sand)								
	Embankment(Fine Sand)								
Polk Co., Site #1A, U.S. 17	Base(Limerock)	19.05	1.91	3.81	1.93	164.98	168.79	3.84	176.46
	Subgrade(Silty Sand)	48.26	4.83	9.65	13.38	37.92	47.57	18.21	83.98
	Embankment(Fine Sand)	139.70	13.97	27.94	1.72	6.90	34.84	15.69	66.22
Polk Co., Site #2A, U.S. 17	Base(Limerock)	19.05	1.91	3.81	9.12	194.36	198.17	11.02	220.21
	Subgrade(Silty Sand)	46.99	4.70	9.40	19.00	43.99	53.39	23.70	100.79
	Embankment(Fine Sand)	138.43	13.84	27.69	1.70	7.08	34.76	15.54	65.84
Alachua Co., Site #3, U.S. 301	Base(Limerock)	22.23	2.22	4.45	4.06	205.53	209.98	6.28	222.55
	Subgrade(Fine Sand)	49.53	4.95	9.91	4.18	59.62	69.52	9.13	87.79
	Embankment(Fine Sand)	135.89	13.59	27.18	1.24	11.25	38.43	14.83	68.09
Alachua Co., Site #4, U.S. 301	Base(Limerock)	20.32	2.03	4.06	19.33	168.56	172.63	21.36	215.34
	Subgrade(Silty Sand)	41.91	4.19	8.38	30.91	42.68	51.06	35.10	121.25
	Embankment(Fine Sand)	147.96	14.80	29.59	1.64	6.66	36.25	16.44	69.13
Clay Co., Site #5, U.S. 17	Base(Limerock)	24.13	2.41	4.83	10.45	170.15	174.97	12.86	200.70
	Subgrade(Fine Sand)	49.53	4.95	9.91	15.21	44.40	54.30	20.17	94.64
	Embankment(Fine Sand)	123.83	12.38	24.77	0.60	9.16	33.92	12.98	59.89
Clay Co., Site #6, U.S. 17	Base(Limerock)	24.13	2.41	4.83	19.09	144.29	149.11	21.50	192.12
	Subgrade(Fine Sand)	50.80	5.08	10.16	10.43	39.53	49.69	15.51	80.70
	Embankment(Fine Sand)	140.97	14.10	28.19	0.52	7.23	35.42	14.62	64.66
Jefferson Co., Site #1A, U.S.27	Base(Limerock)	19.69	1.97	3.94	12.72	226.91	230.85	14.69	260.24
	Subgrade(Silty Clay)	36.20	3.62	7.24	88.56	46.99	54.23	92.18	238.58
	Embankment(Silty Clay)	113.67	11.37	22.73	1.37	7.81	30.55	12.74	56.03
Jefferson Co., Site #2A, U.S.27	Base(Limerock)	21.59	2.16	4.32	9.33	153.80	158.12	11.49	181.10
	Subgrade(Silty Clay)	45.72	4.57	9.14	4.15	54.20	63.34	8.72	80.78
	Embankment(Silty Sand)	121.67	12.17	24.33	1.58	12.73	37.07	13.75	64.57

Table 8.3 Computational Procedures for Determination of State of Stresses Based on Applied Traffic Load (continued)

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa
Gadsden Co., Site #2B, U.S. 27	Base(Limerock)	22.10	2.21	4.42	12.16	230.36	234.78	14.37	263.52
	Subgrade(Silty Sand)	59.06	5.91	11.81	3.89	45.93	57.74	9.79	77.32
	Embankment #1 (Silty Sand)	133.35	13.34	26.67	2.01	11.82	38.49	15.35	69.18
Gadsden Co., Site #3B, U.S. 27	Base(Limerock)	19.69	1.97	3.94	20.99	272.36	276.30	22.96	322.23
	Subgrade(Fine Sand)	59.69	5.97	11.94	3.94	45.59	57.53	9.90	77.34
	Embankment(Clay)	134.62	13.46	26.92	2.29	11.50	38.42	15.75	69.92
Dade Co., Site #1, U.S. 41	Base(Limerock)	24.64	2.46	4.93	0.32	152.84	157.77	2.78	163.32
	Subgrade(Limerock)	57.66	5.77	11.53	5.38	39.83	51.36	11.15	73.65
	Embankment(Limerock)	156.72	15.67	31.34	0.39	6.90	38.24	16.06	70.36
Dade Co., Site #2, U.S. 41	Base(Limerock)								
	Subgrade(Limerock)								
	Embankment(Limerock)								
Martin Co., Site#3, U.S. 1	Base(Limerock)	22.86	2.29	4.57	2.74	128.77	133.34	5.03	143.39
	Subgrade(Fine Sand)	55.88	5.59	11.18	3.56	34.75	45.92	9.15	64.22
	Embankment(Fine Sand)	160.02	16.00	32.00	1.33	6.66	38.67	17.33	73.34
Martin Co., Site#4, U.S. 1	Base(Limerock)	19.05	1.91	3.81	13.97	181.05	184.86	15.87	216.60
	Subgrade(Silty Clay)	45.72	4.57	9.14	8.73	46.61	55.75	13.30	82.36
	Embankment(Fine Sand)	152.40	15.24	30.48	1.42	7.28	37.76	16.66	71.08
Seminole Co., Site #1, U.S.414	Base(Limerock)	30.48	3.05	6.10	6.10	96.35	102.45	9.15	120.75
	Subgrade(Silty Sand)	60.96	6.10	12.19	8.39	28.44	40.64	14.49	69.61
	Embankment(Silty Sand)	114.30	11.43	22.86	1.96	8.59	31.45	13.39	58.22
Seminole Co., Site #2, U.S.414	Base(Limerock)	30.48	3.05	6.10	5.48	98.70	104.79	8.53	121.85
	Subgrade(Silty Sand)	62.87	6.29	12.57	14.05	23.25	35.82	20.34	76.49
	Embankment(Fine Sand)	118.11	11.81	23.62	3.31	9.36	32.98	15.12	63.23
Osceola Co., Site #3, U.S. 441	Base(Coquina)	19.05	1.91	3.81	1.49	211.05	214.86	3.39	221.64
	Subgrade(Fine Sand)	51.05	5.11	10.21	15.72	36.36	46.57	20.82	88.22
	Embankment(Fine Sand)	113.28	11.33	22.66	3.17	8.68	31.34	14.49	60.33
Osceola Co., Site #4, U.S. 441	Base(Coquina)	27.94	2.79	5.59	33.10	68.54	74.13	35.89	145.92
	Subgrade(Fine Sand)	64.77	6.48	12.95	17.64	16.57	29.53	24.12	77.77
	Embankment(Fine Sand)	120.14	12.01	24.03	3.31	9.21	33.24	15.32	63.89

Table 8.4 Laboratory Modulus at In-situ MC and State of Stresses Caused by Traffic versus FWD Modulus

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress	Lab Modulus (Insitu MC)		FWD Modulus	
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa	MPa	ksi	MPa	ksi
Lee Co.	Base(Limerock)	17.02	1.70	3.40	13.01	216.84	220.25	14.71	249.66	181.71	26.35	335.10	48.6
Site #1B	Subgrade(Fine Sand)	44.45	4.45	8.89	17.69	50.24	59.13	22.14	103.40	156.13	22.64	217.88	31.6
S.R.884	Embankment(Fine Sand)	133.99	13.40	26.80	1.60	7.99	34.79	15.00	64.78	117.32	17.01	143.42	20.8
Lee Co.	Base(Limerock)												
Site #2B	Subgrade(Fine Sand)												
S.R.884	Embankment(Fine Sand)												
Polk Co.	Base(Limerock)	19.05	1.91	3.81	1.93	164.98	168.79	3.84	176.46	181.22	26.28	416.46	60.4
Site #1A	Subgrade(Silty Sand)	48.26	4.83	9.65	13.38	37.92	47.57	18.21	83.98	123.50	17.91	253.05	36.7
U.S. 17	Embankment(Fine Sand)	139.70	13.97	27.94	1.72	6.90	34.84	15.69	66.22	97.11	14.08	279.94	40.6
Polk Co.	Base(Limerock)	19.05	1.91	3.81	9.12	194.36	198.17	11.02	220.21			439.90	63.80
Site #2A	Subgrade(Silty Sand)	46.99	4.70	9.40	19.00	43.99	53.39	23.70	100.79	161.86	23.47	303.38	44.00
U.S. 17	Embankment(Fine Sand)	138.43	13.84	27.69	1.70	7.08	34.76	15.54	65.84	160.07	23.21	269.59	39.10
Alachua Co.	Base(Limerock)	22.23	2.22	4.45	4.06	205.53	209.98	6.28	222.55				
Site #3	Subgrade(Fine Sand)	49.53	4.95	9.91	4.18	59.62	69.52	9.13	87.79				
U.S. 301	Embankment(Fine Sand)	135.89	13.59	27.18	1.24	11.25	38.43	14.83	68.09				
Alachua Co.	Base(Limerock)	20.32	2.03	4.06	19.33	168.56	172.63	21.36	215.34				
Site #4	Subgrade(Silty Sand)	41.91	4.19	8.38	30.91	42.68	51.06	35.10	121.25				
U.S. 301	Embankment(Fine Sand)	147.96	14.80	29.59	1.64	6.66	36.25	16.44	69.13				
Clay Co.	Base(Limerock)	24.13	2.41	4.83	10.45	170.15	174.97	12.86	200.70				
Site #5	Subgrade(Fine Sand)	49.53	4.95	9.91	15.21	44.40	54.30	20.17	94.64				
U.S. 17	Embankment(Fine Sand)	123.83	12.38	24.77	0.60	9.16	33.92	12.98	59.89				
Clay Co.	Base(Limerock)	24.13	2.41	4.83	19.09	144.29	149.11	21.50	192.12				
Site #6	Subgrade(Fine Sand)	50.80	5.08	10.16	10.43	39.53	49.69	15.51	80.70				
U.S. 17	Embankment(Fine Sand)	140.97	14.10	28.19	0.52	7.23	35.42	14.62	64.66				
Jefferson Co.	Base(Limerock)	19.69	1.97	3.94	12.72	226.91	230.85	14.69	260.24	289.93	42.04	255.115	37.00
Site #1A	Subgrade(Silty Clay)	36.20	3.62	7.24	88.56	46.99	54.23	92.18	238.58	185.61	26.91	208.229	30.20
U.S.27	Embankment(Silty Clay)	113.67	11.37	22.73	1.37	7.81	30.55	12.74	56.03			188.234	27.30
Jefferson Co.	Base(Limerock)	21.59	2.16	4.32	9.33	153.80	158.12	11.49	181.10				
Site #2A	Subgrade(Silty Clay)	45.72	4.57	9.14	4.15	54.20	63.34	8.72	80.78				
U.S.27	Embankment(Silty Sand)	121.67	12.17	24.33	1.58	12.73	37.07	13.75	64.57				

Table 8.4 Laboratory Modulus at In-situ MC and State of Stresses Caused by Traffic versus FWD Modulus (continued)

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress	Lab Modulus (Insitu MC)		FWD Modulus	
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa	MPa	ksi	MPa	ksi
Gadsden Co. Site #2B U.S. 27	Base(Limerock)	22.10	2.21	4.42	12.16	230.36	234.78	14.37	263.52	214.63	31.12	226.846	32.90
	Subgrade(Silty Sand)	59.06	5.91	11.81	3.89	45.93	57.74	9.79	77.32	104.49	15.15	146.864	21.30
	Embankment #1 (Silty Sand)	133.35	13.34	26.67	2.01	11.82	38.49	15.35	69.18	92.80	13.46	126.868	18.40
Gadsden Co. Site #3B U.S. 27	Base(Limerock)	19.69	1.97	3.94	20.99	272.36	276.30	22.96	322.23	210.59	30.54	219.261	31.80
	Subgrade(Fine Sand)	59.69	5.97	11.94	3.94	45.59	57.53	9.90	77.34	124.19	18.01	122.042	17.70
	Embankment(Clay)	134.62	13.46	26.92	2.29	11.50	38.42	15.75	69.92	111.43	16.16	113.768	16.50
Dade Co. Site #1 U.S. 41	Base(Limerock)	24.64	2.46	4.93	0.32	152.84	157.77	2.78	163.32			601.244	87.20
	Subgrade(Limerock)	57.66	5.77	11.53	5.38	39.83	51.36	11.15	73.65	226.62	32.86	493.682	71.60
	Embankment(Limerock)	156.72	15.67	31.34	0.39	6.90	38.24	16.06	70.36	121.35	17.60	483.34	70.10
Dade Co. Site #2 U.S. 41	Base(Limerock)												
	Subgrade(Limerock)												
	Embankment(Limerock)												
Martin Co. Site#3 U.S. 1	Base(Limerock)	22.86	2.29	4.57	2.74	128.77	133.34	5.03	143.39			511.609	74.20
	Subgrade(Fine Sand)	55.88	5.59	11.18	3.56	34.75	45.92	9.15	64.22	164.80	23.90	383.362	55.60
	Embankment(Fine Sand)	160.02	16.00	32.00	1.33	6.66	38.67	17.33	73.34	146.04	21.18	346.129	50.20
Martin Co. Site#4 U.S. 1	Base(Limerock)	19.05	1.91	3.81	13.97	181.05	184.86	15.87	216.60	323.96	46.97	590.902	85.70
	Subgrade(Silty Clay)	45.72	4.57	9.14	8.73	46.61	55.75	13.30	82.36	190.04	27.56	457.139	66.30
	Embankment(Fine Sand)	152.40	15.24	30.48	1.42	7.28	37.76	16.66	71.08	182.52	26.46	262.7	38.10
Seminole Co. Site #1 U.S.414	Base(Limerock)	30.48	3.05	6.10	6.10	96.35	102.45	9.15	120.75	235.11	34.09	393.705	57.10
	Subgrade(Silty Sand)	60.96	6.10	12.19	8.39	28.44	40.64	14.49	69.61	140.19	20.33	367.504	53.30
	Embankment(Silty Sand)	114.30	11.43	22.86	1.96	8.59	31.45	13.39	58.22	143.29	20.78	214.435	31.10
Seminole Co. Site #2 U.S.414	Base(Limerock)	30.48	3.05	6.10	5.48	98.70	104.79	8.53	121.85	160.64	23.29	419.906	60.90
	Subgrade(Silty Sand)	62.87	6.29	12.57	14.05	23.25	35.82	20.34	76.49	136.09	19.73	300.622	43.60
	Embankment(Fine Sand)	118.11	11.81	23.62	3.31	9.36	32.98	15.12	63.23	141.56	20.53	164.101	23.80
Osceola Co. Site #3 U.S. 441	Base(Coquina)	19.05	1.91	3.81	1.49	211.05	214.86	3.39	221.64	323.67	46.93	1003.91	145.60
	Subgrade(Fine Sand)	51.05	5.11	10.21	15.72	36.36	46.57	20.82	88.22	226.90	32.90	346.819	50.30
	Embankment(Fine Sand)	113.28	11.33	22.66	3.17	8.68	31.34	14.49	60.33	128.72	18.66	188.923	27.40
Osceola Co. Site #4 U.S. 441	Base(Coquina)	27.94	2.79	5.59	33.10	68.54	74.13	35.89	145.92	245.53	35.60	489.545	71.00
	Subgrade(Fine Sand)	64.77	6.48	12.95	17.64	16.57	29.53	24.12	77.77	195.40	28.33	206.85	30.00
	Embankment(Fine Sand)	120.14	12.01	24.03	3.31	9.21	33.24	15.32	63.89	126.52	18.35	148.932	21.60

Table 8.5 FWD Modulus versus Laboratory Modulus at In-situ MC and Confining Pressure 2psi

SITES	STRUCTURE ELEMENT	AASHTO CLASSIFICATION	FWD MODULUS		M_R (σ_3=2psi)		INSITU MC
			ksi	MPa	ksi	MPa	%
Lee Co.	Subgrade	A-3	31.6	217.9	18.8	129.6	4.3
SR884 Site 1B	EMB	A-3	20.8	143.4	17.9	123.4	11.9
Lee Co.	Subgrade	A-3			21.5	148.6	3.5
SR884 Site 2B	EMB	A-3			17.7	122.0	3.3
Polk Co.	Subgrade	A-2-4	36.7	253.0	16.2	111.5	10.1
US17 Site 1A	EMB	A-3	40.6	279.9	14.3	98.3	9.6
Polk Co.	Subgrade	A-2-4	44.0	303.4	19.4	133.8	7.9
US17 Site 2A	EMB	A-3	39.1	269.6	24.0	165.6	11.2
Clay Co.	Subgrade	A-3			14.6	100.7	7.2
US17 Site 5	EMB	A-2-4			15.2	105.0	8.9
Clay Co.	Subgrade	A-3			14.3	98.6	11
US17 Site 6	EMB	A-3			16.8	115.7	8.9
Alachua Co.	Subgrade	A-3			13.8	95.4	11.5
US301 Site 3	EMB	A-2-4					
Alachua Co.	Subgrade	A-2-4			17.2	118.3	9.0
US301 Site 4	EMB	A-6					
Jefferson Co.	Subgrade	A-4	30.2	208.2	14.7	101.6	14.7
US27 Site 1A	EMB	A-2-6	27.3	188.2			
Jefferson Co.	Subgrade	A-4					
US27 Site 2A	EMB	A-2-4			12.0	82.6	13.4
Gadsden Co.	Subgrade	A-2-4	21.3	146.9	14.4	99.1	10.7
US27 Site 2B	EMB	A-2-4	18.4	126.9	13.7	94.6	11.3
Gadsden Co.	Subgrade	A-3	17.1	117.9	17.1	117.6	7.9
US27 Site 3B	EMB	A-6	16.5	113.8			
Martin Co.	Subgrade	A-3	55.6	383.4	24.7	170.4	3.6
US1 Site 3	EMB	A-3	50.2	346.1	20.9	144.2	2.1
Martin Co.	Subgrade	A-4	66.3	457.1	25.7	177.2	4.6
US1 Site 4	EMB	A-3	38.1	262.7	26.1	180.1	3.8

Table 8.5 FWD Modulus versus Laboratory Modulus at In-situ MC and Confining Pressure 2psi (continued)

SITES	STRUCTURE ELEMENT	AASHTO CLASSIFICATION	FWD MODULUS		M_R (σ_3=2psi)		INSITU MC
			ksi	MPa	ksi	MPa	%
Seminole Co. US414 Site 1	Subgrade	A-2-4	53.3	367.5	20.3	139.9	7.3
	EMB	A-2-4	31.1	214.4	22.9	157.8	7.8
Seminole Co. US414 Site 2	Subgrade	A-2-4	43.6	300.6	19.0	131.0	10.7
	EMB	A-3	23.8	164.1	21.4	147.5	10.7
Osceola Co. US441 Site 3	Subgrade	A-3	50.3	346.8	29.3	202.3	4.2
	EMB	A-3	27.4	188.9	20.1	138.4	3.8
Osceola Co. US441 Site 4	Subgrade	A-3	30	206.9	26.9	185.4	6.8
	EMB	A-3	21.6	148.9	19.2	132.7	12.1

Table 8.6 FWD Modulus versus Laboratory Modulus at OMC and State of Stresses Caused by Traffic

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress	Lab Modulus (OMC)		FWD Modulus	
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa	MPa	ksi	MPa	ksi
Lee Co., Site #1B, S.R.884	Base(Limerock)	17.02	1.70	3.40	13.01	216.84	220.25	14.71	249.66				
	Subgrade(Fine Sand)	44.45	4.45	8.89	17.69	50.24	59.13	22.14	103.40	168.73	24.47	217.882	31.6
	Embankment(Fine Sand)	133.99	13.40	26.80	1.60	7.99	34.79	15.00	64.78	155.75	22.58	143.416	20.8
Lee Co., Site #2B, S.R.884	Base(Limerock)												
	Subgrade(Fine Sand)												
	Embankment(Fine Sand)												
Polk Co., Site #1A, U.S. 17	Base(Limerock)	19.05	1.91	3.81	1.93	164.98	168.79	3.84	176.46				
	Subgrade(Silty Sand)	48.26	4.83	9.65	13.38	37.92	47.57	18.21	83.98	139.43	20.22	253.047	36.7
	Embankment(Fine Sand)	139.70	13.97	27.94	1.72	6.90	34.84	15.69	66.22	96.56	14.00	279.937	40.6
Polk Co., Site #2A, U.S. 17	Base(Limerock)	19.05	1.91	3.81	9.12	194.36	198.17	11.02	220.21				
	Subgrade(Silty Sand)	46.99	4.70	9.40	19.00	43.99	53.39	23.70	100.79	168.71	24.46	303.38	44.00
	Embankment(Fine Sand)	138.43	13.84	27.69	1.70	7.08	34.76	15.54	65.84	146.12	21.19	269.595	39.10
Alachua Co., Site #3, U.S. 301	Base(Limerock)	22.23	2.22	4.45	4.06	205.53	209.98	6.28	222.55				
	Subgrade(Fine Sand)	49.53	4.95	9.91	4.18	59.62	69.52	9.13	87.79	127.51	18.49		
	Embankment(Fine Sand)	135.89	13.59	27.18	1.24	11.25	38.43	14.83	68.09				
Alachua Co., Site #4, U.S. 301	Base(Limerock)	20.32	2.03	4.06	19.33	168.56	172.63	21.36	215.34				
	Subgrade(Silty Sand)	41.91	4.19	8.38	30.91	42.68	51.06	35.10	121.25	189.58	27.49		
	Embankment(Fine Sand)	147.96	14.80	29.59	1.64	6.66	36.25	16.44	69.13				
Clay Co., Site #5, U.S. 17	Base(Limerock)	24.13	2.41	4.83	10.45	170.15	174.97	12.86	200.70				
	Subgrade(Fine Sand)	49.53	4.95	9.91	15.21	44.40	54.30	20.17	94.64	108.79	15.77		
	Embankment(Fine Sand)	123.83	12.38	24.77	0.60	9.16	33.92	12.98	59.89	108.61	15.75		
Clay Co., Site #6, U.S. 17	Base(Limerock)	24.13	2.41	4.83	19.09	144.29	149.11	21.50	192.12				
	Subgrade(Fine Sand)	50.80	5.08	10.16	10.43	39.53	49.69	15.51	80.70	96.88	14.05		
	Embankment(Fine Sand)	140.97	14.10	28.19	0.52	7.23	35.42	14.62	64.66	113.81	16.50		
Jefferson Co., Site #1A, U.S.27	Base(Limerock)	19.69	1.97	3.94	12.72	226.91	230.85	14.69	260.24				
	Subgrade(Silty Clay)	36.20	3.62	7.24	88.56	46.99	54.23	92.18	238.58			208.229	30.20
	Embankment(Silty Clay)	113.67	11.37	22.73	1.37	7.81	30.55	12.74	56.03			188.234	27.30
Jefferson Co., Site #2A, U.S.27	Base(Limerock)	21.59	2.16	4.32	9.33	153.80	158.12	11.49	181.10				
	Subgrade(Silty Clay)	45.72	4.57	9.14	4.15	54.20	63.34	8.72	80.78				
	Embankment(Silty Sand)	121.67	12.17	24.33	1.58	12.73	37.07	13.75	64.57				

Table 8.6 FWD Modulus versus Laboratory Modulus at OMC and State of Stresses Caused by Traffic

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress	Lab Modulus (OMC)		FWD Modulus	
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa	MPa	ksi	MPa	ksi
Gadsden Co., Site #2B, U.S. 27	Base(Limerock)	22.10	2.21	4.42	12.16	230.36	234.78	14.37	263.52				
	Subgrade(Silty Sand)	59.06	5.91	11.81	3.89	45.93	57.74	9.79	77.32	192.17	27.86	146.864	21.30
	Embankment #1 (Silty Sand)	133.35	13.34	26.67	2.01	11.82	38.49	15.35	69.18	138.62	20.10	126.868	18.40
Gadsden Co., Site #3B, U.S. 27	Base(Limerock)	19.69	1.97	3.94	20.99	272.36	276.30	22.96	322.23				
	Subgrade(Fine Sand)	59.69	5.97	11.94	3.94	45.59	57.53	9.90	77.34	136.32	19.77	122.042	17.70
	Embankment(Clay)	134.62	13.46	26.92	2.29	11.50	38.42	15.75	69.92			113.768	16.50
Dade Co., Site #1, U.S. 41	Base(Limerock)	24.64	2.46	4.93	0.32	152.84	157.77	2.78	163.32				
	Subgrade(Limerock)	57.66	5.77	11.53	5.38	39.83	51.36	11.15	73.65			493.682	71.60
	Embankment(Limerock)	156.72	15.67	31.34	0.39	6.90	38.24	16.06	70.36			483.34	70.10
Dade Co., Site #2, U.S. 41	Base(Limerock)												
	Subgrade(Limerock)												
	Embankment(Limerock)												
Martin Co., Site#3, U.S. 1	Base(Limerock)	22.86	2.29	4.57	2.74	128.77	133.34	5.03	143.39				
	Subgrade(Fine Sand)	55.88	5.59	11.18	3.56	34.75	45.92	9.15	64.22	201.84	29.27	383.362	55.60
	Embankment(Fine Sand)	160.02	16.00	32.00	1.33	6.66	38.67	17.33	73.34	152.94	22.18	346.129	50.20
Martin Co., Site#4, U.S. 1	Base(Limerock)	19.05	1.91	3.81	13.97	181.05	184.86	15.87	216.60				
	Subgrade(Silty Clay)	45.72	4.57	9.14	8.73	46.61	55.75	13.30	82.36	210.13	30.47	457.139	66.30
	Embankment(Fine Sand)	152.40	15.24	30.48	1.42	7.28	37.76	16.66	71.08	215.36	31.23	262.7	38.10
Seminole Co., Site #1, U.S.414	Base(Limerock)	30.48	3.05	6.10	6.10	96.35	102.45	9.15	120.75				
	Subgrade(Silty Sand)	60.96	6.10	12.19	8.39	28.44	40.64	14.49	69.61	181.54	26.32	367.504	53.30
	Embankment(Silty Sand)	114.30	11.43	22.86	1.96	8.59	31.45	13.39	58.22	133.21	19.32	214.435	31.10
Seminole Co., Site #2, U.S.414	Base(Limerock)	30.48	3.05	6.10	5.48	98.70	104.79	8.53	121.85				
	Subgrade(Silty Sand)	62.87	6.29	12.57	14.05	23.25	35.82	20.34	76.49	173.52	25.16	300.622	43.60
	Embankment(Fine Sand)	118.11	11.81	23.62	3.31	9.36	32.98	15.12	63.23	160.29	23.24	164.101	23.80
Osceola Co., Site #3, U.S. 441	Base(Coquina)	19.05	1.91	3.81	1.49	211.05	214.86	3.39	221.64				
	Subgrade(Fine Sand)	51.05	5.11	10.21	15.72	36.36	46.57	20.82	88.22	250.74	36.36	346.819	50.30
	Embankment(Fine Sand)	113.28	11.33	22.66	3.17	8.68	31.34	14.49	60.33	139.93	20.29	188.923	27.40
Osceola Co., Site #4, U.S. 441	Base(Coquina)	27.94	2.79	5.59	33.10	68.54	74.13	35.89	145.92				
	Subgrade(Fine Sand)	64.77	6.48	12.95	17.64	16.57	29.53	24.12	77.77	212.81	30.86	206.85	30.00
	Embankment(Fine Sand)	120.14	12.01	24.03	3.31	9.21	33.24	15.32	63.89	93.11	13.50	148.932	21.60

Table 8.7 FWD Modulus versus Laboratory Modulus at OMC and Confining Pressure 2 psi

SITES	STRUCTURE ELEMENT	AASHTO CLASSIFICATION	FWD MODULUS		M_R (σ_3=2psi)		OMC
			ksi	MPa	ksi	MPa	%
Lee Co.	Subgrade	A-3	31.6	217.9	20.8	143.3	12.0
SR884 Site 1B	EMB	A-3	20.8	143.4	23.3	160.8	10.8
Lee Co.	Subgrade	A-3			21.2	146.3	10.8
SR884 Site 2B	EMB	A-3			19.3	133.4	13.3
Polk Co.	Subgrade	A-2-4	36.7	253.0	18.4	126.8	10.1
US17 Site 1A	EMB	A-3	40.6	279.9	14.3	98.5	12.4
Polk Co.	Subgrade	A-2-4	44.0	303.4	20.5	141.5	10.5
US17 Site 2A	EMB	A-3	39.1	269.6	21.7	149.4	10.8
Clay Co.	Subgrade	A-3			13.7	94.4	13.5
US17 Site 5	EMB	A-2-4			16.7	115.3	12.8
Clay Co.	Subgrade	A-3			13.1	90.2	14.3
US17 Site 6	EMB	A-3			17.0	117.4	12.4
Alachua Co.	Subgrade	A-3			16.7	114.9	11.7
US301 Site 3	EMB	A-2-4					
Alachua Co.	Subgrade	A-2-4			18.5	127.5	11.2
US301 Site 4	EMB	A-6					
Jefferson Co.	Subgrade	A-4	30.2	208.2			9.4
US27 Site 1A	EMB	A-2-6	27.3	188.2			8.6
Jefferson Co.	Subgrade	A-4					7.4
US27 Site 2A	EMB	A-2-4					8.3
Gadsden Co.	Subgrade	A-2-4	21.3	146.9	26.5	182.9	6.9
US27 Site 2B	EMB	A-2-4	18.4	126.9	20.3	139.7	9.7
Gadsden Co.	Subgrade	A-3	17.1	117.9	18.8	129.4	8.9
US27 Site 3B	EMB	A-6	16.5	113.8	-	-	
Martin Co.	Subgrade	A-3	55.6	383.4	30.2	208.4	8.9
US1 Site 3	EMB	A-3	50.2	346.1	21.8	150.4	9.6
Martin Co.	Subgrade	A-4	66.3	457.1	28.3	195.3	9.5
US1 Site 4	EMB	A-3	38.1	262.7	30.8	212.4	9.5

Table 8.7 FWD Modulus versus Laboratory Modulus at OMC and Confining Pressure 2 psi (continued)

SITES	STRUCTURE ELEMENT	AASHTO CLASSIFICATION	FWD MODULUS		M_R (σ_3=2psi)		OMC
			ksi	MPa	ksi	MPa	%
Seminole Co. US414 Site 1	Subgrade	A-2-4	53.3	367.5	26.0	179.4	6.3
	EMB	A-2-4	31.1	214.4	20.9	143.9	8.4
Seminole Co. US414 Site 2	Subgrade	A-2-4	43.6	300.6	24.6	169.5	8
	EMB	A-3	23.8	164.1	24.2	167.2	12.7
Osceola Co. US441 Site 3	Subgrade	A-3	50.3	346.8	32.9	226.9	9.0
	EMB	A-3	27.4	188.9	21.8	150.5	12.7
Osceola Co. US441 Site 4	Subgrade	A-3	30	206.9	29.2	201.2	8.9
	EMB	A-3	21.6	148.9	14.2	97.6	12.8

Table 8.8 Plate Layer Modulus versus Laboratory Modulus at In-situ MC and Equivalent State of Stresses

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress	Lab Modulus (Insitu MC)		Plate Layer Modulus	
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa	MPa	ksi	MPa	ksi
Lee Co. Site #1B S.R.884	Base(Limerock)	17.02	1.70	3.40	13.01	216.84	220.25	14.71	249.66	181.71	26.35	171.01	24.82
	Subgrade(Fine Sand)	44.45	4.45	8.89	17.69	50.24	59.13	22.14	103.40	156.13	22.64	131.53	19.09
	Embankment(Fine Sand)	133.99	13.40	26.80	1.60	7.99	34.79	15.00	64.78	117.32	17.01	48.68	7.07
Lee Co. Site #2B S.R.884	Base(Limerock)											187.36	27.19
	Subgrade(Fine Sand)											186.10	27.01
	Embankment(Fine Sand)											103.18	14.98
Polk Co. Site #1A U.S. 17	Base(Limerock)	19.05	1.91	3.81	1.93	164.98	168.79	3.84	176.46	181.22	26.28	261.54	37.96
	Subgrade(Silty Sand)	48.26	4.83	9.65	13.38	37.92	47.57	18.21	83.98	123.50	17.91	211.25	30.66
	Embankment(Fine Sand)	139.70	13.97	27.94	1.72	6.90	34.84	15.69	66.22	97.11	14.08	48.68	7.07
Polk Co. Site #2A U.S. 17	Base(Limerock)	19.05	1.91	3.81	9.12	194.36	198.17	11.02	220.21			286.69	41.61
	Subgrade(Silty Sand)	46.99	4.70	9.40	19.00	43.99	53.39	23.70	100.79	161.86	23.47	183.58	26.65
	Embankment(Fine Sand)	138.43	13.84	27.69	1.70	7.08	34.76	15.54	65.84	160.07	23.21	141.20	20.49
Alachua Co. Site #3 U.S. 301	Base(Limerock)	22.23	2.22	4.45	4.06	205.53	209.98	6.28	222.55	249.21	36.14	518.06	75.19
	Subgrade(Fine Sand)	49.53	4.95	9.91	4.18	59.62	69.52	9.13	87.79	107.08	15.53	279.65	40.59
	Embankment(Fine Sand)	135.89	13.59	27.18	1.24	11.25	38.43	14.83	68.09			67.58	9.81
Alachua Co. Site #4 U.S. 301	Base(Limerock)	20.32	2.03	4.06	19.33	168.56	172.63	21.36	215.34	237.42	34.43	598.53	86.87
	Subgrade(Silty Sand)	41.91	4.19	8.38	30.91	42.68	51.06	35.10	121.25	153.33	22.23	1408.32	204.40
	Embankment(Fine Sand)	147.96	14.80	29.59	1.64	6.66	36.25	16.44	69.13			54.47	7.91
Clay Co. Site #5 U.S. 17	Base(Limerock)	24.13	2.41	4.83	10.45	170.15	174.97	12.86	200.70	312.02	45.24		
	Subgrade(Fine Sand)	49.53	4.95	9.91	15.21	44.40	54.30	20.17	94.64	116.77	16.93		
	Embankment(Fine Sand)	123.83	12.38	24.77	0.60	9.16	33.92	12.98	59.89	97.75	14.17		
Clay Co. Site #6 U.S. 17	Base(Limerock)	24.13	2.41	4.83	19.09	144.29	149.11	21.50	192.12	277.47	40.23		
	Subgrade(Fine Sand)	50.80	5.08	10.16	10.43	39.53	49.69	15.51	80.70	107.04	15.52		
	Embankment(Fine Sand)	140.97	14.10	28.19	0.52	7.23	35.42	14.62	64.66	110.59	16.04		
Jefferson Co. Site #1A U.S.27	Base(Limerock)	19.69	1.97	3.94	12.72	226.91	230.85	14.69	260.24	289.93	42.04	178.68	25.92
	Subgrade(Silty Clay)	36.20	3.62	7.24	88.56	46.99	54.23	92.18	238.58	185.61	26.91	136.91	19.86
	Embankment(Silty Clay)	113.67	11.37	22.73	1.37	7.81	30.55	12.74	56.03			82.39	11.95
Jefferson Co. Site #2A U.S.27	Base(Limerock)	21.59	2.16	4.32	9.33	153.80	158.12	11.49	181.10	240.74	34.91	201.33	29.20
	Subgrade(Silty Clay)	45.72	4.57	9.14	4.15	54.20	63.34	8.72	80.78			147.73	21.43
	Embankment(Silty Sand)	121.67	12.17	24.33	1.58	12.73	37.07	13.75	64.57	77.86	11.29	115.15	16.70

Table 8.8 Plate Layer Modulus versus Laboratory Modulus at In-situ MC and Equivalent State of Stresses (continued)

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress	Lab Modulus (Insitu MC)		Plate Layer Modulus	
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa	MPa	ksi	MPa	ksi
Gadsden Co. Site #2B U.S. 27	Base(Limerock)	22.10	2.21	4.42	12.16	230.36	234.78	14.37	263.52	214.63	31.12	219.61	31.85
	Subgrade(Silty Sand)	59.06	5.91	11.81	3.89	45.93	57.74	9.79	77.32	104.49	15.15	108.11	15.68
	Embankment#1(Silty Sand)	133.35	13.34	26.67	2.01	11.82	38.49	15.35	69.18	92.80	13.46	82.33	11.94
Gadsden Co. Site #3B U.S. 27	Base(Limerock)	19.69	1.97	3.94	20.99	272.36	276.30	22.96	322.23	210.59	30.54	212.37	30.80
	Subgrade(Fine Sand)	59.69	5.97	11.94	3.94	45.59	57.53	9.90	77.34	124.19	18.01	120.66	17.50
	Embankment(Clay)	134.62	13.46	26.92	2.29	11.50	38.42	15.75	69.92	111.43	16.16	94.53	13.71
Dade Co. Site #1 U.S. 41	Base(Limerock)	24.64	2.46	4.93	0.32	152.84	157.77	2.78	163.32			647.96	93.98
	Subgrade(Limerock)	57.66	5.77	11.53	5.38	39.83	51.36	11.15	73.65	226.62	32.86	441.62	64.05
	Embankment(Limerock)	156.72	15.67	31.34	0.39	6.90	38.24	16.06	70.36	121.35	17.60	422.10	61.22
Dade Co. Site #2 U.S. 41	Base(Limerock)												
	Subgrade(Limerock)												
	Embankment(Limerock)												
Martin Co. Site#3 U.S. 1	Base(Limerock)	22.86	2.29	4.57	2.74	128.77	133.34	5.03	143.39			246.15	35.70
	Subgrade(Fine Sand)	55.88	5.59	11.18	3.56	34.75	45.92	9.15	64.22	164.80	23.90	178.58	25.90
	Embankment(Fine Sand)	160.02	16.00	32.00	1.33	6.66	38.67	17.33	73.34	146.04	21.18	58.26	8.45
Martin Co. Site#4 U.S. 1	Base(Limerock)	19.05	1.91	3.81	13.97	181.05	184.86	15.87	216.60	323.96	46.97	255.80	37.10
	Subgrade(Silty Clay)	45.72	4.57	9.14	8.73	46.61	55.75	13.30	82.36	190.04	27.56	125.49	18.20
	Embankment(Fine Sand)	152.40	15.24	30.48	1.42	7.28	37.76	16.66	71.08	182.52	26.46	90.49	13.12
Seminole Co. Site #1 U.S.414	Base(Limerock)	30.48	3.05	6.10	6.10	96.35	102.45	9.15	120.75	235.11	34.09	266.91	38.71
	Subgrade(Silty Sand)	60.96	6.10	12.19	8.39	28.44	40.64	14.49	69.61	140.19	20.33	110.66	16.05
	Embankment(Silty Sand)	114.30	11.43	22.86	1.96	8.59	31.45	13.39	58.22	143.29	20.78	109.99	15.95
Seminole Co. Site #2 U.S.414	Base(Limerock)	30.48	3.05	6.10	5.48	98.70	104.79	8.53	121.85	160.64	23.29	248.56	36.05
	Subgrade(Silty Sand)	62.87	6.29	12.57	14.05	23.25	35.82	20.34	76.49	136.09	19.73	99.18	14.39
	Embankment(Fine Sand)	118.11	11.81	23.62	3.31	9.36	32.98	15.12	63.23	141.56	20.53	95.06	13.79
Osceola Co. Site #3 U.S. 441	Base(Coquina)	19.05	1.91	3.81	1.49	211.05	214.86	3.39	221.64	323.67	46.93	337.86	49.00
	Subgrade(Fine Sand)	51.05	5.11	10.21	15.72	36.36	46.57	20.82	88.22	226.90	32.90	114.87	16.66
	Embankment(Fine Sand)	113.28	11.33	22.66	3.17	8.68	31.34	14.49	60.33	128.72	18.66	58.26	8.45
Osceola Co. Site #4 U.S. 441	Base(Coquina)	27.94	2.79	5.59	33.10	68.54	74.13	35.89	145.92	245.53	35.60	295.38	42.84
	Subgrade(Fine Sand)	64.77	6.48	12.95	17.64	16.57	29.53	24.12	77.77	195.40	28.33	111.97	16.24
	Embankment(Fine Sand)	120.14	12.01	24.03	3.31	9.21	33.24	15.32	63.89	126.52	18.35	57.33	8.31

Table 8.9 Laboratory Modulus (In-situ MC) versus Laboratory Modulus (OMC) under Same State of Stresses

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress	Modulus Calculated from Lab (in-situ)		Modulus Calculated from Lab (OMC)	
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa	MPa	ksi	MPa	ksi
Lee Co., Site #1B, S.R.884	Base(Limerock)	17.02	1.70	3.40	13.01	216.84	220.25	14.71	249.66				
	Subgrade(Fine Sand)	44.45	4.45	8.89	17.69	50.24	59.13	22.14	103.40	156.13	22.64	168.73	24.47
	Embankment(Fine Sand)	133.99	13.40	26.80	1.60	7.99	34.79	15.00	64.78	117.32	17.01	155.75	22.58
Polk Co., Site #1A, U.S. 17	Base(Limerock)	19.05	1.91	3.81	1.93	164.98	168.79	3.84	176.46				
	Subgrade(Silty Sand)	48.26	4.83	9.65	13.38	37.92	47.57	18.21	83.98	123.50	17.91	139.43	20.22
	Embankment(Fine Sand)	139.70	13.97	27.94	1.72	6.90	34.84	15.69	66.22	97.11	14.08	96.56	14.00
Polk Co., Site #2A, U.S. 17	Base(Limerock)	19.05	1.91	3.81	9.12	194.36	198.17	11.02	220.21				
	Subgrade(Silty Sand)	46.99	4.70	9.40	19.00	43.99	53.39	23.70	100.79	161.86	23.47	168.71	24.46
	Embankment(Fine Sand)	138.43	13.84	27.69	1.70	7.08	34.76	15.54	65.84	160.07	23.21	146.12	21.19
Alachua Co., Site #3, U.S. 301	Base(Limerock)	22.23	2.22	4.45	4.06	205.53	209.98	6.28	222.55				
	Subgrade(Fine Sand)	49.53	4.95	9.91	4.18	59.62	69.52	9.13	87.79	107.08	15.53	127.51	18.49
	Embankment(Fine Sand)	135.89	13.59	27.18	1.24	11.25	38.43	14.83	68.09				
Alachua Co., Site #4, U.S. 301	Base(Limerock)	20.32	2.03	4.06	19.33	168.56	172.63	21.36	215.34				
	Subgrade(Silty Sand)	41.91	4.19	8.38	30.91	42.68	51.06	35.10	121.25	153.33	22.23	189.58	27.49
	Embankment(Fine Sand)	147.96	14.80	29.59	1.64	6.66	36.25	16.44	69.13				
Clay Co., Site #5, U.S. 17	Base(Limerock)	24.13	2.41	4.83	10.45	170.15	174.97	12.86	200.70				
	Subgrade(Fine Sand)	49.53	4.95	9.91	15.21	44.40	54.30	20.17	94.64	116.77	16.93	108.79	15.77
	Embankment(Fine Sand)	123.83	12.38	24.77	0.60	9.16	33.92	12.98	59.89	97.75	14.17	108.61	15.75
Clay Co., Site #6, U.S. 17	Base(Limerock)	24.13	2.41	4.83	19.09	144.29	149.11	21.50	192.12				
	Subgrade(Fine Sand)	50.80	5.08	10.16	10.43	39.53	49.69	15.51	80.70	107.04	15.52	96.88	14.05
	Embankment(Fine Sand)	140.97	14.10	28.19	0.52	7.23	35.42	14.62	64.66	110.59	16.04	113.81	16.50
Jefferson Co., Site #1A, U.S.27	Base(Limerock)	19.69	1.97	3.94	12.72	226.91	230.85	14.69	260.24	289.93	42.04		
	Subgrade(Silty Clay)	36.20	3.62	7.24	88.56	46.99	54.23	92.18	238.58	185.61	26.91		
	Embankment(Silty Clay)	113.67	11.37	22.73	1.37	7.81	30.55	12.74	56.03				
Jefferson Co., Site #2A, U.S.27	Base(Limerock)	21.59	2.16	4.32	9.33	153.80	158.12	11.49	181.10	240.74	34.91		
	Subgrade(Silty Clay)	45.72	4.57	9.14	4.15	54.20	63.34	8.72	80.78				
	Embankment(Silty Sand)	121.67	12.17	24.33	1.58	12.73	37.07	13.75	64.57	77.86	11.29		

Table 8.9 Laboratory Modulus (In-situ MC) versus Laboratory Modulus (OMC) under Same State of Stresses (continued)

Sites	Layers	Depth	Horizontal stress due to weight	Vertical stress due to weight	Horizontal stress due to applied load	Vertical stress due to applied load	Total vertical stress	Total horizontal stress	Total bulk stress	Modulus Calculated from Lab (insitu)		Modulus Calculated from Lab (OMC)	
		cm	kPa	kPa	kPa	kPa	kPa	kPa	kPa	MPa	ksi	MPa	ksi
Gadsden Co., Site #2B, U.S. 27	Base(Limerock)	22.10	2.21	4.42	12.16	230.36	234.78	14.37	263.52				
	Subgrade(Silty Sand)	59.06	5.91	11.81	3.89	45.93	57.74	9.79	77.32	104.49	15.15	192.17	27.86
	Embankment #1 (Silty Sand)	133.35	13.34	26.67	2.01	11.82	38.49	15.35	69.18	92.80	13.46	138.62	20.10
Gadsden Co., Site #3B, U.S. 27	Base(Limerock)	19.69	1.97	3.94	20.99	272.36	276.30	22.96	322.23				
	Subgrade(Fine Sand)	59.69	5.97	11.94	3.94	45.59	57.53	9.90	77.34	124.19	18.01	136.32	19.77
	Embankment(Clay)	134.62	13.46	26.92	2.29	11.50	38.42	15.75	69.92				
Dade Co., Site #1, U.S. 41	Base(Limerock)	24.64	2.46	4.93	0.32	152.84	157.77	2.78	163.32				
	Subgrade(Limerock)	57.66	5.77	11.53	5.38	39.83	51.36	11.15	73.65				
	Embankment(Limerock)	156.72	15.67	31.34	0.39	6.90	38.24	16.06	70.36				
Martin Co., Site#3, U.S. 1	Base(Limerock)	22.86	2.29	4.57	2.74	128.77	133.34	5.03	143.39				
	Subgrade(Fine Sand)	55.88	5.59	11.18	3.56	34.75	45.92	9.15	64.22	164.80	23.90	201.84	29.27
	Embankment(Fine Sand)	160.02	16.00	32.00	1.33	6.66	38.67	17.33	73.34	146.04	21.18	152.94	22.18
Martin Co., Site#4, U.S. 1	Base(Limerock)	19.05	1.91	3.81	13.97	181.05	184.86	15.87	216.60				
	Subgrade(Silty Clay)	45.72	4.57	9.14	8.73	46.61	55.75	13.30	82.36	190.04	27.56	210.13	30.47
	Embankment(Fine Sand)	152.40	15.24	30.48	1.42	7.28	37.76	16.66	71.08	182.52	26.46	215.36	31.23
Seminole Co., Site #1, U.S.414	Base(Limerock)	30.48	3.05	6.10	6.10	96.35	102.45	9.15	120.75				
	Subgrade(Silty Sand)	60.96	6.10	12.19	8.39	28.44	40.64	14.49	69.61	140.19	20.33	181.54	26.32
	Embankment(Silty Sand)	114.30	11.43	22.86	1.96	8.59	31.45	13.39	58.22	143.29	20.78	133.21	19.32
Seminole Co., Site #2, U.S.414	Base(Limerock)	30.48	3.05	6.10	5.48	98.70	104.79	8.53	121.85				
	Subgrade(Silty Sand)	62.87	6.29	12.57	14.05	23.25	35.82	20.34	76.49	136.09	19.73	173.52	25.16
	Embankment(Fine Sand)	118.11	11.81	23.62	3.31	9.36	32.98	15.12	63.23	141.56	20.53	160.29	23.24
Osceola Co., Site #3, U.S. 441	Base(Coquina)	19.05	1.91	3.81	1.49	211.05	214.86	3.39	221.64				
	Subgrade(Fine Sand)	51.05	5.11	10.21	15.72	36.36	46.57	20.82	88.22	226.90	32.90	250.74	36.36
	Embankment(Fine Sand)	113.28	11.33	22.66	3.17	8.68	31.34	14.49	60.33	128.72	18.66	139.93	20.29
Osceola Co., Site #4, U.S. 441	Base(Coquina)	27.94	2.79	5.59	33.10	68.54	74.13	35.89	145.92				
	Subgrade(Fine Sand)	64.77	6.48	12.95	17.64	16.57	29.53	24.12	77.77	195.40	28.33	212.81	30.86
	Embankment(Fine Sand)	120.14	12.01	24.03	3.31	9.21	33.24	15.32	63.89	126.52	18.35	93.11	13.50

Table 8.10 Laboratory Modulus (In-situ MC) versus Laboratory Modulus (OMC) at Confining Pressure 2 psi

SITES	STRUCTURE ELEMENT	AASHTO CLASSIFICATION	LAB MODULUS (OMC)		LAB MODULUS (INSITU MC)	
			ksi	MPa	ksi	MPa
Lee Co.	Subgrade	A-3	20.8	143.3	18.8	129.6
SR884 Site 1B	EMB	A-3	23.3	160.8	17.9	123.4
Lee Co.	Subgrade	A-3	21.2	146.3	21.5	148.6
SR884 Site 2B	EMB	A-3	19.3	133.4	17.7	122.0
Polk Co.	Subgrade	A-2-4	18.4	126.8	16.2	111.5
US17 Site 1A	EMB	A-3	14.3	98.5	14.3	98.3
Polk Co.	Subgrade	A-2-4	20.5	141.5	19.4	133.8
US17 Site 2A	EMB	A-3	21.7	149.4	24.0	165.6
Clay Co.	Subgrade	A-3	13.7	94.4	14.6	100.7
US17 Site 5	EMB	A-2-4	16.7	115.3	15.2	105.0
Clay Co.	Subgrade	A-3	13.1	90.2	14.3	98.6
US17 Site 6	EMB	A-3	17.0	117.4	16.8	115.7
Alachua Co.	Subgrade	A-3	16.7	114.9	13.8	95.4
US301 Site 3	EMB	A-2-4				
Alachua Co.	Subgrade	A-2-4	18.5	127.5	17.2	118.3
US301 Site 4	EMB	A-6				
Jefferson Co.	Subgrade	A-4			14.7	101.6
US27 Site 1A	EMB	A-2-6				
Jefferson Co.	Subgrade	A-4				
US27 Site 2A	EMB	A-2-4			12.0	82.6
Gadsden Co.	Subgrade	A-2-4	26.5	182.9	14.4	99.1
US27 Site 2B	EMB	A-2-4	20.3	139.7	13.7	94.6
Gadsden Co.	Subgrade	A-3	18.8	129.4	17.1	117.6
US27 Site 3B	EMB	A-6				
Martin Co.	Subgrade	A-3	30.2	208.4	24.7	170.4
US1 Site 3	EMB	A-3	21.8	150.4	20.9	144.2
Martin Co.	Subgrade	A-4	28.3	195.3	25.7	177.2
US1 Site 4	EMB	A-3	30.8	212.4	26.1	180.1

Table 8.10 Laboratory Modulus (In-situ MC) versus Laboratory Modulus (OMC) at Confining Pressure 2 psi (continued)

SITES	STRUCTURE ELEMENT	AASHTO CLASSIFICATION	LAB MODULUS (OMC)		LAB MODULUS (INSITU MC)	
			ksi	MPa	ksi	MPa
Seminole Co. US414 Site 1	Subgrade	A-2-4	26.0	179.4	20.3	139.9
	EMB	A-2-4	20.9	143.9	22.9	157.8
Seminole Co. US414 Site 2	Subgrade	A-2-4	24.6	169.5	19.0	131.0
	EMB	A-3	24.2	167.2	21.4	147.5
Osceola Co. US441 Site 3	Subgrade	A-3	32.9	226.9	29.3	202.3
	EMB	A-3	21.8	150.5	20.1	138.4
Osceola Co. US441 Site 4	Subgrade	A-3	29.2	201.2	26.9	185.4
	EMB	A-3	14.2	97.6	19.2	132.7

Table 8.11 Plate Layer Modulus versus LBR

SITES	PAVEMENT STRUCTURE	AASHTO CLASSIFICATION	PLM		LBR
			MPa	ksi	
Lee Co. SR884 Site 1B	Base	Limerock	234.26	34.00	65
	Subgrade	A-3	180.17	26.15	43
	Embankment	A-3	48.68	7.07	19
Lee Co. SR884 Site 2B	Base	Limerock	256.65	37.25	113
	Subgrade	A-3	254.93	37.00	49
	Embankment	A-3	103.18	14.98	33
Polk Co. US17 Site 1A	Base	Limerock	358.28	52.00	110
	Subgrade	A-2-4	289.38	42.00	47
	Embankment	A-3	48.68	7.07	16
Polk Co. US17 Site 2A	Base	Limerock	392.73	57.00	90
	Subgrade	A-2-4	251.49	36.50	64
	Embankment	A-3	141.20	20.49	30
Alachua Co. US301 Site 3	Base	Limerock	709.67	103.00	126
	Subgrade	A-3	383.08	55.60	49
	Embankment	A-3	67.58	9.81	53
Alachua Co. US301 Site 4	Base	Limerock	819.91	119.00	132
	Subgrade	A-2-4			
	Embankment	A-6	54.47	7.91	68
Clay Co. US17 Site 5	Base	Limerock	275.60	40.00	118
	Subgrade	A-3	172.25	25.00	38
	Embankment	A-2-4	119.77	17.38	29
Clay Co. US17 Site 6	Base	Limerock	351.39	51.00	90
	Subgrade	A-3	165.36	24.00	46
	Embankment	A-3	110.10	15.98	29
Jefferson Co. US27 Site 1A	Base	Limerock	244.60	35.50	128
	Subgrade	A-4	187.41	27.20	69
	Embankment	A-2-6	82.33	11.95	61
Jefferson Co. US27 Site 2A	Base	Limerock	275.60	40.00	138
	Subgrade	A-4	202.22	29.35	116
	Embankment	A-2-4	115.06	16.70	87

Table 8.11 Plate Layer Modulus versus LBR (continued)

SITES	PAVEMENT STRUCTURE	AASHTO CLASSIFICATION	PLM		LBR
			MPa	ksi	
Gadsden Co. US27 Site 2B	Base	Limerock	313.50	45.50	96
	Subgrade	A-2-4	154.34	22.40	145
	Embankment	A-2-4	82.27	11.94	59
Gadsden Co. US27 Site 3B	Base	Limerock	303.16	44.00	84
	Subgrade	A-3	172.25	25.00	121
	Embankment	A-6	94.46	13.71	54
Dade Co. US41 Site 1	Base	Limerock	924.98	134.25	128
	Subgrade	Limerock	630.44	91.50	147
	Embankment	Limerock	421.79	61.22	172
Dade Co. US41 Site 2	Base	Limerock	709.67	103.00	121
	Subgrade	Limerock	633.88	92.00	125
	Embankment	Limerock	346.57	50.30	100
Martin Co. US1 Site 3	Base	Limerock	351.39	51.00	191
	Subgrade	A-3	254.93	37.00	70
	Embankment	A-3	58.22	8.45	21
Martin Co. US1 Site 4	Base	Limerock	365.17	53.00	122
	Subgrade	A-4	179.14	26.00	45
	Embankment	A-3	90.42	13.12	29
Seminole Co. US414 Site 1	Base	Limerock	381.02	55.30	109
	Subgrade	A-2-4	110.58	16.05	79
	Embankment	A-2-4	109.91	15.95	20
Seminole Co. US414 Site 2	Base	Limerock	354.84	51.50	112
	Subgrade	A-2-4	141.59	20.55	93
	Embankment	A-3	108.77	15.79	31
Osceola Co. US441 Site 3	Base	Coquina	482.30	70.00	146
	Subgrade	A3	163.98	23.80	56
	Embankment	A3	58.22	8.45	18
Osceola Co. US441 Site 3	Base	Coquina	421.67	61.20	211
	Subgrade	A3	159.85	23.20	85
	Embankment	A3	57.28	8.31	60

Table 8.12 LBR versus FWD Modulus

SITES	PAVEMENT STRUCTURE	AASHTO CLASSIFICATION	LBR	FWD MODULUS	
				MPa	ksi
Lee Co. SR884 Site 1B	Base	Limerock	65	337.8	48.6
	Subgrade	A-3	43	219.6	31.6
	Embankment	A-3	19	144.6	20.8
Polk Co. US17 Site 1A	Base	Limerock	110	419.8	60.4
	Subgrade	A-2-4	47	255.1	36.7
	Embankment	A-3	16	282.2	40.6
Polk Co. US17 Site 2A	Base	Limerock	90	443.4	63.8
	Subgrade	A-2-4	64	305.8	44.0
	Embankment	A-3	30	271.7	39.1
Jefferson Co. US27 Site 1A	Base	Limerock	128	257.2	37.0
	Subgrade	A-4	69	209.9	30.2
	Embankment	A-2-6	61	189.7	27.3
Gadsden Co. US27 Site 2B	Base	Limerock	96	228.7	32.9
	Subgrade	A-2-4	145	148.0	21.3
	Embankment	A-2-4	81	127.9	18.4
Gadsden Co. US27 Site 3B	Base	Limerock	84	221.0	31.8
	Subgrade	A-3	121	123.0	17.7
	Embankment	A-6	54	114.7	16.5
Dade Co. US41 Site 1	Base	Limerock	128	606.0	87.2
	Subgrade	Limerock	147	497.6	71.6
	Embankment	Limerock	172	487.2	70.1
Martin Co. US1 Site 3	Base	Limerock	191	515.7	74.2
	Subgrade	A-3	70	386.4	55.6
	Embankment	A-3	21	348.9	50.2
Martin Co. US1 Site 4	Base	Limerock	122	595.6	85.7
	Subgrade	A-4	45	460.8	66.3
	Embankment	A-3	29	264.8	38.1

Table 8.12 LBR versus FWD Modulus (continued)

SITES	PAVEMENT STRUCTURE	AASHTO CLASSIFICATION	LBR	FWD MODULUS	
				MPa	ksi
Seminole Co. US414 Site 1	Base	Limerock	109	396.8	57.1
	Subgrade	A-2-4	79	370.4	53.3
	Embankment	A-2-4	20	216.1	31.1
Seminole Co. US414 Site 2	Base	Limerock	112	423.3	60.9
	Subgrade	A-2-4	93	303.0	43.6
	Embankment	A-3	31	165.4	23.8
Osceola Co. US441 Site 3	Base	Coquina	146	1011.9	145.6
	Subgrade	A3	56	349.6	50.3
	Embankment	A3	18	190.4	27.4
Osceola Co. US441 Site 4	Base	Coquina	211	493.5	71.0
	Subgrade	A3	85	208.5	30.0
	Embankment	A3	60	150.1	21.6

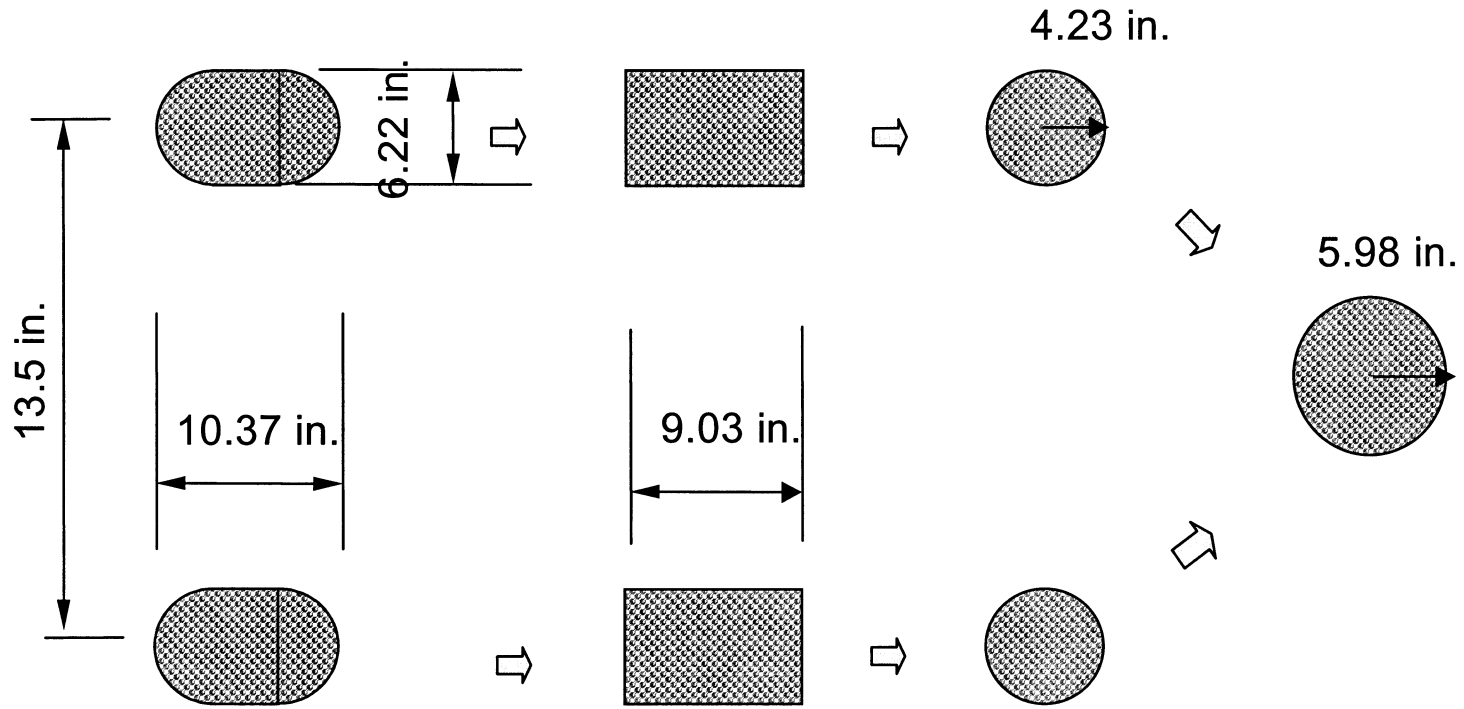


Figure 8.1. Equivalent contact radius for dual tires

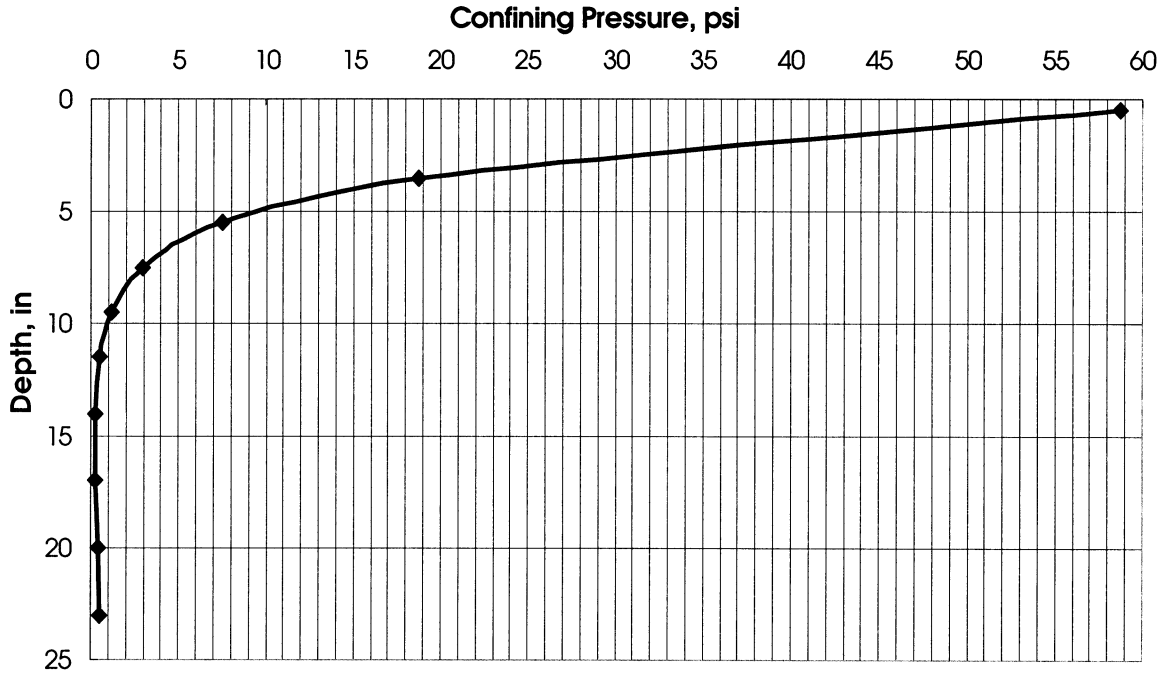


Figure 8.2 Confining pressure under one load and soil selfweight

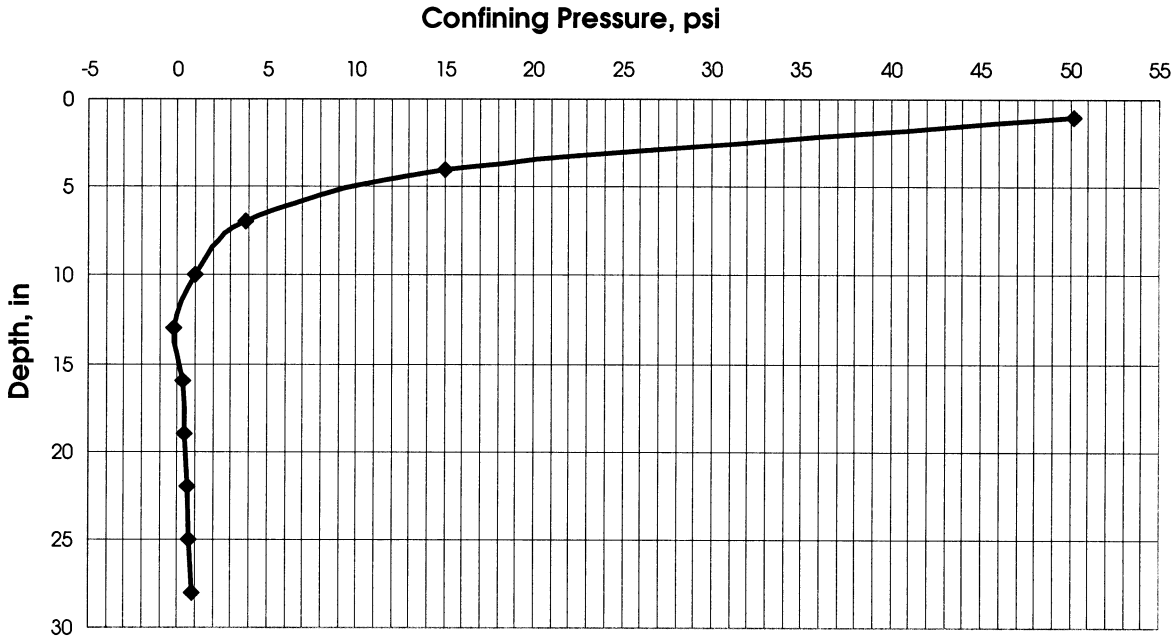


Figure 8.3 Confining pressure under two loads and soil selfweight

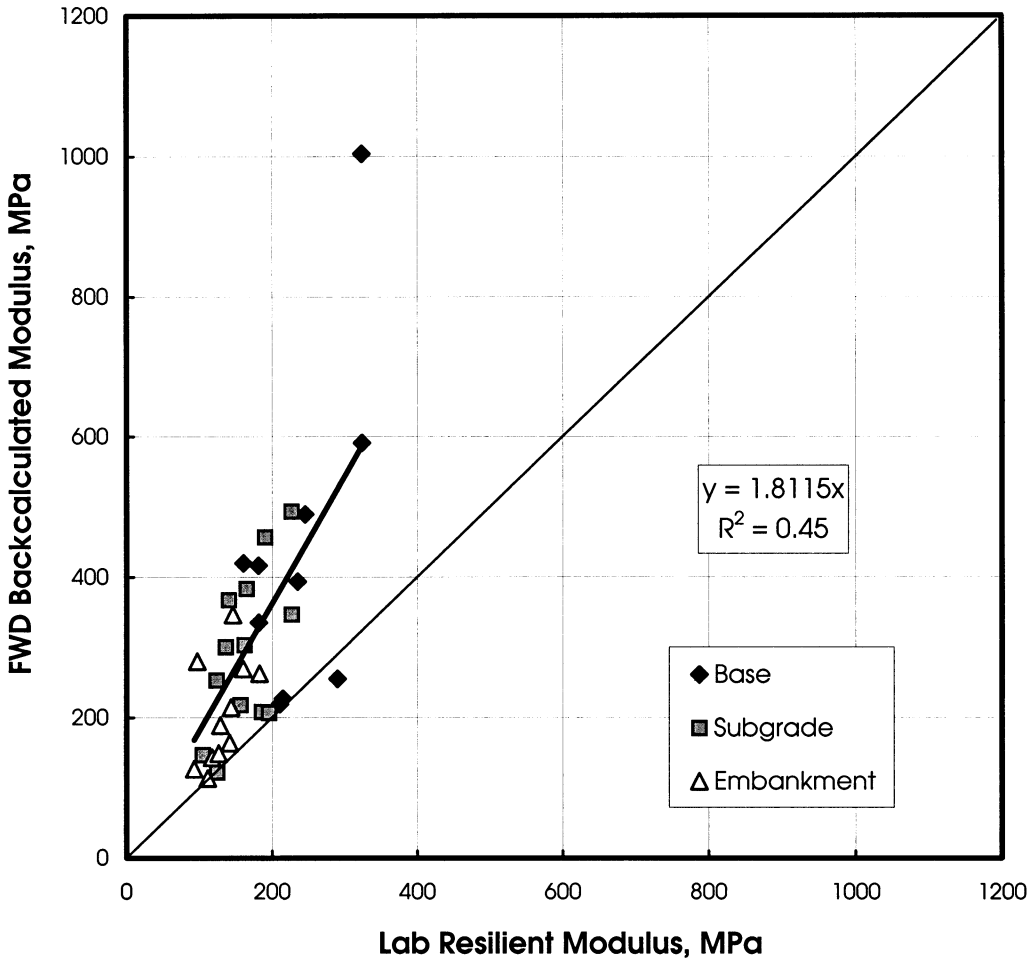


Figure 8.4a Laboratory resilient modulus (at insitu MC and state of stresses caused by traffic) versus FWD backcalculated modulus

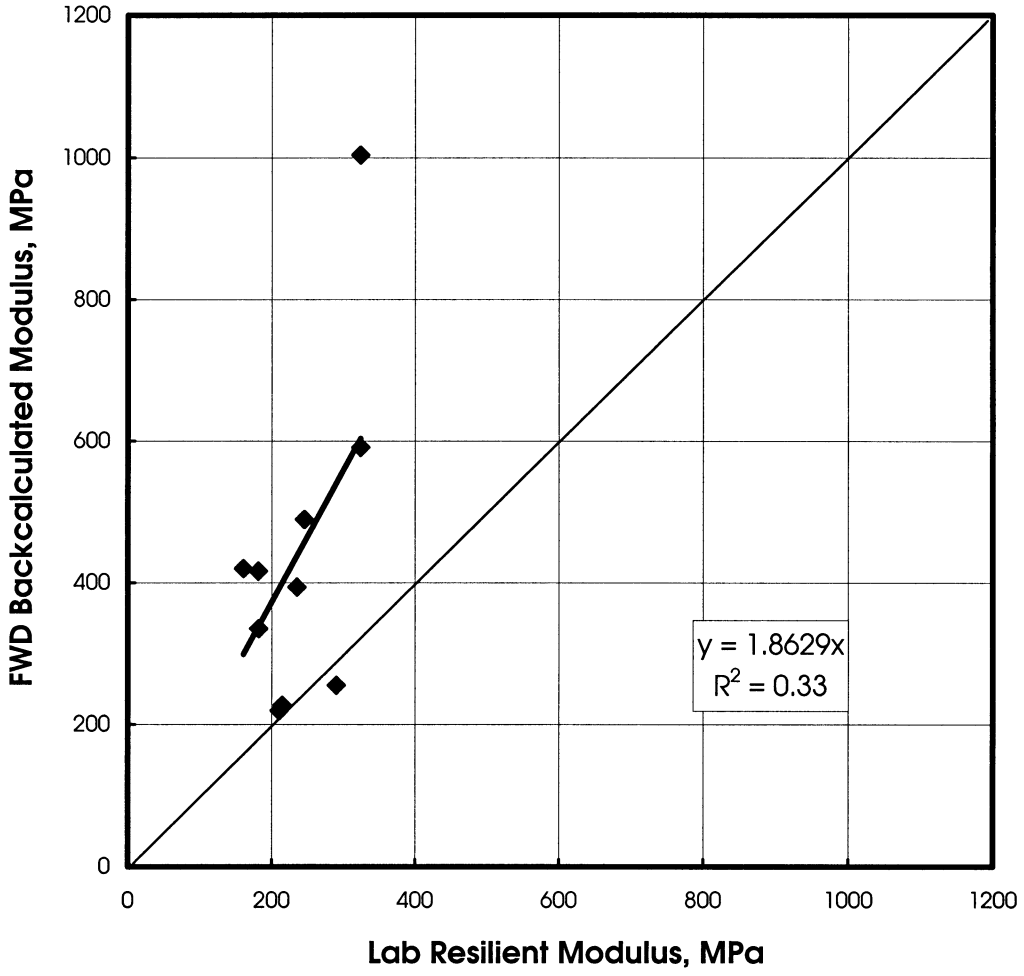


Figure 8.4b Laboratory resilient modulus (at insitu MC and state of stresses caused by traffic) versus FWD backcalculated modulus (base)

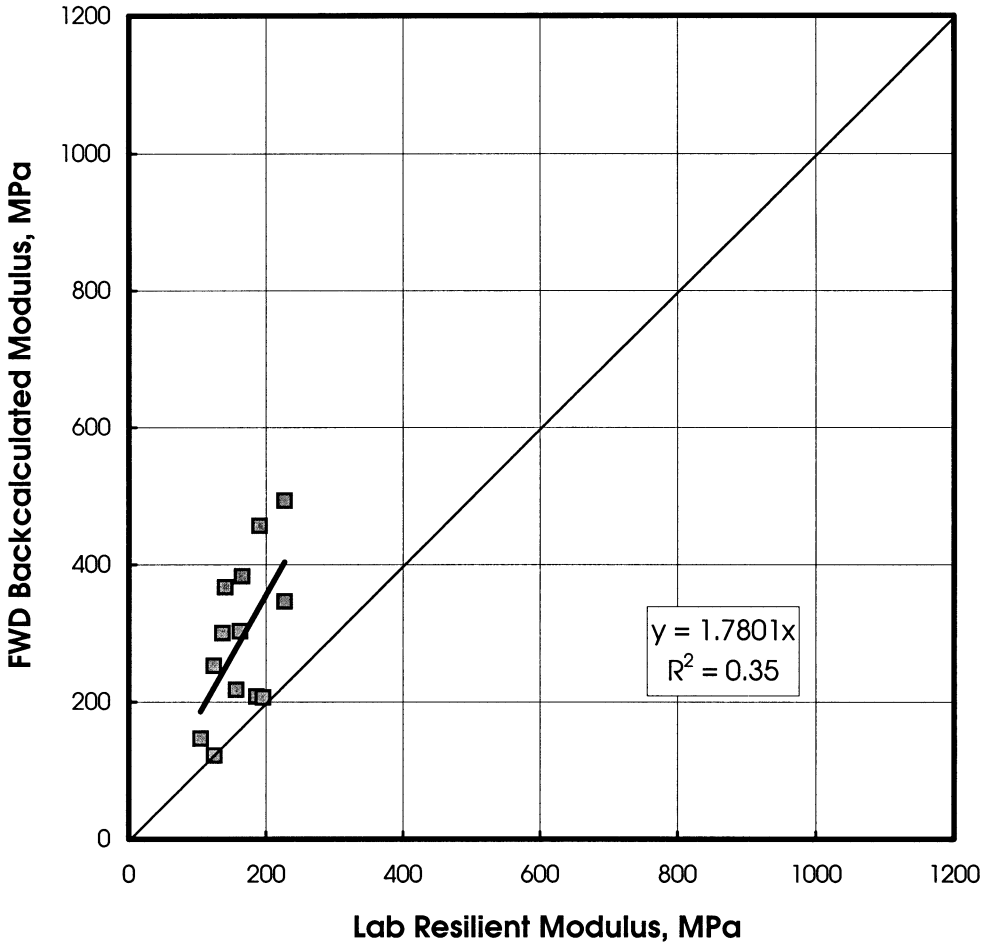


Figure 8.4c Laboratory resilient modulus (at insitu MC and state of stresses caused by traffic) versus FWD backcalculated modulus (subgrade)

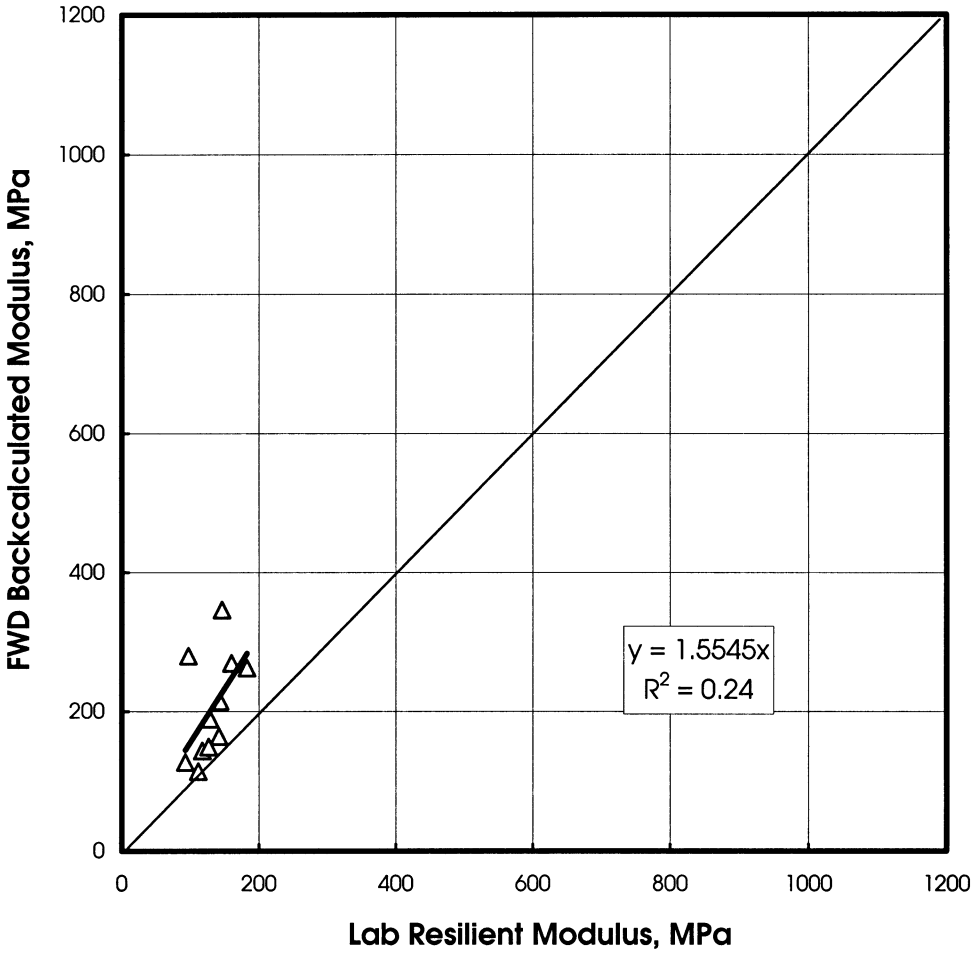


Figure 8.4d Laboratory resilient modulus (at insitu MC and state of stresses caused by traffic) versus FWD backcalculated modulus (embankment)

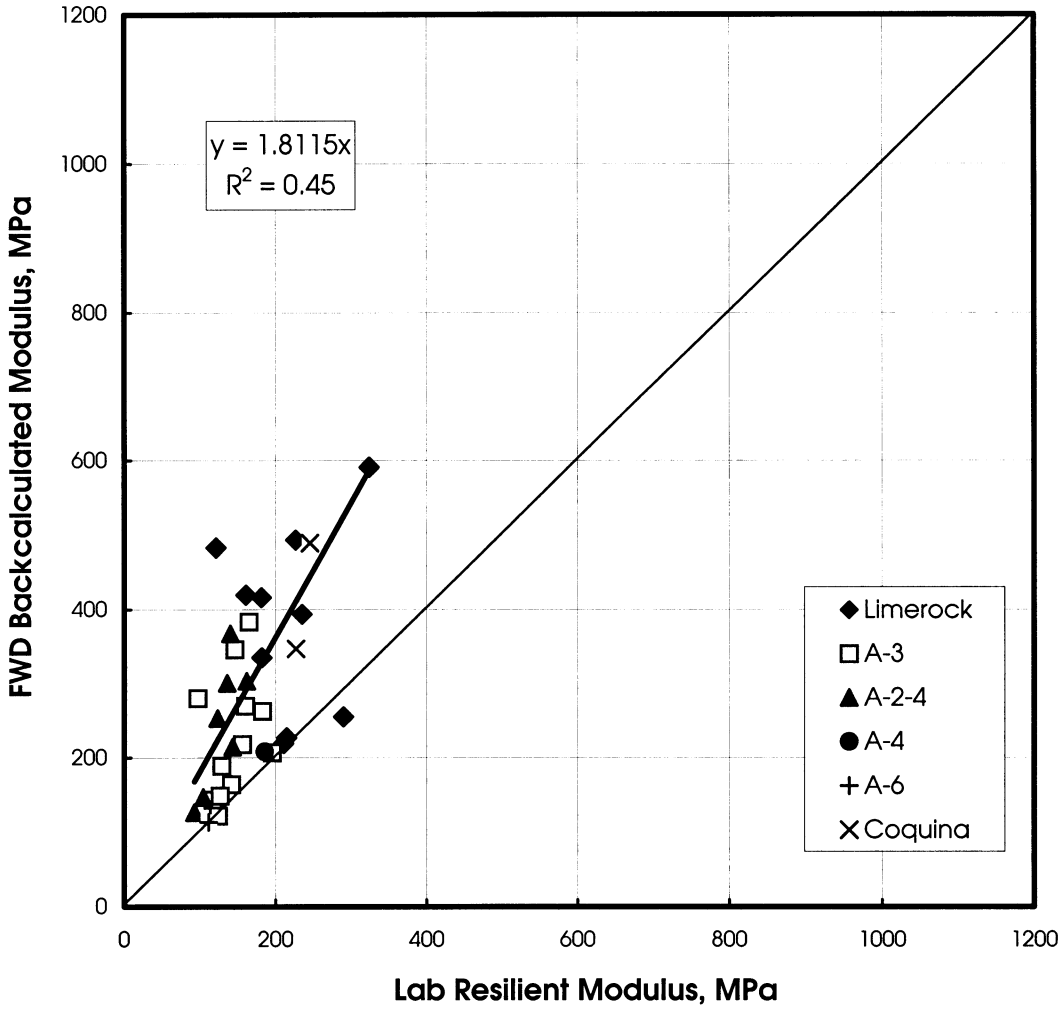


Figure 8.5a Laboratory resilient modulus (at insitu MC and state of stresses caused by traffic) versus FWD backcalculated modulus (by pavement materials)

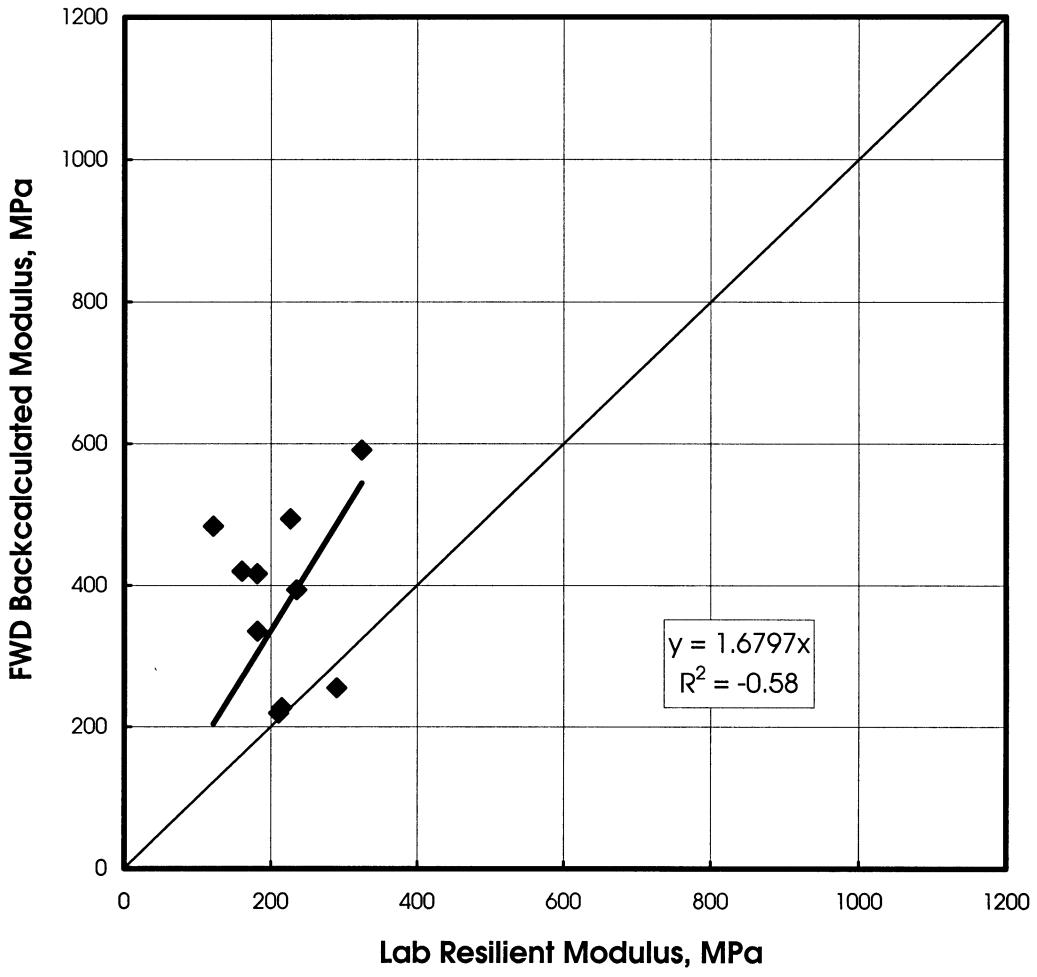


Figure 8.5b Laboratory resilient modulus (at insitu MC and state of stresses caused by traffic) versus FWD backcalculated modulus (limerock)

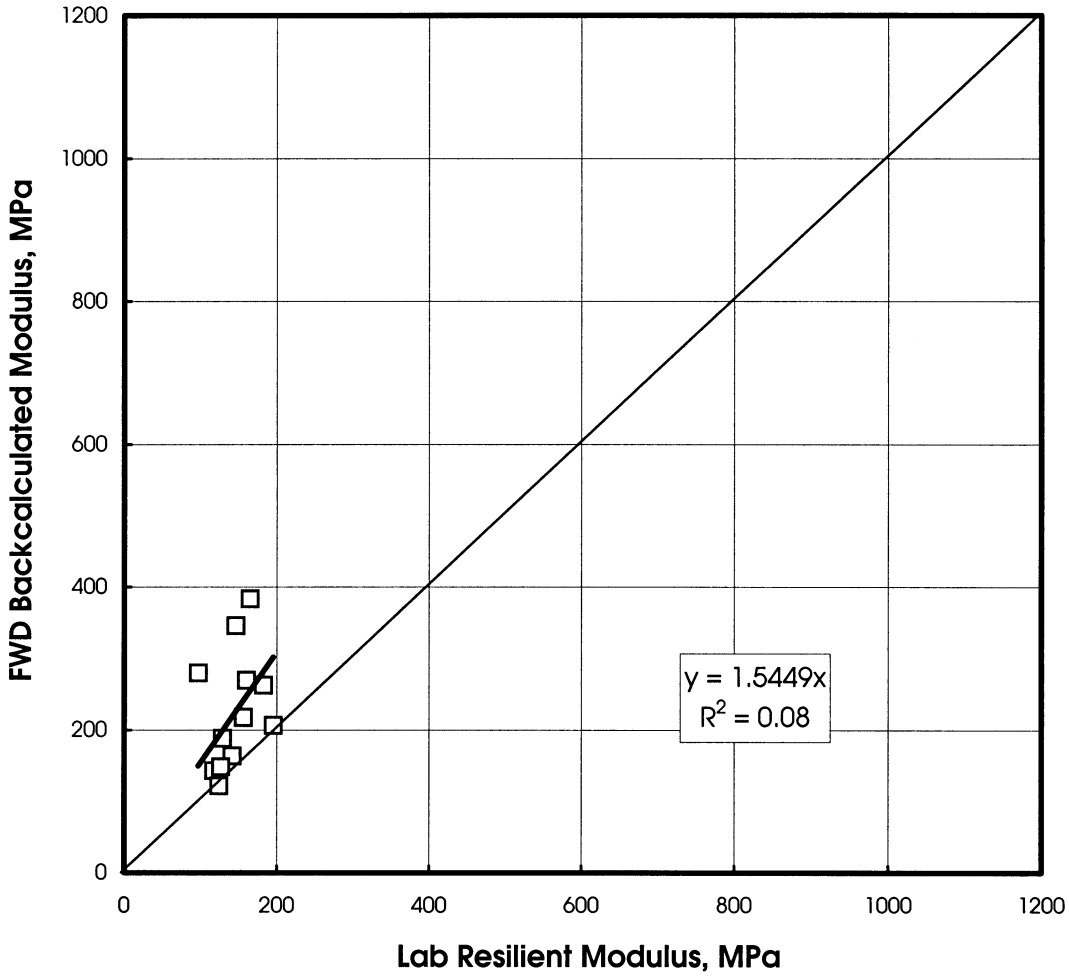


Figure 8.5c Laboratory resilient modulus (at insitu MC and state of stresses caused by traffic) versus FWD backcalculated modulus (A-3)

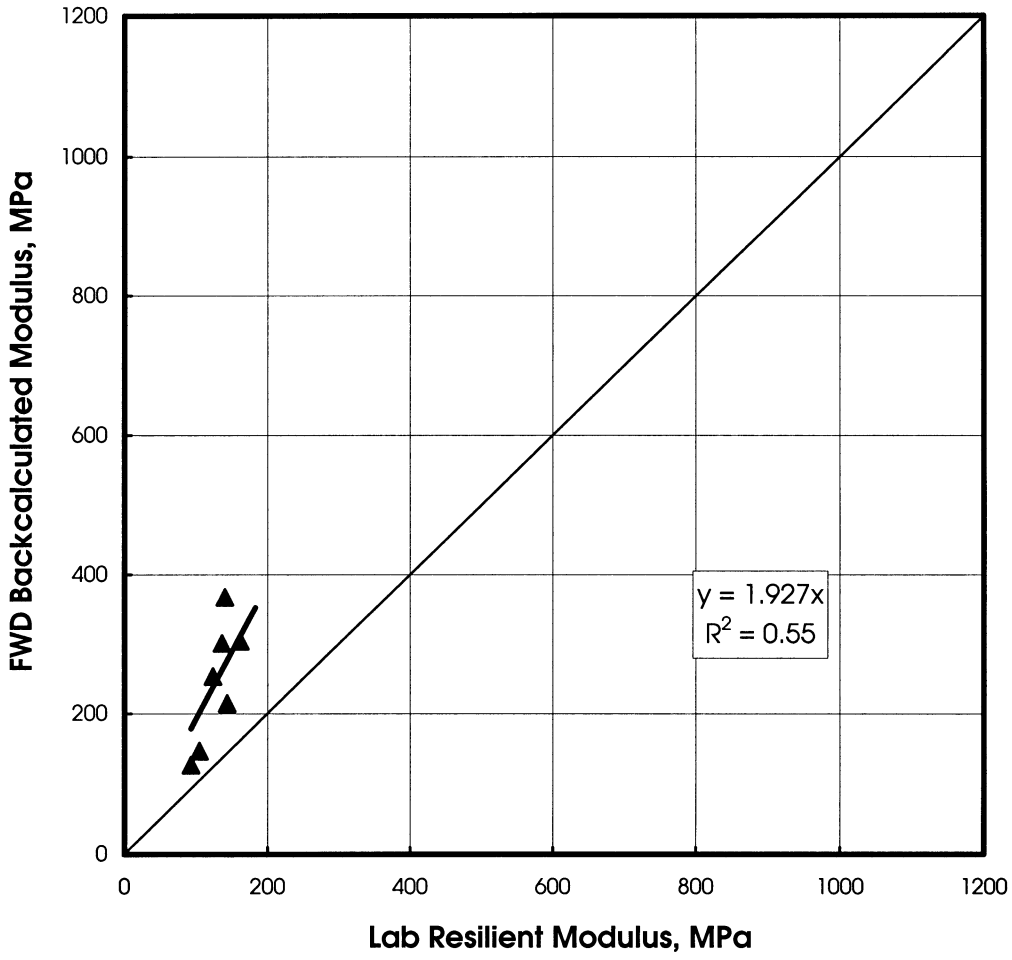


Figure 8.5d Laboratory resilient modulus (at insitu MC and state of stresses caused by traffic) versus FWD backcalculated modulus (A-2-4)

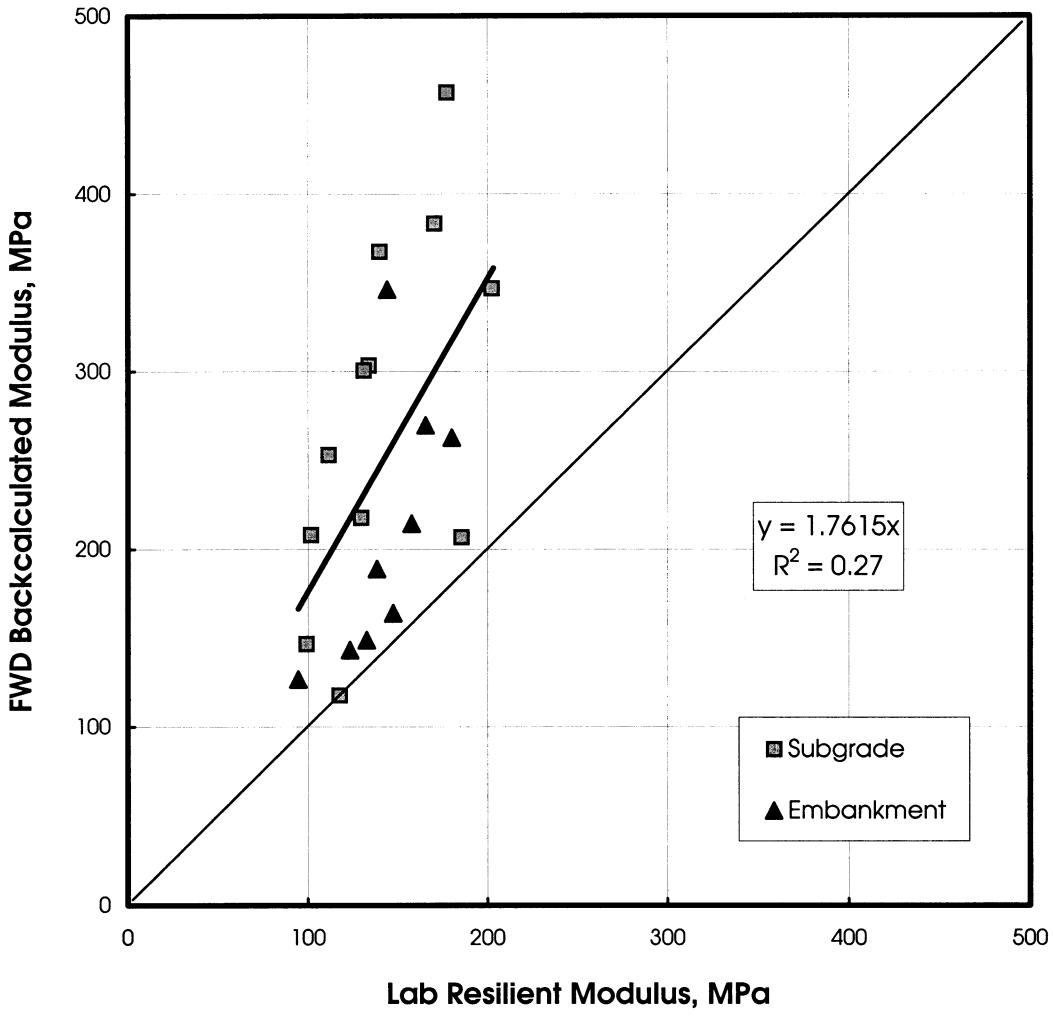


Figure 8.6a Laboratory resilient modulus (at insitu MC and confining pressure 2 psi) versus FWD backcalculated modulus

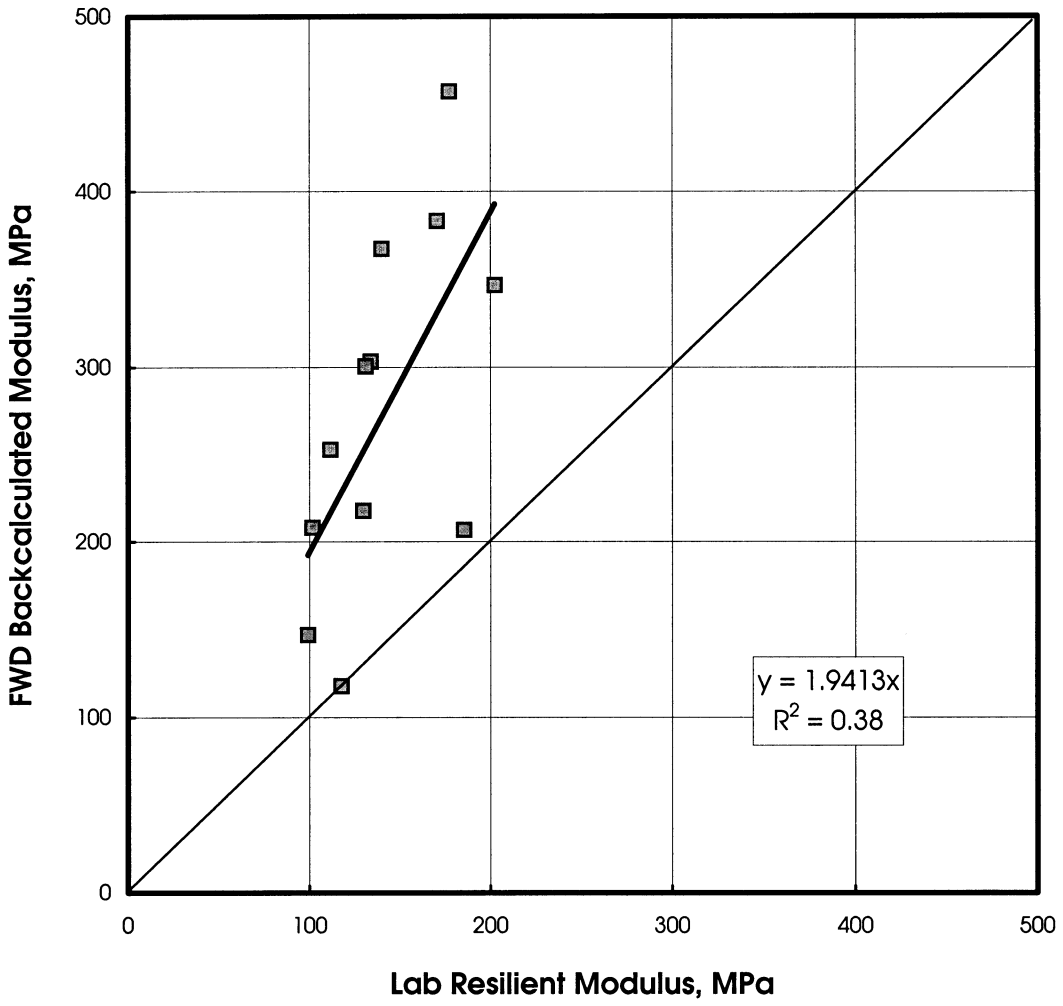


Figure 8.6b Laboratory resilient modulus (at insitu MC and confining pressure 2 psi) versus FWD backcalculated modulus (subgrade)

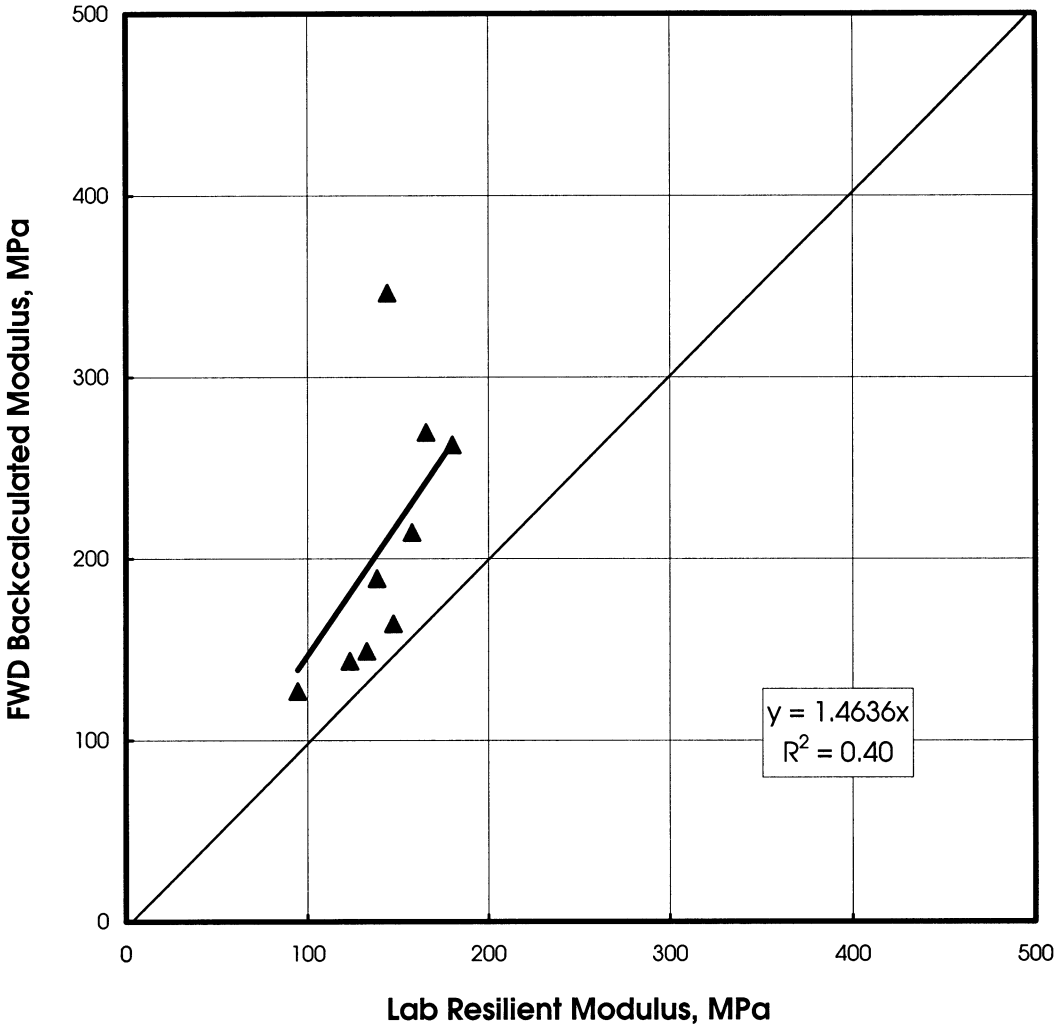


Figure 8.6c Laboratory resilient modulus (at insitu MC and confining pressure 2 psi) versus FWD backcalculated modulus (embankment)

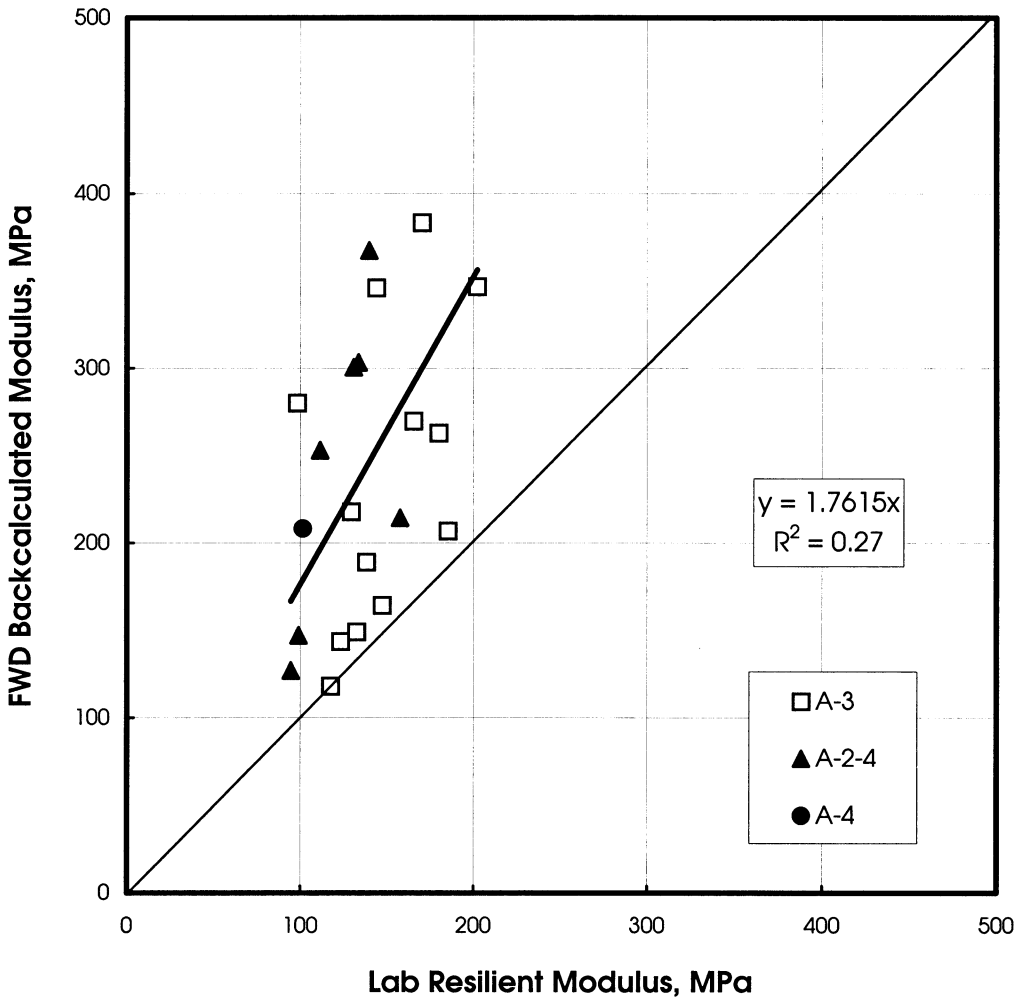


Figure 8.7a Laboratory resilient modulus (at insitu MC and confining pressure 2 psi) versus FWD backcalculated modulus (by pavement materials)

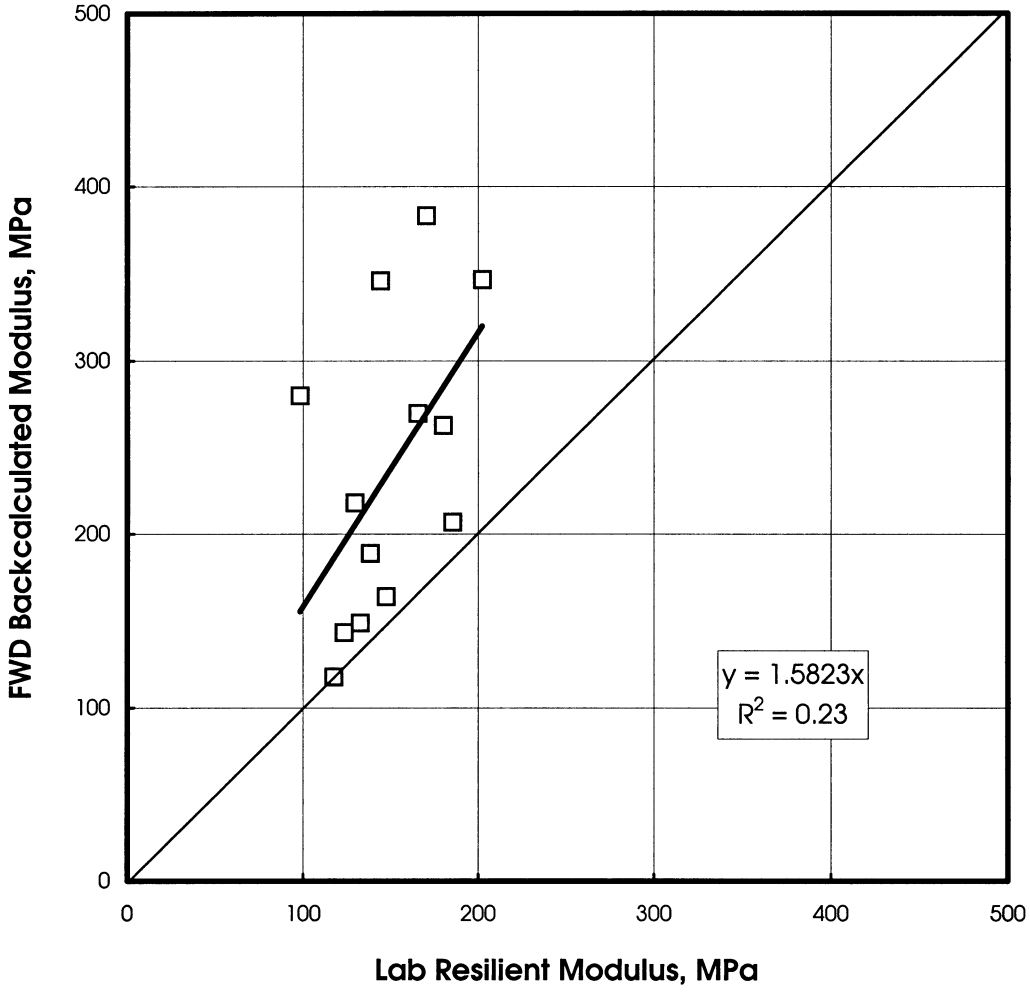


Figure 8.7b Laboratory resilient modulus (at insitu MC and confining pressure 2 psi) versus FWD backcalculated modulus (A-3)

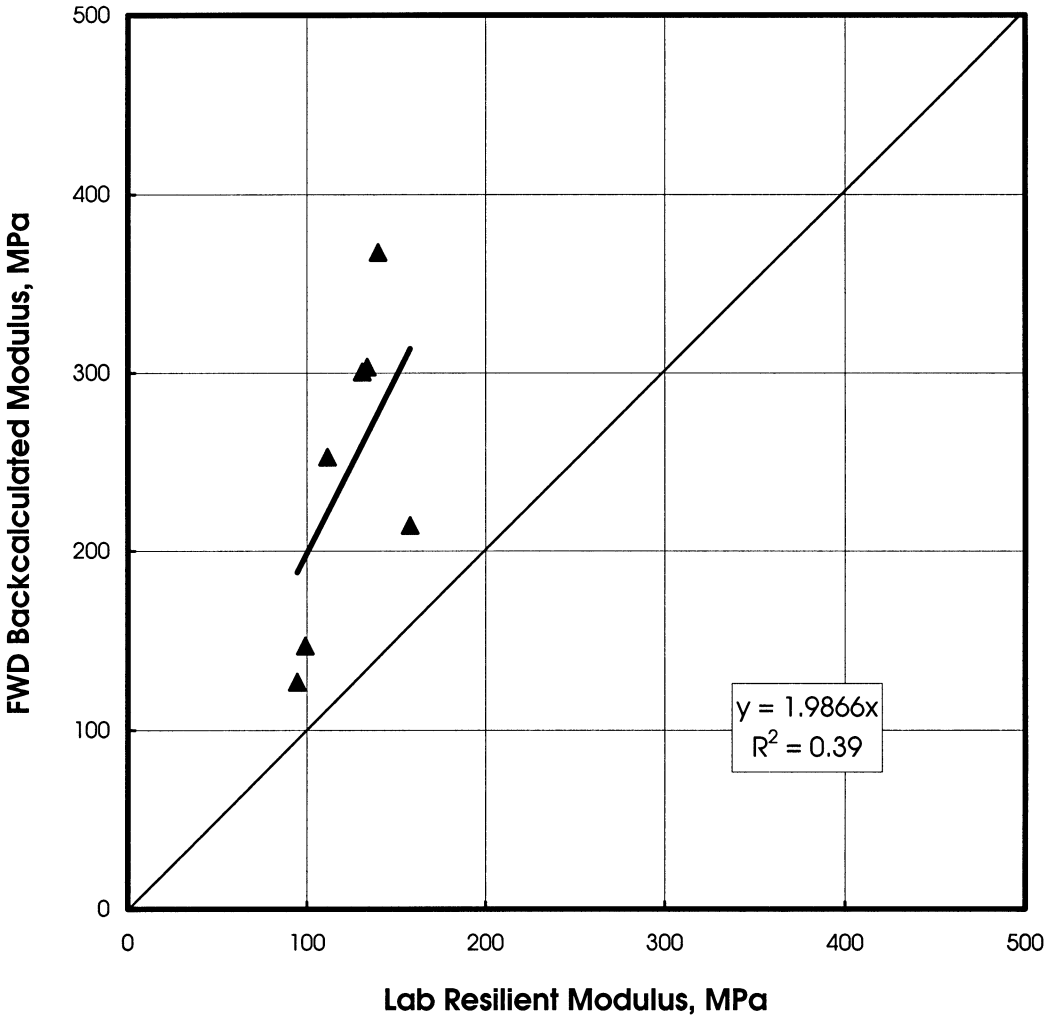


Figure 8.7c Laboratory resilient modulus (at insitu MC and confining pressure 2 psi) versus FWD backcalculated modulus (A-2-4)

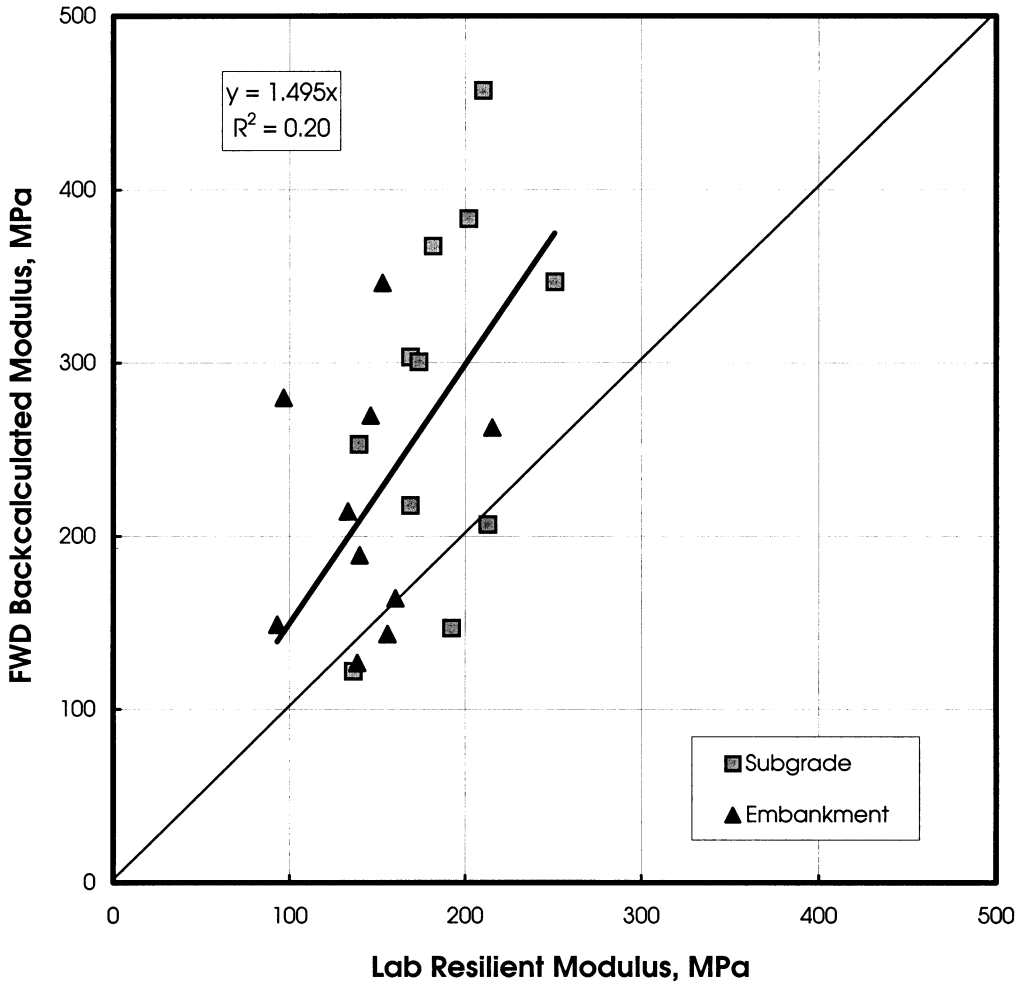


Figure 8.8a Laboratory resilient modulus (at OMC and state of stresses caused by traffic) versus FWD backcalculated modulus

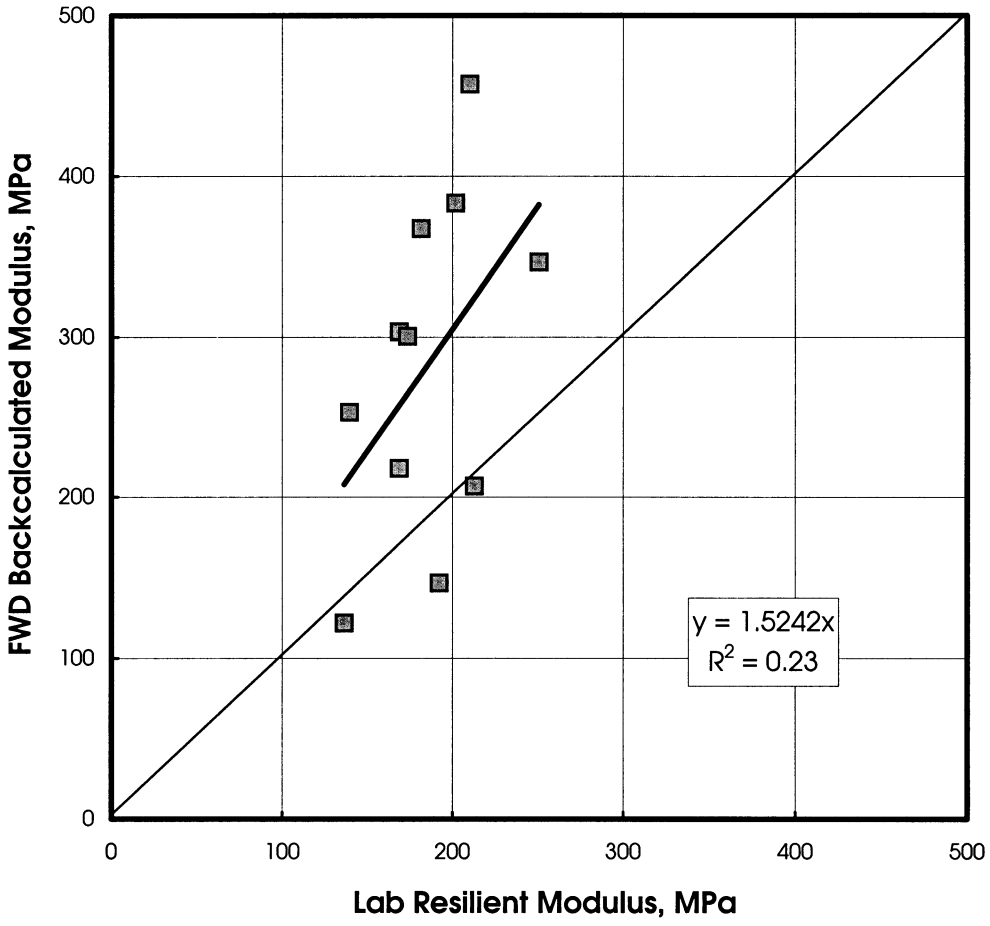


Figure 8.8b Laboratory resilient modulus (at OMC and state of stresses caused by traffic) versus FWD backcalculated modulus (subgrade)

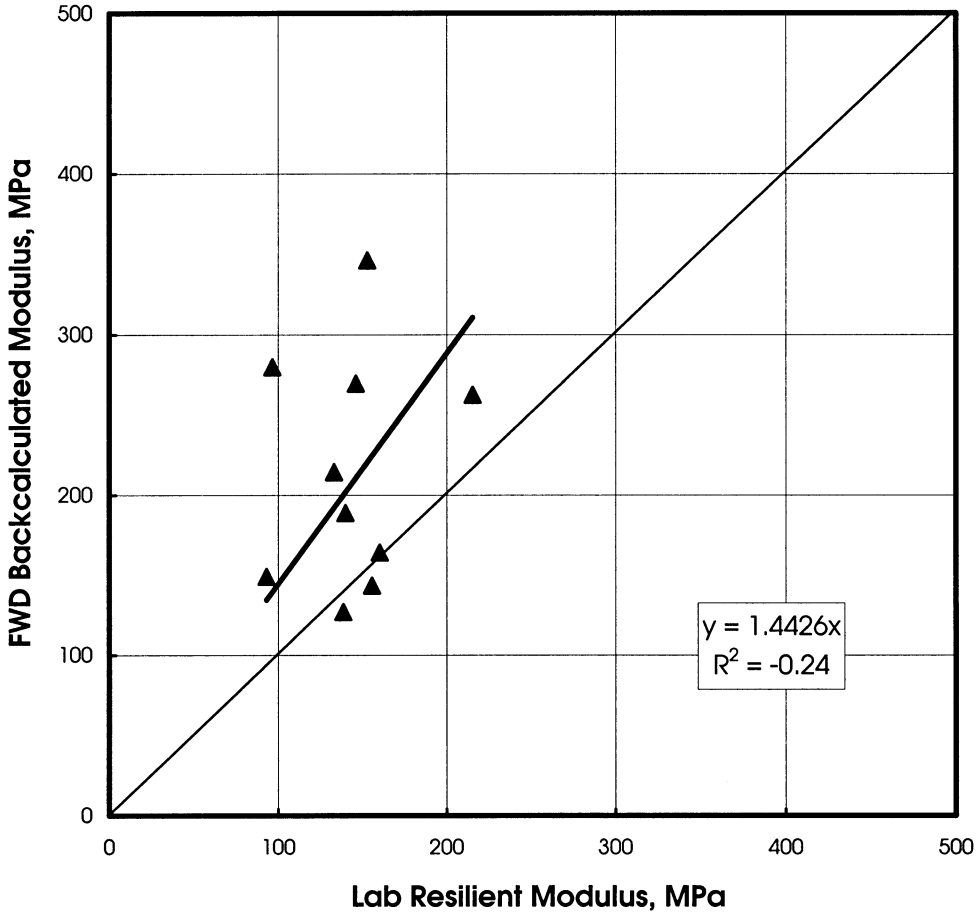


Figure 8.8c Laboratory resilient modulus (at OMC and state of stresses caused by traffic) versus FWD backcalculated modulus (embankment)

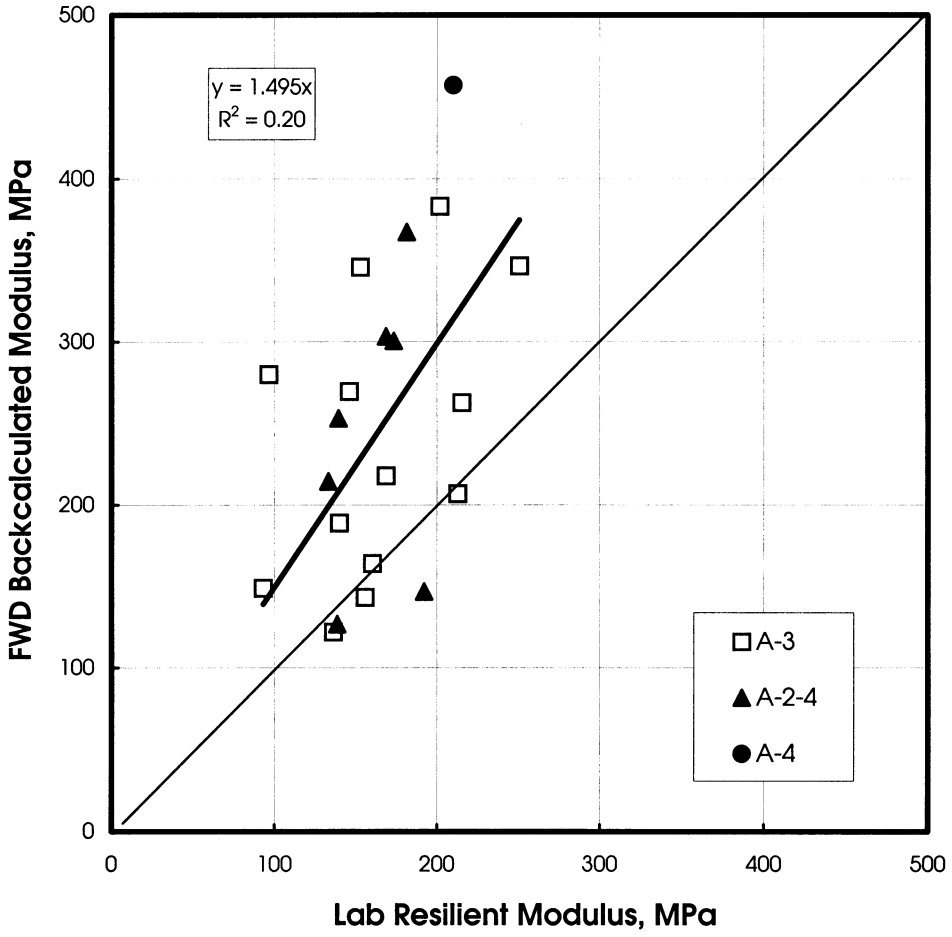


Figure 8.9a Laboratory resilient modulus (at OMC and state of stresses caused by traffic) versus FWD backcalculated modulus (by pavement materials)

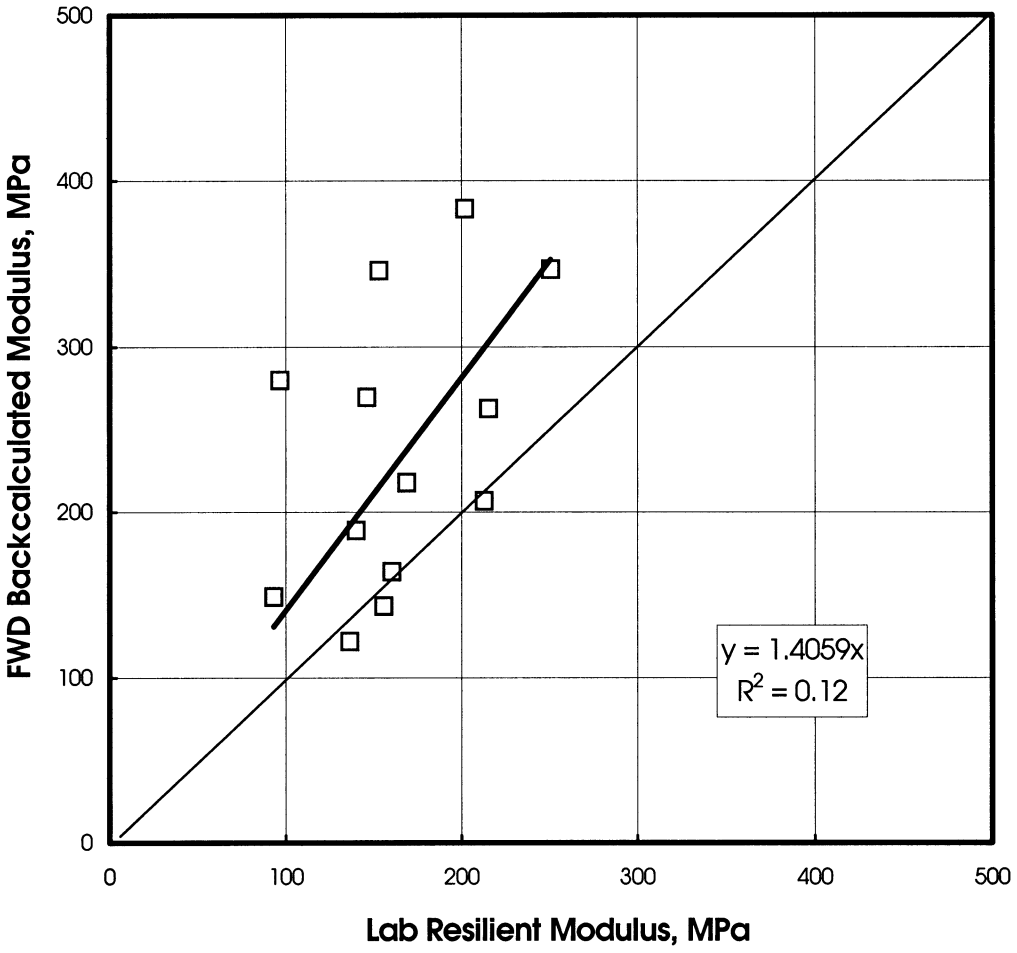


Figure 8.9b Laboratory resilient modulus (at OMC and state of stresses caused by traffic) versus FWD backcalculated modulus (A-3)

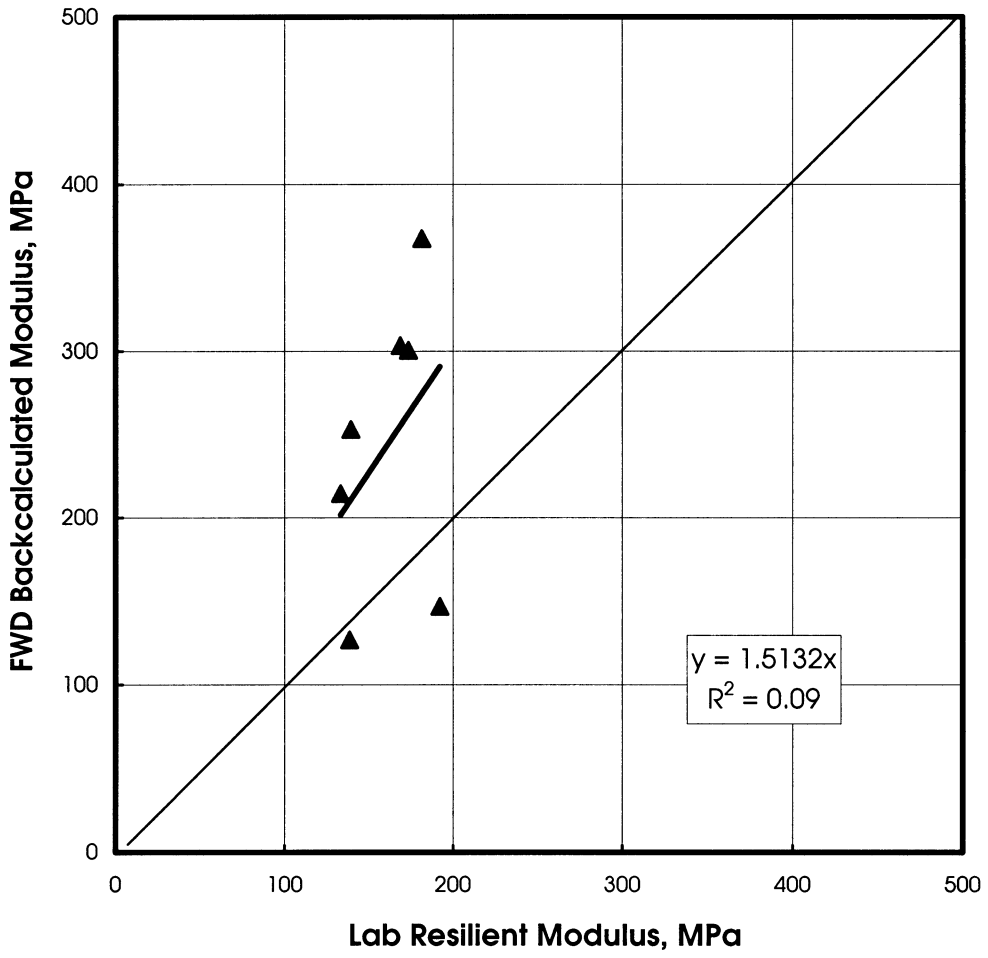


Figure 8.9c Laboratory resilient modulus (at OMC and state of stresses caused by traffic) versus FWD backcalculated modulus (A-2-4)

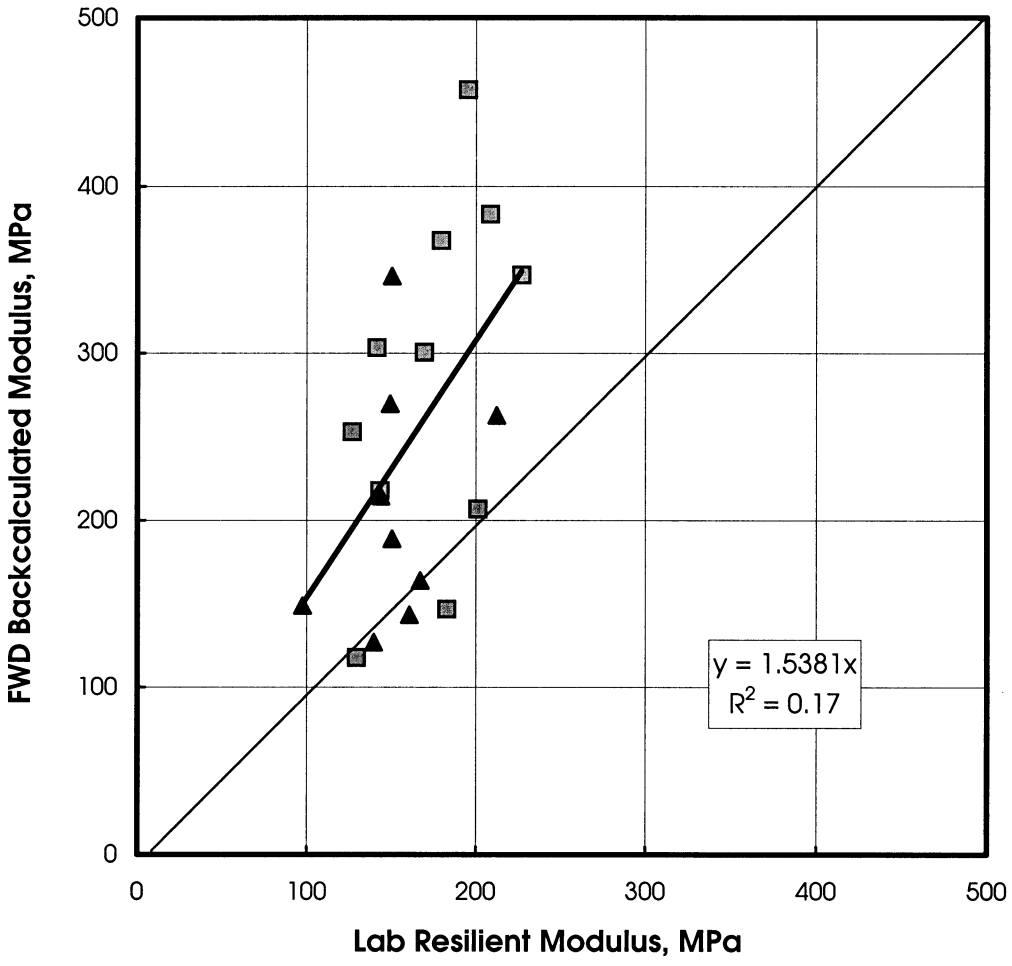


Figure 8.10a Laboratory resilient modulus (at OMC and confining pressure 2 psi) versus FWD backcalculated modulus

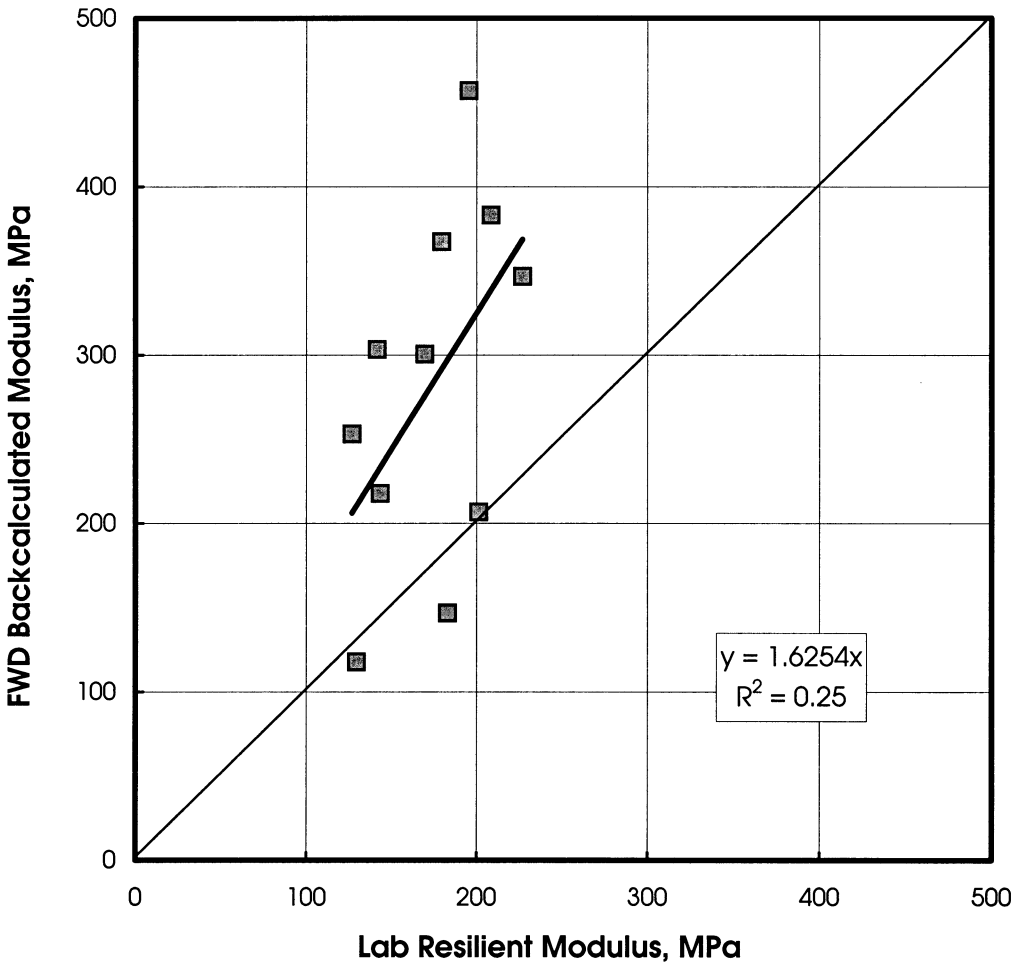


Figure 8.10b Laboratory resilient modulus (at OMC and confining pressure 2 psi) versus FWD backcalculated modulus (subgrade)

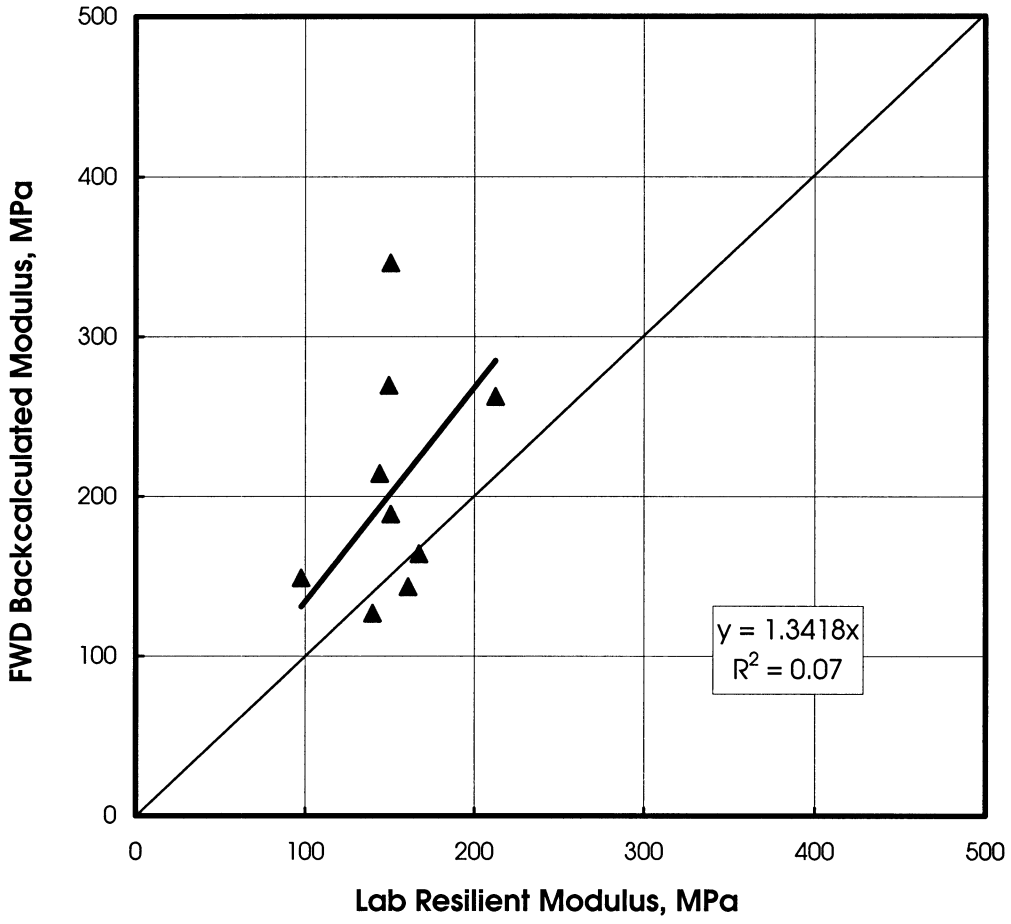


Figure 8.10c Laboratory resilient modulus (at OMC and confining pressure 2 psi) versus FWD backcalculated modulus (embankment)

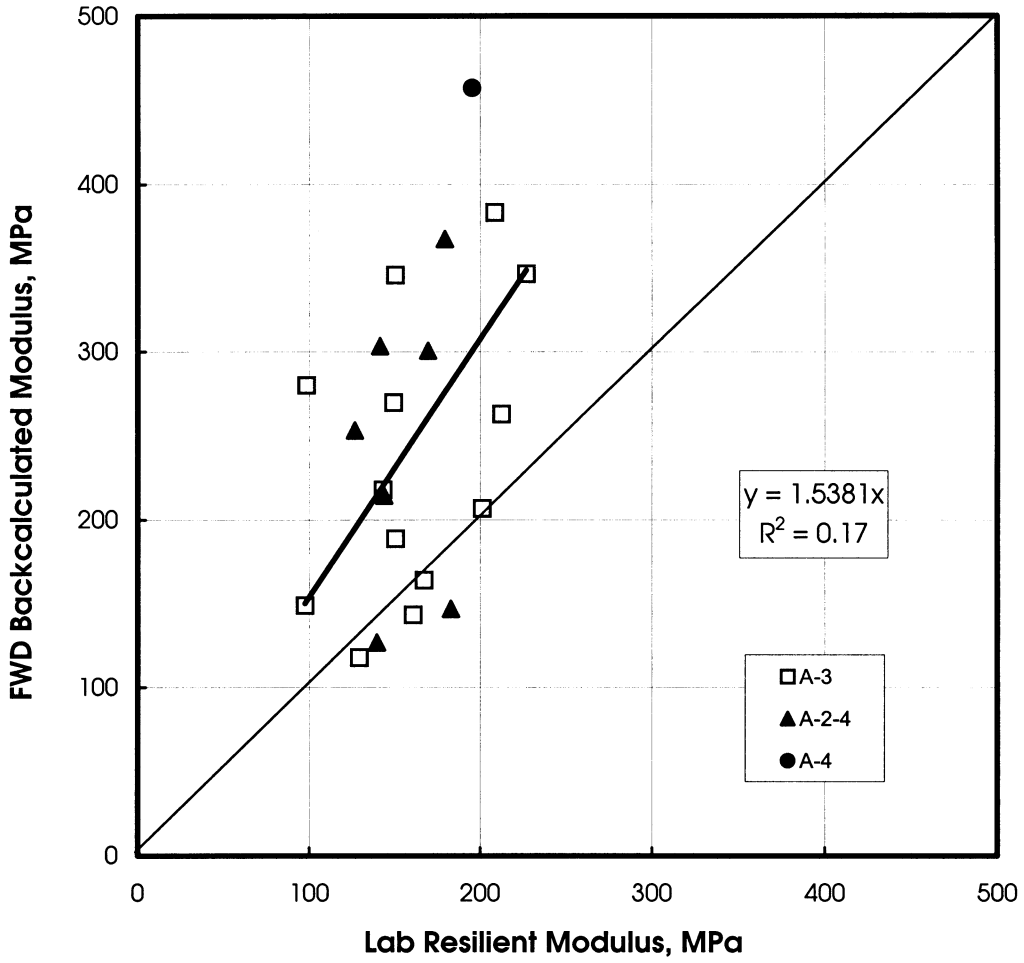


Figure 8.11a Laboratory resilient modulus (at OMC and confining pressure 2 psi) versus FWD backcalculated modulus (by pavement materials)

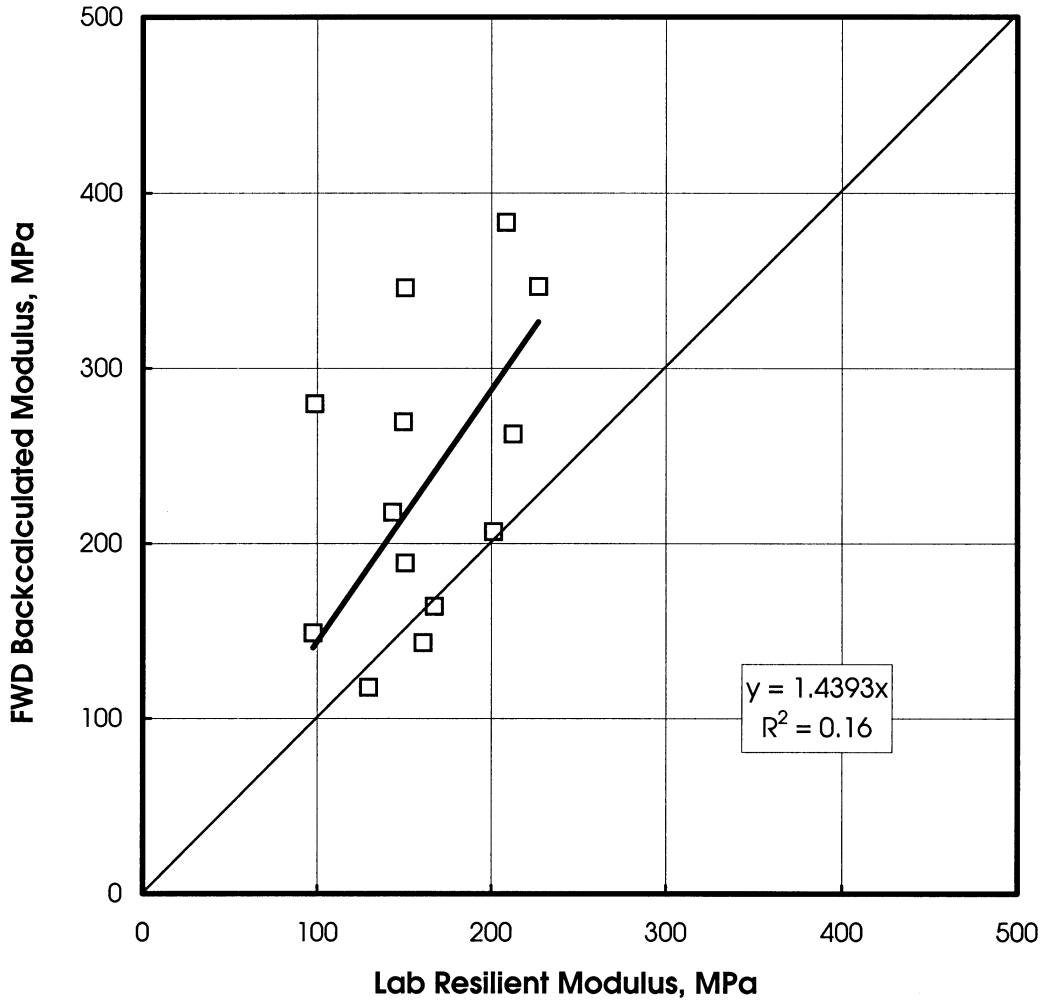


Figure 8.11b Laboratory resilient modulus (at OMC and confining pressure 2 psi) versus FWD backcalculated modulus (A-3)

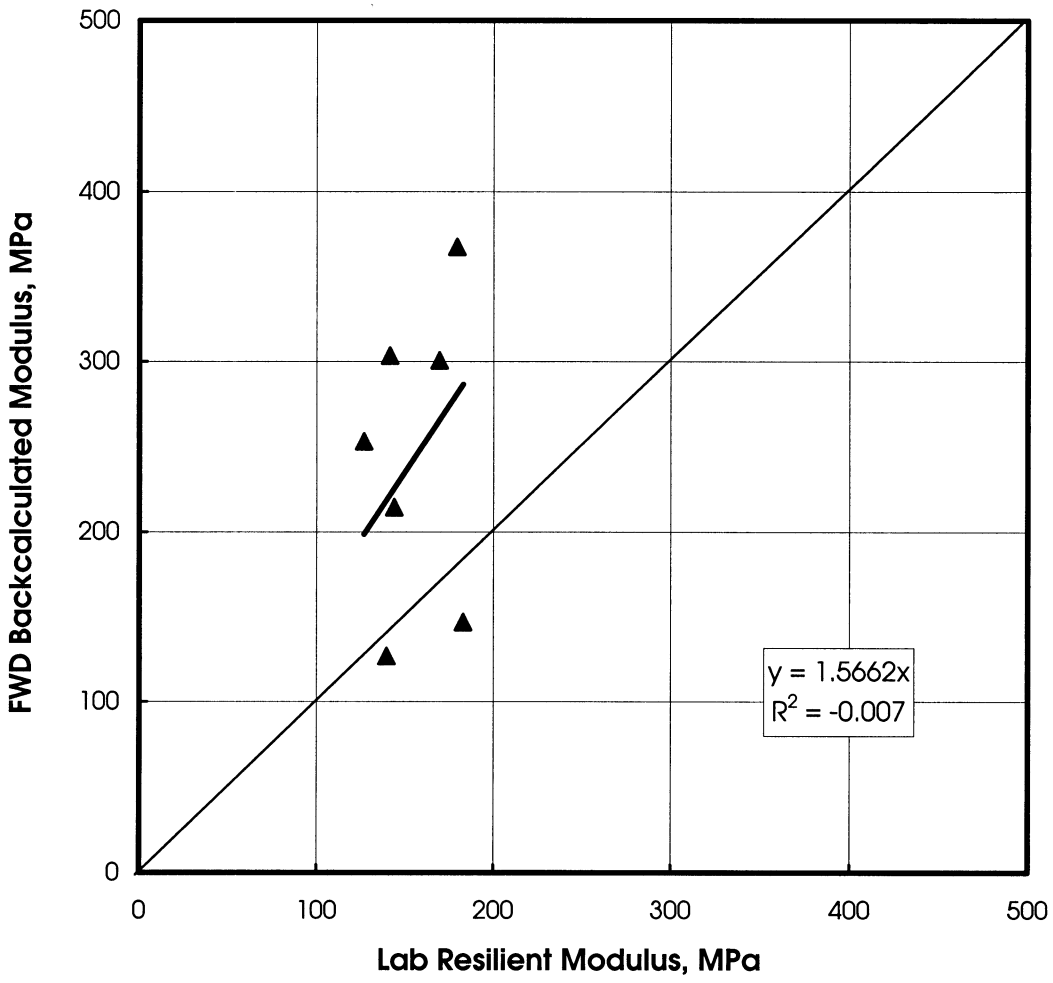


Figure 8.11c Laboratory resilient modulus (at OMC and confining pressure 2 psi) versus FWD backcalculated modulus (A-2-4)

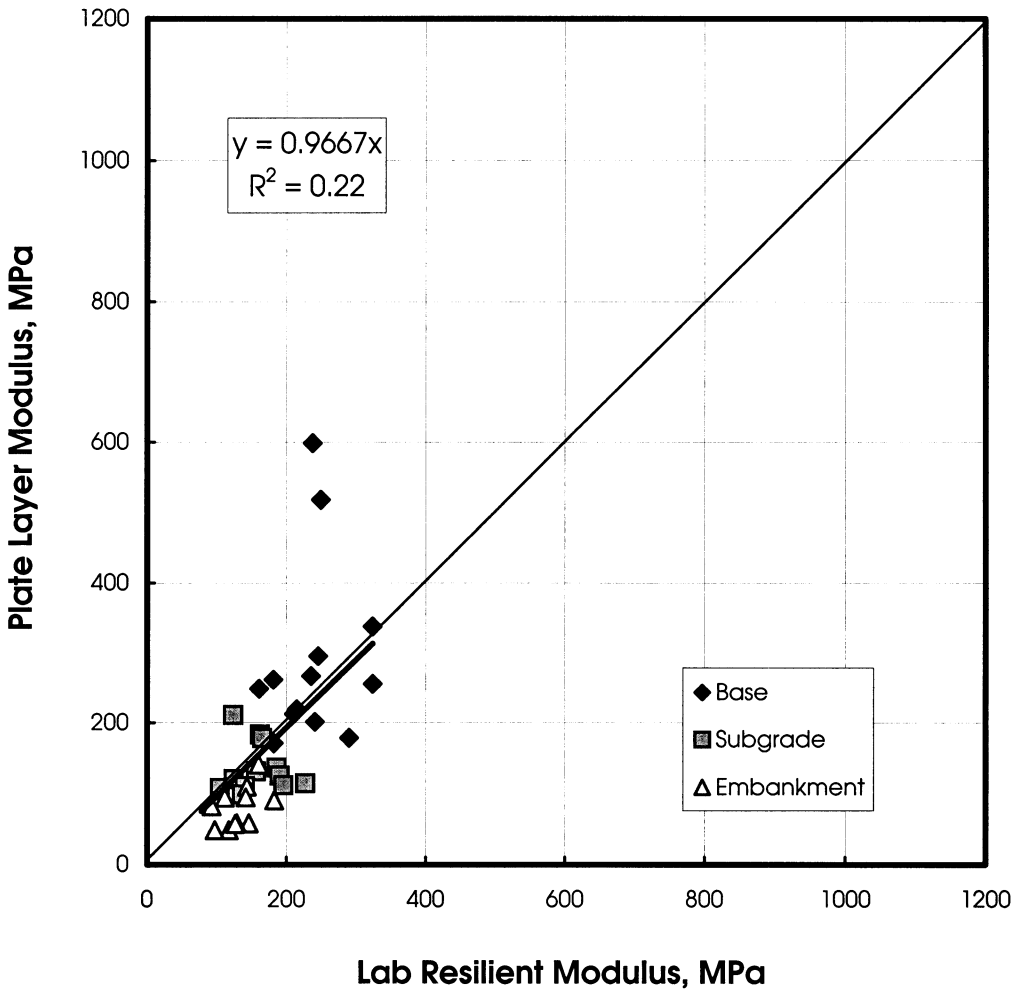


Figure 8.12a Laboratory resilient modulus (at insitu MC and state of stresse caused by traffic) versus plate layer modulus

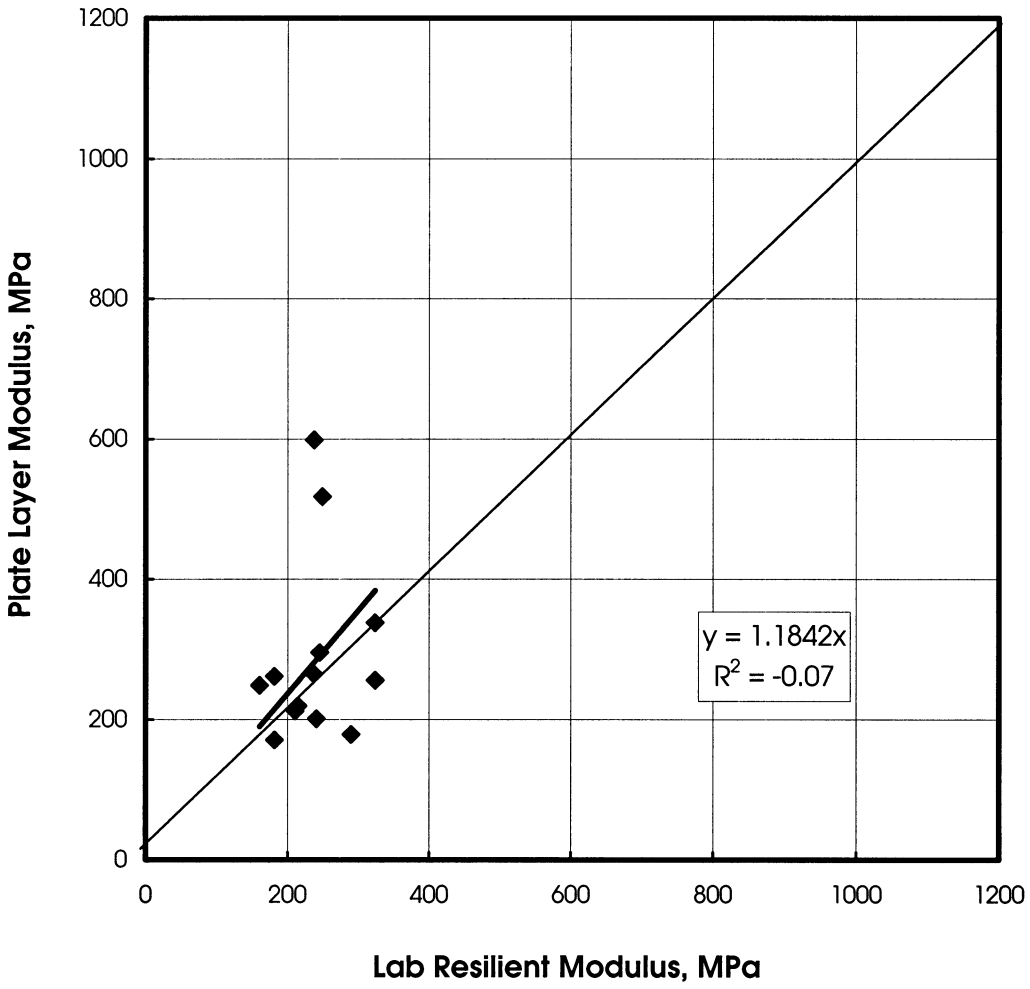


Figure 8.12b Laboratory resilient modulus (at insitu MC and state of stresse caused by traffic) versus plate layer modulus (base)

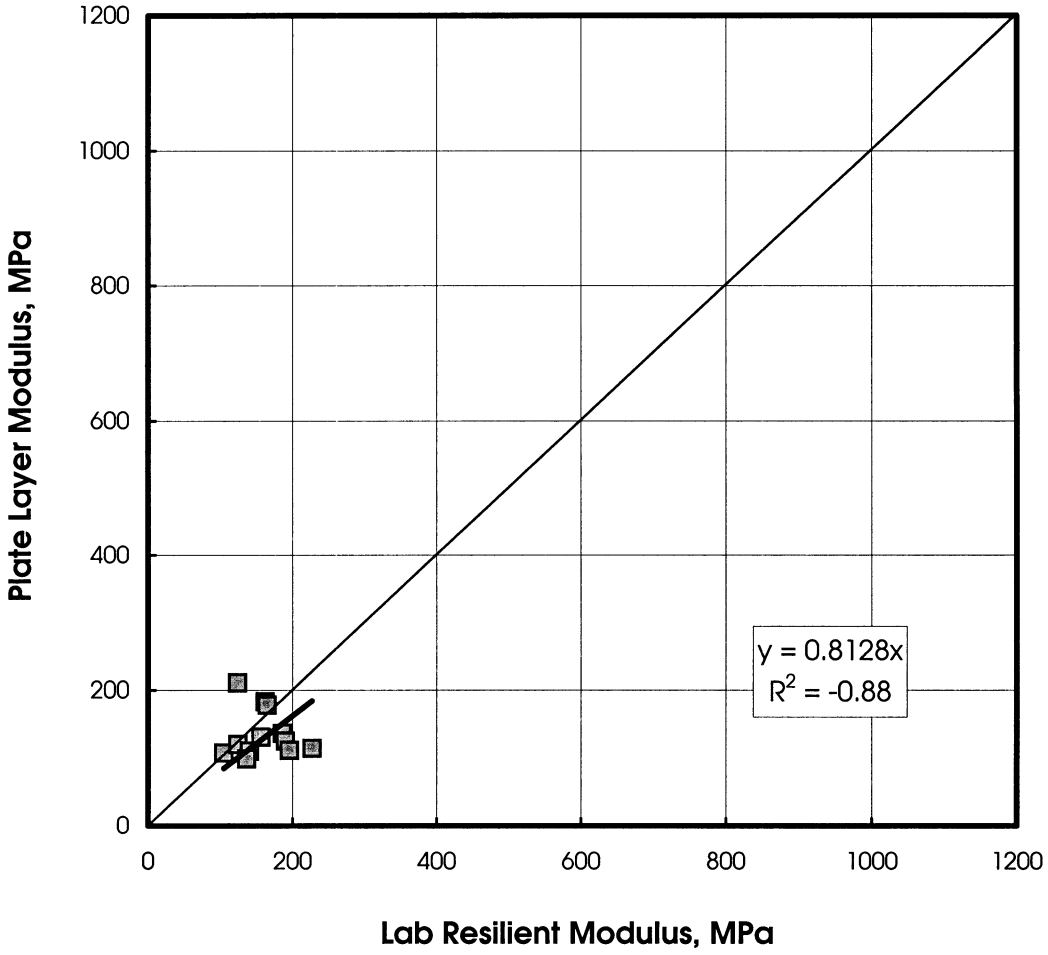


Figure 8.12c Laboratory resilient modulus (at insitu MC and state of stresse caused by traffic) versus plate layer modulus (subgrade)

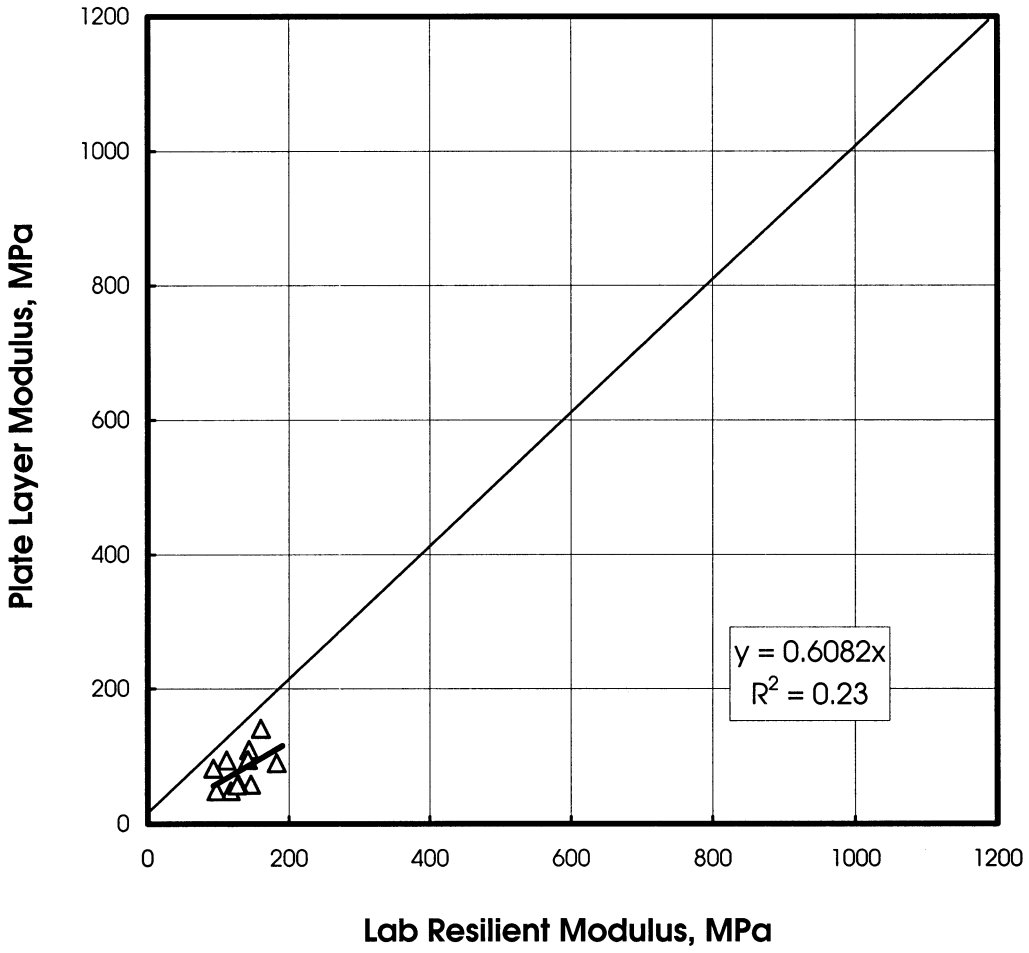


Figure 8.12d Laboratory resilient modulus (at insitu MC and state of stresse caused by traffic) versus plate layer modulus (embankment)

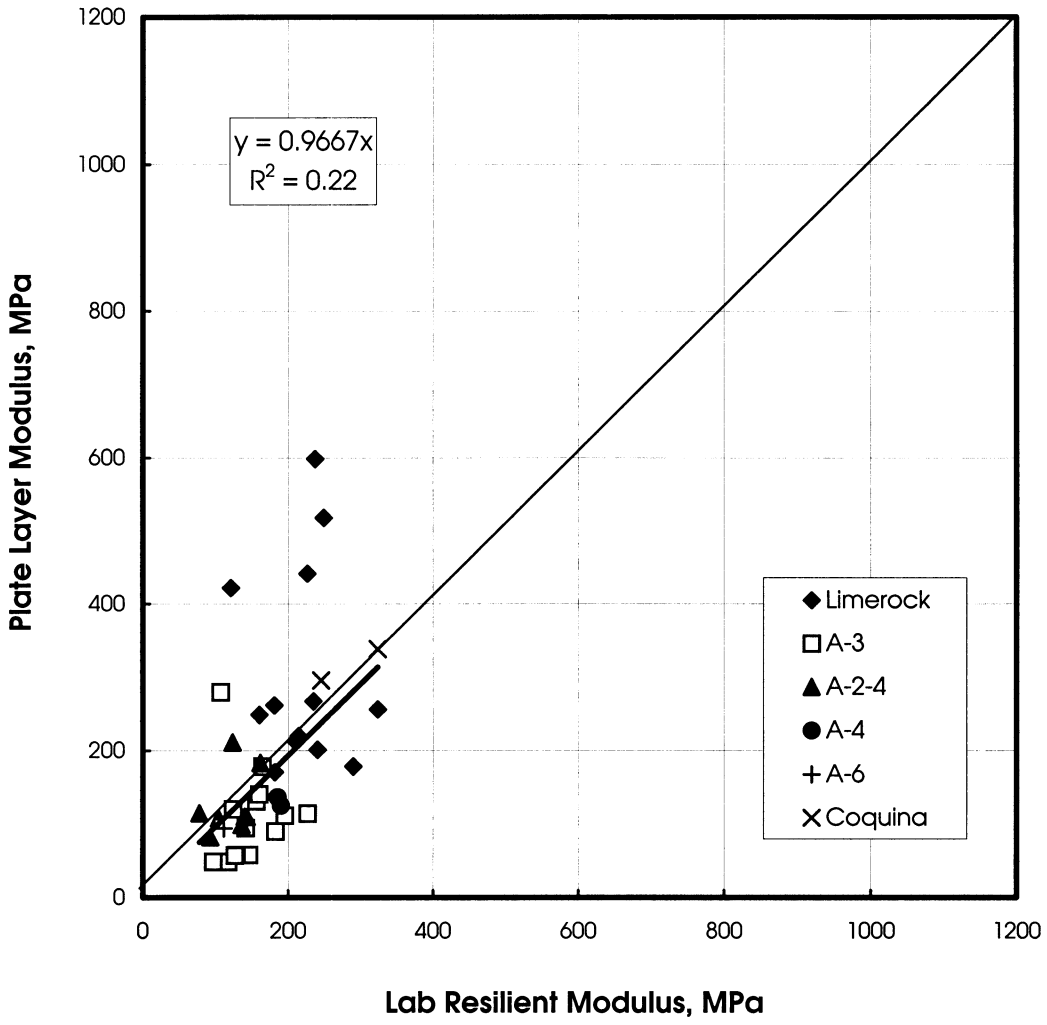


Figure 8.13a Laboratory resilient modulus (at insitu MC and state of stresse caused by traffic) versus plate layer modulus (by pavement materials)

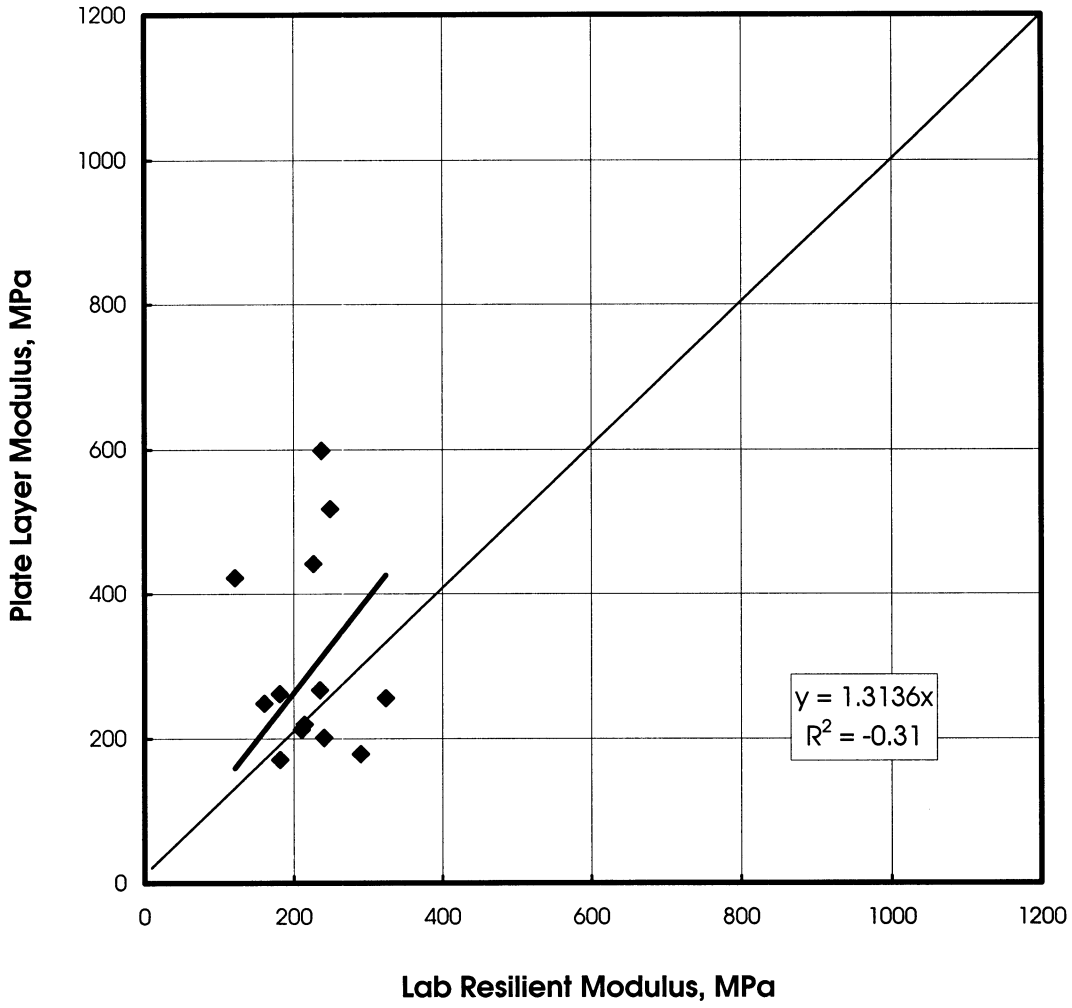


Figure 8.13b Laboratory resilient modulus (at insitu MC and state of stresse caused by traffic) versus plate layer modulus (limerock)

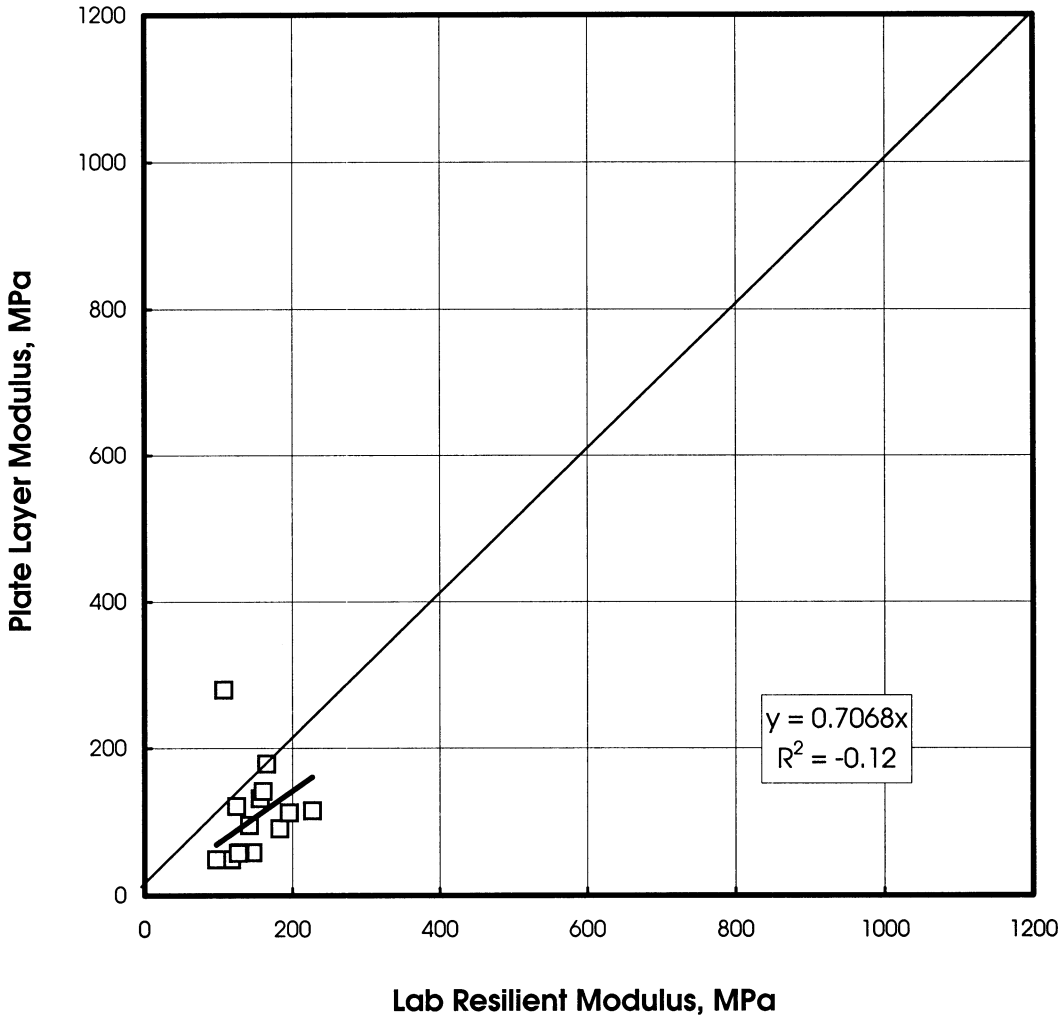


Figure 8.13c Laboratory resilient modulus (at insitu MC and state of stresse caused by traffic) versus plate layer modulus (A-3)

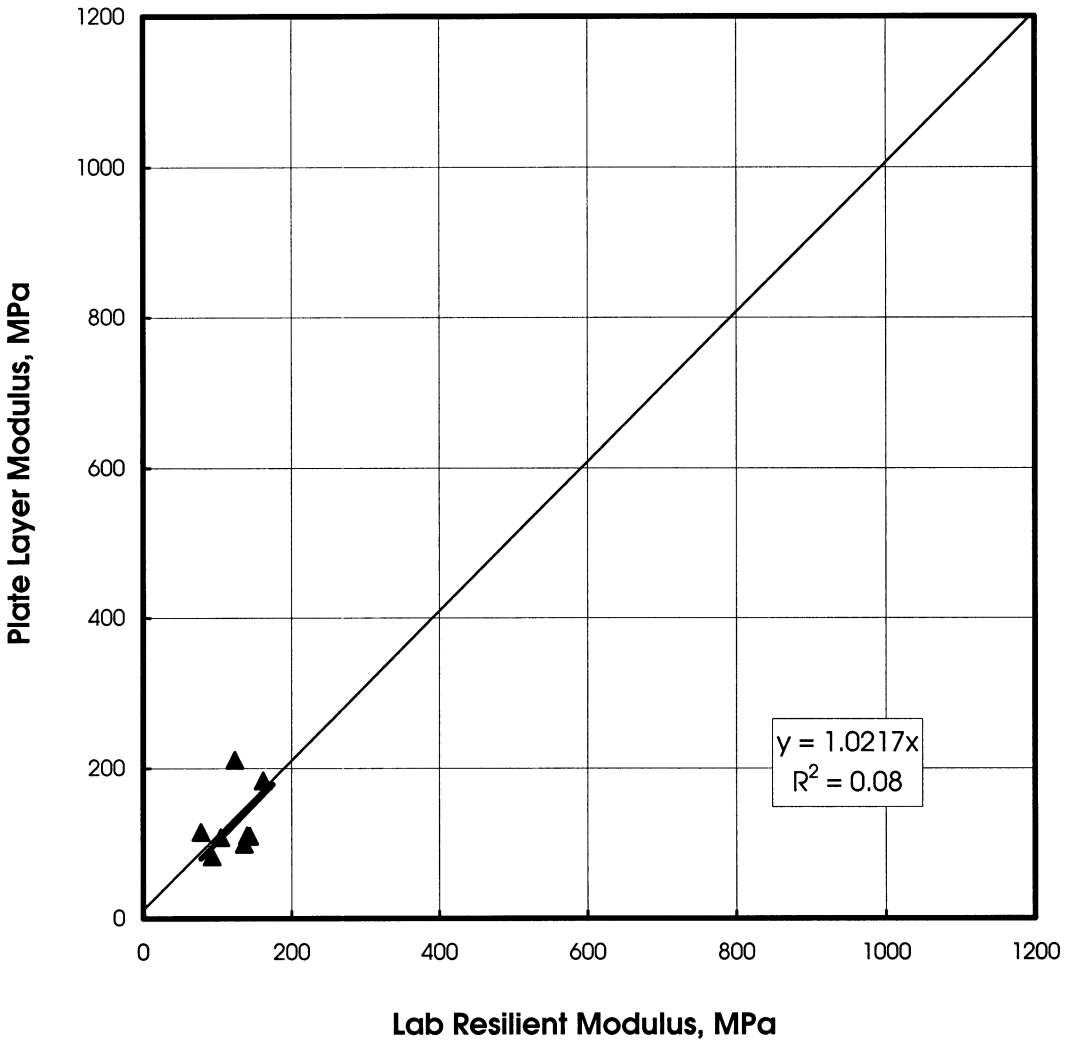


Figure 8.13d Laboratory resilient modulus (at insitu MC and state of stresse caused by traffic) versus plate layer modulus (A-2-4)

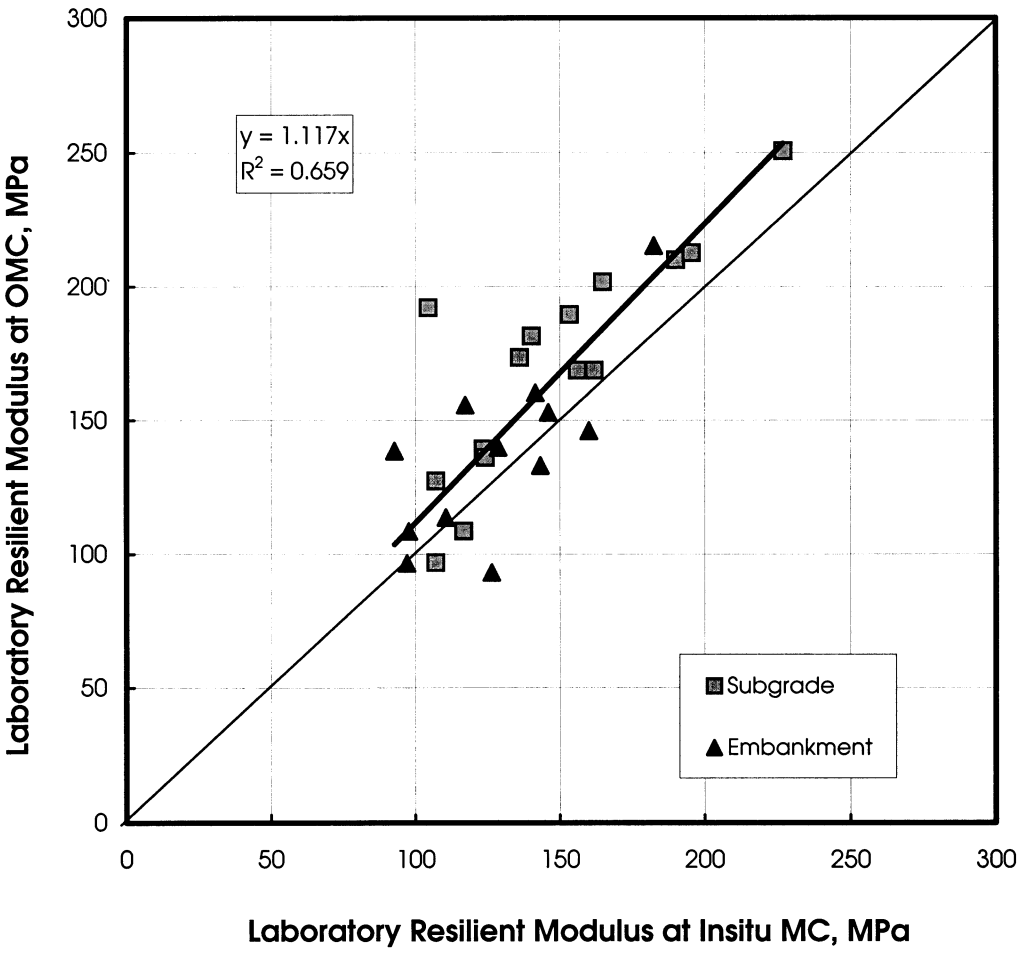


Figure 8.14a Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) under same state of stresses

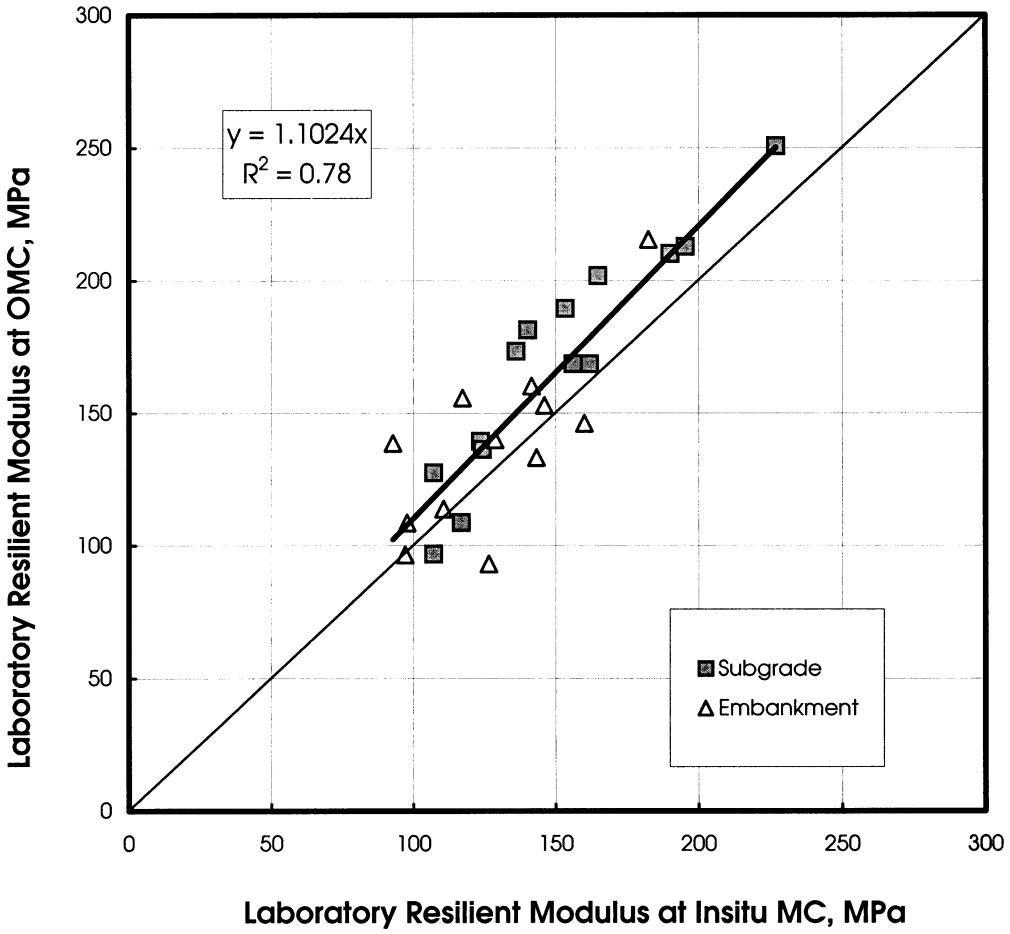


Figure 8.14b Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) under same state of stresses (without outlier)

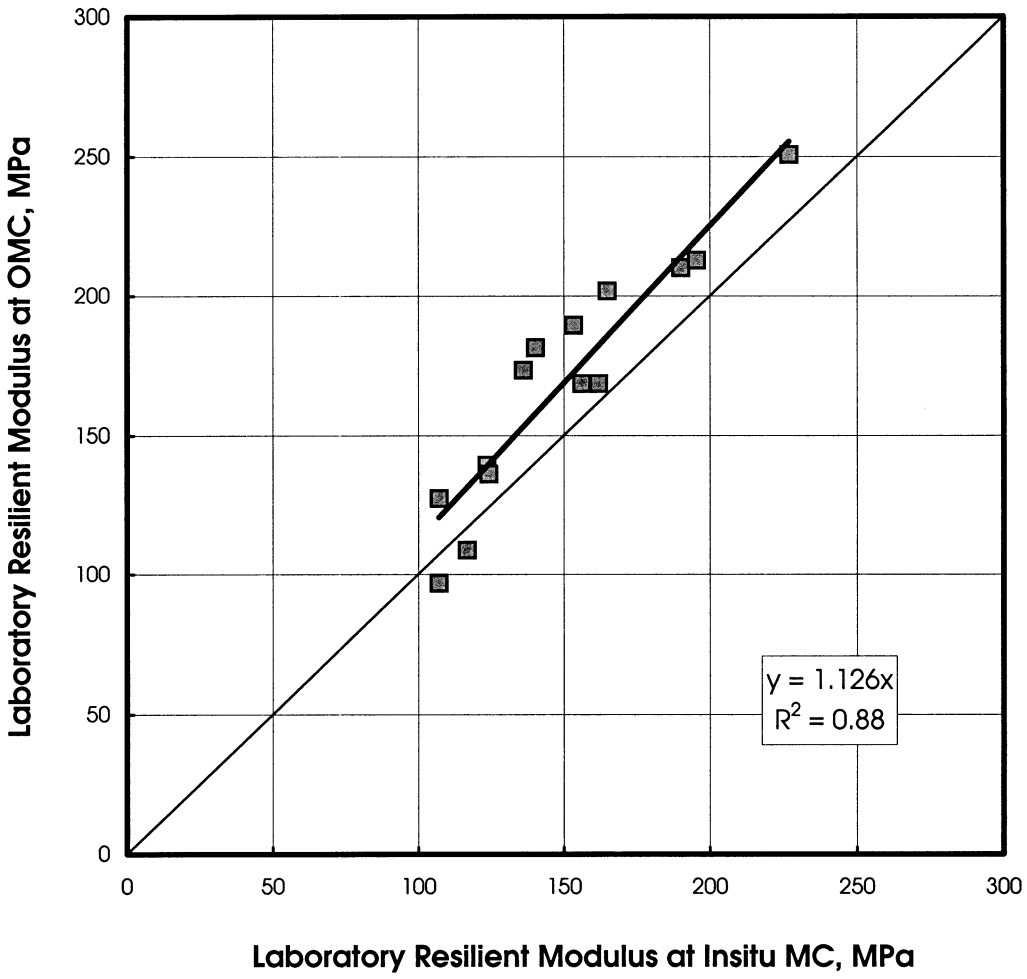


Figure 8.14c Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) under same state of stresses (subgrade layers)

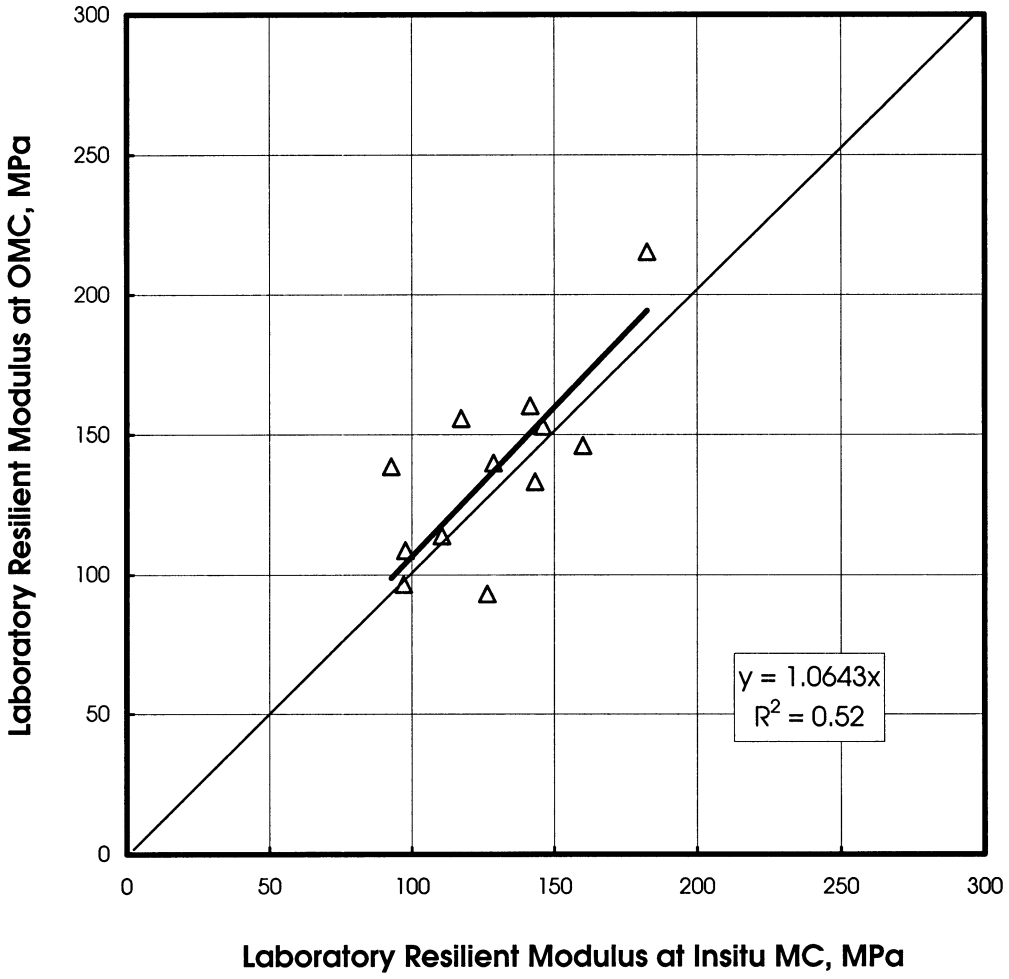


Figure 8.14d Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) under same state of stresses (embankment layers)

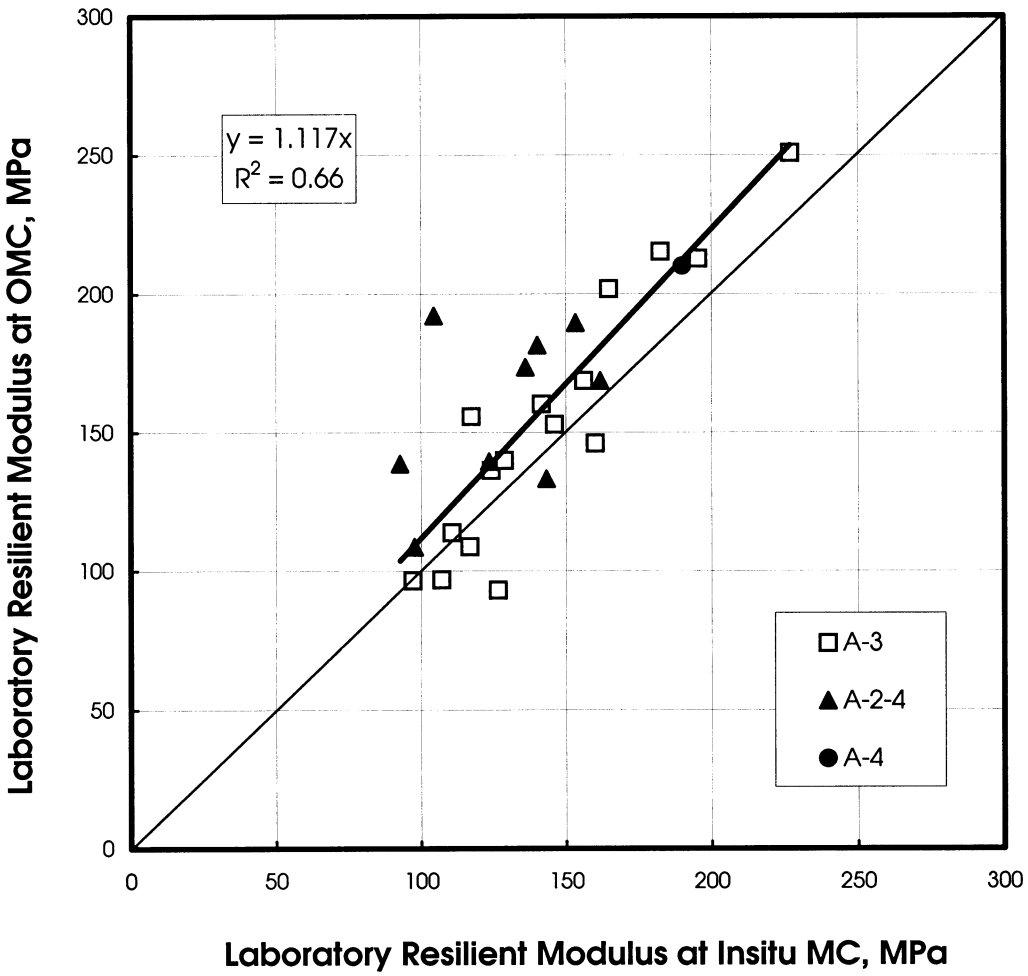


Figure 8.15a Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) under same state of stresses (by pavement materials)

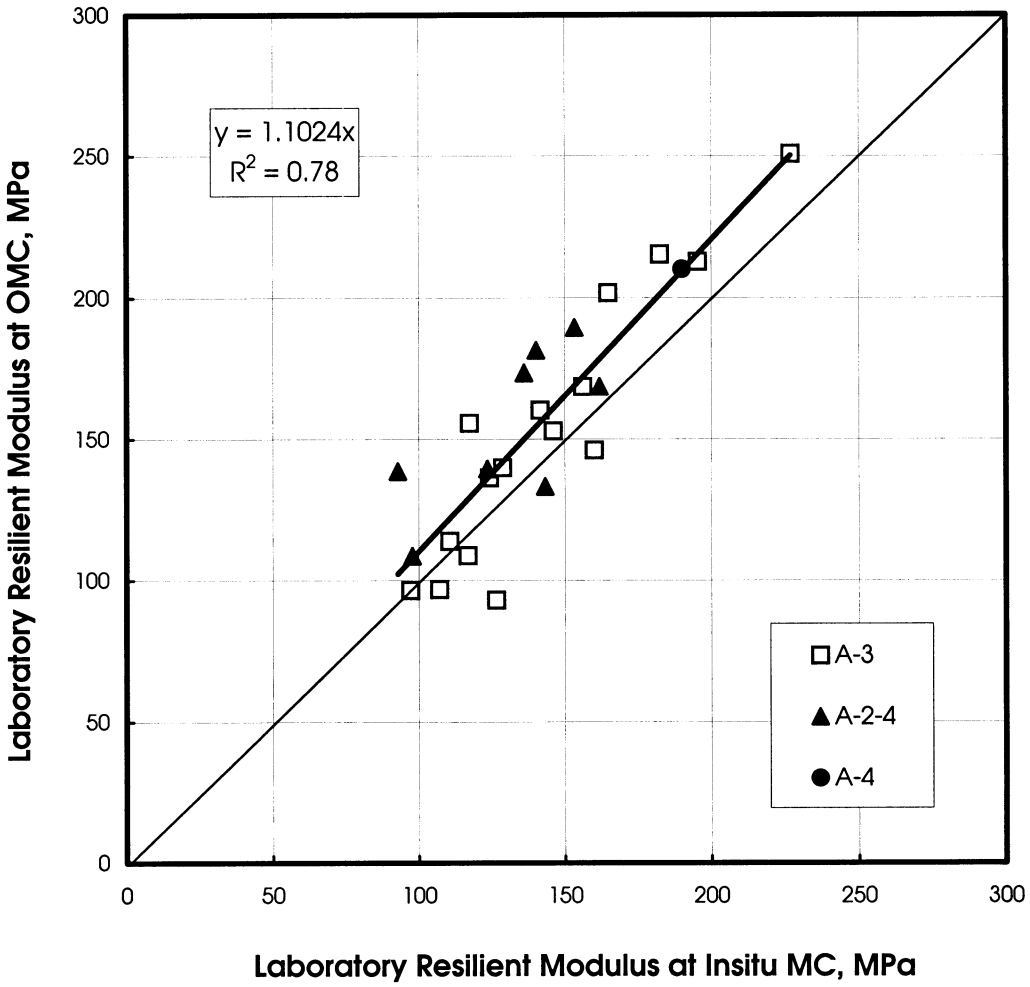


Figure 8.15b Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) under same state of stresses (by pavement materials, without outlier)

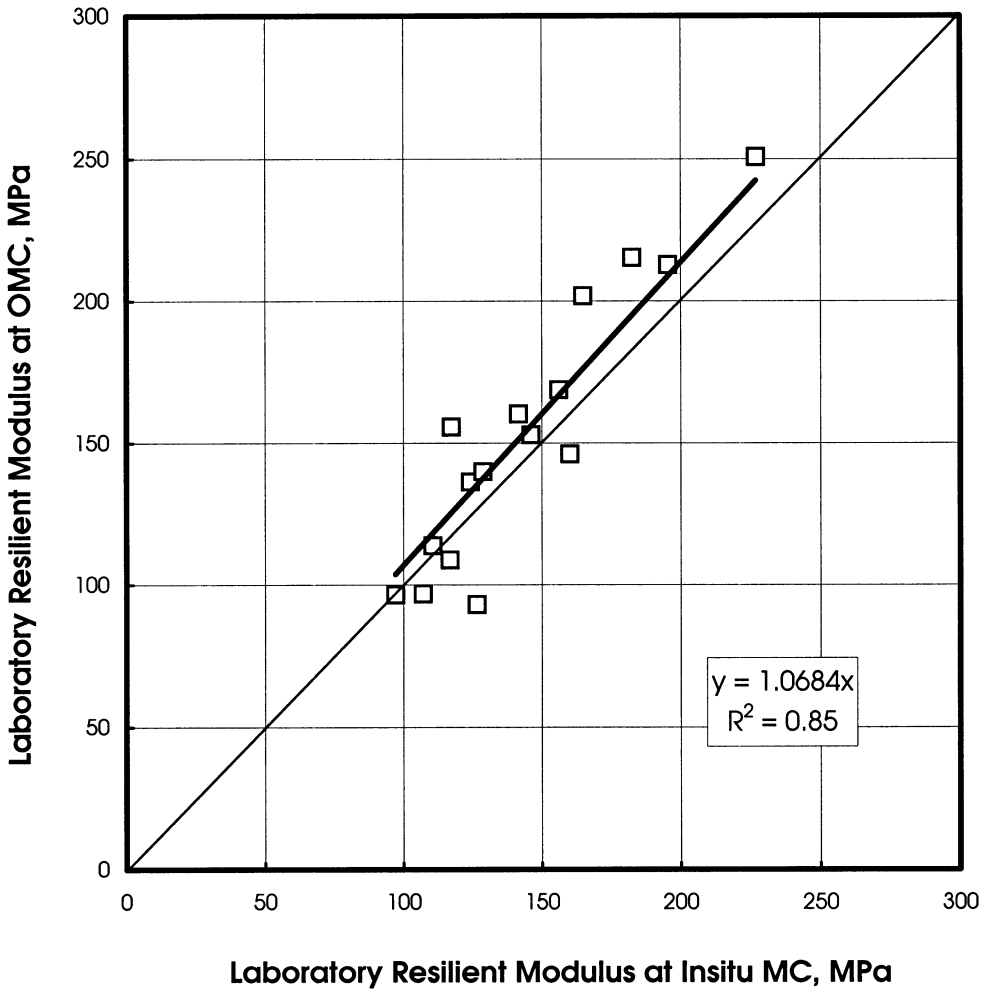


Figure 8.15c Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) under same state of stresses (A-3 soils)

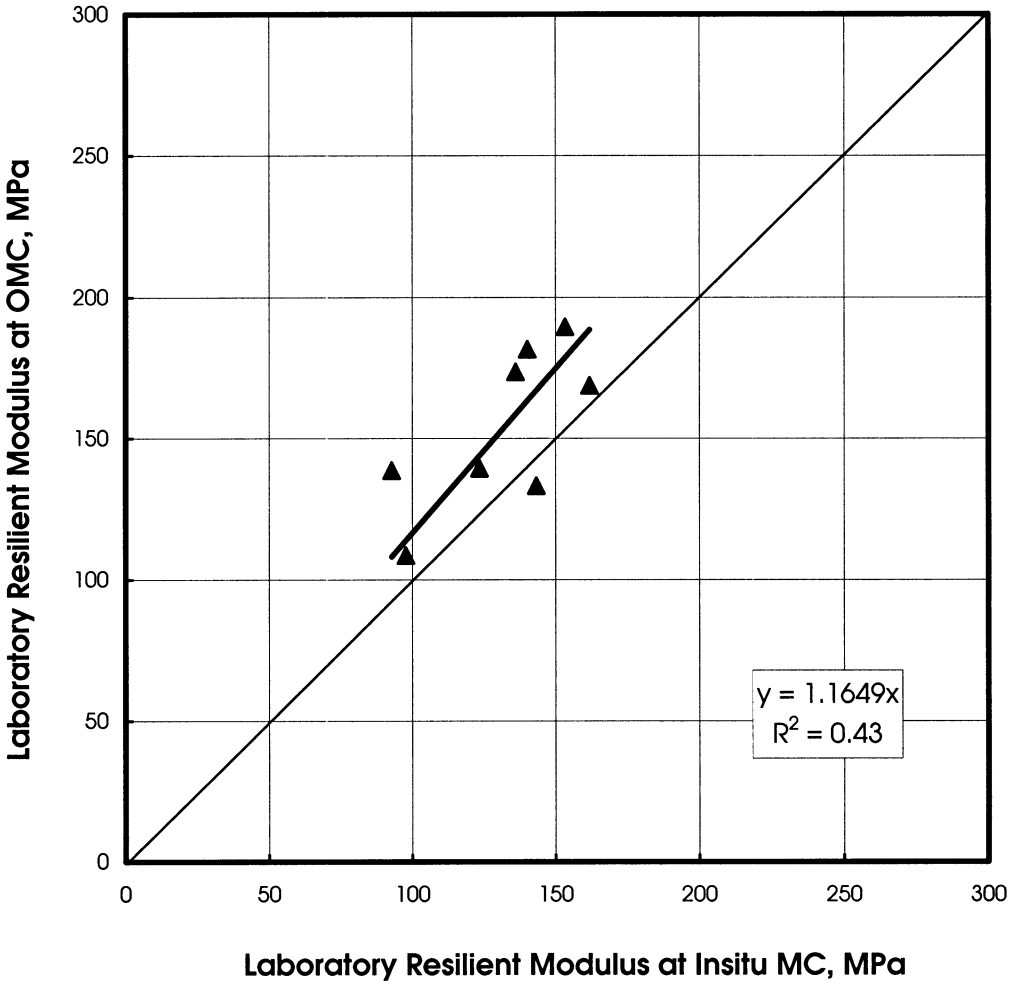


Figure 8.15d Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) under same state of stresses (A-2-4 soils)

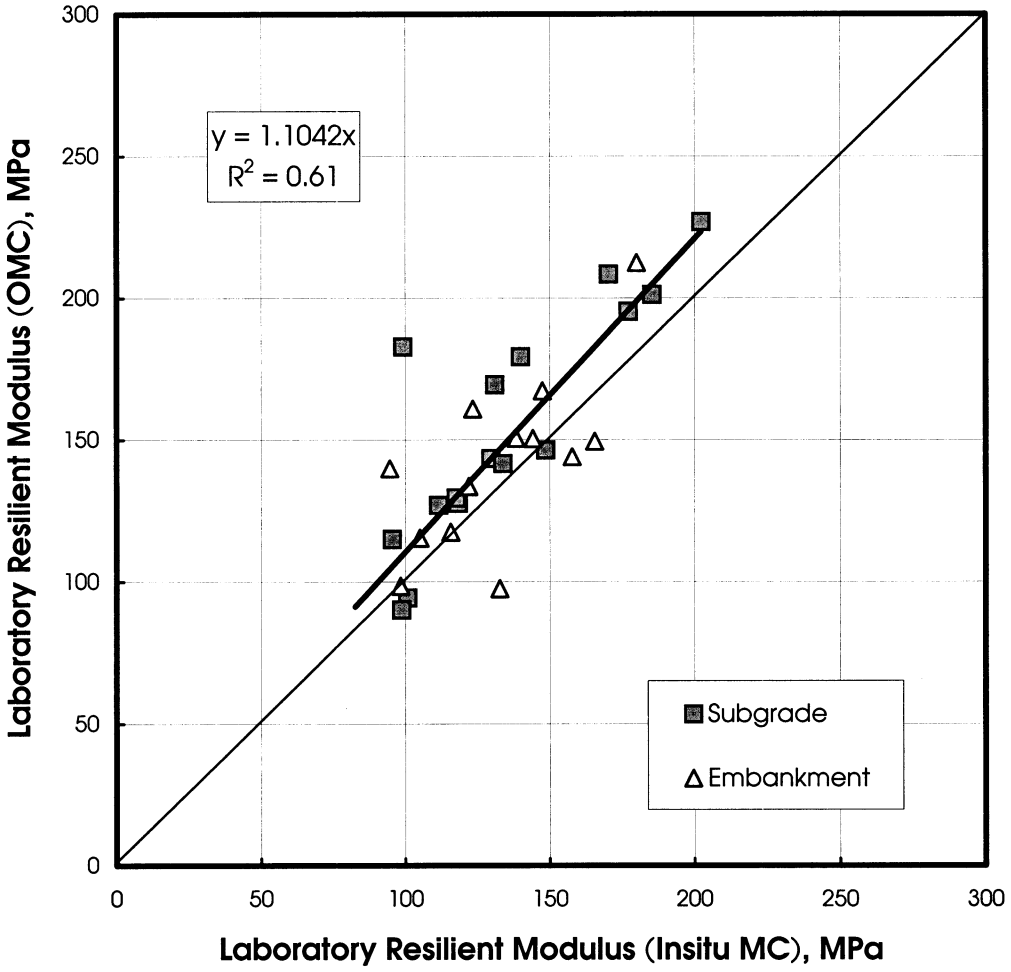


Figure 8.16a Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) at confining pressure 2 psi

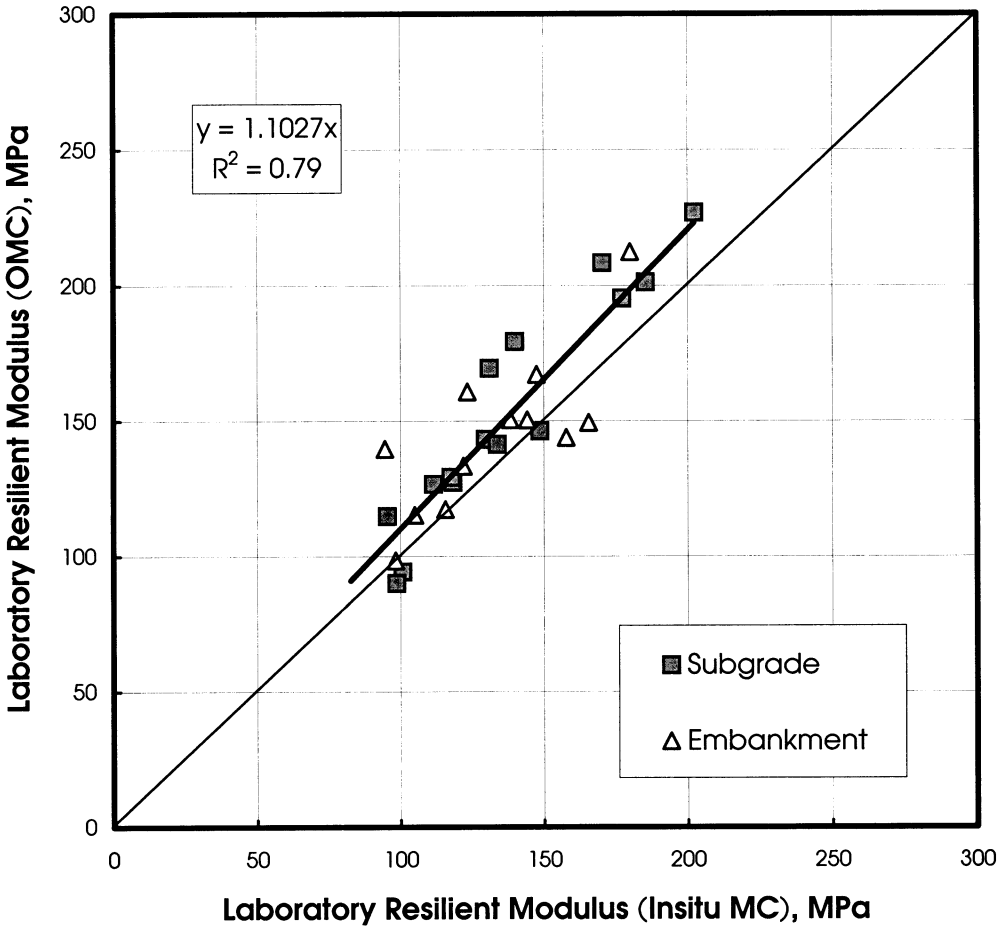


Figure 8.16b Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) at confining pressure 2 psi (without outlier)

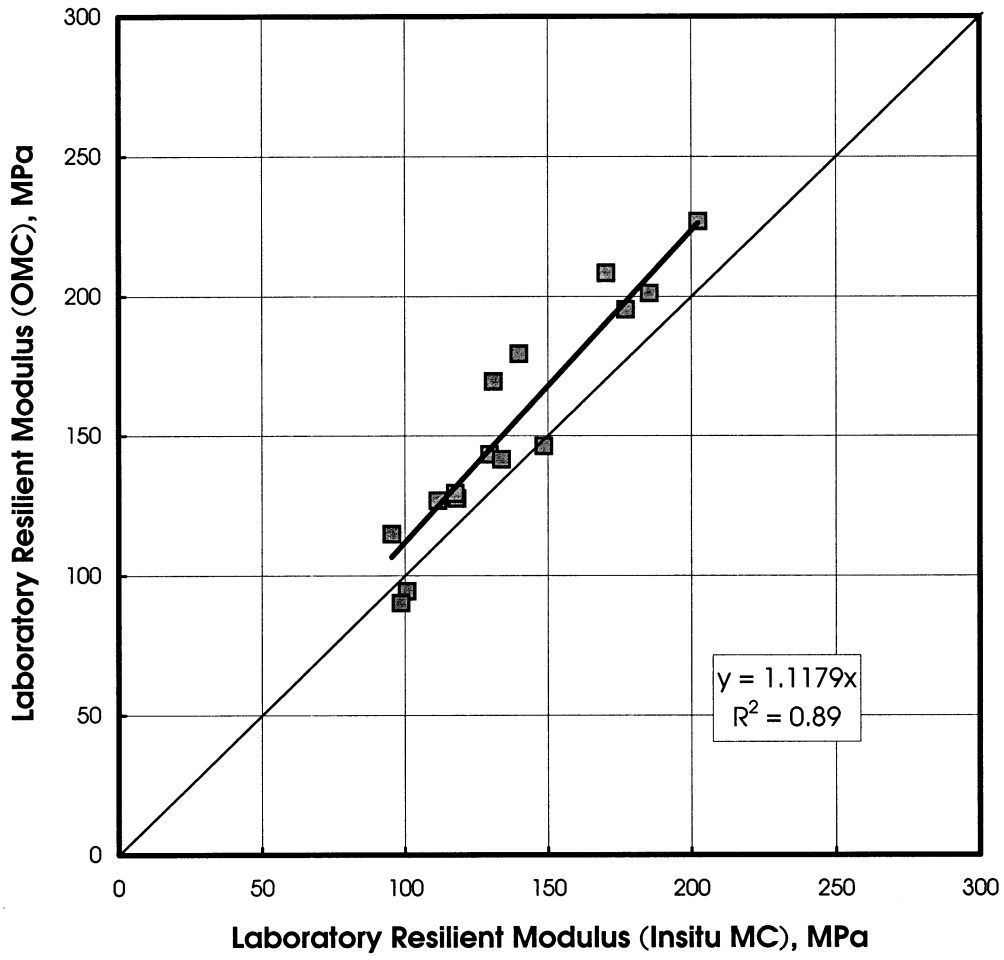


Figure 8.16c Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) at confining pressure 2 psi (subgrade layers)

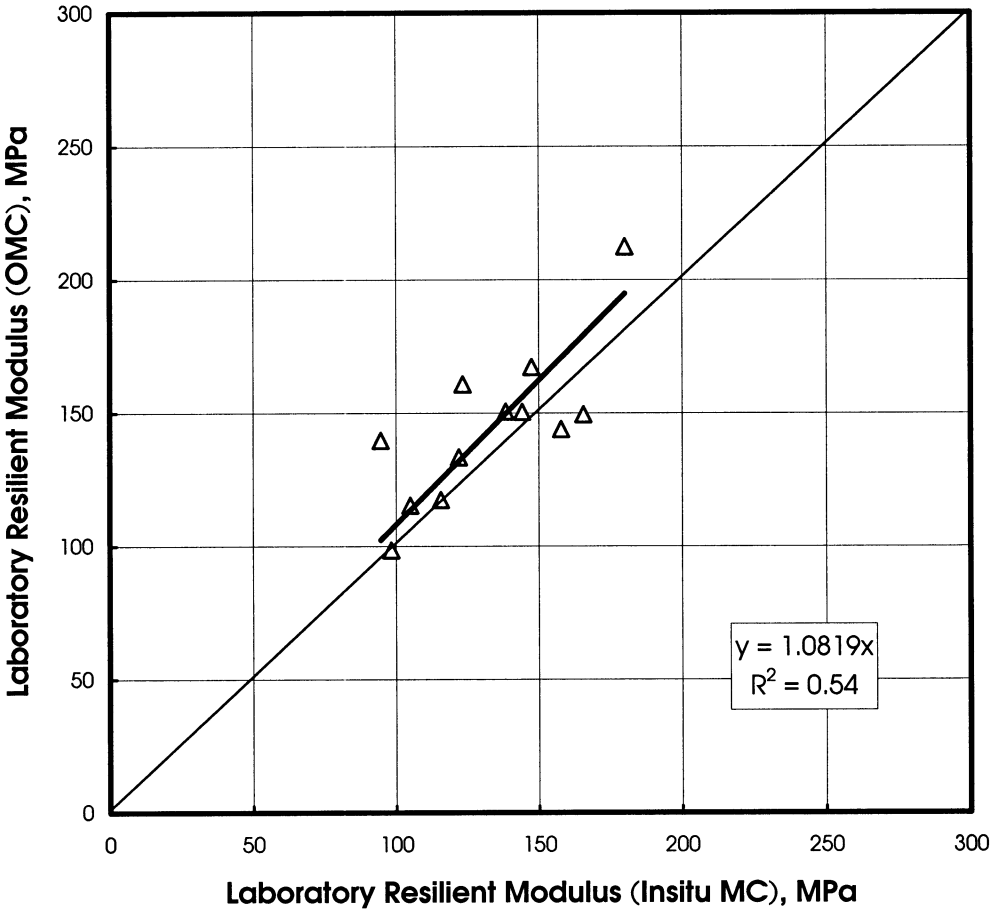


Figure 8.16d Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) at confining pressure 2 psi (embankment layers)

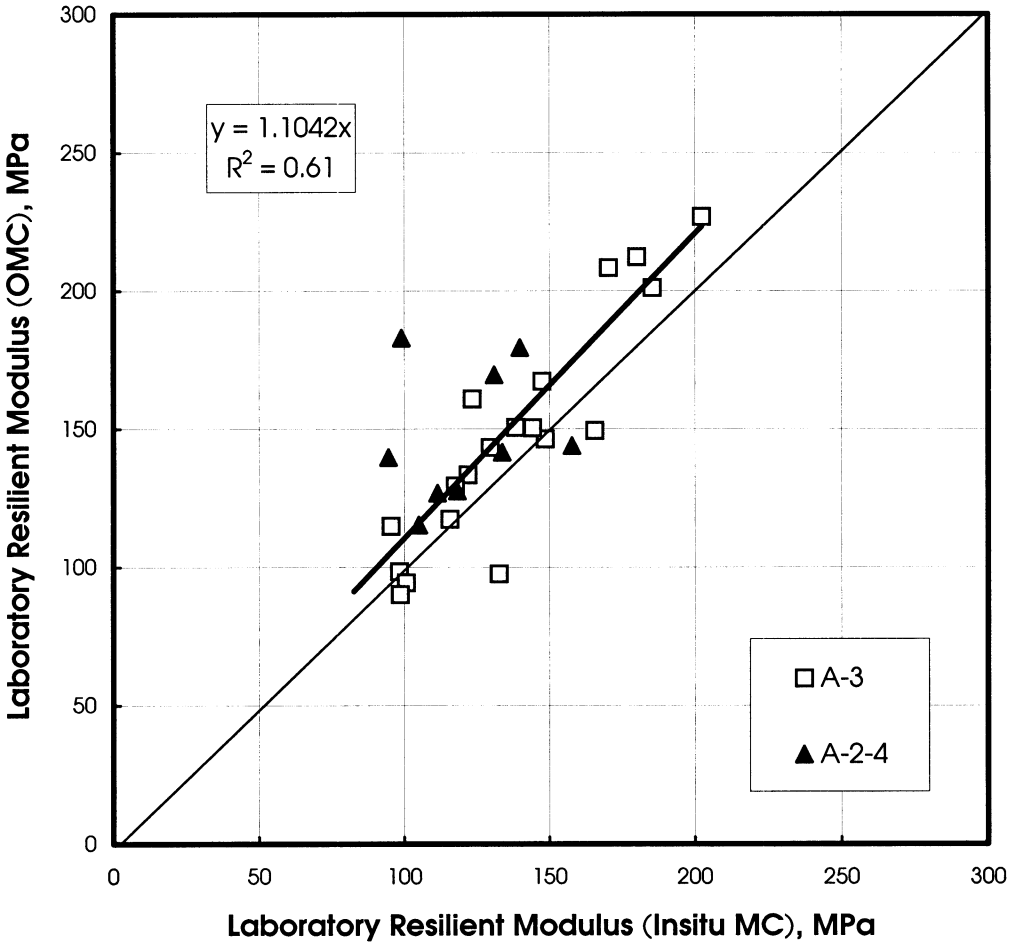


Figure 8.17a Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) at confining pressure 2 psi (by pavement materials)

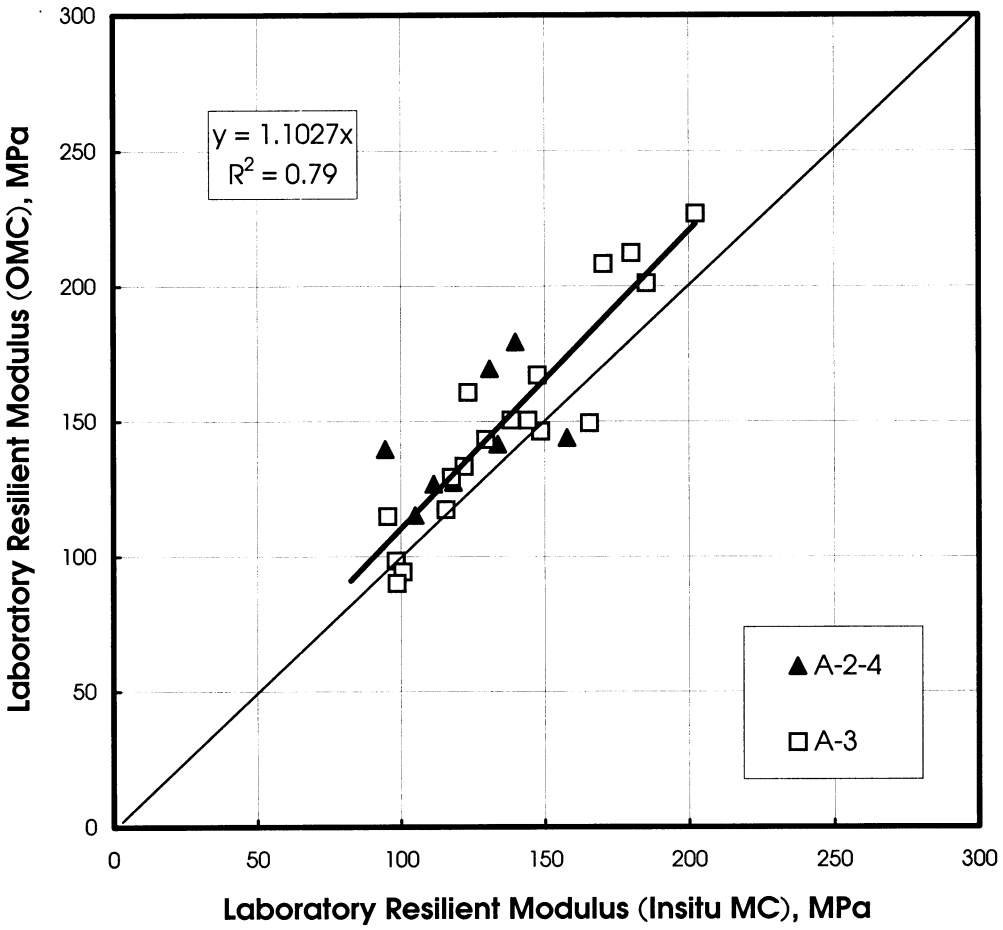


Figure 8.17b Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) at confining pressure 2 psi (by pavement materials, without outlier)

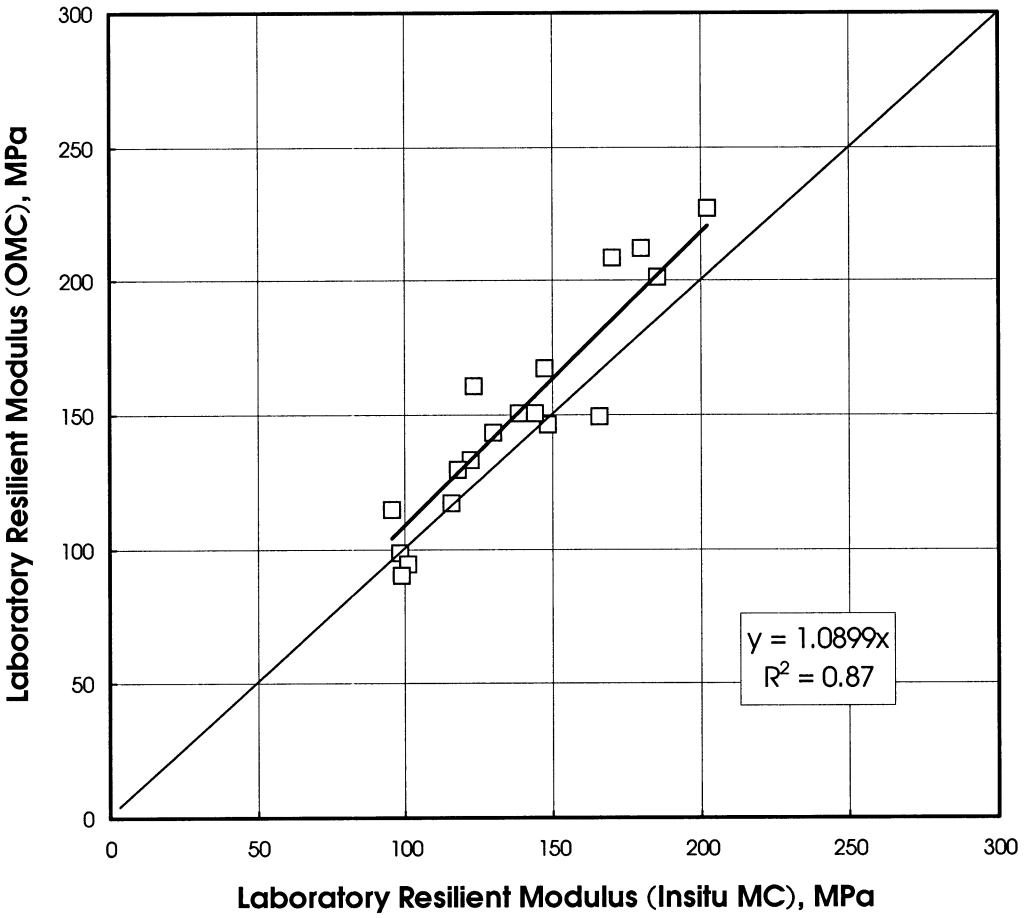


Figure 8.17c Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) at confining pressure 2 psi (A-3 soils)

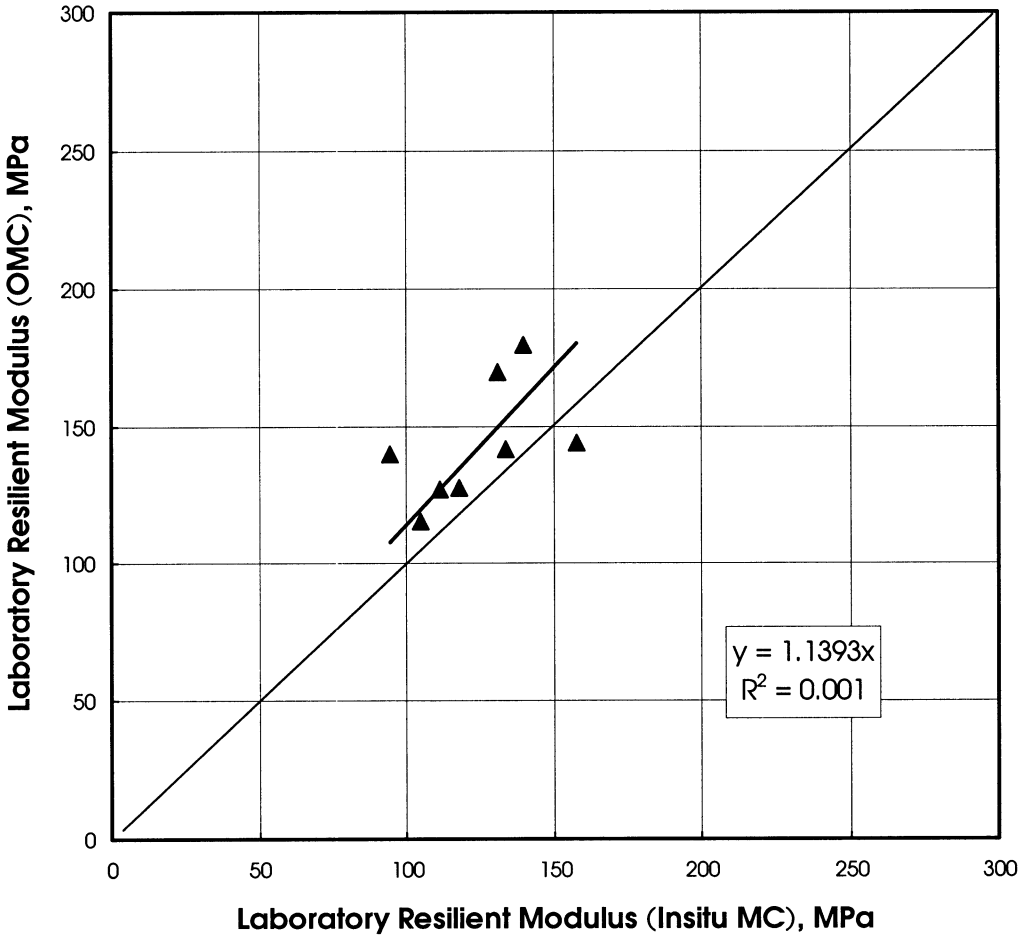


Figure 8.17d Laboratory resilient modulus (insitu MC) versus laboratory resilient modulus (OMC) at confining pressure 2 psi (A-2-4 soils)

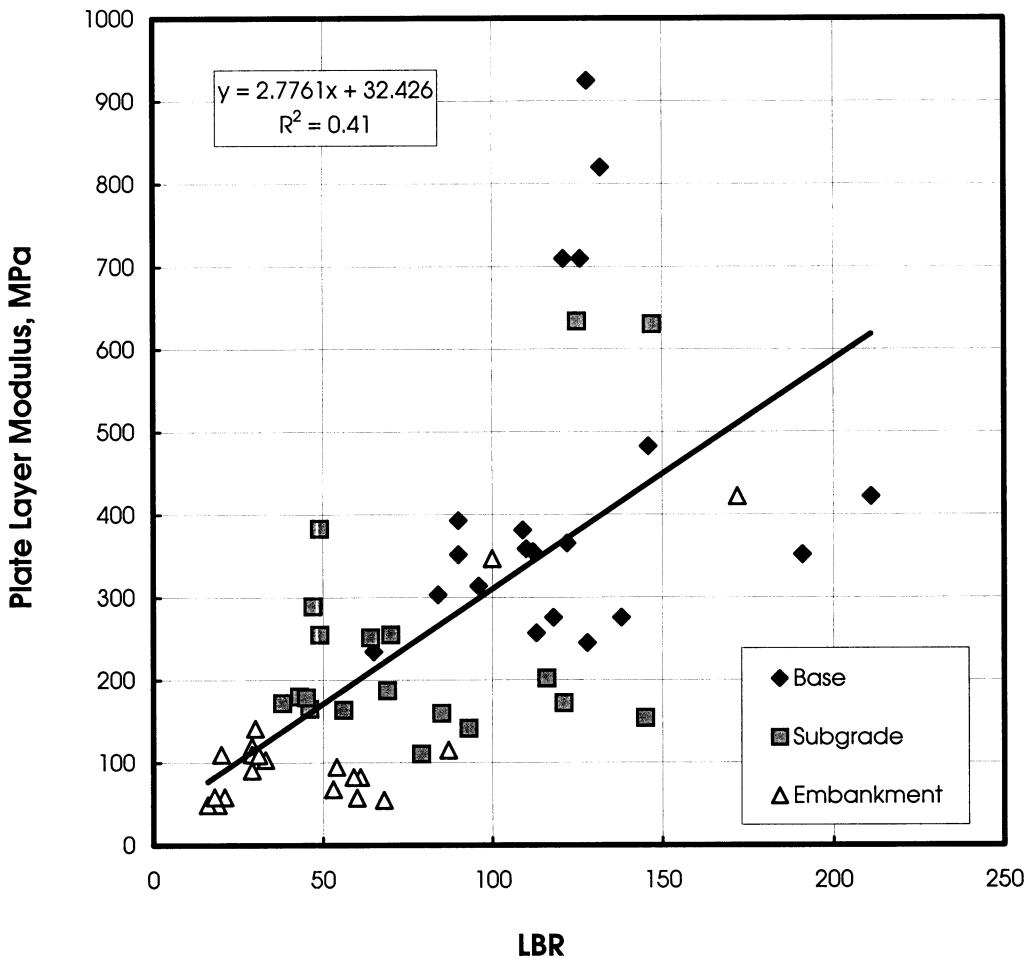


Figure 8.18a Comparison of LBR with plate layer modulus

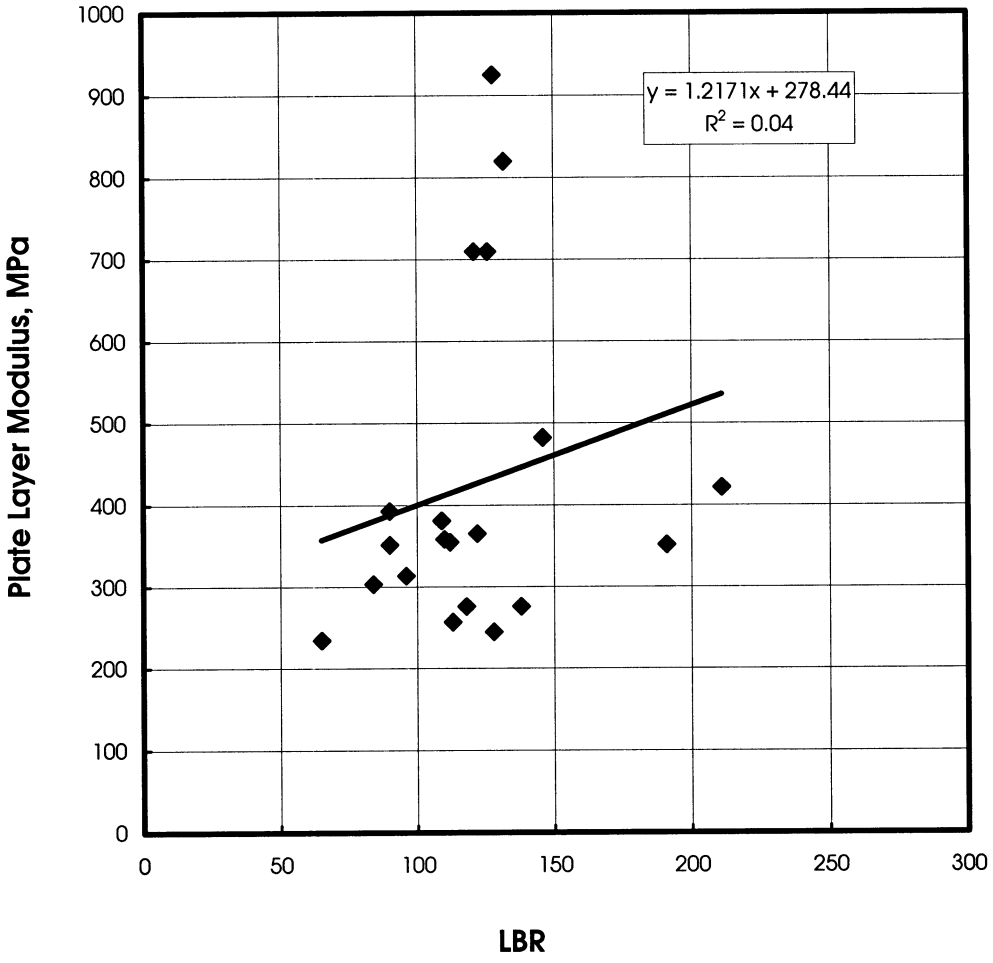


Figure 8.18b Comparison of LBR with plate layer modulus (base layers)

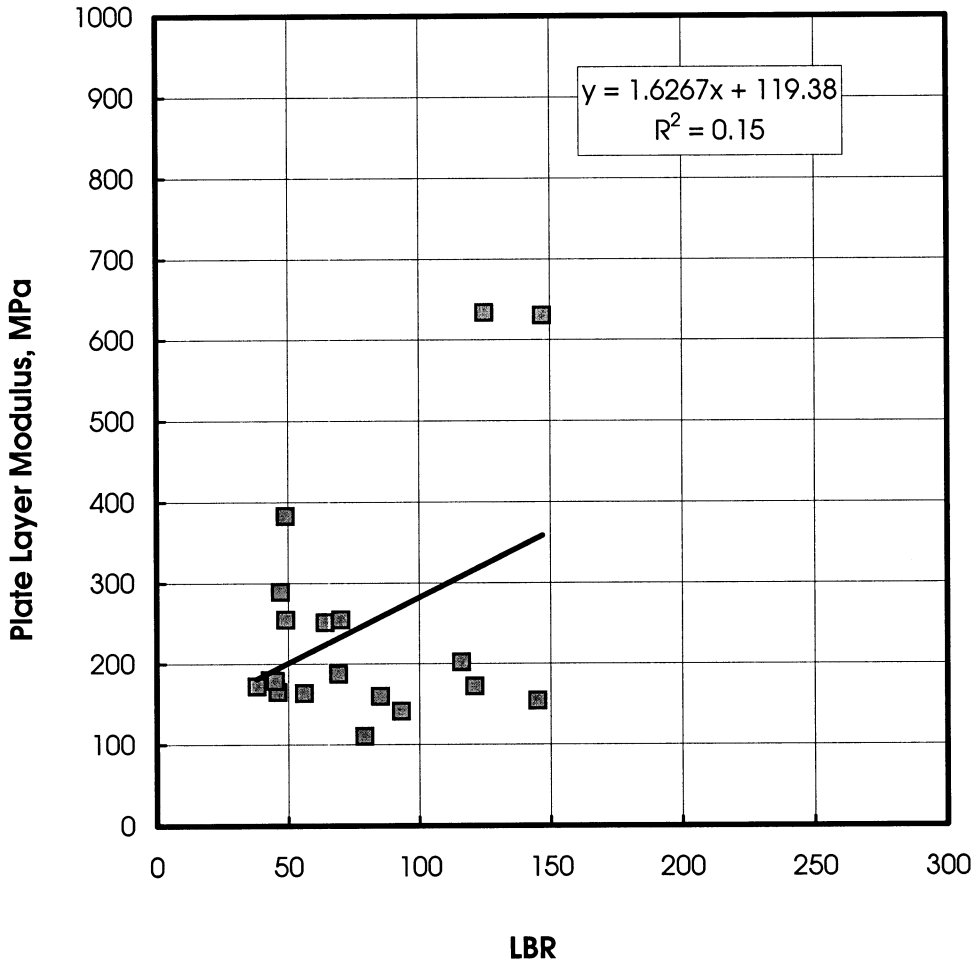


Figure 8.18c Comparison of LBR with plate layer modulus (subgrade layers)

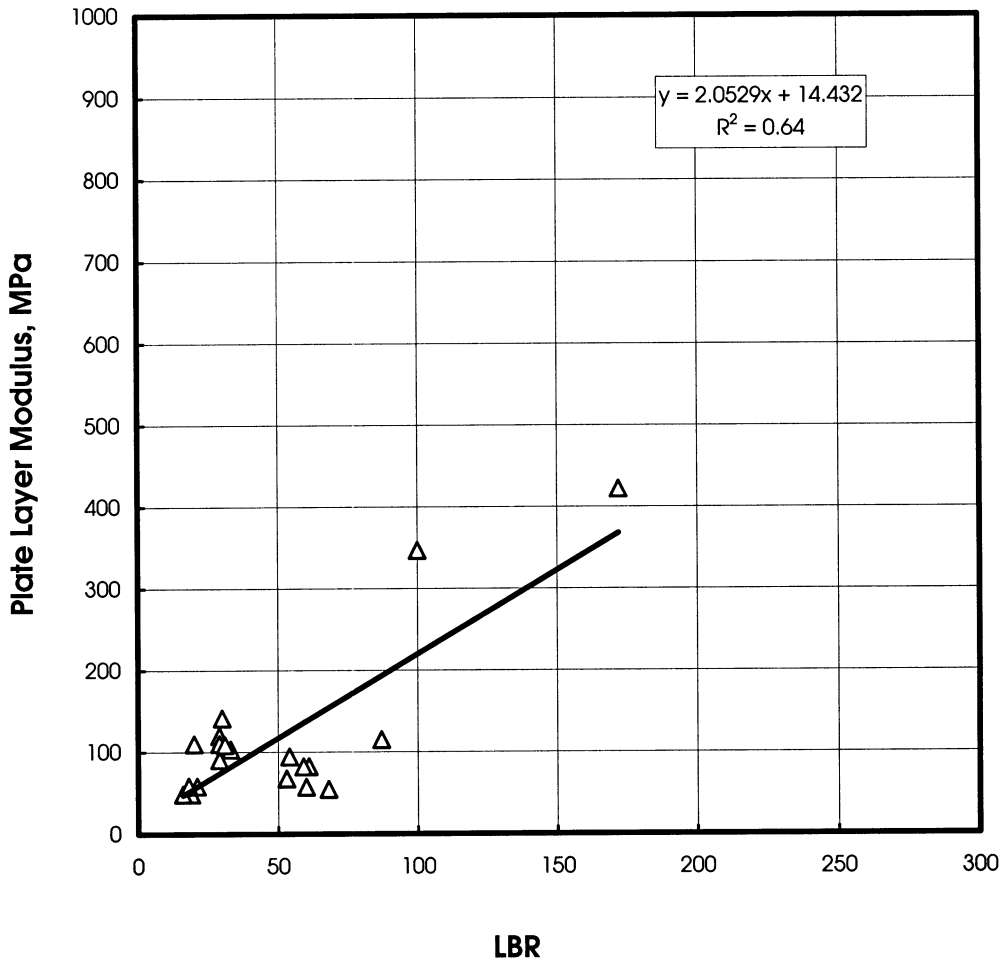


Figure 8.18d Comparison of LBR with plate layer modulus (embankment layers)

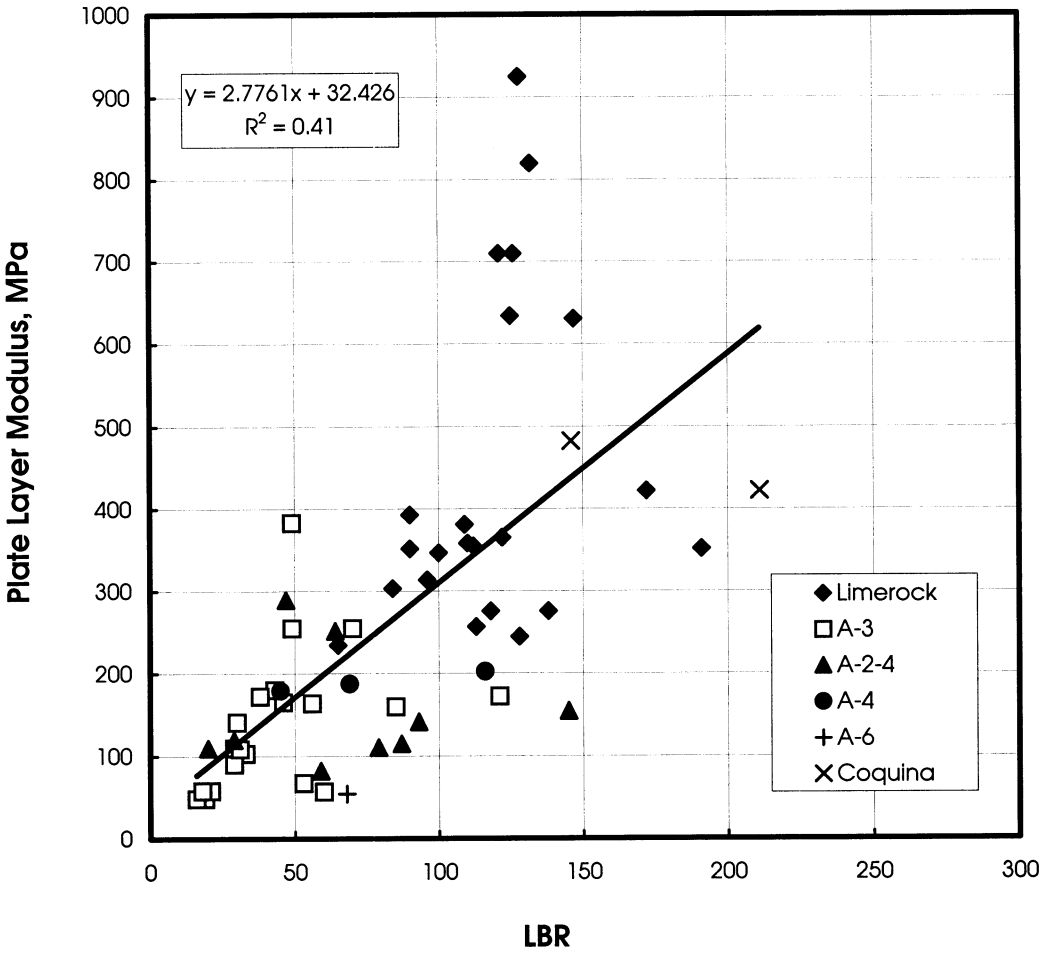


Figure 8.19a Comparison of LBR with plate layer modulus (by pavement materials)

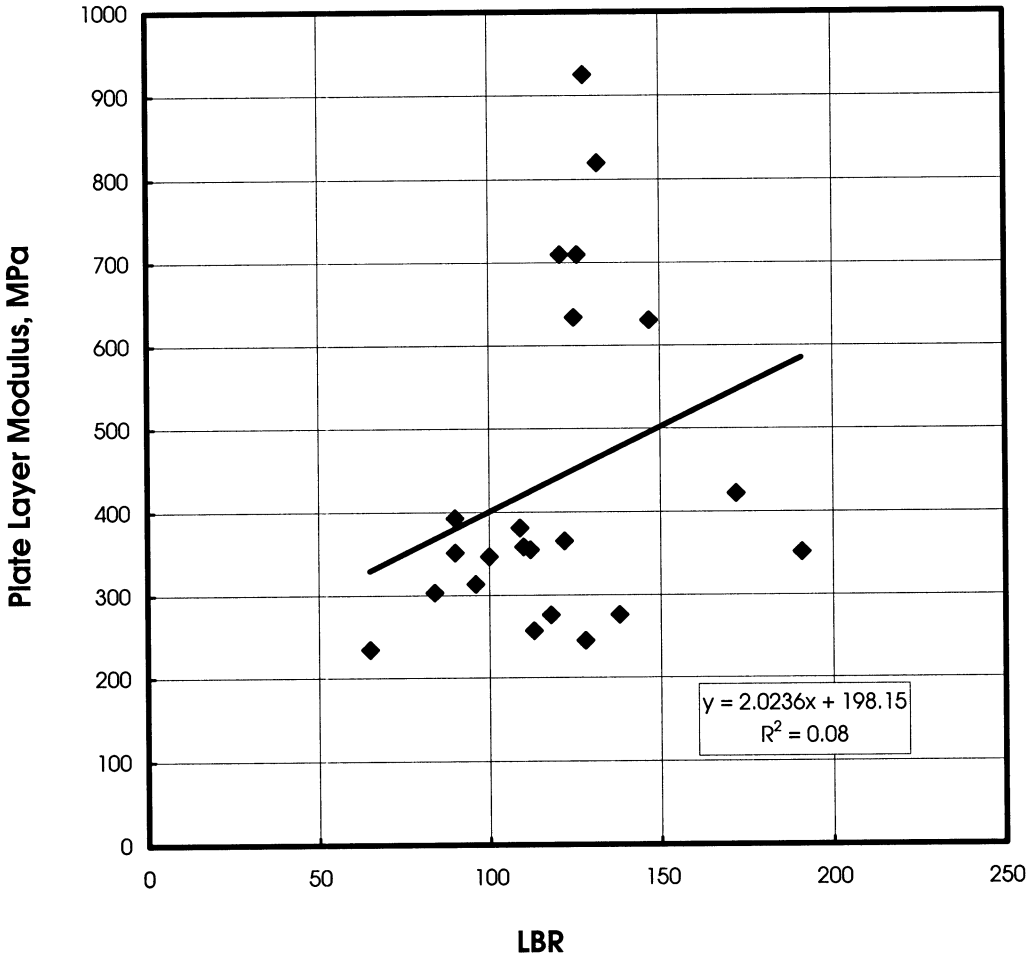


Figure 8.19b Compasison of LBR with plate layer modulus (limerock)

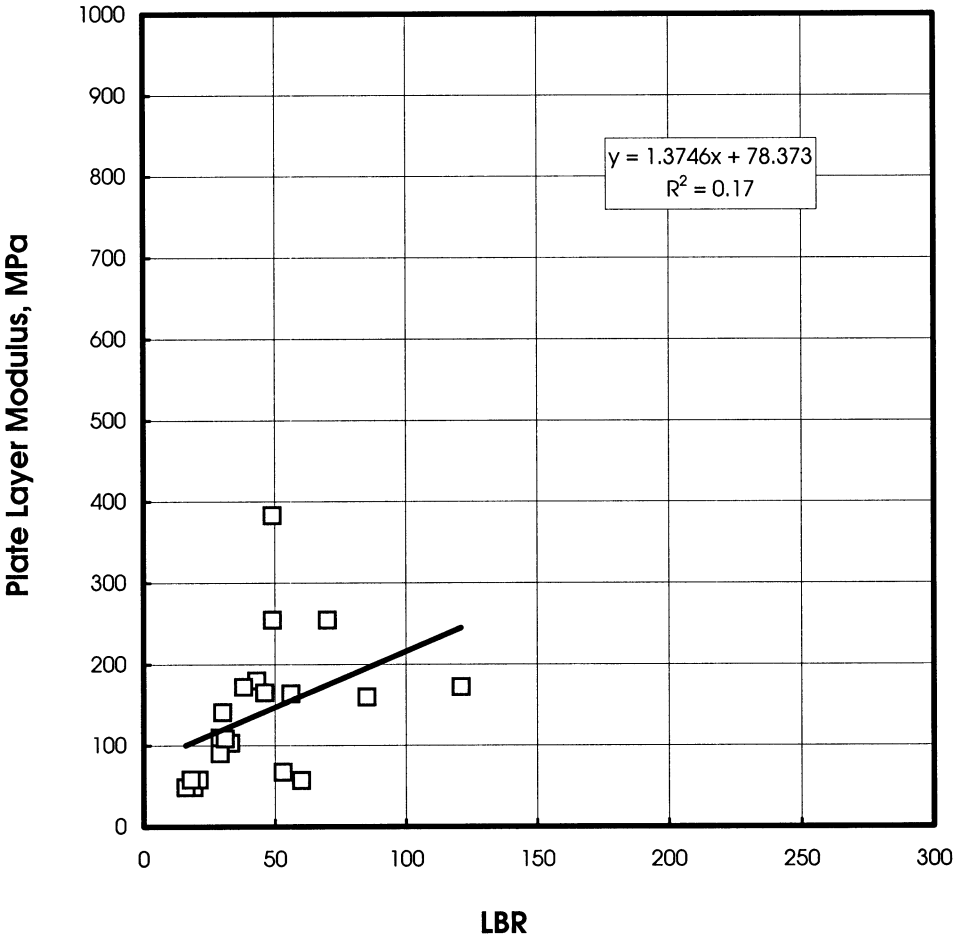


Figure 8.19c Comparison of LBR with plate layer modulus (A-3)

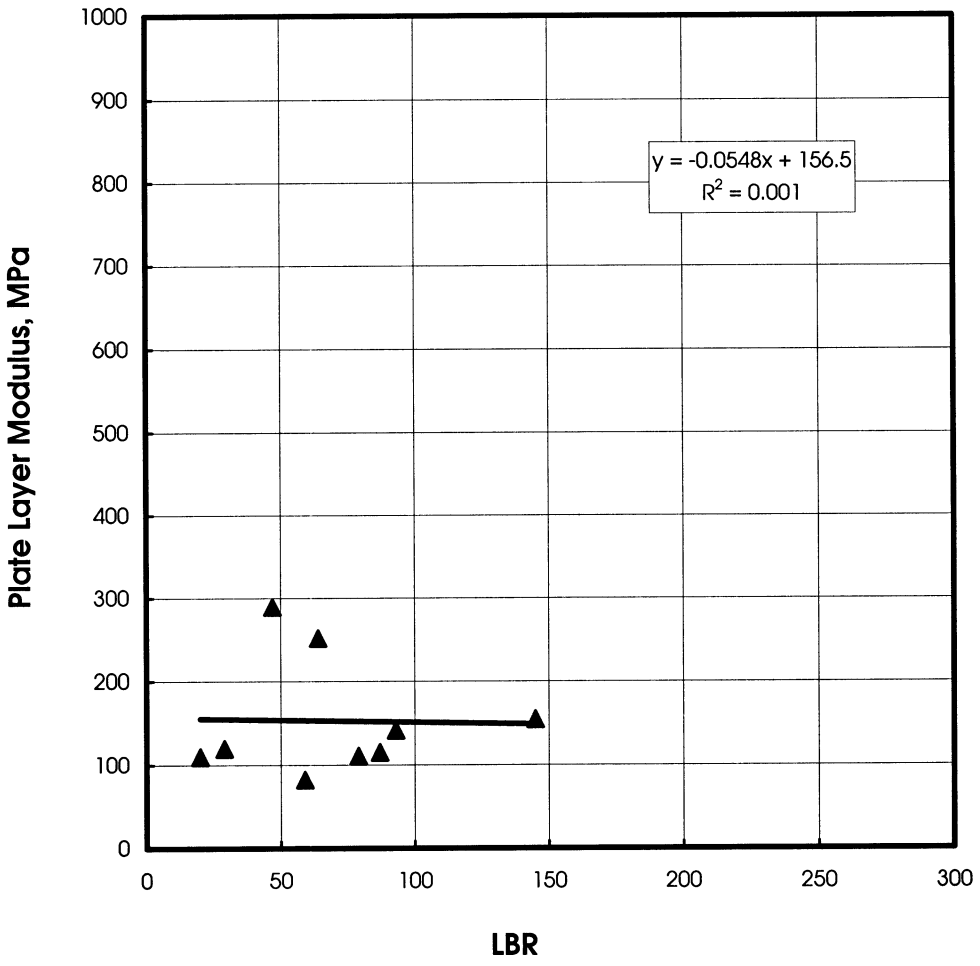


Figure 8.19d Comparison of LBR with plate layer modulus (A-2-4)

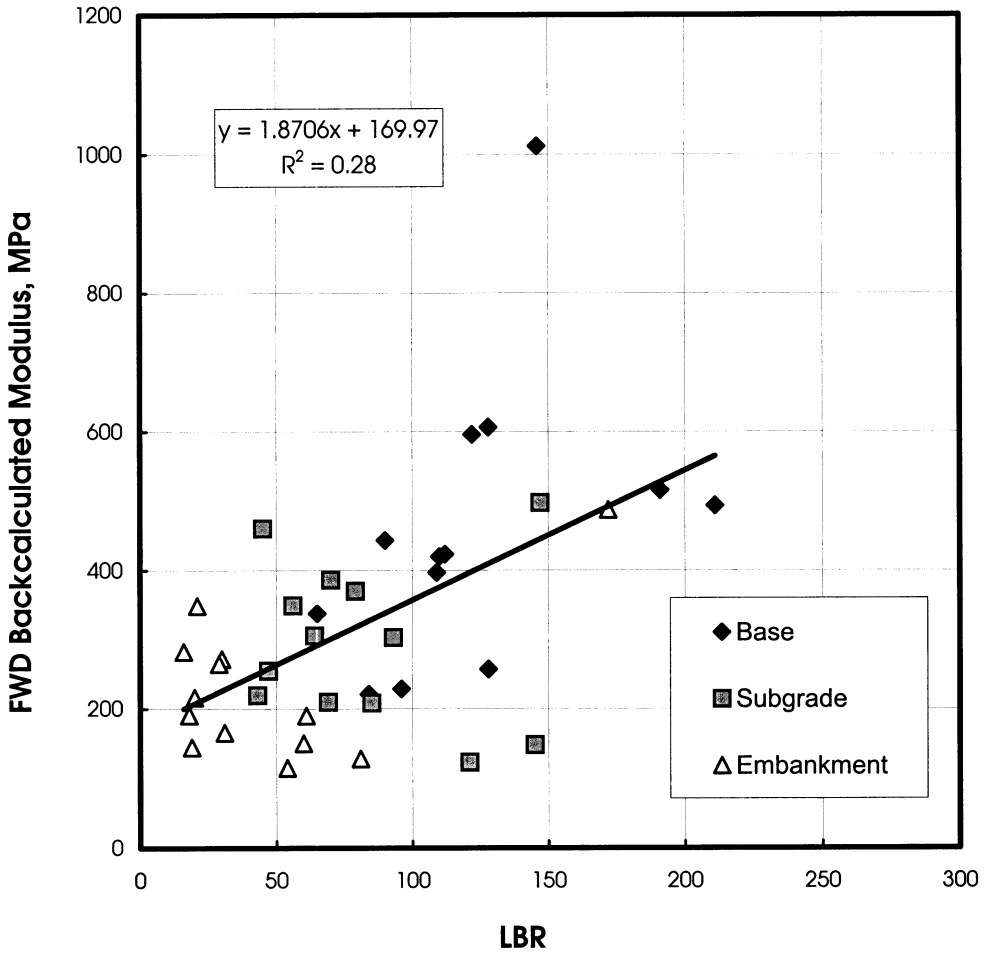


Figure 8.20a Comparison of LBR with FWD backcalculated modulus

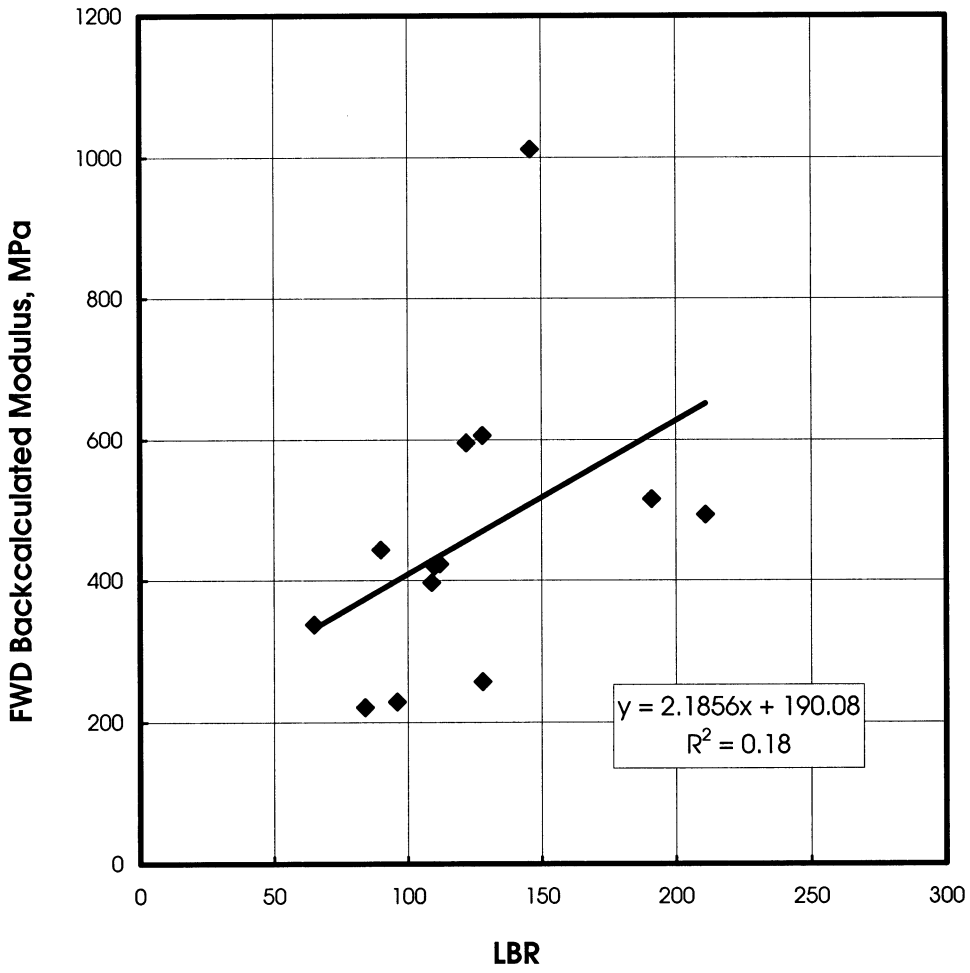


Figure 8.20b Comparison of LBR with FWD backcalculated modulus (base layers)

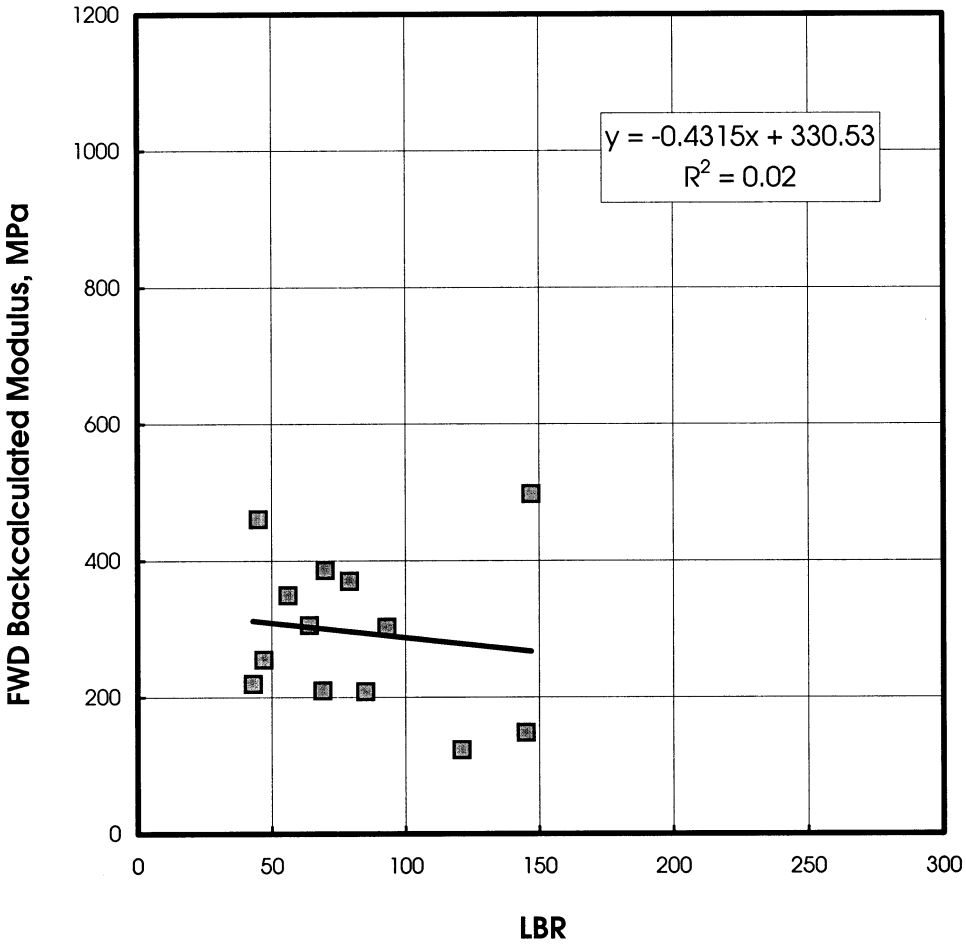


Figure 8.20c Comparison of LBR with FWD backcalculated modulus (subgrade layers)

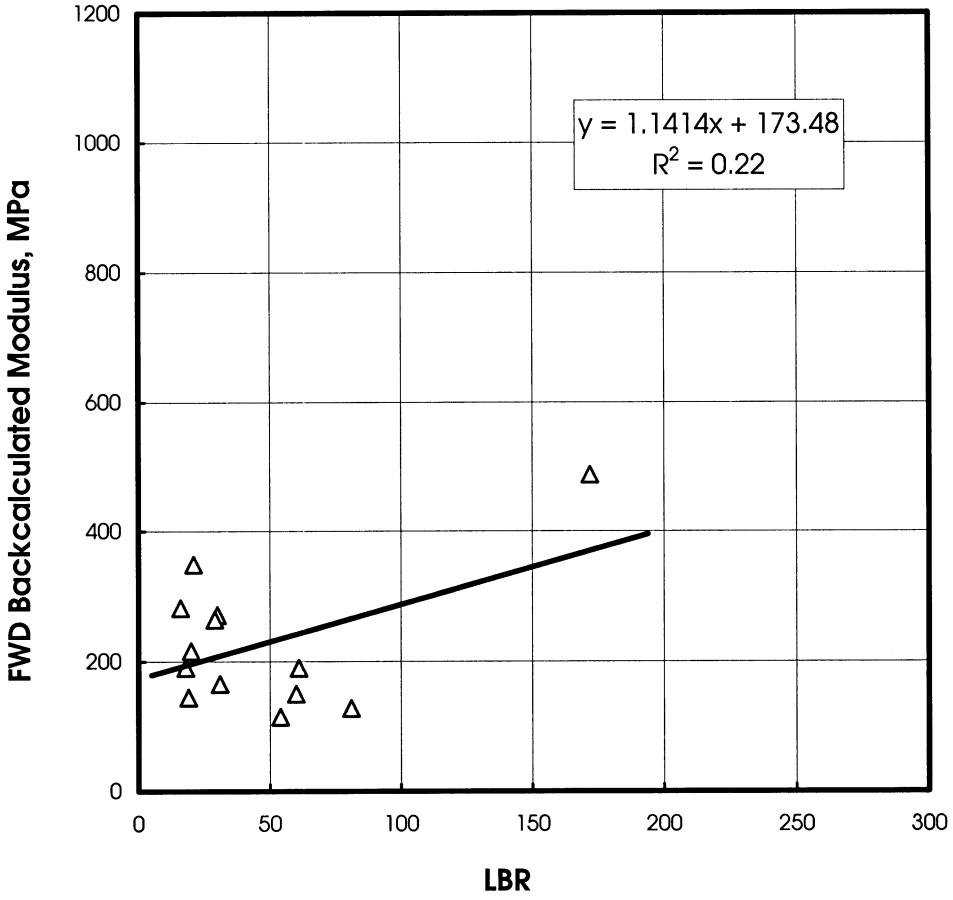


Figure 8.20d Comparison of LBR with FWD backcalculated modulus (embankment layers)

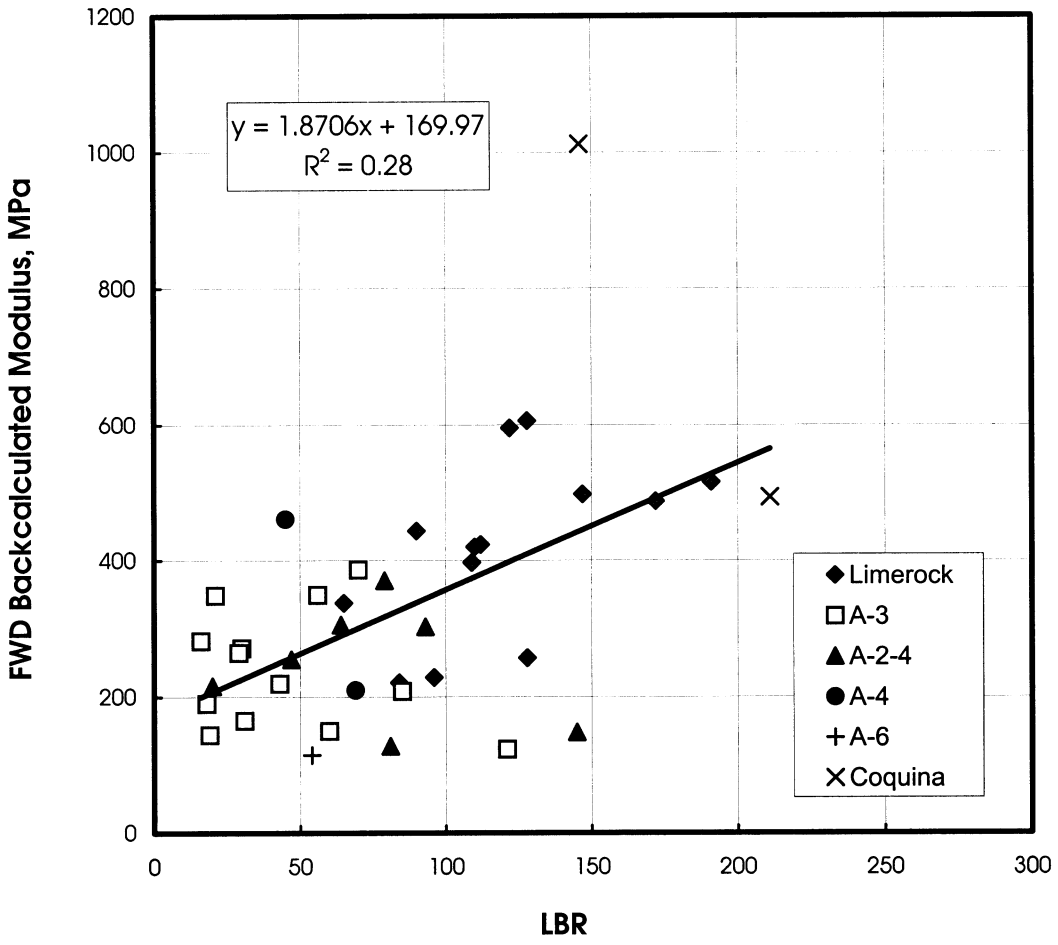


Figure 8.21a Comparison of LBR with FWD backcalculated modulus (by pavement materials)

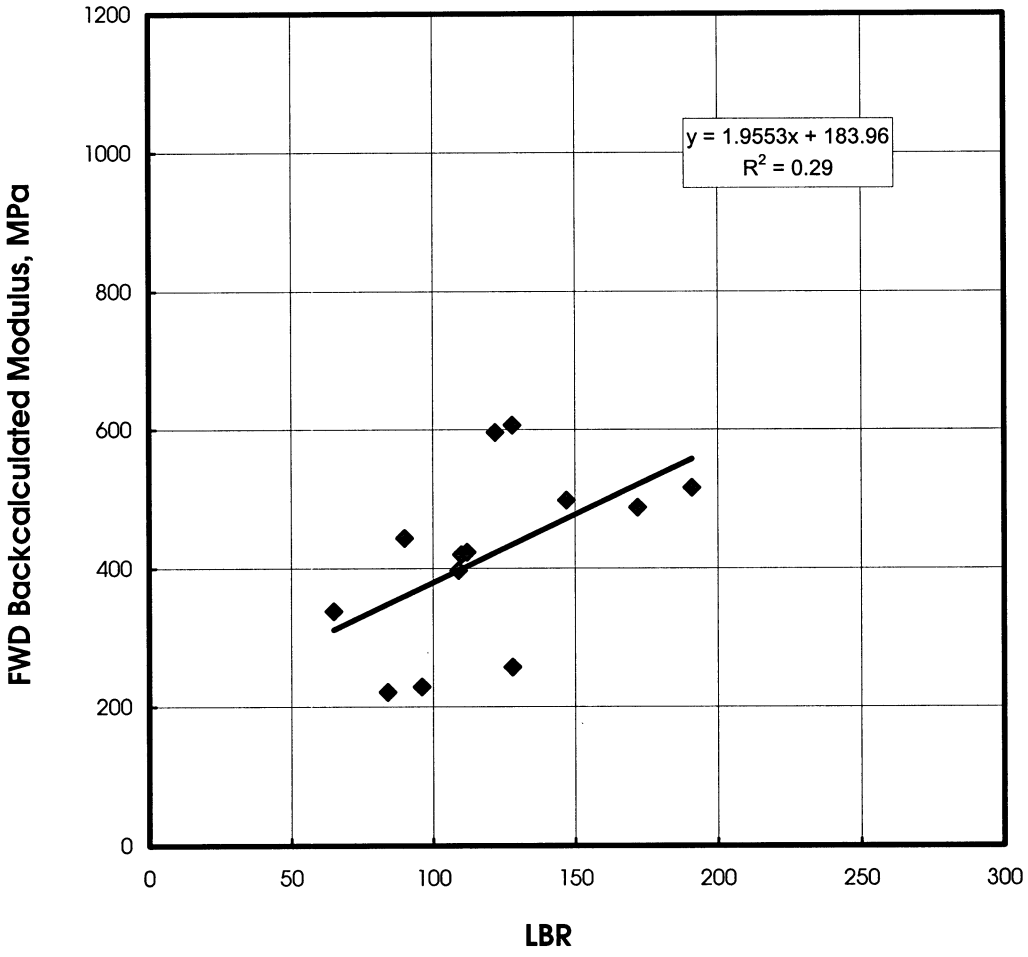


Figure 8.21b Comparison of LBR with FWD backcalculated modulus (limerock)

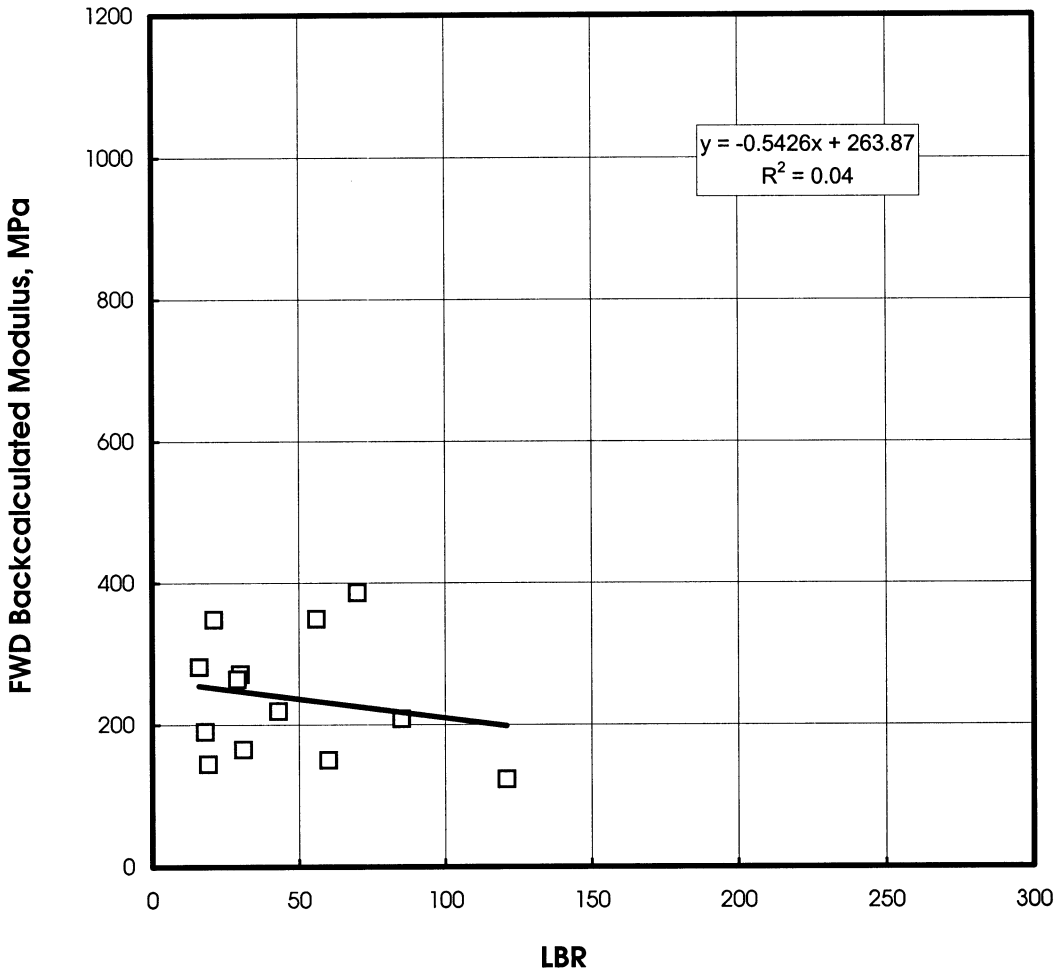


Figure 8.21c Comparison of LBR with FWD backcalculated modulus (A-3)

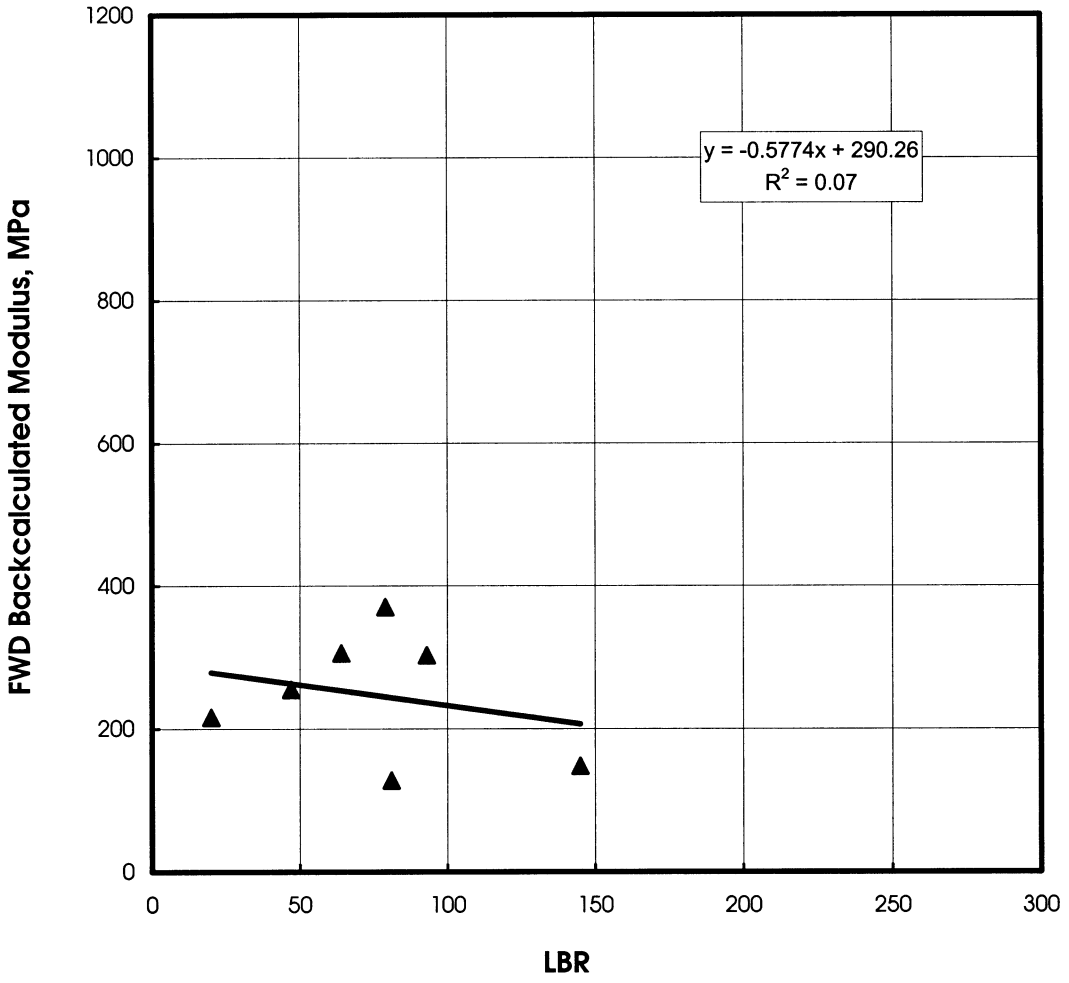


Figure 8.21d Comparison of LBR with FWD backcalculated modulus (A-2-4)

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The main objectives of this study were:

- To develop reliable correlations between laboratory measured resilient modulus and in-situ layer modulus of pavement soils as measured by field plate bearing load test.
- To correlate field plate bearing values and laboratory resilient modulus measurements with LBR values and FWD test results on Florida soils.
- To evaluate testing methodology for determining resilient modulus.
- To investigate the effect of using a larger sample size (6-in diameter samples) on resilient modulus measurements.

In order to fulfill the objectives, a series of experimental programs, including a field experimental program and a laboratory experimental program, were planed and conducted. Twenty field sites were tested throughout Florida. The field experimental program included a plate bearing load test, an FWD test, and a Dynaflect test. The laboratory experimental program consisted of a laboratory resilient modulus test and an LBR test. Various test procedures and conditions were adopted to acquire test results that may conceivably cover every typical situation related to pavement design. Analyses were carefully performed to achieve the objectives.

The conclusions based on the research and analysis from field and laboratory experimental studies are summarized below.

9.1.1 Field Experimental Program

The field experimental program focused on investigating the bearing characteristics of in-place pavement layers. By analyzing the test results, the following conclusions have been made:

1. A hyperbolic model was used to represent the relationship of load-deformation curve obtained

from a field plate bearing load test. The average modulus of a load-deformation curve could be represented by the secant modulus at which the applied load would be equal to one-half of the ultimate load.

2. Results of the average plate layer (secant) modulus based on the hyperbolic model were considered to be representative of the layer modulus of pavement materials.

3. FWD backcalculated moduli are 1.5 times greater than plate layer moduli.

   The regression equation is:

   $$M_{FWD} = 1.53 M_{PLT}$$

   The effective modulus range was: 50 ~ 650 MPa for plate layer modulus. This correlation should be used with caution, because both M_{FWD} and M_{PLT} depended on the type of soil.

4. Dynaflect deflection readings versus plate layer moduli did not show a strong correlation for all data. Within a certain type of material, no clear trend was established.

9.1.2 Laboratory Experimental Program

The laboratory experimental program was used to evaluate the laboratory test for resilient modulus measurement and to conduct the LBR test on pavement materials. The following conclusions have been made based on the research results:

1. The resilient modulus measured from the middle LVDTs was significantly different from those of the full length LVDTs because of the end effects and system compliance. For the T 292-91I test procedure, the average ratios of the resilient modulus values between the 20.3-cm and 10.2-cm measurements ranged from about 0.75 at lower confining pressures to about 0.85 at higher confining pressures. The resilient modulus measured from the middle LVDTs was used for the purpose of comparison in this study.
2. The significant differences between T 292-91I and T 294-92 were attributed to the stress history and the positions of the LVDTs. The effect of stress history was evaluated for each procedure by testing at the same LVDT position. The T294-92

yielded slightly higher values than those of the T 292-91I. However, resilient modulus values measured from the external measurements of T 294-92 were less than that of the internal full length measurements of T 292-91I because of the system compliance.

3. The conditioning partially eliminated the imperfect contacts between end platens and minimized disturbance effects caused by laboratory preparation. Nevertheless, the conditioning changed the stress history of the specimen prior to testing by stiffening the specimen.
4. Based on the comparison of the two test methods, the effect of stress history resulted in only a 15 to 20% difference in resilient modulus, while the difference in the LVDT position was 25 to 30%.
5. The resilient moduli measured from the 6-in. diameter specimen and 4-in. diameter specimen were not significantly different for the limerock and granular pavement materials.

6. The comparison of LBR and laboratory resilient modulus values under optimum moisture conditions showed no clear correlation between them.

However, a good correlation appeared to exist between the laboratory resilient modulus and LBR values for the A-2-4 soils. The correlation relationship is as follows:

$$MR_{lab(OMC)} = 0.62(LBR) + 112.59 \quad \text{(MPa)} \quad (R^2 = 0.75)$$

for A-2-4 soils.

7. The LBR and laboratory resilient modulus values under in-situ moisture conditions had a certain degree of correlation.

The regression equation is:

$$MR_{lab(In-situ)} = 0.77(LBR) + 112.57 \quad \text{(MPa)} \quad (R^2 = 0.31)$$

for range of LBR values from 20 to 150.

9.1.3 Correlation Relationships between Field and Laboratory Experimental Results

The basis of comparisons made in this study are grouped into two areas: moisture condition and state of stresses. The moisture condition was a major factor that influenced the values of resilient modulus of the pavement materials.

This study considered two moisture conditions: optimum moisture content and in-situ moisture content.

The stress state was another important factor for determining the resilient modulus of the pavement materials. This study found through scientific computation that the 14 kPa (2 psi) confining pressure reflected the real state of confinement, which the subgrade and embankment may experience under traffic load. Bulk stress of each pavement layer was calculated according to the pavement profiles and layer system theory.

The comparison showed:

1. FWD backcalculated moduli were generally 1.5-1.9 times greater than laboratory resilient moduli. This is in agreement with the AASHTO guide, which suggests that the FWD backcalculated moduli are approximately two to three times higher than the laboratory determined moduli.
2. Laboratory resilient moduli under in-situ moisture condition were 1.03 times greater than plate layer moduli. This may imply that plate layer moduli were approximately equivalent to laboratory resilient moduli. However, the correlation

relationship depended on the type of soil, and it should be used with caution.

3. The laboratory resilient modulus under optimum moisture content was 1.1 times higher than the laboratory resilient modulus under an in-situ moisture content. Observations showed that after construction the resilient modulus of the pavement materials tended to decrease due to the effects of many influencing factors.

4. Plate layer moduli (in MPa) were about 2.8 times higher than LBR values. The regression equation is:

$$M_{PLT} = 2.78(LBR) + 32.426 \quad (MPa)$$

(R^2=0.41, within the range of LBR values from 16 to 211).

5. The correlation relationship between FWD back-calculated moduli and LBR values was not very high.

The regression equation is:

$$M_{FWD} = 1.87(LBR) + 169.97 \quad (MPa)$$

(R^2=0.28, within the range of LBR values from 16 to 211).

However, the correlation relationship was dependent upon the type of material, and the correlation should be used with caution.

9.2 Recommendations

The main thrust of this research project was to ultimately implement the 1986 & 1993 AASHTO design guide for pavement structures with the resilient modulus test for Florida conditions. Under these major guidelines, the project objectives were planned, and the test and analyses were performed.

The following recommendations are made based on the findings and observations from this study:

1. The hyperbolic form for the nonlinear load-deformation response is a reasonable representation over a large range of deformation for the field plate load test and may be useful in design.
2. When the FWD backcalculated modulus or the plate layer modulus are known, the following relationships may be used to estimate the laboratory resilient modulus for granular materials:

- $MR_{Lab} = 0.55M_{FWD} \quad (MPa)$
- $MR_{Lab} = 1.03M_{PLT} \quad (MPa)$

3. The relationship $MR_{OMC} = 1.10MR_{insituMC} \quad (MPa)$ is recommended for converting between the laboratory resilient modulus under OMC and laboratory resilient modulus under in-situ moisture condition.
4. This study found three correlations related to LBR. Among the three, LBR versus plate layer moduli exhibited the correlation. LBR versus laboratory resilient moduli and LBR versus FWD moduli yielded some acceptable correlations. LBR is highly dependent upon the type of material used. Because LBR presents different aspects of characteristics of the pavement materials from the resilient modulus, this study suggests further investigation before adoption of any of the correlations.
5. A 4-in. diameter specimen test is recommended for conducting the resilient modulus test because no difference existed between 4-in. diameter and 6-

in. diameter test results. However, specimen samples that are 4-in. are easier to prepare.

6. Test procedure T 292-91I is recommended for conducting the resilient modulus test according to the research results.
7. A resilient modulus test under different moisture levels is recommended for further research to investigate the relationship of resilient modulus and various moisture content.
8. From this research, the resilient moduli at an in-situ moisture content condition were more compatible with other field test results than the resilient moduli at an OMC condition.
9. One of the major concerns in resilient modulus measurement is the positioning of the deformation measurement devices. Non-contact measurement devices, such as an electro-optical biaxial tracking system, may be a possible solution to avoid errors and provide accurate measurements of the true resilient modulus.
10. For granular materials, vibratory or gyratory compaction may be a better choice for preparation of test specimens in the laboratory.

11. For clay materials, further research is needed to characterize the resilient properties of fine grain soils.

12. Pavement design procedures using the resilient modulus should be carried out with practical trials and calibrations prior to actual implementation. Pilot projects may be undertaken for calibration and verification.

APPENDIX A

FWD BACKCALCULATED MODULUS RESULTS

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Table A1. FWD Backcalculated Modulus Results -- Lee County, SR884, Site 1B

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

District: 1
County: LEE
Highway/Road: SR 884
Site: #1B
Date: 970422

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum
Pavement:	1.70	500,000	1,800,000
Limerock Base:	9.50	20,000	100,000
Fine Sand Subbase:	12.00	15,000	80,000
Fine Sand Subgrade:	151.30	18,000	

Poisson Ratio Values: H1: δ = 0.30; H2: δ = 0.40; H3: δ = 0.45; H4: δ = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	9,231	15.85	10.65	7.72	5.41	4.11	2.45	1.09	1800.	60.8	24.0	19.7	0.72	171.81	*
0.020	9,103	18.08	12.78	9.21	5.94	4.15	2.33	1.05	1800.	32.9	37.4	17.0	6.86	123.14	*
0.030	9,151	17.34	11.74	8.48	5.86	4.39	2.69	1.25	1800.	51.8	23.2	17.8	0.85	195.73	*
0.040	8,991	16.47	10.41	7.44	5.09	3.78	2.29	1.13	1437.	51.3	28.3	20.1	0.06	214.96	
0.050	9,215	17.96	12.26	8.60	5.66	4.15	2.45	1.13	1800.	41.8	27.3	18.6	1.91	172.20	*
0.060	9,103	17.01	11.62	8.16	5.29	3.86	2.33	1.17	1800.	44.7	26.5	19.9	1.77	300.00	*
0.070	9,119	15.28	10.85	7.96	5.29	3.78	2.29	1.13	1800.	63.1	20.7	21.0	2.55	197.54	*
0.075	9,167	17.58	11.78	8.52	5.74	4.15	2.49	1.21	1800.	51.0	20.2	19.5	1.05	197.90	*
0.080	9,175	19.03	13.26	9.41	6.15	4.31	2.41	1.05	1800.	38.4	23.3	18.2	3.45	120.71	*
0.090	9,095	18.00	12.30	8.64	5.62	4.03	2.41	1.09	1800.	32.9	39.8	17.5	4.24	179.66	*
0.100	9,103	16.10	10.93	7.40	4.68	3.29	1.96	0.93	1800.	33.0	60.4	20.1	6.83	143.61	*
0.110	9,023	18.24	12.78	9.21	5.98	4.31	2.49	1.09	1800.	41.5	22.3	18.1	2.34	147.33	*
0.120	9,055	17.75	12.14	8.44	5.54	4.15	2.65	1.33	1800.	39.7	32.4	17.2	2.04	300.00	*
0.130	9,031	16.06	10.93	7.76	5.21	3.90	2.49	1.29	1800.	52.5	26.7	19.4	2.04	291.44	*
0.140	9,071	15.65	10.77	7.64	5.01	3.66	2.33	1.17	1800.	51.3	29.2	20.1	2.58	300.00	*
2.010	9,175	16.27	10.61	7.48	5.21	4.23	3.06	1.69	1800.	41.5	68.0	14.5	1.67	300.00	*
2.020	9,159	16.14	10.69	7.52	5.05	3.78	2.37	1.01	1800.	49.0	31.8	19.8	1.15	152.72	*
2.030	9,087	15.15	10.37	7.56	5.17	3.94	2.37	1.01	1800.	64.8	22.8	20.3	1.13	153.98	*
2.040	9,175	14.78	9.73	7.11	4.48	3.25	2.04	0.93	1800.	55.8	28.9	23.9	2.69	155.51	*
2.050	9,135	15.57	9.93	6.91	4.36	3.17	1.88	0.89	1800.	48.2	29.7	24.9	1.17	160.63	*
2.060	9,119	16.97	11.58	8.24	5.58	4.11	2.57	1.25	1800.	51.7	22.9	19.0	1.76	226.89	*
2.070	9,055	17.26	11.42	8.24	5.78	4.43	2.74	1.25	1800.	48.1	28.7	16.8	0.52	185.05	*
2.075	9,103	16.14	10.61	7.64	5.25	3.90	2.37	1.01	1800.	53.5	26.6	19.9	0.41	153.66	*
2.080	9,143	16.02	10.25	6.99	4.56	3.33	2.08	0.93	1800.	45.1	33.7	22.7	1.25	170.50	*
2.090	9,175	16.31	10.85	7.24	4.44	3.21	2.04	0.93	1800.	41.5	33.4	23.3	3.03	99.47	*
2.100	9,103	14.70	9.45	6.71	4.40	3.21	2.00	0.76	1800.	56.0	29.9	24.1	1.50	122.63	*
2.110	9,087	14.21	9.16	6.19	3.99	2.85	1.67	0.76	1800.	55.6	29.3	28.0	1.43	158.27	*
2.120	9,095	14.87	9.69	6.59	4.11	2.85	1.67	0.80	1800.	52.8	24.8	28.6	2.20	116.20	*
2.130	9,159	14.54	9.45	6.31	3.95	2.81	1.67	0.76	1800.	40.7	51.6	25.7	3.92	136.77	*
2.140	8,975	11.86	7.36	5.15	3.54	2.68	1.63	0.76	1793.	68.5	45.6	27.8	0.47	190.50	
Mean:		16.24	10.88	7.68	5.08	3.73	2.27	1.06	1788.	48.6	31.6	20.8	2.12	174.48	
Std. Dev:		1.49	1.25	0.96	0.68	0.53	0.35	0.21	66.	9.2	11.3	3.6	1.64	52.15	
Var Coeff(%):		9.18	11.51	12.50	13.46	14.10	15.27	19.37	4.	19.0	35.8	17.2	77.29	29.89	

Table A2. FWD Backcalculated Modulus Results -- Polk County, US17, Site 1A

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

District: 1
County: Polk
Highway/Road: US 17
Site: #1A
Date: 970318

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum
Pavement:	4.90	200,000	450,000
Limerock Base:	9.00	30,000	100,000
Silty Sand Subbase:	14.00	15,000	90,000
Fine Sand Subgrade:	INFINITY	18,000	

Poisson Ratio Values
H1: δ = 0.30
H2: δ = 0.40
H3: δ = 0.45
H4: δ = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
0.010	8,863	8.11	5.71	4.34	2.97	2.03	1.10	0.48	450.	90.2	20.2	66.8	1.07	62.38 *
0.020	8,895	7.45	5.31	3.98	2.69	1.87	0.94	0.40	450.	99.4	22.4	74.6	1.82	55.50 *
0.030	8,759	8.52	6.11	4.78	3.30	2.40	1.43	0.68	450.	76.0	26.0	49.1	1.03	86.27 *
0.040	9,111	11.00	8.00	6.39	4.76	3.66	2.37	1.37	450.	56.4	32.4	28.8	0.65	168.00 *
0.050	9,047	9.06	6.75	5.27	3.83	2.89	1.88	1.13	450.	61.4	50.5	34.2	2.69	161.39 *
0.060	9,039	8.94	6.63	5.15	3.70	2.81	1.84	1.09	450.	58.5	57.6	34.7	2.89	172.48 *
0.070	9,039	9.02	6.75	5.31	3.87	2.97	1.96	1.17	450.	63.0	53.5	32.8	2.80	196.49 *
0.080	9,039	10.13	7.40	5.83	4.27	3.29	2.25	1.33	450.	64.8	34.8	31.0	0.96	206.96 *
0.090	8,743	10.17	7.36	5.71	4.11	3.05	2.00	1.17	450.	53.5	33.0	33.5	0.85	170.05 *
0.100	8,703	10.30	7.56	5.87	4.19	3.05	1.92	1.17	450.	50.1	31.6	33.6	1.21	117.11 *
0.110	8,831	10.25	7.72	5.99	4.27	3.21	2.08	1.21	450.	51.2	32.3	32.3	1.27	159.19 *
0.120	9,263	10.34	7.64	5.79	3.99	2.89	1.88	1.13	450.	40.2	40.2	38.9	3.80	103.52 *
0.130	8,647	10.91	7.96	6.03	4.23	3.13	1.92	1.09	450.	35.8	34.0	34.0	2.03	104.67 *
0.140	8,823	8.85	6.35	4.78	3.38	2.44	1.55	0.97	450.	45.5	45.5	44.7	4.42	98.84 *
Mean:		9.50	6.95	5.37	3.83	2.83	1.79	1.03	450.	60.4	36.7	40.6	1.96	123.20
Std. Dev:		1.08	0.85	0.70	0.57	0.49	0.41	0.30	0.	17.9	11.4	13.9	1.18	54.89
Var Coeff(%):		11.40	12.25	13.02	14.83	17.38	22.63	28.93	0.	29.7	31.0	34.2	60.28	44.55

Table A3. FWD Backcalculated Modulus Results -- Polk County, US17, Site 2A

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

			Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
District:	1					
County:	Polk					
Highway/Road:	US 17	Pavement:	4.90	200,000	300,000	H1: ō = 0.30
Site:	#2A	Limerock Base:	9.00	30,000	100,000	H2: ō = 0.40
Date:	970318	Silty Sand Subbase:	13.00	15,000	90,000	H3: ō = 0.45
		Fine Sand Subgrade:	INFINITY		18,000	H4: ō = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	8,799	10.34	7.44	5.67	3.95	2.93	1.92	1.09	300.	86.8	17.2	40.3	3.08	164.23	*
0.020	8,751	9.10	6.27	4.58	3.13	2.24	1.35	0.80	300.	81.3	26.2	51.4	1.66	89.75	*
0.030	9,255	9.97	6.83	5.02	3.42	2.48	1.59	0.89	300.	72.9	32.1	45.3	1.88	103.72	*
0.040	8,727	11.16	7.80	5.79	3.91	2.77	1.71	0.89	300.	43.2	37.1	36.4	2.39	82.50	*
0.050	9,135	9.27	5.59	4.22	2.81	2.03	1.31	0.68	268.	75.2	45.8	52.6	0.95	95.10	
0.060	8,703	9.60	6.63	4.82	3.26	2.32	1.43	0.72	300.	69.2	27.6	47.8	1.87	84.30	*
0.070	8,807	10.54	7.15	5.23	3.50	2.60	1.67	0.89	300.	45.5	45.5	39.0	1.61	119.03	*
0.080	8,927	10.09	6.83	5.15	3.62	2.77	1.92	1.21	300.	54.6	58.2	34.5	1.07	300.00	*
0.090	8,775	10.09	6.95	5.19	3.66	2.81	2.04	1.37	300.	53.2	58.2	33.2	1.90	300.00	*
0.100	8,719	9.84	7.11	5.51	4.03	3.17	2.29	1.37	300.	91.8	30.6	30.6	2.53	215.37	*
0.110	8,727	10.25	6.99	5.15	3.54	2.68	1.96	1.33	300.	50.2	61.1	33.6	2.06	300.00	*
0.120	8,759	9.88	6.63	4.94	3.42	2.64	1.96	1.33	300.	58.1	58.0	34.7	2.18	300.00	*
0.130	8,743	9.64	6.55	4.86	3.38	2.60	1.92	1.25	300.	58.4	60.6	35.0	2.21	300.00	*
0.140	8,863	10.09	7.07	5.27	3.70	2.81	1.92	1.21	300.	53.5	58.2	33.6	2.24	300.00	*
Mean:		9.99	6.85	5.10	3.52	2.63	1.78	1.07	298.	63.8	44.0	39.1	1.97	148.28	
Std. Dev:		0.52	0.53	0.42	0.33	0.29	0.28	0.25	9.	15.6	15.3	7.2	0.55	77.62	
Var Coeff(%):		5.20	7.68	8.14	9.39	11.15	15.94	23.56	3.	24.4	34.8	18.5	28.08	52.35	

Table A4. FWD Backcalculated Modulus Results -- Jefferson County, US27, Site 1A

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

District:	3			
County:	Jefferson		Thickness(in)	MODULI RANGE(psi) Minimum / Maximum
Highway/Road:	US 27	Pavement:	4.20	200,000 / 450,000
Site:	#1A	Limerock Base:	6.50	30,000 / 100,000
Date:	970304	Silty Sand Subbase:	6.50	15,000 / 90,000
		Silty Sand Subgrade:	120.00	18,000

Poisson Ratio Values: H1: δ = 0.30; H2: δ = 0.40; H3: δ = 0.45; H4: δ = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	9,015	11.90	7.96	5.47	3.18	1.95	1.06	0.64	412.	36.9	33.7	36.9	2.78	40.87	*
0.020	9,135	11.86	8.32	6.07	3.83	2.40	1.27	0.72	450.	42.4	29.9	32.1	2.57	44.10	*
0.030	9,255	9.64	6.79	5.19	3.50	2.40	1.31	0.56	450.	75.4	49.9	31.6	2.55	64.35	*
0.040	9,007	12.11	8.36	6.03	3.75	2.44	1.27	0.64	450.	41.0	31.3	31.0	1.44	50.13	*
0.050	8,863	13.22	9.29	6.83	4.40	2.85	1.39	0.68	450.	30.0	23.2	29.4	4.68	50.50	*
0.060	9,015	12.93	8.68	5.91	3.30	2.07	1.10	0.68	359.	34.3	32.0	34.3	3.38	39.82	*
0.070	9,175	10.67	7.07	5.10	3.09	2.03	1.10	0.60	450.	46.0	46.0	37.0	1.68	50.81	*
0.080	8,767	17.67	12.50	9.45	6.43	4.47	2.33	1.01	369.	30.4	22.0	17.0	0.42	64.08	
0.090	8,647	19.81	14.31	10.81	7.16	4.76	2.45	1.09	303.	30.0	15.0	15.5	1.46	57.70	*
0.100	8,799	17.26	12.18	8.92	5.70	3.70	1.92	0.97	352.	30.0	17.5	20.4	1.43	51.18	*
0.110	8,711	18.57	13.51	10.13	6.47	4.19	2.08	1.05	325.	30.0	15.0	17.8	2.29	51.03	*
0.120	8,943	14.66	9.81	7.03	4.27	2.81	1.63	0.93	345.	30.0	37.1	25.6	2.65	52.01	*
0.130	9,031	14.04	9.65	6.87	4.15	2.64	1.51	0.89	403.	30.0	32.7	27.6	3.10	45.77	*
0.140	9,055	13.47	9.33	6.79	4.27	2.81	1.55	0.89	450.	31.3	37.4	26.6	1.69	52.54	*
Mean:		14.13	9.84	7.19	4.54	2.97	1.57	0.81	398.	37.0	30.2	27.3	2.29	50.11	
Std. Dev:		3.08	2.37	1.88	1.35	0.93	0.46	0.18	54.	12.3	10.7	7.2	1.05	6.88	
Var Coeff(%):		21.83	24.07	26.13	29.66	31.46	29.17	22.57	14.	33.4	35.6	26.5	45.95	13.73	

Table A5. FWD Backcalculated Modulus Results -- Gadsden County, US27, Site 2B

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

			Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
District:	3					
County:	Gadsden					
Highway/Road:	US 27	Pavement:	4.40	150,000	310,000	H1: ð = 0.30
Site:	#2B	Limerock Base:	6.50	30,000	100,000	H2: ð = 0.40
Date:	970305	Silty Sand Subbase:	6.50	15,000	90,000	H3: ð = 0.45
		Clay Subgrade:	60.00	18,000		H4: ð = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
0.010	9,279	15.69	10.61	7.72	4.93	3.05	1.27	0.48	310.	39.8	21.6	19.4	0.98	44.47 *
0.020	9,151	17.96	11.38	8.16	4.93	2.93	1.02	0.44	232.	34.5	15.0	21.1	0.93	40.74 *
0.030	8,839	17.91	12.30	8.92	5.46	3.33	1.22	0.52	286.	30.0	15.0	17.6	0.83	43.21 *
0.040	8,911	16.68	11.38	8.36	5.17	3.21	1.22	0.44	310.	33.2	17.0	18.4	0.29	44.51 *
0.050	9,095	19.07	12.78	9.16	5.66	3.46	1.31	0.56	253.	30.3	15.3	17.4	0.45	43.57
0.060	8,959	15.03	10.41	7.60	4.84	3.09	1.27	0.48	310.	30.0	39.2	17.7	2.57	46.93 *
0.070	8,807	19.81	13.39	9.61	5.66	3.13	0.98	0.44	190.	30.0	15.0	17.3	8.31	35.79 *
0.080	8,895	18.41	12.54	9.04	5.50	3.38	1.31	0.48	268.	30.0	15.3	17.3	1.11	43.91 *
0.090	8,735	17.83	12.50	9.04	5.66	3.46	1.31	0.44	297.	30.0	15.0	16.6	0.95	43.54 *
0.100	8,759	16.68	11.70	8.52	5.33	3.29	1.22	0.44	310.	33.4	15.2	17.8	0.98	44.00 *
0.110	8,871	14.41	9.93	7.40	4.72	3.01	1.22	0.40	310.	34.6	34.5	18.2	2.63	46.41 *
0.120	8,791	14.29	9.97	7.20	4.52	2.81	1.10	0.40	310.	30.0	23.2	21.9	5.46	45.07 *
0.130	8,743	14.04	9.65	7.07	4.56	2.93	1.35	0.56	310.	40.3	31.5	18.3	1.60	49.62 *
0.140	8,607	15.03	10.21	7.40	4.64	2.97	1.27	0.56	310.	34.5	25.7	18.3	0.94	48.28 *
Mean:		16.63	11.34	8.23	5.11	3.15	1.22	0.47	286.	32.9	21.3	18.4	2.00	44.83
Std. Dev:		1.91	1.23	0.84	0.43	0.21	0.11	0.06	37.	3.6	8.4	1.5	2.25	3.55
Var Coeff(%):		11.46	10.80	10.17	8.40	6.71	9.12	11.86	13.	10.9	39.2	8.0	112.23	7.92

Table A6. FWD Backcalculated Modulus Results -- Gadsden County, US27, Site 3B

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

			Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
District:	3					
County:	Gadsden					
Highway/Road:	US 27	Pavement:	4.10	150,000	280,000	H1: ð = 0.30
Site:	#3B	Limerock Base:	8.50	30,000	100,000	H2: ð = 0.40
Date:	970305	Fine Sand Subbase:	23.00	15,000	90,000	H3: ð = 0.45
		Clay Subgrade:	25.00	18,000		H4: ð = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	9,191	16.76	11.70	8.40	5.09	3.01	1.06	0.44	280.	38.7	15.2	15.2	3.03	53.54	*
0.020	9,111	17.21	11.50	7.84	4.52	2.44	0.69	0.40	280.	30.0	16.9	22.2	2.41	47.71	*
0.030	8,911	15.36	10.97	7.88	4.76	2.85	1.02	0.36	280.	40.3	15.9	15.9	2.69	55.00	*
0.040	8,839	18.90	12.74	8.92	5.05	2.77	0.82	0.48	215.	30.0	15.0	17.0	4.92	48.23	*
0.050	8,943	18.41	12.54	8.96	5.33	3.17	1.06	0.48	278.	30.0	15.0	14.1	1.81	54.13	*
0.060	8,871	17.67	11.90	8.40	4.89	2.85	1.06	0.48	280.	30.0	16.3	15.0	2.88	52.08	*
0.070	8,799	16.06	11.13	7.80	4.64	2.72	0.90	0.48	280.	30.0	17.8	17.5	4.35	52.65	*
0.080	8,791	16.64	11.30	7.96	4.68	2.64	0.86	0.48	280.	31.6	16.6	16.6	2.78	49.69	*
0.090	8,807	15.98	10.57	7.48	4.32	2.44	0.73	0.36	280.	31.2	18.6	19.3	2.13	49.79	*
0.100	8,863	16.10	10.85	7.52	4.32	2.44	0.82	0.40	280.	31.2	18.5	18.5	2.66	49.79	*
0.110	8,815	17.50	11.78	8.04	4.56	2.56	0.82	0.48	273.	30.0	15.3	20.7	3.13	49.40	*
0.120	8,807	16.35	11.01	7.72	4.56	2.77	1.18	0.56	280.	30.0	22.6	10.7	2.17	57.02	*
0.130	8,927	15.53	10.61	7.36	4.52	2.77	1.31	0.60	280.	30.0	27.0	9.5	3.10	58.50	*
0.140	8,831	16.10	10.97	7.68	4.52	2.64	0.94	0.48	280.	32.8	17.2	18.1	3.41	52.31	*
Mean:		16.76	11.40	8.00	4.70	2.72	0.95	0.46	275.	31.8	17.7	16.5	2.96	51.95	
Std. Dev:		1.06	0.67	0.50	0.30	0.22	0.18	0.07	17.	3.4	3.4	3.5	0.84	3.06	
Var Coeff(%):		6.30	5.87	6.26	6.31	7.91	18.53	14.66	6.	10.6	19.0	21.2	28.33	5.89	

Table A7. FWD Backcalculated Modulus Results -- Dade County, US41, Site 1

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

			Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
District:	4 & 6					
County:	Dade					
Highway/Road:	US 41	Pavement:	3.60	100,000	650,000	H1: ð = 0.30
Site:	#1	Limerock Base:	13.00	10,000	150,000	H2: ð = 0.40
Date:	970423	Limerock Subbase:	13.00	10,000	90,000	H3: ð = 0.45
		Limerock Subgrade:	100.00	28,000		H4: ð = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
1.010	9,271	6.92	4.10	2.69	1.59	1.02	0.57	0.28	650.	76.1	85.1	68.6	0.94	70.16	*
1.020	9,031	6.55	4.06	2.81	1.63	1.02	0.53	0.28	650.	89.9	46.0	80.7	2.66	63.04	*
1.030	9,239	8.36	5.47	3.78	2.20	1.30	0.61	0.32	650.	63.7	35.3	67.0	2.89	53.72	*
1.040	9,111	7.08	4.34	3.01	1.87	1.18	0.57	0.32	650.	87.3	37.7	75.7	0.80	65.12	*
1.050	9,199	6.75	4.22	2.93	1.79	1.14	0.53	0.28	650.	92.3	39.8	79.6	1.66	67.77	*
1.060	9,279	6.34	4.06	2.65	1.55	1.06	0.61	0.32	650.	97.0	57.1	75.1	4.06	72.22	*
1.070	9,159	6.18	3.90	2.65	1.59	1.06	0.61	0.28	650.	104.2	51.8	74.5	3.64	89.24	*
1.075	9,031	9.35	5.71	3.54	1.59	1.02	0.57	0.32	550.	42.4	90.0	65.6	4.90	49.64	*
1.080	9,071	6.38	3.86	2.57	1.51	0.94	0.49	0.28	650.	92.6	48.7	89.3	2.33	61.88	*
1.090	9,327	7.00	4.14	2.65	1.47	0.89	0.53	0.28	650.	71.0	90.0	76.9	2.66	55.31	*
1.100	9,231	6.14	3.78	2.49	1.47	0.98	0.61	0.32	650.	92.5	90.0	68.8	3.37	77.38	*
1.110	9,199	6.30	4.14	2.85	1.75	1.22	0.73	0.32	650.	115.2	35.0	72.7	4.98	116.89	*
1.120	9,279	7.12	4.42	3.01	1.91	1.26	0.73	0.36	650.	83.7	62.5	57.2	1.64	82.56	*
1.130	9,223	7.33	4.34	2.97	1.71	1.14	0.69	0.36	650.	70.5	90.0	57.8	1.97	65.37	*
1.140	9,231	6.67	4.30	2.85	1.67	1.10	0.57	0.28	650.	93.0	40.1	82.1	3.45	73.12	*
2.010	9,295	6.34	3.82	2.61	1.59	1.06	0.61	0.32	650.	95.6	73.1	69.0	1.69	89.26	*
2.020	9,191	6.18	3.42	2.25	1.30	0.85	0.49	0.24	540.	96.2	90.0	83.6	1.59	66.77	*
2.030	9,271	6.75	3.86	2.61	1.55	1.06	0.61	0.32	567.	86.9	90.0	65.6	0.92	81.23	*
2.040	9,287	6.84	4.18	2.69	1.55	0.98	0.57	0.28	650.	78.1	74.2	73.3	2.75	65.68	*
2.050	9,367	6.30	3.86	2.45	1.47	0.94	0.53	0.28	650.	90.1	78.2	78.2	2.31	69.10	*
2.060	9,295	5.52	3.26	2.21	1.34	0.94	0.61	0.28	646.	118.7	90.0	74.5	3.47	99.86	*
2.070	9,375	7.37	4.18	2.65	1.47	0.94	0.57	0.32	534.	72.8	90.0	72.8	2.37	55.31	*
2.075	9,079	8.57	4.22	2.73	1.71	1.18	0.69	0.36	209.	85.2	78.9	59.6	0.58	126.28	
2.080	9,167	6.05	3.62	2.41	1.47	0.94	0.57	0.32	650.	95.2	90.0	71.1	2.31	69.10	*
2.090	9,335	6.34	3.94	2.77	1.79	1.26	0.73	0.40	650.	105.7	67.5	57.0	1.07	170.60	*
2.100	9,271	6.42	3.90	2.61	1.63	1.14	0.73	0.40	649.	93.4	90.0	58.3	2.61	153.06	*
2.110	9,287	6.51	4.14	2.85	1.91	1.38	0.94	0.48	650.	99.6	90.0	43.5	2.76	300.00	*
2.120	9,215	7.54	4.58	3.05	1.83	1.18	0.69	0.36	650.	69.2	74.2	58.4	1.55	71.97	*
2.130	9,255	7.04	4.14	2.73	1.59	0.98	0.57	0.28	650.	73.7	82.0	70.0	1.84	59.85	*
2.140	9,263	6.88	3.86	2.41	1.42	0.89	0.57	0.28	486.	84.6	90.0	75.4	3.28	63.46	*
Mean:		6.84	4.13	2.75	1.63	1.07	0.61	0.32	616.	87.2	71.6	70.1	2.43	72.81	
Std. Dev:		0.80	0.49	0.33	0.19	0.13	0.09	0.05	89.	15.6	20.5	9.8	1.13	21.10	
Var Coeff(%):		11.68	11.82	11.88	11.76	12.60	15.23	15.50	14.	17.9	28.6	14.0	46.56	28.98	

Table A8. FWD Backcalculated Modulus Results -- Martin County, US1, Site 3

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

			Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
District:	4 & 6					
County:	Martin					
Highway/Road:	US 1	Pavement:	3.00	100,000	850,000	H1: ð = 0.30
Site:	#3	Limerock Base:	10.00	10,000	150,000	H2: ð = 0.40
Date:	970402	Fine Sand Subbase:	16.00	10,000	90,000	H3: ð = 0.45
		Fine Sand Subgrade:	INFINITY	28,000		H4: ð = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	8,911	9.18	6.39	4.78	3.42	2.72	2.00	1.29	850.	80.2	55.1	33.2	1.40	300.00	*
0.020	8,911	10.54	7.36	5.39	3.66	2.77	1.84	1.05	850.	66.3	34.0	37.4	1.35	300.00	*
0.030	9,047	10.30	6.75	4.66	3.01	2.11	1.39	0.84	850.	53.8	46.6	47.4	1.02	158.01	*
0.040	8,983	9.14	5.83	3.90	2.44	1.83	1.31	0.80	850.	54.4	78.9	49.8	1.30	157.72	*
0.050	9,015	8.20	5.35	3.78	2.48	1.83	1.22	0.68	850.	80.6	55.2	55.1	1.14	300.00	*
0.060	9,055	8.11	5.67	4.14	2.69	1.99	1.35	0.76	850.	88.8	48.9	50.6	2.82	300.00	*
0.070	8,895	7.91	5.31	3.90	2.56	1.83	1.18	0.64	850.	90.5	44.2	57.1	1.62	233.40	*
0.080	8,999	7.91	5.27	3.54	2.32	1.71	1.14	0.72	850.	82.9	53.6	60.6	2.39	300.00	*
0.090	9,007	7.66	5.06	3.46	2.20	1.55	1.06	0.68	850.	80.2	62.1	62.8	2.36	172.96	*
0.100	9,247	8.07	5.39	3.58	2.28	1.63	1.14	0.72	850.	76.4	62.8	61.1	2.71	234.27	*
0.110	9,055	7.87	5.15	3.62	2.32	1.71	1.18	0.72	850.	83.4	59.5	58.2	2.19	279.28	*
0.120	9,103	8.44	5.35	3.50	2.20	1.63	1.14	0.72	850.	62.8	77.5	58.5	1.59	173.01	*
0.130	9,015	9.47	6.47	4.74	3.30	2.56	1.80	1.05	850.	73.1	51.1	37.6	1.04	300.00	*
0.140	8,983	10.42	7.03	5.10	3.66	2.85	1.96	1.13	792.	65.7	48.6	33.6	0.61	300.00	
Mean:		8.80	5.88	4.15	2.75	2.05	1.41	0.84	846.	74.2	55.6	50.2	1.68	292.31	
Std. Dev:		1.03	0.77	0.66	0.55	0.47	0.34	0.20	15.	11.9	12.2	10.7	0.69	171.07	
Var Coeff(%):		11.73	13.02	15.79	19.84	22.84	24.00	23.99	2.	16.0	21.9	21.3	41.09	58.52	

Table A9. FWD Backcalculated Modulus Results -- Martin County, US1, Site 4

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

District: 4 & 6
County: Martin
Highway/Road: US 1
Site: #4
Date: 970402

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
Pavement:	3.00	100,000	600,000	H1: δ = 0.30
Limerock Base:	9.00	10,000	150,000	H2: δ = 0.40
Fine Sand Subbase:	12.00	10,000	90,000	H3: δ = 0.45
Fine Sand Subgrade:	INFINITY	28,000		H4: δ = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	9,015	9.43	6.43	4.66	3.30	2.56	1.96	1.29	600.	82.8	59.5	36.7	2.83	300.00	*
0.020	8,935	10.54	6.99	4.86	3.34	2.56	1.92	1.29	600.	59.6	65.7	35.9	2.22	300.00	*
0.030	8,919	10.13	6.71	5.02	3.58	2.81	2.08	1.37	600.	74.8	59.1	33.1	1.45	300.00	*
0.040	8,879	10.50	7.03	5.23	3.70	2.89	2.08	1.33	600.	73.9	48.7	32.9	1.38	300.00	*
0.050	8,903	10.01	6.55	4.82	3.54	2.89	2.12	1.37	600.	70.8	79.7	31.3	0.50	300.00	*
0.060	8,983	9.51	6.43	4.82	3.54	2.81	2.08	1.45	600.	86.7	63.6	32.9	1.31	300.00	*
0.070	9,095	9.27	6.19	4.50	3.18	2.48	2.04	1.37	600.	81.5	73.1	36.7	3.60	300.00	*
0.080	9,015	9.39	6.23	4.62	3.38	2.72	2.12	1.45	600.	81.1	82.1	32.8	1.82	300.00	*
0.090	8,855	8.81	5.87	4.26	2.97	2.28	1.63	1.05	600.	91.7	52.4	42.5	2.00	300.00	*
0.100	9,031	8.32	5.27	3.70	2.52	1.87	1.31	0.84	600.	89.5	61.1	53.3	1.54	300.00	*
0.110	9,015	8.20	5.19	3.74	2.61	1.95	1.39	0.89	600.	94.3	65.7	50.0	1.29	300.00	*
0.120	9,119	7.08	4.70	3.42	2.40	1.83	1.31	0.84	600.	125.6	69.7	53.7	2.30	300.00	*
0.130	8,967	9.35	6.51	5.02	3.70	2.93	2.29	1.49	600.	85.7	83.1	28.9	2.33	300.00	*
0.140	9,175	9.02	6.27	4.74	3.46	2.77	2.20	1.49	600.	101.8	64.0	33.3	3.07	300.00	*
Mean:		9.25	6.17	4.53	3.23	2.53	1.89	1.25	600.	85.7	66.3	38.1	1.97	300.00	
Std. Dev:		0.95	0.69	0.55	0.44	0.39	0.34	0.24	0.	15.7	10.4	8.4	0.82	86.03	
Var Coeff(%):		10.22	11.13	12.15	13.57	15.53	17.86	19.24	0.	18.3	15.7	21.9	41.67	28.68	

Table A10. FWD Backcalculated Modulus Results -- Seminole County, US414, Site 1

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

			Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
District:	5					
County:	Seminole					
Highway/Road:	US 414	Pavement:	5.30	250,000	500,000	H1: δ = 0.30
Site:	#1	Limerock Base:	12.00	30,000	100,000	H2: δ = 0.40
Date:	970317	Silty Sand Subbase:	12.00	15,000	90,000	H3: δ = 0.45
		Silty Sand Subgrade:	160.00	18,000		H4: δ = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	9,839	8.73	6.47	5.27	3.83	2.85	1.71	1.05	500.	54.8	36.7	36.0	7.08	90.45	*
0.020	9,935	8.81	6.79	5.55	3.99	2.97	1.92	1.05	500.	54.8	76.7	25.4	3.74	129.21	*
0.030	9,479	8.03	5.83	4.70	3.38	2.60	1.76	1.01	500.	100.0	19.1	36.2	2.78	153.99	*
0.040	9,327	7.78	5.79	4.66	3.30	2.44	1.55	0.97	500.	60.8	64.5	31.1	2.72	121.21	*
0.050	9,551	8.28	6.11	4.82	3.46	2.44	1.63	0.93	500.	75.7	35.5	32.7	2.47	74.47	*
0.060	9,543	8.40	6.11	4.78	3.34	2.44	1.47	0.93	500.	69.5	34.3	35.9	1.32	89.42	*
0.070	9,183	8.81	6.31	4.90	3.42	2.40	1.55	0.93	500.	52.7	46.9	32.2	1.78	72.61	*
0.080	9,631	8.15	6.03	4.82	3.42	2.48	1.51	0.89	500.	60.6	58.2	32.8	2.61	93.81	*
0.090	9,511	8.11	5.83	4.66	3.34	2.48	1.59	0.93	500.	67.2	67.9	28.7	2.02	131.26	*
0.100	9,583	8.77	6.99	5.39	3.87	2.89	1.59	1.09	500.	54.4	34.4	33.2	4.32	68.97	*
0.110	9,759	10.46	7.48	5.79	4.03	2.85	1.80	1.05	500.	38.6	61.7	27.8	0.98	79.51	*
0.120	9,591	13.67	8.36	6.15	4.07	2.85	1.84	1.09	250.	30.8	87.7	25.2	1.08	73.24	*
0.130	9,655	10.62	7.28	5.59	3.83	2.68	1.71	1.09	441.	35.8	90.0	27.4	0.86	71.93	*
0.140	9,551	9.02	6.55	5.15	3.62	2.60	1.67	1.01	500.	61.1	37.1	31.8	1.88	91.57	*
0.150	9,863	10.54	7.64	5.95	4.03	2.89	1.76	1.05	500.	40.1	49.2	29.4	1.34	92.57	*
Mean:		9.21	6.64	5.21	3.66	2.66	1.67	1.00	479.	57.1	53.3	31.1	2.47	90.06	
Std. Dev:		1.54	0.77	0.50	0.30	0.21	0.13	0.07	65.	17.5	21.2	3.6	1.62	20.28	
Var Coeff(%):		16.74	11.62	9.62	8.07	7.76	7.78	6.87	14.	30.7	39.8	11.7	65.76	22.52	

Table A11. FWD Backcalculated Modulus Results -- Seminole County, US414, Site 2

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

			Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
District:	5					
County:	Seminole					
Highway/Road:	US 414	Pavement:	5.50	250,000	450,000	H1: δ = 0.30
Site:	#2	Limerock Base:	12.00	30,000	100,000	H2: δ = 0.40
Date:	970317	Silty Sand Subbase:	13.00	15,000	90,000	H3: δ = 0.45
		Fine Sand Subgrade:	140.00	18,000		H4: δ = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	9,423	7.50	5.75	4.82	3.70	2.85	1.84	1.05	450.	100.0	27.8	27.8	2.81	148.68	*
0.020	9,471	7.87	5.95	4.82	3.66	2.77	1.76	1.05	450.	77.2	77.2	22.0	4.16	127.66	*
0.030	9,271	8.90	6.43	5.27	3.83	2.93	1.92	1.05	450.	74.9	32.0	25.3	1.18	132.24	*
0.040	9,071	8.77	6.63	5.47	3.99	3.01	1.92	1.13	450.	58.2	67.3	19.7	3.55	134.14	*
0.050	9,351	8.98	6.75	5.51	4.11	3.09	1.96	1.13	450.	61.8	53.0	21.3	2.63	129.10	*
0.060	8,975	8.57	6.43	5.27	3.83	2.93	1.84	1.09	450.	70.7	22.0	29.7	3.05	119.27	*
0.070	8,639	8.94	6.91	5.63	4.19	3.21	2.08	1.29	450.	56.1	56.1	17.7	2.92	162.67	*
0.080	9,231	9.35	6.83	5.43	3.87	2.85	1.84	1.13	450.	50.3	52.6	24.0	1.09	137.88	*
0.090	9,191	9.35	6.99	5.63	4.03	3.01	1.92	1.09	450.	67.8	22.0	27.4	2.15	132.98	*
0.100	8,639	9.02	6.55	5.35	3.87	2.93	1.84	1.09	450.	62.4	28.7	24.6	0.83	120.25	*
0.110	9,263	10.21	7.52	6.07	4.32	3.21	1.96	1.17	450.	44.6	43.6	22.7	1.08	101.04	*
0.120	9,399	10.25	7.64	6.03	4.23	3.09	1.88	1.21	450.	44.6	38.7	24.6	1.55	97.62	*
0.130	9,311	10.30	7.72	6.07	4.32	3.13	1.92	1.17	450.	42.4	39.3	24.1	1.18	102.35	*
0.140	9,103	10.25	7.44	5.91	4.15	3.09	1.96	1.17	450.	41.0	50.5	22.4	0.90	127.98	*
Mean:		9.16	6.82	5.52	4.01	3.01	1.90	1.13	450.	60.9	43.6	23.8	2.08	124.26	
Std. Dev:		0.87	0.60	0.41	0.22	0.14	0.08	0.07	0.	16.5	16.7	3.2	1.10	17.72	
Var Coeff(%):		9.54	8.82	7.43	5.48	4.53	4.10	6.05	0.	27.1	38.4	13.5	53.05	14.26	

Table A12. FWD Backcalculated Modulus Results -- Osceola County, US441, Site 3

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

District: 5
County: Osceola
Highway/Road: US 441
Site: #3
Date: 970401

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum
Pavement:	3.40	200,000	6,000,000
Coquina Base:	8.00	10,000	250,000
Fine Sand Subbase:	18.00	10,000	100,000
Fine Sand Subgrade:	INFINITY	18,000	

Poisson Ratio Values
H1: ð = 0.30
H2: ð = 0.40
H3: ð = 0.45
H4: ð = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	9,143	6.96	5.55	5.02	4.36	3.82	2.86	1.69	1976.	250.0	60.2	21.5	1.76	300.00	*
0.020	9,039	7.21	5.83	5.15	4.27	3.62	2.49	1.33	2393.	250.0	21.9	30.3	1.07	300.00	*
0.030	8,927	7.41	6.19	5.51	4.64	3.94	2.61	1.53	3009.	250.0	14.6	30.0	1.37	300.00	*
0.040	9,127	6.88	5.43	4.74	3.91	3.33	2.53	1.49	1245.	244.4	56.6	25.9	0.26	300.00	
0.050	9,055	6.47	5.27	4.62	3.95	3.33	2.45	1.61	2626.	250.0	41.5	27.6	0.97	300.00	*
0.060	9,007	10.46	7.15	5.23	3.58	2.77	1.92	1.29	836.	46.0	60.6	33.3	0.57	300.00	
0.070	8,935	8.24	6.55	5.27	4.03	3.29	2.25	1.37	1929.	87.1	45.0	28.9	0.97	300.00	
0.080	9,471	8.77	6.55	5.15	3.75	2.97	2.16	1.41	1775.	46.9	88.6	30.0	0.19	300.00	
0.090	8,927	10.17	7.48	5.55	3.75	2.64	1.71	1.09	1582.	24.4	67.0	36.6	0.59	169.63	
0.100	8,991	9.39	6.87	4.98	3.30	2.44	1.67	1.05	1522.	26.0	99.6	37.0	0.91	300.00	
0.110	9,183	11.16	8.68	6.99	5.37	4.35	3.14	1.89	1568.	45.6	53.6	20.1	0.49	300.00	
0.120	9,135	9.72	7.44	6.19	4.97	4.15	3.06	1.93	1025.	111.4	47.4	21.2	0.32	300.00	
0.130	9,095	9.22	7.84	6.91	5.90	5.12	3.88	2.29	2529.	156.2	37.8	16.3	0.44	300.00	
0.140	9,039	7.95	6.71	6.03	5.29	4.68	3.51	2.01	6000.	250.0	10.0	25.0	3.08	300.00	*
Mean:		8.57	6.68	5.52	4.36	3.60	2.59	1.57	2144.	145.6	50.3	27.4	0.93	300.00	
Std. Dev:		1.49	0.99	0.74	0.77	0.79	0.65	0.36	1273.	99.1	25.4	6.2	0.76	188.42	
Var Coeff(%):		17.38	14.76	13.46	17.61	21.91	25.15	22.83	59.	68.1	50.5	22.5	82.17	62.81	

Table A13. FWD Backcalculated Modulus Results -- Osceola County, US441, Site 4

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 4.2)

			Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
District:	5					
County:	Osceola					
Highway/Road:	US 441	Pavement:	4.70	200,000	3,000,000	H1: δ = 0.30
Site:	#4	Coquina Base:	11.00	30,000	100,000	H2: δ = 0.40
Date:	970401	Fine Sand Subbase:	18.00	20,000	90,000	H3: δ = 0.45
		Fine sand Subgrade:	INFINITY	15,000		H4: δ = 0.45

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock	
0.010	9,431	11.49	9.81	8.72	7.37	6.22	4.41	2.05	1825.	46.7	22.0	15.8	0.93	101.56	
0.020	9,055	12.19	9.89	8.72	7.21	5.98	4.12	2.01	1059.	53.3	20.0	16.3	1.32	113.34	*
0.030	8,903	9.84	7.76	6.75	5.54	4.55	3.23	1.81	783.	92.1	21.3	21.3	0.68	167.74	*
0.040	9,015	7.41	5.67	5.02	4.19	3.54	2.65	1.53	1229.	100.0	51.2	23.8	1.69	172.88	*
0.050	9,135	7.45	5.99	5.39	4.72	4.07	3.10	1.89	2109.	100.0	40.8	21.0	2.43	300.00	*
0.060	9,183	7.17	5.19	4.18	3.18	2.52	1.71	1.05	755.	100.0	41.6	41.6	0.80	300.00	*
0.070	9,159	8.65	6.11	4.78	3.50	2.64	1.67	0.97	608.	65.8	40.7	40.7	0.82	123.00	*
0.080	9,143	7.78	5.91	4.94	4.03	3.38	2.57	1.57	768.	100.0	61.2	24.3	0.43	300.00	*
0.090	8,847	13.71	10.21	8.44	6.51	5.12	3.35	1.89	474.	46.4	20.0	19.9	1.03	189.63	*
0.100	8,815	12.11	9.65	8.20	6.64	5.41	3.67	1.85	801.	53.1	20.0	18.1	0.98	121.34	*
0.110	8,903	14.04	11.66	10.29	8.47	6.91	4.53	2.09	1137.	30.0	20.0	14.1	1.74	105.62	*
0.120	9,079	13.96	11.38	10.17	8.59	7.16	4.82	2.33	1299.	33.1	20.0	13.6	2.25	118.00	*
0.130	9,087	11.32	9.16	8.24	7.12	6.10	4.49	2.33	818.	100.0	20.7	14.4	1.44	132.03	*
0.140	9,175	12.11	9.41	8.20	6.80	5.65	3.88	1.73	659.	73.8	20.0	17.5	1.70	95.44	*
Mean:		10.66	8.41	7.29	5.99	4.95	3.44	1.79	1023.	71.0	30.0	21.6	1.30	142.78	
Std. Dev:		2.56	2.25	2.07	1.80	1.52	1.02	0.41	468.	27.2	14.2	9.0	0.60	48.97	
Var Coeff(%):		24.04	26.69	28.43	29.98	30.75	29.62	22.70	46.	38.3	47.3	41.5	45.95	34.30	

APPENDIX B

DYNAFLECT BACKCALCULATED MODULUS RESULTS

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Table B1. Dynaflect Backcalculated Modulus Results -- Lee County, SR884, Site 1B

```
*   *    *****    ***      *****    *****    *   *    *****          *****
** **    *   *    *  *     *        *   *    ** **    *   *            *
* * *    *   *    *   *    *        *   *    * * *    *   *            *
*   *    *   *    *   *    *        *   *    *   *    *****          *****
*   *    *   *    *   *    *        *   *    *   *    *                *
*   *    *   *    *  *     *        *   *    *   *    *                *
*   *    *****    ***      *****    *****    *   *    *              *****

                    Version 3.6  Release R (Jan. 21, 1995)

                      Processed: Mar. 26, 1999 @ 14:14
                      Data File: E:\THESIS\NEWDYNA2\LEE1B.DAT

*********          Dist. 1, Lee Co., SR 884, Site #1B                *********
```

* * * Load / Deflection Parameters * * *

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.45	.33	.19	.15	.10

* * * Layered System Parameters * * *

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	500000.	.30	2.0	.00	.0	.00	.000
2	U	0	100000.	.35	11.5	.00	.0	.00	.000
3	K	0	60000.	.40	12.0	.00	.0	.00	.000
4	U	0	45300.	.45	Infinite	.00	.0	.00	.000

* * * Tolerances * * *

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

* * * Deflection Assignments * * *

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00

Table B1. Dynaflect Backcalculated Modulus Results -- Lee County, SR884, Site 1B (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 492000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 112000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 60000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 48800.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.45	.45 Measured	-.37	1	-.238
15.62	.32	.33 Measured	-1.77		
26.00	.21	.19 Measured	+12.46		
37.36	.15	.15 Measured	+.47	4	-1.001
49.00	.11	.10 Measured	+13.58		

Root Mean Square Error = 8.28 percent

Elapsed time: 0:00:00 (.2 sec.)

Table B1. Dynaflect Backcalculated Modulus Results -- Lee County, SR884, Site 1B (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 483000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 109000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 60000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 49100.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.45	.45 Measured	+.11	1	-.228
15.62	.32	.33 Measured	-1.83		
26.00	.21	.19 Measured	+11.95		
37.36	.15	.15 Measured	-.12	4	-1.001
49.00	.11	.10 Measured	+12.90		

Root Mean Square Error = 7.91 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 2 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B2. Dynaflect Backcalculated Modulus Results -- Lee County, SR884, Site 2B

```
*   *     *****     ***       *****     *****     *   *     *****              *****
** **     *   *     *  *      *         *   *     ** **     *   *                  *
* * *     *   *     *   *     *         *   *     * * *     *   *                  *
*   *     *   *     *   *     *         *   *     *   *     *****              *****
*   *     *   *     *   *     *         *   *     *   *     *                      *
*   *     *   *     *  *      *         *   *     *   *     *                      *
*   *     *****     ***       *****     *****     *   *     *                  *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Apr. 12, 1999 @ 10:26
Data File: E:\THESIS\NEWDYNA2\LEE2.DAT

********* Dist. 1, Lee Co., SR 884, Site #2B *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.50	.31	.18	.13	.08

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	500000.	.30	2.0	.00	.0	.00	.000
2	U	0	80000.	.35	9.5	.00	.0	.00	.000
3	K	0	60000.	.40	12.0	.00	.0	.00	.000
4	U	0	52300.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 3 at Radius = 26.00
Layer Number 2: User Assigned Deflection Number 3 at Radius = 26.00
Layer Number 4: User Assigned Deflection Number 4 at Radius = 37.36

Table B2. Dynaflect Backcalculated Modulus Results -- Lee County, SR884, Site 2B (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 133000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 25900.	--	E = Constant (linear layer)
3	Known	E (PSI) = 60000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 55400.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.60	.50 Measured	+20.84		
15.62	.31	.31 Measured	-.96		
26.00	.18	.18 Measured	-.68	1	-.020
37.36	.13	.13 Measured	-3.10	4	-1.044
49.00	.10	.08 Measured	+19.63		

Root Mean Square Error = 12.89 percent

Elapsed time: 0:00:00 (.1 sec.)

Computation terminated because deflection at radius 26.00 in. is NOT very sensitive to the modulus oflayer 1.

Note: Insensitivity is usually due to a layer being too thin, too deep, or buried under a stiff layer. One approach is to give the layer an assigned (known) modulus. Or try combining layers, if appropriate, or assigning a different sensor to the layer. Check the sensitivity matrix on the .LST file for the best sensor/layer combination.

Warning: Tolerances have not been satisfied, so the reported moduli do not constitute a satisfactory solution.

Table B3. Dynaflect Backcalculated Modulus Results -- Polk County, US17, Site 1A



Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 14:57
Data File: E:\THESIS\NEWDYNA2\POLK1.DAT

********* Dist. 1, Polk Co. US 17, Site #1A *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.42	.29	.21	.18	.14

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	800000.	.30	4.9	.00	.0	.00	.000
2	U	0	100000.	.35	9.0	.00	.0	.00	.000
3	K	0	75000.	.40	14.0	.00	.0	.00	.000
4	U	0	37000.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 2: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 4: User Assigned Deflection Number 4 at Radius = 37.36

Table B3. Dynaflect Backcalculated Modulus Results -- Polk County, US17, Site 1A (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 614000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 172000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 39600.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.42	.42 Measured	+.21	1	-.052
15.62	.33	.29 Measured	+15.18		
26.00	.24	.21 Measured	+15.19		
37.36	.18	.18 Measured	+1.21	4	-.934
49.00	.14	.14 Measured	+1.74		

Root Mean Square Error = 9.65 percent

Elapsed time: 0:00:00 (.2 sec.)

Table B3. Dynaflect Backcalculated Modulus Results -- Polk County, US17, Site 1A (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 578000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 170000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 40100.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.42	.42 Measured	+.00	1	-.199
15.62	.33	.29 Measured	+14.51		
26.00	.24	.21 Measured	+14.10		
37.36	.18	.18 Measured	-.02	4	-.934
49.00	.14	.14 Measured	+.34		

Root Mean Square Error = 9.05 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 2 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B4. Dynaflect Backcalculated Modulus Results -- Polk County, US17, Site 2A

```
*   *    *****    ***      *****    *****    *   *    *****          *****
** **    *   *    *  *     *        *   *    ** **    *   *              *
* * *    *   *    *   *    *        *   *    * * *    *   *              *
*   *    *   *    *   *    *        *   *    *   *    *****          *****
*   *    *   *    *   *    *        *   *    *   *    *                  *
*   *    *   *    *  *     *        *   *    *   *    *                  *
*   *    *****    ***      *****    *****    *   *    *              *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 15:00
Data File: E:\THESIS\NEWDYNA2\PORK2.DAT

********* Dist. 1, Polk Co., US 17,, Site #2A *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.38	.25	.18	.16	.11

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	850000.	.30	4.9	.00	.0	.00	.000
2	U	0	100000.	.35	9.0	.00	.0	.00	.000
3	K	0	75000.	.40	13.0	.00	.0	.00	.000
4	U	0	42500.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00

Table B4. Dynaflect Backcalculated Modulus Results -- Polk County, US17, Site 2A (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 640000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 206000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 45000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.38	.38 Measured	+.24	1	-.053
15.62	.30	.25 Measured	+21.34		
26.00	.22	.18 Measured	+21.50		
37.36	.16	.16 Measured	+1.74	4	-.953
49.00	.13	.11 Measured	+14.46		

Root Mean Square Error = 15.03 percent

Elapsed time: 0:00:00 (.2 sec.)

Table B4. Dynaflect Backcalculated Modulus Results -- Polk County, US17, Site 2A (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 583000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 203000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 45900.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.38	.38 Measured	+.00	1	-.197
15.62	.30	.25 Measured	+20.42		
26.00	.22	.18 Measured	+19.88		
37.36	.16	.16 Measured	-.03	4	-.953
49.00	.12	.11 Measured	+12.17		

Root Mean Square Error = 13.86 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 2 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B5. Dynaflect Backcalculated Modulus Results -- Alachua County, US301, Site 3

```
*   *     *****     ***       *****     *****     *   *     *****             *****
** **     *   *     *  *      *         *   *     ** **     *   *               *
* * *     *   *     *   *     *         *   *     * * *     *   *               *
*   *     *   *     *   *     *         *   *     *   *     *****             *****
*   *     *   *     *   *     *         *   *     *   *     *                   *
*   *     *   *     *  *      *         *   *     *   *     *                   *
*   *     *****     ***       *****     *****     *   *     *                 *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 25, 1999 @ 12:36
Data File: E:\THESIS\NEWDYNA2\ALCH3.DAT

********* Dist. 2, Alachua Co., US 301, Site #3 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.41	.28	.20	.16	.13

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	600000.	.30	5.4	.00	.0	.00	.000
2	U	0	115000.	.35	9.3	.00	.0	.00	.000
3	K	0	75000.	.40	12.0	.00	.0	.00	.000
4	U	0	45000.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.50
Deflection Basin Fit Tolerance (percent): .300
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00

Table B5. Dynaflect Backcalculated Modulus Results -- Alachua County, US301, Site 3 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 573000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 132000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 45600.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.41	.41 Measured	-.01	1	-.236
15.62	.31	.28 Measured	+12.48		
26.00	.22	.20 Measured	+9.06		
37.36	.16	.16 Measured	-.04	4	-.954
49.00	.12	.13 Measured	-5.23		

Root Mean Square Error = 7.28 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .30 percent after 2 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B6. Dynaflect Backcalculated Modulus Results -- Alachua County, US301, Site 4

```
*   *     *****     ***       *****     *****     *   *     *****              *****
** **     *   *     *  *      *         *   *     ** **     *   *                  *
* * *     *   *     *   *     *         *   *     * * *     *   *                  *
*   *     *   *     *   *     *         *   *     *   *     *****              *****
*   *     *   *     *   *     *         *   *     *   *     *                      *
*   *     *   *     *  *      *         *   *     *   *     *                      *
*   *     *****     ***       *****     *****     *   *     *                  *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 25, 1999 @ 13:02
Data File: E:\THESIS\NEWDYNA2\ALCH4.DAT

********* Dist. 2, Alachua Co., US 301, Site #4 *********

* * * Load / Deflection Parameters * * *

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.39	.26	.18	.13	.11

* * * Layered System Parameters * * *

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	1000000.	.30	4.3	.00	.0	.00	.000
2	U	0	120000.	.35	9.0	.00	.0	.00	.000
3	K	0	75000.	.40	8.0	.00	.0	.00	.000
4	U	0	50000.	.45	Infinite	.00	.0	.00	.000

* * * Tolerances * * *

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

* * * Deflection Assignments * * *

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 2: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 4: User Assigned Deflection Number 4 at Radius = 37.36

Table B6. Dynaflect Backcalculated Modulus Results -- Alachua County, US301, Site 4 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 985000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 124000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 56500.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.39	.39 Measured	+.00	1	-.248
15.62	.29	.26 Measured	+10.07		
26.00	.19	.18 Measured	+2.95		
37.36	.13	.13 Measured	-.03	4	-1.016
49.00	.10	.11 Measured	-11.16		

Root Mean Square Error = 6.85 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 2 iterations.

Modulus convergence rate of ñ1.00 percent was also satisfied.

Warning: Solution is not acceptable because RMS error is too large.

Table B7. Dynaflect Backcalculated Modulus Results -- Clay County, US17, Site 5

```
*   *     *****     ***       *****     *****     *   *     *****              *****
** **     *   *     *  *      *         *   *     ** **     *   *                  *
* * *     *   *     *   *     *         *   *     * * *     *   *                  *
*   *     *   *     *   *     *         *   *     *   *     *****              *****
*   *     *   *     *   *     *         *   *     *   *     *                      *
*   *     *   *     *  *      *         *   *     *   *     *                      *
*   *     *****     ***       *****     *****     *   *     *                  *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 25, 1999 @ 13:09
Data File: E:\THESIS\NEWDYNA2\CLAY5.DAT

********* Dist. 2, Clay Co., US 17, Site #5 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.52	.37	.29	.23	.19

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	600000.	.30	7.4	.00	.0	.00	.000
2	U	0	100000.	.40	7.8	.00	.0	.00	.000
3	K	0	50000.	.40	12.0	.00	.0	.00	.000
4	U	0	27300.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 2: User Assigned Deflection Number 1 at Radius = 10.00

Table B7. Dynaflect Backcalculated Modulus Results -- Clay County, US17, Site 5 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 591000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 110000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 50000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 32000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.52	.52 Measured	-.08	1	-.165
15.62	.43	.37 Measured	+15.37		
26.00	.31	.29 Measured	+6.98		
37.36	.23	.23 Measured	+.11	4	-.920
49.00	.18	.19 Measured	-6.56		

Root Mean Square Error = 8.10 percent

Elapsed time: 0:00:00 (.2 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 1 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B8. Dynaflect Backcalculated Modulus Results -- Clay County, US17, Site 6

```
*   *    *****    ***      *****    *****    *   *    *****          *****
** **    *   *    *  *     *        *   *    ** **    *   *              *
* * *    *   *    *   *    *        *   *    * * *    *   *              *
*   *    *   *    *   *    *        *   *    *   *    *****          *****
*   *    *   *    *   *    *        *   *    *   *    *                  *
*   *    *   *    *  *     *        *   *    *   *    *                  *
*   *    *****    ***      *****    *****    *   *    *              *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 25, 1999 @ 13:29
Data File: E:\THESIS\NEWDYNA2\CLAY6.DAT

********* Dist. 2, Clay Co., US 17, Site #6 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.53	.35	.27	.22	.19

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	500000.	.30	7.8	.00	.0	.00	.000
2	U	0	100000.	.35	6.9	.00	.0	.00	.000
3	K	0	60000.	.40	14.0	.00	.0	.00	.000
4	U	0	27300.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 2: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 4: User Assigned Deflection Number 4 at Radius = 37.36

Table B8. Dynaflect Backcalculated Modulus Results -- Clay County, US17, Site 6 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 586000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 62700.	--	E = Constant (linear layer)
3	Known	E (PSI) = 60000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 32900.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.53	.53 Measured	-.34	1	-.128
15.62	.43	.35 Measured	+22.03		
26.00	.30	.27 Measured	+11.75		
37.36	.22	.22 Measured	+.35	4	-.909
49.00	.17	.19 Measured	-10.42		

Root Mean Square Error = 12.10 percent

Elapsed time: 0:00:00 (.2 sec.)

Table B8. Dynaflect Backcalculated Modulus Results -- Clay County, US17, Site 6 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 564000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 62700.	--	E = Constant (linear layer)
3	Known	E (PSI) = 60000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 33000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.53	.53 Measured	+.00	1	-.128
15.62	.43	.35 Measured	+22.09		
26.00	.30	.27 Measured	+11.48		
37.36	.22	.22 Measured	+.00	4	-.909
49.00	.17	.19 Measured	-10.75		

Root Mean Square Error = 12.13 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 2 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B9. Dynaflect Backcalculated Modulus Results -- Jefferson County, US27, Site 1A

```
*   *     *****     ***       *****     *****     *   *     *****             *****
** **     *   *     *  *      *         *   *     ** **     *   *               *
* * *     *   *     *   *     *         *   *     * * *     *   *               *
*   *     *   *     *   *     *         *   *     *   *     *****             *****
*   *     *   *     *   *     *         *   *     *   *     *                   *
*   *     *   *     *  *      *         *   *     *   *     *                   *
*   *     *****     ***       *****     *****     *   *     *                 *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 10, 1999 @ 09:35
Data File: E:\THESIS\NEWDYNA2\JEFF1.DAT

********* Dist. 3, Jefferson Co. US 27, Site #1A *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.54	.32	.17	.11	.07

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	K	0	300000.	.30	4.0	.00	.0	.00	.000
2	U	0	70000.	.40	9.0	.00	.0	.00	.000
3	U	0	50000.	.45	8.0	.00	.0	.00	.000
4	U	0	20000.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 2: Computer Assigned Deflection Number 1 at Radius = 10.00
Layer Number 3: Computer Assigned Deflection Number 2 at Radius = 15.62

Table B9. Dynaflect Backcalculated Modulus Results -- Jefferson County, US27, Site 1A (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Known	E (PSI) = 300000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 94200.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 6910.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 132000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.56	.54 Measured	+2.99	2	-.360
15.62	.35	.32 Measured	+8.11	3	-.427
26.00	.14	.17 Measured	-17.61	4	-.500
37.36	.05	.11 Measured	-53.70		
49.00	.03	.07 Measured	-63.66		

Root Mean Square Error = 38.27 percent

Elapsed time: 0:00:00 (.3 sec.)

Table B9. Dynaflect Backcalculated Modulus Results -- Jefferson County, US27, Site 1A (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 3

Layer	Type	Model	Coeff. (R)	Comments
1	Known	E (PSI) = 300000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 67800.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 16800.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 81800.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.55	.54 Measured	+1.76	2	-.322
15.62	.33	.32 Measured	+1.88	3	-.319
26.00	.14	.17 Measured	-15.96	4	-.840
37.36	.08	.11 Measured	-31.22		
49.00	.05	.07 Measured	-21.91		

Root Mean Square Error = 18.53 percent

Elapsed time: 0:00:00 (.5 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 3 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B10. Dynaflect Backcalculated Modulus Results--Jefferson County, US27, Site2A

```
*   *     *****     ***       *****     *****     *   *     *****              *****
** **     *   *     *  *      *         *   *     ** **     *   *                  *
* * *     *   *     *   *     *         *   *     * * *     *   *                  *
*   *     *   *     *   *     *         *   *     *   *     *****              *****
*   *     *   *     *   *     *         *   *     *   *     *                      *
*   *     *   *     *  *      *         *   *     *   *     *                      *
*   *     *****     ***       *****     *****     *   *     *                  *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 14:06
Data File: E:\THESIS\NEWDYNA2\JEFF2.DAT

********* Dist. 3, Jefferson Co., US 27, Site #2A *********

* * * Load / Deflection Parameters * * *

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.52	.31	.16	.12	.07

* * * Layered System Parameters * * *

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	500000.	.30	5.0	.00	.0	.00	.000
2	U	0	100000.	.35	7.4	.00	.0	.00	.000
3	U	0	70000.	.40	11.5	.00	.0	.00	.000
4	U	0	52400.	.45	Infinite	.00	.0	.00	.000

* * * Tolerances * * *

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

* * * Deflection Assignments * * *

Layer Number 1: Computer Assigned Deflection Number 1 at Radius = 10.00
Layer Number 2: Computer Assigned Deflection Number 2 at Radius = 15.62
Layer Number 3: Computer Assigned Deflection Number 3 at Radius = 26.00

Table B10. Dynaflect Backcalculated Modulus Results--Jefferson County, US27, Site2A (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 21800000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 1950.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 160000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 60600.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.47	.52 Measured	-9.92	1	-.372
15.62	.43	.31 Measured	+39.88	2	-.153
26.00	.36	.16 Measured	+126.74	3	-.125
37.36	.29	.12 Measured	+139.20	4	-1.027
49.00	.22	.07 Measured	+212.79		

Root Mean Square Error = 128.38 percent

Elapsed time: 0:00:00 (.2 sec.)

*** Warning: MODCOMP3 -- modulus (976.86) < MINMOD computed for layer number 2, MINMOD assigned. ***

*** 9 warnings remaining.

*** Warning: MODCOMP3 -- modulus (.30000E+13) > MAXMOD computed for layer number 4, MAXMOD assigned. ***

*** 8 warnings remaining.

*** Warning: MODCOMP3 -- modulus (.98621+308) > MAXMOD computed for layer number 3, MAXMOD assigned. ***

Table B10. Dynaflect Backcalculated Modulus Results--Jefferson County, US27, Site2A (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 1820000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 6200.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 100000000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 100000000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.52	.52 Measured	+.45	1	-.394
15.62	.35	.31 Measured	+13.44	2	-.392
26.00	.13	.16 Measured	-17.64	3	.000
37.36	.02	.12 Measured	-81.96	4	-.074
49.00	-.01	.07 Measured	-114.27		

Root Mean Square Error = 63.67 percent

Elapsed time: 0:00:00 (.4 sec.)

Computation terminated because deflection at radius 26.00 in. is NOT very sensitive to the modulus oflayer 3.

Note: Insensitivity is usually due to a layer being too thin, too deep, or buried under a stiff layer. One approach is to give the layer an assigned (known) modulus. Or try combining layers, if appropriate, or assigning a different sensor to the layer. Check the sensitivity matrix on the .LST file for the best sensor/layer combination.

Warning: Tolerances have not been satisfied, so the reported moduli do not constitute a satisfactory solution.

Table B11. Dynaflect Backcalculated Modulus Results -- Gadsden County, US27, Site 2B

```
*   *     *****     ***       *****     *****     *   *     *****             *****
** **     *   *     *  *      *         *   *     ** **     *   *               *
* * *     *   *     *   *     *         *   *     * * *     *   *               *
*   *     *   *     *   *     *         *   *     *   *     *****           *****
*   *     *   *     *   *     *         *   *     *   *     *                   *
*   *     *   *     *  *      *         *   *     *   *     *                   *
*   *     *****     ***       *****     *****     *   *     *               *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 10, 1999 @ 09:29
Data File: E:\THESIS\NEWDYNA2\GADS1.DAT

********* Dist. 3, Gadsden Co., US 27, Site 2B *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.47	.27	.14	.10	.06

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	K	0	200000.	.30	4.0	.00	.0	.00	.000
2	U	0	90000.	.40	10.0	.00	.0	.00	.000
3	U	0	65000.	.40	20.0	.00	.0	.00	.000
4	U	0	30000.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 2: Computer Assigned Deflection Number 1 at Radius = 10.00
Layer Number 3: Computer Assigned Deflection Number 2 at Radius = 15.62

Table B11. Dynaflect Backcalculated Modulus Results -- Gadsden County, US27, Site 2B (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Known	E (PSI) = 200000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 72300.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 39000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 93400.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.48	.47 Measured	+1.34	2	-.300
15.62	.29	.27 Measured	+7.76	3	-.479
26.00	.15	.14 Measured	+3.67	4	-.669
37.36	.08	.10 Measured	-19.02		
49.00	.05	.06 Measured	-10.27		

Root Mean Square Error = 10.42 percent

Elapsed time: 0:00:00 (.2 sec.)

Table B11. Dynaflect Backcalculated Modulus Results -- Gadsden County, US27, Site 2B (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 3

Layer	Type	Model	Coeff. (R)	Comments
1	Known	E (PSI) = 200000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 57100.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 52100.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 83400.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.47	.47 Measured	+.00	2	-.347
15.62	.27	.27 Measured	+.04	3	-.484
26.00	.14	.14 Measured	-1.88	4	-.767
37.36	.09	.10 Measured	-14.62		
49.00	.06	.06 Measured	+2.92		

Root Mean Square Error = 6.72 percent

Elapsed time: 0:00:00 (.5 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 3 iterations.

Modulus convergence rate of ñ1.00 percent was also satisfied.

Warning: Solution is not acceptable because RMS error is too large.

Table B12. Dynaflect Backcalculated Modulus Results -- Gadsden County, US27, Site 3B

```
*   *    *****    ***      *****    *****    *   *    *****          *****
**  **   *   *    *  *     *        *   *    ** **    *   *              *
* * *    *   *    *   *    *        *   *    * * *    *   *              *
*   *    *   *    *   *    *        *   *    *   *    *****          *****
*   *    *   *    *   *    *        *   *    *   *    *                  *
*   *    *   *    *  *     *        *   *    *   *    *                  *
*   *    *****    ***      *****    *****    *   *    *              *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 10, 1999 @ 09:32
Data File: E:\THESIS\NEWDYNA2\GADS2.DAT

********* Dist. 3, Gadsden Co.,US 27, Site 3B *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.46	.24	.11	.09	.05

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	K	0	120000.	.30	4.0	.00	.0	.00	.000
2	U	0	90000.	.40	9.0	.00	.0	.00	.000
3	U	0	65000.	.40	23.0	.00	.0	.00	.000
4	U	0	20000.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

Table B12. Dynaflect Backcalculated Modulus Results -- Gadsden County, US27, Site 3B (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Known	E (PSI) = 120000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 55100.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 35500.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 265000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.48	.46 Measured	+3.67	2	-.288
15.62	.25	.24 Measured	+3.11	3	-.741
26.00	.09	.11 Measured	-22.40	4	-.507
37.36	.03	.09 Measured	-69.46		
49.00	.01	.05 Measured	-77.45		

Root Mean Square Error = 47.64 percent

Elapsed time: 0:00:00 (.2 sec.)

Table B12. Dynaflect Backcalculated Modulus Results -- Gadsden County, US27, Site 3B (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 3

Layer	Type	Model	Coeff. (R)	Comments
1	Known	E (PSI) = 120000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 48300.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 50600.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 118000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.46	.46 Measured	+.00	2	-.333
15.62	.24	.24 Measured	-.37	3	-.635
26.00	.11	.11 Measured	-3.34	4	-.699
37.36	.06	.09 Measured	-34.04		
49.00	.04	.05 Measured	-18.25		

Root Mean Square Error = 17.34 percent

Elapsed time: 0:00:00 (.5 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 3 iterations.

Modulus convergence rate of ñ1.00 percent was also satisfied.

Warning: Solution is not acceptable because RMS error is too large.

Table B13. Dynaflect Backcalculated Modulus Results -- Dade County, US41, Site 1



Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 15:23
Data File: E:\THESIS\NEWDYNA2\DADE1.DAT

********* Dist. 4&6, Dade Co., US41, Site #1 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 16.00	3<Radius>3 26.00	4<Radius>4 37.00	5<Radius>5 49.00
1	1000.	31.	3.19	.23	.13	.06	.04	.02

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	300000.	.30	3.6	.00	.0	.00	.000
2	U	0	150000.	.35	13.0	.00	.0	.00	.000
3	K	0	130000.	.40	13.0	.00	.0	.00	.000
4	U	0	100000.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 2 at Radius = 16.00
Layer Number 2: User Assigned Deflection Number 2 at Radius = 16.00
Layer Number 4: User Assigned Deflection Number 2 at Radius = 16.00

Table B13. Dynaflect Backcalculated Modulus Results -- Dade County, US41, Site 1 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 300000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 150000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 130000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 136000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.21	.23 Measured	-8.89		
16.00	.13	.13 Measured	-.10	1	-.621
26.00	.08	.06 Measured	+31.65		
37.00	.05	.04 Measured	+34.94		
49.00	.04	.02 Measured	+99.25		

Root Mean Square Error = 49.30 percent

Elapsed time: 0:00:00 (.1 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 1 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B14. Dynaflect Backcalculated Modulus Results -- Dade County, US41, Site 2

```
*   *    *****    ***      *****    *****    *   *    *****          *****
** **    *   *    *  *     *        *   *    ** **    *   *              *
* * *    *   *    *   *    *        *   *    * * *    *   *              *
*   *    *   *    *   *    *        *   *    *   *    *****          *****
*   *    *   *    *   *    *        *   *    *   *    *                  *
*   *    *   *    *  *     *        *   *    *   *    *                  *
*   *    *****    ***      *****    *****    *   *    *              *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 10, 1999 @ 09:21
Data File: E:\THESIS\NEWDYNA2\DADE2.DAT

********* Dist. 4&6, Dade Co., US41, Site #2 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	32.	3.15	.13	.11	.06	.05	.03

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	K	0	1000000.	.30	3.0	.00	.0	.00	.000
2	U	0	300000.	.35	10.0	.00	.0	.00	.000
3	U	0	150000.	.35	13.0	.00	.0	.00	.000
4	U	0	120000.	.35	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

Table B14. Dynaflect Backcalculated Modulus Results -- Dade County, US41, Site 2 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 5

Layer	Type	Model	Coeff. (R)	Comments
1	Known	E (PSI) = 1000000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 1610000.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 127000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 137000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.13	.13 Measured	+.00	2	-.176
15.62	.11	.11 Measured	-.08	3	-.616
26.00	.08	.06 Measured	+35.28		
37.36	.06	.05 Measured	+18.27		
49.00	.04	.03 Measured	+47.93		

Root Mean Square Error = 27.85 percent

Elapsed time: 0:00:00 (.7 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 5 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B15. Dynaflect Backcalculated Modulus Results -- Martin County, US1, Site 3

```
*   *     *****     ***       *****     *****     *   *     *****              *****
** **     *   *     *  *      *         *   *     ** **     *   *                *
* * *     *   *     *   *     *         *   *     * * *     *   *                *
*   *     *   *     *   *     *         *   *     *   *     *****              *****
*   *     *   *     *   *     *         *   *     *   *     *                    *
*   *     *   *     *  *      *         *   *     *   *     *                    *
*   *     *****     ***       *****     *****     *   *     *                *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 14:36
Data File: E:\THESIS\NEWDYNA2\MARTIN1.DAT

********* Dist. 4&6, Martin Co., US 1, Site #3 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.32	.21	.16	.13	.10

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	650000.	.30	3.0	.00	.0	.00	.000
2	U	0	100000.	.35	10.0	.00	.0	.00	.000
3	K	0	75000.	.40	16.0	.00	.0	.00	.000
4	U	0	51800.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

Table B15. Dynaflect Backcalculated Modulus Results -- Martin County, US1, Site 3 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 661000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 322000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 55400.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.32	.32 Measured	+.35	1	-.247
15.62	.26	.21 Measured	+22.62		
26.00	.18	.16 Measured	+15.19		
37.36	.13	.13 Measured	+3.66	4	-.968
49.00	.10	.10 Measured	+2.76		

Root Mean Square Error = 12.36 percent

Elapsed time: 0:00:00 (.1 sec.)

Table B15. Dynaflect Backcalculated Modulus Results -- Martin County, US1, Site 3 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 3

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 656000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 297000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 57400.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.32	.32 Measured	-.01	1	-.177
15.62	.25	.21 Measured	+20.74		
26.00	.18	.16 Measured	+12.01		
37.36	.13	.13 Measured	+.05	4	-.968
49.00	.10	.10 Measured	-1.17		

Root Mean Square Error = 10.73 percent

Elapsed time: 0:00:00 (.4 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 3 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B16. Dynaflect Backcalculated Modulus Results -- Martin County, US1, Site 4



Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 14:39
Data File: E:\THESIS\NEWDYNA2\MARTIN2.DAT

********* Dist. 4&6, Martin Co., US 1, Site #4 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 16.00	3<Radius>3 26.00	4<Radius>4 37.00	5<Radius>5 49.00
1	1000.	21.	3.91	.40	.30	.23	.20	.16

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	1000000.	.30	3.0	.00	.0	.00	.000
2	U	0	150000.	.35	9.0	.00	.0	.00	.000
3	K	0	75000.	.40	12.0	.00	.0	.00	.000
4	U	0	32400.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

Table B16. Dynaflect Backcalculated Modulus Results -- Martin County, US1, Site 4 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 953000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 431000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 75000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 37300.	--	E = Constant (linear layer)

Table B16. (continued)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.40	.40 Measured	+.12	1	-.147
16.00	.34	.30 Measured	+11.81		
26.00	.26	.23 Measured	+12.57		
37.00	.20	.20 Measured	-.09	4	-.951
49.00	.15	.16 Measured	-3.29		

Root Mean Square Error = 7.85 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 2 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B17. Dynaflect Backcalculated Modulus Results--Seminole County, US414, Site1

```
*   *     *****     ***       *****     *****     *   *     *****             *****
** **     *   *     *  *      *         *   *     ** **     *   *               *
* * *     *   *     *   *     *         *   *     * * *     *   *               *
*   *     *   *     *   *     *         *   *     *   *     *****             *****
*   *     *   *     *   *     *         *   *     *   *     *                   *
*   *     *   *     *  *      *         *   *     *   *     *                   *
*   *     *****     ***       *****     *****     *   *     *                 *****
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Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 15:05
Data File: E:\THESIS\NEWDYNA2\SEMIN1.DAT

********* Dist. 5, Seminole Co. US 414, Site #1 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 16.00	3<Radius>3 26.00	4<Radius>4 37.00	5<Radius>5 49.00
1	1000.	31.	3.19	.58	.40	.25	.19	.12

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	300000.	.30	5.3	.00	.0	.00	.000
2	U	0	75000.	.35	12.0	.00	.0	.00	.000
3	U	0	55000.	.40	12.0	.00	.0	.00	.000
4	U	0	36100.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 2: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 3: User Assigned Deflection Number 2 at Radius = 16.00

Table B17. Dynaflect Backcalculated Modulus Results--Seminole County, US414, Site1 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 305000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 68300.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 45900.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 38500.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.58	.58 Measured	+.48	1	-.323
16.00	.41	.40 Measured	+2.51	3	-.199
26.00	.27	.25 Measured	+7.59		
37.00	.19	.19 Measured	+1.05	4	-.949
49.00	.14	.12 Measured	+20.17		

Root Mean Square Error = 9.72 percent

Elapsed time: 0:00:00 (.2 sec.)

Table B17. Dynaflect Backcalculated Modulus Results--Seminole County, US414, Site1 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 3

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 288000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 63500.	--	E = Constant (linear layer)
3	Unknown	E (PSI) = 54700.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 38400.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.58	.58 Measured	+.00	1	-.340
16.00	.40	.40 Measured	+.50	3	-.199
26.00	.26	.25 Measured	+5.15		
37.00	.19	.19 Measured	-.15	4	-.949
49.00	.14	.12 Measured	+20.09		

Root Mean Square Error = 9.28 percent

Elapsed time: 0:00:00 (.4 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 3 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B18. Dynaflect Backcalculated Modulus Results--Seminole County, US414, Site2

```
*   *    *****    ***      *****    *****    *   *    *****          *****
** **    *   *    *  *     *        *   *    ** **    *   *              *
* * *    *   *    *   *    *        *   *    * * *    *   *              *
*   *    *   *    *   *    *        *   *    *   *    *****          *****
*   *    *   *    *   *    *        *   *    *   *    *                  *
*   *    *   *    *  *     *        *   *    *   *    *                  *
*   *    *****    ***      *****    *****    *   *    *              *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 15:10
Data File: E:\THESIS\NEWDYNA2\SEMIN2.DAT

********* Dist. 5, Seminol Co., US 414, Site #2 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 16.00	3<Radius>3 26.00	4<Radius>4 37.00	5<Radius>5 49.00
1	1000.	31.	3.19	.54	.36	.23	.17	.11

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	300000.	.30	5.5	.00	.0	.00	.000
2	U	0	75000.	.35	12.0	.00	.0	.00	.000
3	K	0	55000.	.40	13.0	.00	.0	.00	.000
4	U	0	40400.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 2 at Radius = 16.00
Layer Number 2: User Assigned Deflection Number 2 at Radius = 16.00
Layer Number 4: User Assigned Deflection Number 4 at Radius = 37.00

Table B18. Dynaflect Backcalculated Modulus Results--Seminole County, US414, Site2 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 1

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 300000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 75600.	--	E = Constant (linear layer)
3	Known	E (PSI) = 55000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 43200.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.51	.54 Measured	-4.96		
16.00	.36	.36 Measured	-.03	1	-.196
26.00	.24	.23 Measured	+2.95		
37.00	.17	.17 Measured	+.04	4	-.946
49.00	.13	.11 Measured	+16.79		

Root Mean Square Error = 7.94 percent

Elapsed time: 0:00:00 (.2 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 1 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B19. Dynaflect Backcalculated Modulus Results--Osceola County, US441, Site 3

```
*   *    *****    ***      *****    *****    *   *    *****          *****
** **    *   *    *  *     *        *   *    ** **    *   *              *
* * *    *   *    *   *    *        *   *    * * *    *   *              *
*   *    *   *    *   *    *        *   *    *   *    *****          *****
*   *    *   *    *   *    *        *   *    *   *    *                  *
*   *    *   *    *  *     *        *   *    *   *    *                  *
*   *    *****    ***      *****    *****    *   *    *              *****
```

Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 14:47
Data File: E:\THESIS\NEWDYNA2\OSLA3.DAT

********* Dist. 5, Osceola Co., US 441, Site #3 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.35	.29	.23	.20	.17

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	1000000.	.30	3.4	.00	.0	.00	.000
2	U	0	150000.	.35	8.0	.00	.0	.00	.000
3	K	0	100000.	.40	18.0	.00	.0	.00	.000
4	U	0	30500.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 1 at Radius = 10.00
Layer Number 2: User Assigned Deflection Number 1 at Radius = 10.00

Table B19. Dynaflect Backcalculated Modulus Results--Osceola County, US441, Site 3 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 1340000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 759000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 100000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 34000.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.35	.35 Measured	+.00	1	-.074
15.62	.31	.29 Measured	+6.07		
26.00	.25	.23 Measured	+7.88		
37.36	.20	.20 Measured	-.02	4	-.890
49.00	.16	.17 Measured	-3.94		

Root Mean Square Error = 4.78 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 2 iterations.

Warning: Solution is not acceptable because RMS error is too large.

Table B20. Dynaflect Backcalculated Modulus Results--Osceola County, US441, Site 4



Version 3.6 Release R (Jan. 21, 1995)

Processed: Mar. 26, 1999 @ 14:51
Data File: E:\THESIS\NEWDYNA2\OSLA4.DAT

********* Dist. 5, Osceola Co., US 441, Site #4 *********

*** Load/Deflection Parameters ***

Load Number	Load (lb)	Pressure (psi)	Load Radius (in)	Input Deflections (mils) 1<Radius>1 10.00	2<Radius>2 15.62	3<Radius>3 26.00	4<Radius>4 37.36	5<Radius>5 49.00
1	1000.	31.	3.19	.37	.29	.22	.18	.14

*** Layered System Parameters ***

Layer Number	Type	Model	Seed Modulus (psi)	Poisson's Ratio	Thickness (inches)	Ko	Density (lb/cu ft)	Non-linear Characteristics K1 (psi)	K2
1	U	0	500000.	.30	4.7	.00	.0	.00	.000
2	U	0	150000.	.35	11.0	.00	.0	.00	.000
3	K	0	100000.	.40	18.0	.00	.0	.00	.000
4	U	0	37000.	.45	Infinite	.00	.0	.00	.000

*** Tolerances ***

Modulus Rate of Convergence (percent): 1.00
Deflection Basin Fit Tolerance (percent): .150
Maximum Number of Iterations to Achieve Tolerance: 20

*** Deflection Assignments ***

Layer Number 1: User Assigned Deflection Number 2 at Radius = 15.62

Table B20. Dynaflect Backcalculated Modulus Results--Osceola County, US441, Site 4 (continued)

*** Summary of Results of MODCOMP 3 Execution ***

Iteration Number: 2

Layer	Type	Model	Coeff. (R)	Comments
1	Unknown	E (PSI) = 482000.	--	E = Constant (linear layer)
2	Unknown	E (PSI) = 257000.	--	E = Constant (linear layer)
3	Known	E (PSI) = 100000.	--	E = Constant (linear layer)
4	Unknown	E (PSI) = 37400.	--	E = Constant (linear layer)

Calculated/Supplied Deflection Agreement for Load Number: 1

Radius	Calculated Deflection	Measured/Interpolated Deflection	Percent Difference	Assigned to Layer	Sensitivity of Deflection to Layer Modulus
10.00	.35	.37 Measured	-5.32		
15.62	.29	.29 Measured	+.03	1	-.092
26.00	.23	.22 Measured	+2.62		
37.36	.18	.18 Measured	-.02	4	-.870
49.00	.15	.14 Measured	+4.83		

Root Mean Square Error = 3.42 percent

Elapsed time: 0:00:00 (.3 sec.)

Computation terminated because deflection match for the assigned sensors was within ñ .15 percent after 2 iterations.

Note: Solution is questionable because RMS error is more than 2 percent.

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