
# Developing Specifications for Using Recycled Asphalt Pavement as Base, Subbase or General Fill Materials, Phase II

# Final Report

**Florida Institute of Technology**
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January 31, 2003

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**Technical Report Documentation Page**

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| FL/DOT/RMC/06650-7754 | | |

| | |
|---|---|
| 4. Title and Subtitle<br>Developing Specifications for Using Recycled Asphalt Pavement as Base, Subbase or General Fill Materials, Phase II | 5. Report Date<br>July 10, 2003 |
| | 6. Performing Organization Code |
| 7. Author's<br>P. J. Cosentino, E. H. Kalajian, C. S. Shieh, W. J. K. Mathurin, F. A. Gomez, E. D. Cleary. A. Treeratrakoon | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>Florida Institute of Technology (321) 674-7555<br>Civil Engineering Department<br>150 West University Blvd.<br>Melbourne, FL 32901-6975 | 10. Work Unit No. (TRAIS) |
| | 11. Contract or Grant No.<br>Contract Number BC 819 |
| 12. Sponsoring Agency Name and Address<br>Florida Department of Transportation<br>605 Suwannee Street<br>Tallahassee, Florida 32399-0450 | 13. Type of Report and Period Covered<br>Final Report<br>November 2000 to April 2003 |
| | 14. Sponsoring Agency Code<br>99700-7601-119 |

15. Supplementary Notes


This Phase II work focused on 1) validating the Phase I developmental specifications for using Recycled Asphalt Pavement (RAP) as a base, sub-base or general fill, 2) evaluating the strength gain of RAP within the first two months after construction, 3) evaluating RAP-Soil mixes in the laboratory and 4) evaluating the environmental performance of RAP in the field.

The Phase I Developmental Specifications were updated to allow RAP as a sub-base below rigid pavements. A second field site was constructed using RAP and a Limerock control section. It included surface water and leachate water collection systems in both the RAP and Limerock. The initial strength gains were evaluated over an 8-week period and the environmental performance was analyzed over 12-months. Construction with RAP was equivalent to or better than construction with Limerock.

RAP's strength-deformation behavior increased throughout the 8-week study period based on Field California Bearing Ratio (CBR) data converted to Limerock Bearing Ratio (LBR), Initial Stiffness Modulus (ISM) values from the Falling Weight Deflectometer (FWD), and stiffness values from both the Clegg Impact Hammer and the Soil Stiffness Gage (SSG). LBR, Clegg and ISM data indicated that RAP experienced a 50 percent strength gain over 8-weeks while the SSG results indicated that the strength gain was 15 percent. The Clegg, FWD and SSG testing also indicated that RAP stiffness was similar to Limerock.

RAP-Soil mixes were evaluated by adding varying percentages of a poorly graded sand with clay, an A-2-6 (SM-SP) soil dredged from the Turkey Creek area in Palm Bay Florida. The 80 percent RAP- 20 percent soil mix produced the most desirable engineering behavior. Preliminary creep testing indicated that both the 100 percent RAP and the 80/20 Rap-Soil mix may pose long term deformation concerns.

The environmental evaluation indicated that RAP poses no environmental concerns when used as a highway material. The concentrations of heavy metals were well below the EPA standards. Samples were taken over a 12-month period and subjected to four different environmental testing procedures. All four yielded the same conclusions, indicating that the testing program was valid.


| 17. Key Words | 18. Distribution Statement |
|---|---|
| Recycled Asphalt Pavement, Base, Subbase, Subgrade | Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161 |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 261 | |

**Form DOT 1700.7** (8-72)

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# Executive Summary

## Developing Specifications for Using Recycled Asphalt Pavement as Base, Subbase, or General Fill Materials, Phase II

by

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Reclaimed Asphalt Pavement (RAP) stockpiles in Florida have grown because more stringent asphalt pavement SUPERPAVE specifications prevent re-using RAP as aggregate in Hot Mix Asphalt (HMA) production. The application of RAP as a Florida Department of Transportation (FDOT) approved base course, sub-base, and subgrade has been hindered due to low reported laboratory LBR tests.

During a Phase I study, a thorough laboratory and field investigation was conducted. The lab studies focused on evaluating the Limerock Bearing Ratio (LBR) performance of RAP and developing a database of the elementary geotechnical strength parameters such as friction, cohesion and elastic modulus.

The field study involved evaluating the strength gains of RAP over 12-months, through a variety of tests.

RAP was classified as a well-graded sand or gravel, with a top size of 1.5 inches. Measured asphalt content, specific gravity and absorption values were 6.73, 2.27 and 2.57 %. The moisture-density behavior did not follow traditional Proctor behavior. The resulting curves did not display a well-defined peak.

The basic geotechnical properties of friction, cohesion and elastic modulus were evaluated for RAP. The engineering properties of RAP proved to be desirable. They provide a sound basis to establish RAP as an accepted structural fill, or as a base or sub-base course in roadway construction.

The field site was constructed of RAP and a control section of cemented coquina. As was shown in the laboratory studies, the field strength of RAP was highly dependent on temperature. It increased and decreased during the cooler spring and warmer summer testing cycles respectively.

Initial LBR values for RAP averaged 16 and increased to 40 within two months. RAP LBR values exceeding 100 were recorded during the cooler months but could not be sustained during the warmer months.

A linear correlation was developed between the Impulse Stiffness Modulus (ISM) determined from the Falling Weight Deflectometer (FWD) and LBR values. FWD testing proved to be very reliable, quick, and accurate.

Based on the results of Phase I, it was concluded that RAP has potential to be used as a sub-base or subgrade, but did not display evidence that it could be used as an FDOT-approved base course.

The Phase II work focused on 1) validating the Phase I developmental specifications for using RAP as a base, sub-base or general fill, 2) evaluating the strength gain of RAP with in the first two months after construction, 3) evaluating RAP-Soil mixes in the laboratory and 4) evaluating the environmental performance of RAP in the field.

The Phase I Specifications were updated to allow RAP as a sub-base below rigid pavements. A second field site was constructed with RAP and a Limerock control section plus surface water and leachate water collection systems in both the RAP and Limerock. The initial strength gains were evaluated over an 8-week period and the environmental performance was analyzed over 12-months. Construction with RAP was equivalent or better to the construction with Limerock.

The strength-deformation behavior of RAP increased throughout the 8-week study period based on Field CBR data converted to LBR, ISM values from the FWD, and stiffness values from both the Clegg Impact Hammer and the Soil Stiffness Gage (SSG). LBR, Clegg and ISM data indicated that RAP experienced a 50 percent strength gain over 8-weeks while the SSG results indicated that the strength gain was 15 percent. The Clegg, FWD and SSG testing also indicated that RAP had stiffness similar to Limerock.

RAP-Soil mixes were evaluated by adding varying percentages of poorly graded sand with clay classified as an A-2-6 (SM-SP) soil. This soil was processed from dredged from the Turkey Creek area in Palm Bay Florida. The 80 percent RAP- 20 percent soil mix produced the most desirable engineering behavior. Preliminary creep testing indicated that both the 100 percent RAP and the 80/20 Rap-Soil mix may pose long term deformation concerns.

The environmental evaluation indicated that RAP poses no environmental concerns when used as a highway material. All concentrations reported of the heavy metals were well below the EPA standards. Samples were taken over a 12-month period and subjected to four different environmental testing procedures. All four yielded the same conclusions, indicating that the testing program was valid.

# Acknowledgements

This work was completed under FDOT contract number BC – 819. The authors would like to acknowledge the following people for their invaluable guidance and help in the completion of this study.

Dr. David Horhota of the Florida Department of Transportation, thank you for your support throughout the entire project.

Ron Lewis, Rick Venick, Tim Blanton, Todd Britton, and David Benefield (FDOT, State Materials Office) – Thank you for your sharing your expertise and guidance in the testing of the field site.

Pam Jones, Vice President of APAC Florida Inc., MacAsphalt Division – Thank you for providing equipment, labor, material and your expertise in constructing the field site. Without your help, this study would have been considerably more difficult.

The following Florida Tech students, specifically Wilbur Mathurin, Francis Gomez, Elizabeth Cleary, Ailada Treerattrakoon, Chaiyo Juisiri, Paul Eggers, and Eric Whikehart.

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# 1. Introduction

This report summarizes the findings of a second phase research project conducted for the Florida Department of Transportation. The first phase report entitled "Developing Specifications for Using Recycled Asphalt Pavement as Base Sub-base or General Fill Materials" was completed in March 2001 under Contract Number BB-892 (Cosentino and Kalajian, 2001).

## 1.1 Definition and Availability

Reclaimed asphalt pavement (RAP) is defined as pavement materials, containing asphalt and aggregates, which have been removed and/or reprocessed. In the United States asphalt pavement is the material that is most often recycled (Davis, 2000). There are an estimated 90 million tons of RAP milled yearly with 80% to 90% being reused in roadway repaving, translating into 18 million tons of RAP being available for other uses (Cosentino and Kalajian, 2001). With this volume available, there has been growing interest in using RAP for roadway construction and other fill applications.

## 1.2 RAP Usage in Florida

Florida, once led the nation in volume of recycled mix used in hot mix asphalt (HMA) production. There has been a steady decline in the amount of RAP being included in the HMA mixes. This decline can be attributed to the implementation of the SUPERPAVE (Superior Performing Asphalt Pavement) design mix adopted by Florida in 1998. In 1999, approximately 587 Mg (647,000 tons) of RAP were used in the production of approximately 2348 Mg (2,589,000 tons) of recycled mix, resulting in a 25% inclusion rate. This is a 2% decrease from the 27% inclusion rate of 1998. The use of RAP saved the state of Florida $13 million in materials costs in 1999 (FDOT, Asphalt Pavement Recycling Summary, 1994).

## 1.3 Engineering Characteristics

Previous research has shown that RAP has potential highway material uses. Doig (2000) reported RAPs' angle of internal friction ($\phi$) ranged from 37 to 40 degrees, slightly less than the $\phi$-values for limerock and cemented coquina of 44 and 41 degrees reported by Bosso (1995). Rodriquez (2001) reported that RAP was installed on high moisture content subsurface soils without construction difficulties or need for dewatering. Equipment operators likened installing RAP under these high moisture conditions to constructing with cemented coquina under favorable conditions (Rodriquez, 2001).

The main drawback preventing the use of RAP as a base course, has been the relatively low Limerock Bearing Ratio (LBR) values reported from laboratory testing (Rodriquez, 2001). Highway materials are typically categorized using stiffness and/or strength criteria. LBR-values are considered to be strength parameters, however, stiffness values obtained from falling weight deflectometer (FWD) tests indicate that RAP may be as stiff as cemented coquina (Rodriquez, 2001). This initial study showed that RAP gained stiffness throughout a 24-month period, with a significant gain in the first two months. Rodriquez (2001) also showed a possible linear relationship between the stiffness parameter obtained from FWD testing and the LBR-values determined from field CBR tests.

## 1.4 Environmental Characteristics

Townsend and Brantley (1998) investigated the leaching characteristics of RAP in a thorough laboratory investigation. The results lead to the conclusion that RAP poses minimal risk to groundwater as a result of pollutant leaching under normal land disposal or beneficial reuse. The pollutants investigated were volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and selected heavy metals (Ba, Ca, Cr, Cu, Pb, Ni, and Zn).

To further validate RAP from environmental standpoint, field testing should be conducted.

## 1.5 Existing Specifications

The specifications that currently govern the selection and use of fill material used in Florida roadway construction were developed for use with conventional aggregates such as limerock, sand-clay, shell and rock material. These materials have to meet the specifications outlined in sections 911, 912, 913, and 913A respectively of the *Florida Department of Transportation Standard Specifications for Road and Bridge Construction, (2000).* The specifications include requirements for liquid and plastic limits, gradation and size, and Limerock Bearing Ratio.

Recycled RAP returned to the roadway can typically be incorporated into asphalt paving by means of hot or cold recycling, but it can also be used as an aggregate in base or subbase construction. According to the latest FDOT Road and

Bridge Specification in Section 283, RAP can be used as a base course only on paved shoulders, bike paths and other non-traffic applications (FDOT, 2000). An FDOT memorandum dated November 13, 2000 states that RAP is not permitted below the high water table elevation, in the top 6-inches of slopes and shoulders that will have grass or other type of vegetative establishment and as MSE backfill (Malerk and Xanders, 2000). Base course materials used in Florida are typically required to achieve a minimum LBR of 100, and subbase materials must have an LBR of at least 40 (Florida Department of Transportation, 2000).

## 1.6 Objective

The study objectives were to; 1) validate the Phase I Developmental Specifications for using RAP material as a base, sub-base or general fill, 2) evaluate the strength-deformation characteristics of RAP-Soil mixes and to 3) evaluate its environmental performance.

## 1.7 Approach

To meet these objectives both laboratory and field-testing programs were developed and completed over a 24-month period. The lab testing focused on determining the engineering properties of RAP-Soil mixes and the field testing focused on evaluating three items; the strength gains of RAP during the first 8-weeks after placement, the relationship between stiffness and strength of RAP and the environmental impacts of RAP.

To conduct the field-testing an outdoor test site composed of RAP and limerock was constructed and monitored at the APAC-Florida, Central Florida

Division – Melbourne Branch asphalt plant in Melbourne, Florida. Strength-deformation characteristics were measured during the eight weeks immediately following construction through the use of the following field tests: Field California Bearing Ratio (CBR), Falling Weight Deflectometer (FWD), Clegg Impact (CIT), and Soil Stiffness Gauge (SSG). Limerock was chosen as a control material, because along with cemented coquina, it is one of the most commonly used materials used in Florida roadway construction. Field CBR, FWD, CIT, and SSG tests were performed the first, second, fourth, sixth, and eighth week following construction. For each test, the results for RAP were compared to the results of the limerock. The effects of humidity, air, and ground temperature on the initial strength gains were also studied.

Environmental analysis samples were obtained from the surface water and leachate water collection systems, constructed in both the RAP and Limerock at the field site. Sampling was performed after significant rainfall events over a 12-month period. Laboratory studies, including Toxicity Characteristics Leaching Procedure (TCLP) tests (US EPA, 1992), Synthetic Precipitation Leaching Procedure (SPLP) tests (US EPA, 1994) and column leaching tests were conducted to produce a comparison between the surface water and leachate of the RAP and Limerock that would verify RAP's acceptance from an environmental standpoint.

# 2. Background & Theory

A complete literature review was conducted during phase I of this work. It included a summary table that indicated that RAP had compacted densities ranging from 109 to 130 pcf (17.1 to 20.4 kN/$m^3$), at moisture contents ranging from 4 to 7 percent. Rap classifies as a coarse grained material with a Unified Soils Classification System (USCS) symbol of GW or American Association of State Highway and Transportation Officials (AASHTO) symbol of A-1-a. The LBR values ranged from 11 to 239, however, the majority of values were less than 50 (Cosentino and Kalajian, 2001). RAP also displayed significant strength gains over the 12-month study. Depending upon the test method used, strength gains from 80 to 550 percent were determined. A large portion of these gains might have occurred during the 8-weeks immediately after construction. However, there was no testing during this time frame since the initial testing program called for testing at 2-month intervals for 12-months after construction.

Rap was also classified according to the process used after milling was completed. Two "post-milling-processes" were described, the hammermill and tubgrinder processes. The hammermill impact crusher is a type of horizontal impact crusher that is composed of a solid rotor and solid breaking bars. The RAP initially undergoes a high speed impact causing particles to rebound between the chamber and with other particles. The RAP is subjected to a second impact as the solid breaking bars and the striker plate collide. This second impact effectively crushes the RAP. When the impact speed is increased and/or when the distance between the striker plate and solid breaking bars is decreased, the hammermill process produces smaller particles. The hammermill crusher has a pivoting breaking bar on a rotor that produces a swinging-hammer type movement (Cosentino and Kalajian, 2001). In the tubgrinder process, a wall pushes the RAP towards a rotating drum containing milling spokes. This process compresses the RAP between two solid plates. The tubgrinder produces mostly coarse sand size material when grinding aggregate material. Upon completion of this study it was concluded that the post-milling processes evaluated had little effect on the engineering behavior of RAP. However, the post-milling portion of this study was not comprehensive since for example, the grinder settings were not varied from sample to sample to evaluate the effects on the grain size of the RAP.

## 2.1 Previous Lab Testing

Figure 2.1 depicts three typical Modified Proctor moisture-density curves for RAP obtained from various stockpiles at the APAC Florida Macasphalt plant located in Melbourne Florida. The results did not exhibit a classical moisture-density peak; rather the curves remained relatively flat indicating that RAP is insensitive to moisture content. Several other compaction techniques were evaluated including vibratory, a Modified Marshall compaction and Static compaction. Neither the Modified Marshall nor Static compaction techniques resulted in a more pronounced peak in the moisture-density curves. Figure 2.2 depicts the results from the vibratory compaction using relative density equipment. As is the case with sandy soils, RAP exhibited its highest densities at moisture contents near zero and at the largest moisture values. It was concluded that vibratory compaction at high moisture contents would result in the highest densities (Cosentino and Kalajian, 2001).

RAP compaction in the field site, constructed during Phase I, was accomplished using vibratory equipment after the site was thoroughly wetted with a water truck. The maximum dry density was achieved with this approach.

Vibratory compaction was also attempted at moisture contents near 5%, the optimum from Figure 2.1, and the results showed that the required density could not be achieved. This further substantiated the lab-testing conclusion (Cosentino and Kalajian, 2001).

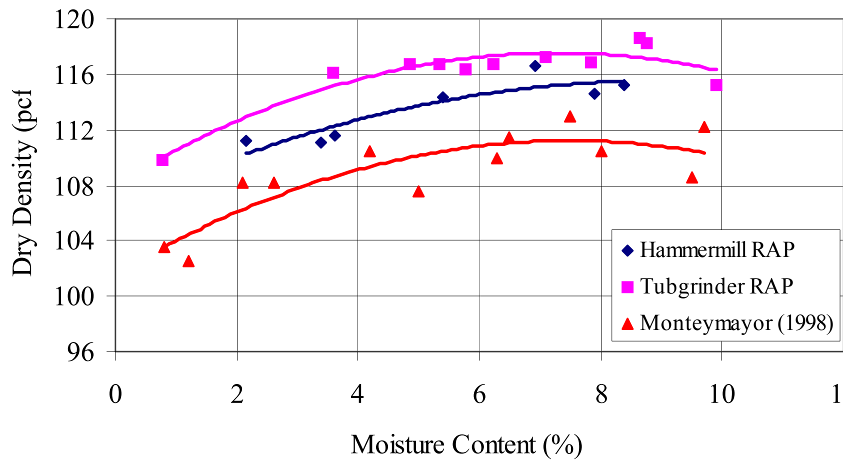


Figure 2.1 Typical Modified Proctor Moisture Density Relationships for Post Milled Process RAP (Cosentino and Kalajian, 2001)

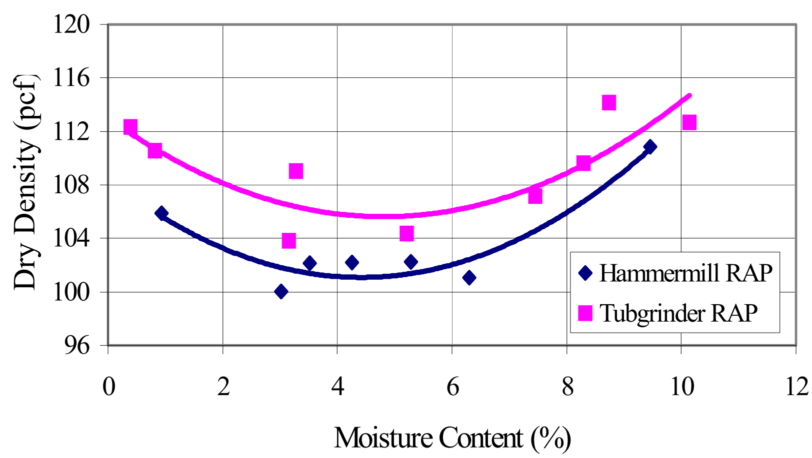


Figure 2.2 Dry density versus moisture content for RAP subjected to vibratory compaction (Cosentino and Kalajian, 2001)

The methods used to compact the RAP samples yielded a range of compacted dry densities between 100 and 125 pcf. As the dry density increases an increase in the bearing strength occurs, shown in Figure 2.3. To yield the required LBR strength of 100 for base courses, a density greater than 118 pcf had to be reached. These densities were only reached using the static method with a compaction pressure of 1000 psi.

Three distinct zones are shown in Figure 2.3. RAP samples with a compacted dry density below 109 pcf had LBR values below 30. RAP compacted to a dry density between 109 and 118 pcf had an LBR's from 10 to 75. The samples compacted statically typically had the larger LBR values. All samples with compacted dry density above 118 pcf had LBR values greater than 40, and as high as 149. Again, the higher LBR values occurred due to static compaction rather than the dynamic, vibratory or Proctor compaction methods. This trend seemed to indicate that a change in structure or binding with asphalt, increasing the bearing strength of the RAP.

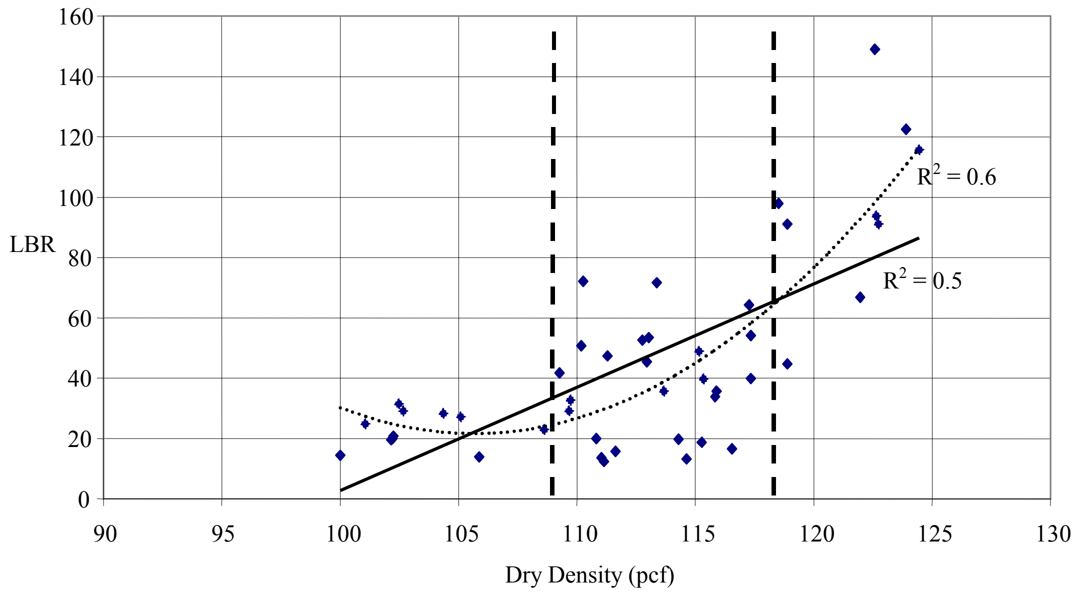


Figure 2.3 LBR versus dry density for RAP showing two possible regression lines through data (1 pcf=0.157 kN/m$^3$) (Cosentino and Kalajian, 2001)

The effects of compaction method were compared to the bearing strength as measured by the LBR test for the RAP. Figure 2.4 displays the range of bearing strengths, as measured by the LBR value.

The bearing strength of RAP, compacted using Proctor, vibratory, modified Marshall and 212 psi static was less than 45. The modified Marshall compaction method yielded the highest LBR values for a dynamic compaction method. This is attributed to the confinement provided by the plate during compaction. RAP samples displayed an increase in strength, as measured by the LBR value, when compacted statically. The minimum LBR value for soil used as a base in the state of Florida is 100. This was only reached by compacting RAP statically at an applied pressure of 1000 psi. An apparent change in the structure of the RAP occurred as the samples were statically compacted at greater pressures.

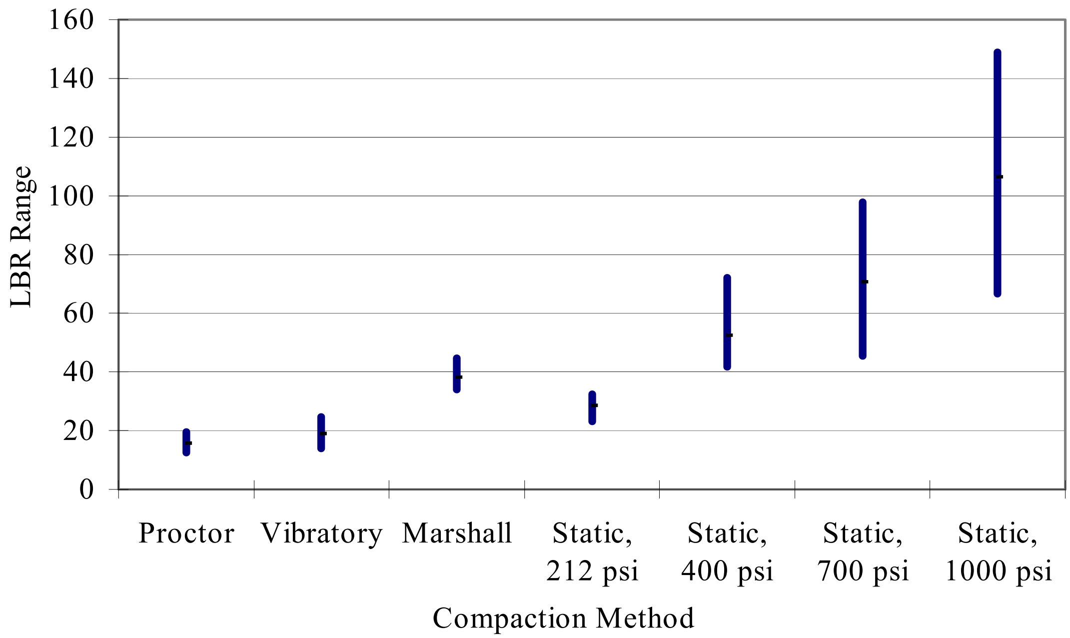


Figure 2.4 LBR versus compaction method for RAP (Cosentino and Kalajian, 2001)

## 2.2 Previous In-Situ Tests

In-situ tests on highways can be classified as destructive or non-destructive. Destructive tests can be defined as any test that alters the engineering characteristics of the material after it has been tested, therefore affecting ensuing tests. Non-destructive tests do not alter the engineering characteristics of the material (Rodriquez, 2001).

Rodriguez (2001) showed correlations from the results of dynamic testing with the Falling Weight Deflectometer (FWD) and the Automated Dynamic Cone Penetrometer (ADCPT) and LBR values determined from field CBR tests. Figure 2.5 shows the relationships developed from the ADCPT and LBR values. Webster et al (1992) developed a formula to predict bearing values based on the dynamic cone penetrometer index (DCPI) in blows/mm and it was included in this plot. Based on the DCPI values in the top 6-inches and Webster formula which is

$$LBR=365/(DCPI)^{1.12} \qquad (2.1)$$

it was concluded that the DCPI is related to the LBR.

Figure 2.6 shows the relationship between the Impulse Stiffness Modulus (ISM) determined from the FWD load-deflection data and the LBR. ISM values are determined by dividing the peak impulse force (kips) by the deflection of the first geophone (mils). Although the regression coefficient is somewhat low, the data still shows an increasing linear relationship between ISM and LBR.

The destructive tests performed during this investigation include the Limerock Bearing Ratio and the Nuclear Density Gauge. Non-destructive tests include the Falling Weight Deflectometer, Clegg Impact Hammer, and Soil Stiffness Gauge. The Clegg Impact Hammer and Soil Stiffness Gauge tests are relatively new. They are currently being evaluated by FDOT for uses in measuring in place soil stiffness and as a possible replacement of in-situ density testing. A brief description of each test is given in subsequent sections.

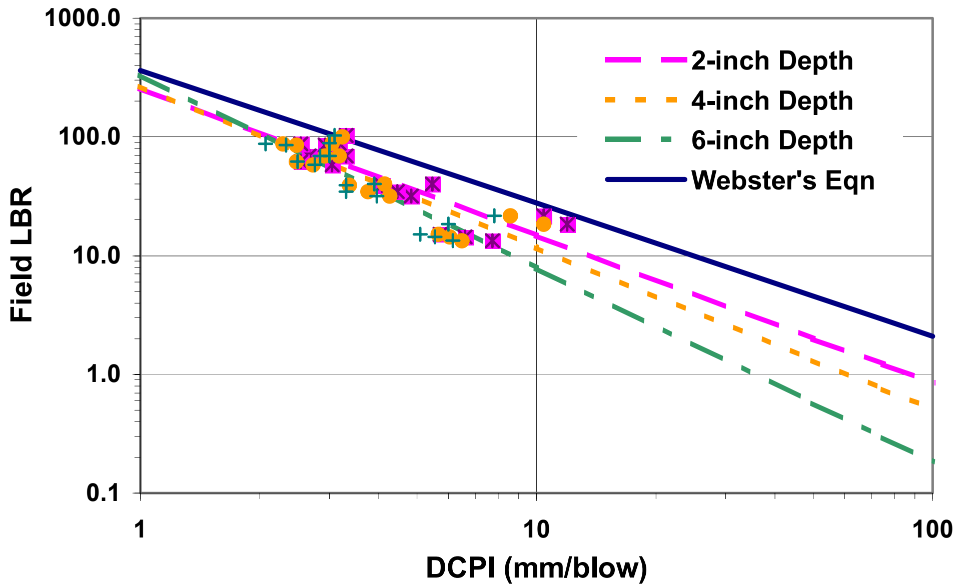


Figure 2.5 LBR values from field CBR tests versus DCPI determined at various depths (Cosentino and Kalajian, 2001)

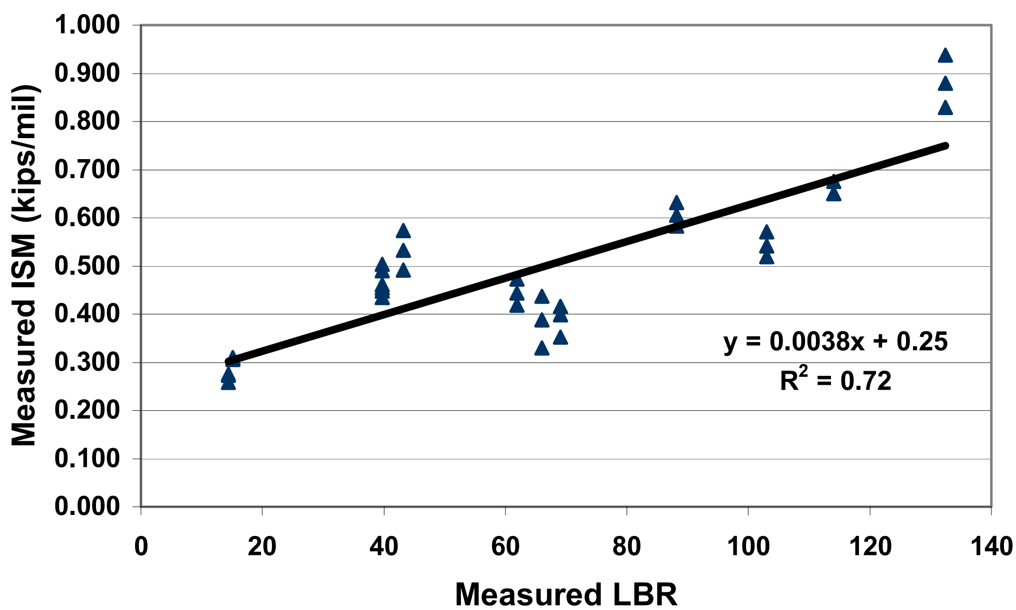


Figure 2.6 LBR vales from field CBR tests versus ISM from FWD tests (Cosentino and Kalajian, 2001)

### 2.2.1 Stiffness and Strength

Strength and stiffness are two terms that are often used interchangeably, however, they are two separate concepts. Strength is defined as a measure of the maximum load per unit area, and can be in relation to tension, compression, shear, flexure, torsion, or impact. Stiffness is a relative measure of the deformability of a material under load (Somayaji, 2001). The field tests conducted during this investigation were classified as either strength or stiffness tests. The FWD, CIT, and SSG measure the stiffness of the material, whereas, the Limerock Bearing Ratio is a measure of shear strength (Head, 1981). Although the LBR is considered a strength parameter, it can also be considered as a stiffness parameter. It measures the load of a desired material, in pounds per inch, as compared to the load of an acceptable limerock at a deflection of 0.1 inch; therefore, it is a measure of relative stiffness. In other words material A with an LBR of 60 is not as stiff as a material B with an LBR of 100 since it takes more force to cause material B to deflect 0.1 inches than it does to deflect material A that same distance.

### 2.2.2 Falling Weight Deflectometer

The Falling Weight Deflectometer is one of the most common types of non-destructive testing equipment used for pavement evaluation and management. Use of the FWD has grown rapidly because of its ability to simulate traffic loading. The FWD produces a dynamic impulse load that simulates a moving wheel load, rather than a static, semi-static or vibratory load (Dynatest, 2000).

The loading range can be varied between 1,500 and 27,000 lbf (7 and 120 kN). A mass is dropped from a known height producing a dynamic load and a deflection basin. The loads, measured using a load cell, are transferred to the roadway through an 11.8-inch (30 centimeter) diameter rubber plate. The deflections are measured by a series of up to seven geophones. The first geophone is located directly underneath the loading plate while the remaining geophones can be positioned up to 8 feet (2.45 m) from the loading plate (Dynatest, 2000). A picture of the FWD is shown in Figure 2.7.

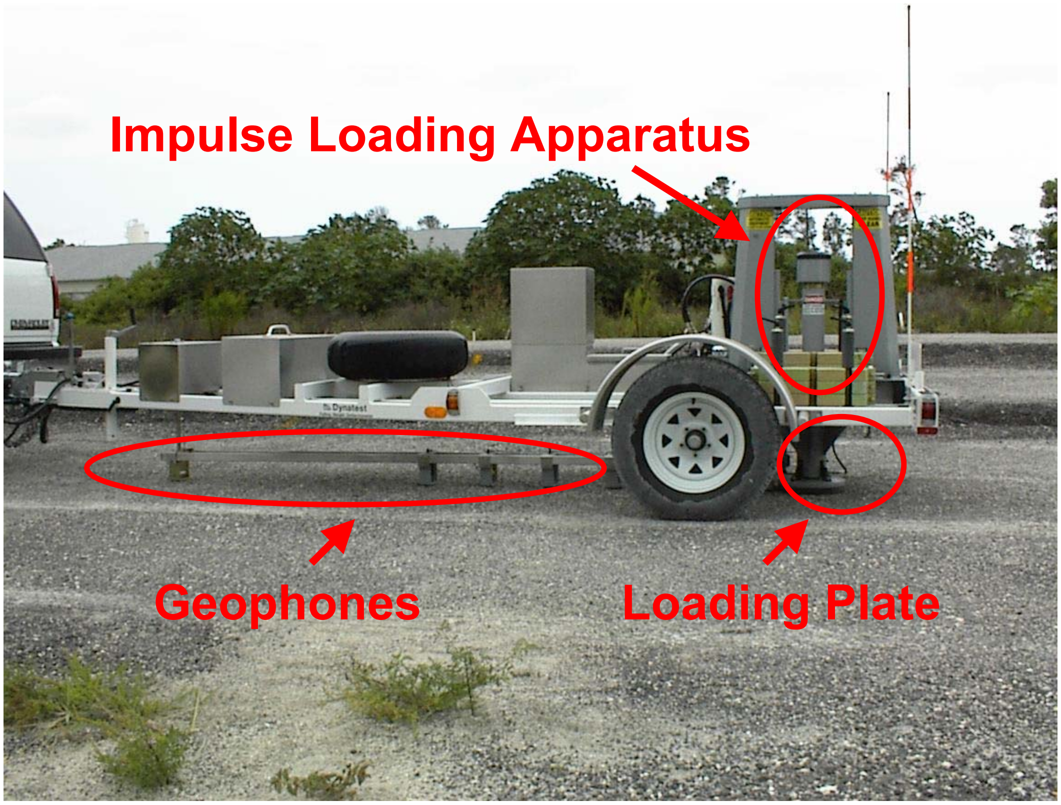


Figure 2.7 Falling Weight Deflectometer

FWD data, combined with layer thickness, is typically used for back calculating the elastic moduli of individual layers of the pavement structure. The complexities of these calculations make software packages such as MODULUS 5.1 developed by Michelak and Scullion (1995) necessary. MODULUS 5.1, developed at the Texas Transportation Insitute, generates a database of deflection basins for a range of layer moduli. It then searches the database to obtain a match between measured and calculated deflections (Newcomb and Birgisson, 1999). Backcalculation techniques require accurate knowledge of the pavement profile in order to produce reliable results. Calculations done using MODULUS 5.1 showed that very slight changes to layer thickness caused extreme changes in moduli values; the tolerance for layer thickness required by this program was not met at this field site. For this reason typical back calculations of elastic moduli are not performed. A simpler, more straightforward method of analyzing FWD data is to look at the Impulse Stiffness Modulus (ISM).

The Impulse Stiffness Modulus (ISM) measures the overall pavement stiffness. The center plate deflection represents the total deflection of the pavement and thus is indicative of the total stiffness of the pavement section including the subgrade (Newcomb and Birgisson, 1999). The formula for the ISM (Bush and Thompson, 1990) is:

$$ISM = \frac{Load(kips)}{CenterPlateDeflection(mils)} \qquad (2.2)$$

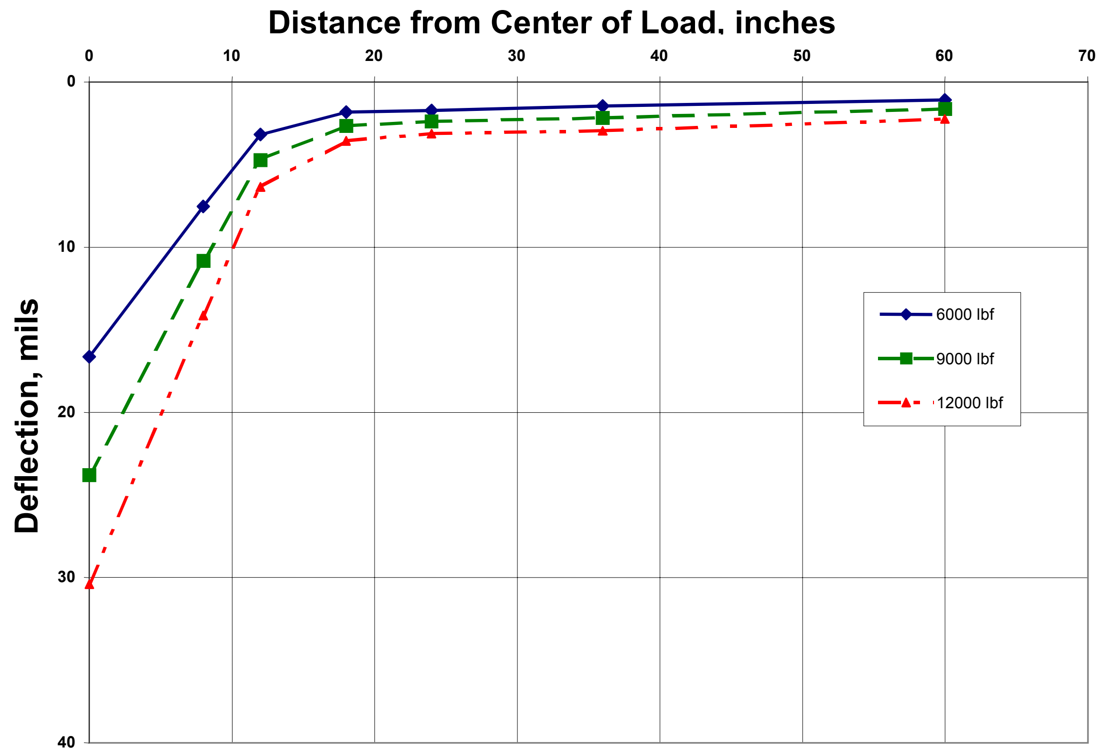


Figure 2.8 Typical FWD Deflection Basin on RAP

A typical deflection basin produced by the FWD on RAP for each load is shown in Figure 2.8. The largest deflection occurs under the first geophone, with the remainder of the deflections decreasing as the radial distance from the load increases. No noticeable changes in deflection occurred beyond a radial distance of twenty inches.

The FWD has been used in several other investigations for evaluating the strength characteristics of RAP. Garg and Thompson (1996) conducted a study to evaluate the potential of RAP as a base material. The project consisted of the construction of a road section with RAP as the base material. The control material in this study was a road section using CA-6 (1.5 inch top size) crushed stone as the base. FWD tests (9 kip load) were conducted. Pavement surface deflections were recorded at 0, 12, 24 and 36 inches offsets from the center of the load plate. The center peak deflection ($D_o$) was used to compare the CA-6 and RAP bases. Among the conclusions drawn by Garg and Thompson (1996) were that FWD results indicate that RAP can be successfully used as a conventional flexible pavement base material based on the FWD deflection data. Center plate deflections for RAP and CA-6 ranged from 14 to 20 and 13 to 18, respectively. FWD data indicates that the RAP base provided adequate structural support and subgrade protection. The authors also noted that the performance of RAP base pavement is comparable to that of the crushed base stone (Garg and Thompson, 1996).

Sayed et al. (1996) performed a study to assess the applicability of UNtreated Recycled Asphalt Pavement (UNRAP) as a base for pavement sections. Limerock was used for a control material in this study. FWD tests were conducted immediately after construction and four months later. UNRAP produced lower deflections during both testing cycles. This suggests the limerock base is less stiff compared to the UNRAP base. Sayed et al. (1993) concluded that the Falling Weight Deflectometer tests suggest that "UNRAP is at least equivalent to limerock".

### 2.2.3 Clegg Impact Test

During the 1970s Dr.Baden Clegg developed the Clegg Impact Soil Tester, commonly known as the Clegg Hammer. Although not commonly used in the United States, it is routinely used in other countries for quality control of density and strength requirements of base, subbase, and subgrade layers (Janoo, 1998). The basic principle of this test is that the peak deceleration of a compaction hammer when it is brought to rest is directly related to the resistance offered at contact resulting from the stiffness and shearing resistance of the material (Clegg, 1980). A schematic of the Clegg Hammer is shown in Figure 2.9. It consists of a hammer to which a piezoelectric accelerometer is attached, a guide tube and an electronic display. The hammer is a Modified Proctor compaction hammer weighing 10 lbs (4.5 kg), and the drop height is 18 inches (45 cm). The diameter of the hammer is 1.97 inches (5 cm) which is the same as that of the California Bearing Ratio (CBR) plunger (Main Roads, 2000).

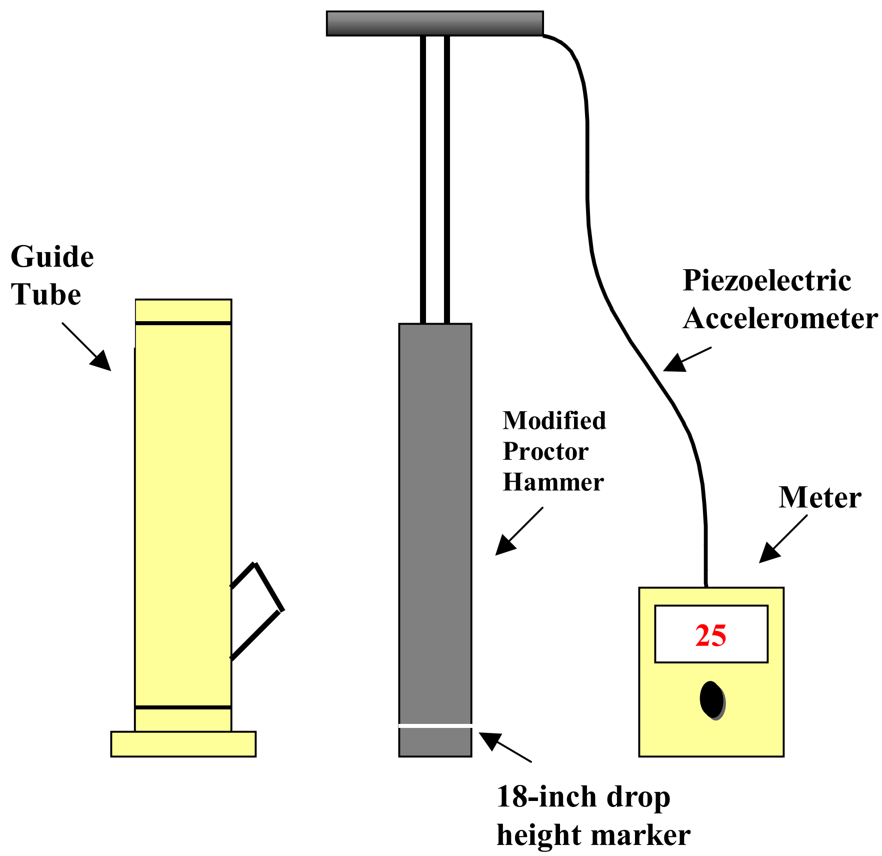


Figure 2.9 Schematic of the Clegg Impact Hammer

The Clegg Impact Test is performed by raising the hammer in the guide tube until a white 18-inch drop height line etched on the hammer is even with the top of the tube. The hammer is released and an accelerometer measures the peak deceleration when the hammer impacts the soil surface. The hammer is dropped four times at each test location and the fourth blow reading is taken as a Clegg Impact Value (CIV) (Clegg, 1980). The first one or two blows flatten and compact and too many blows would pulverize and loosen the immediate surface or may continue to density the material. Thus the recommended practice is to use the fourth blow reading (Clegg, 1980). CIV is defined as the measurement of the peak deceleration in units of tens of gravities of a 10-lb steel mass freefalling 18-inches (Crandell, 2001). The CIV is influenced primarily by the material in the upper 6 inches (15 cm) directly under the hammer (Main Roads, 2000).

The Clegg Impact Test shows promise both in theory and in practice as a possible alternative to the CBR. CBR has become one of the most widely used and recognized soil strength parameters. Some of the similarities between the two tests are that approximately the same area and volume of soil are tested; applicability to both laboratory and fieldwork, and both produce force-penetration parameters. One of the major differences is that the CBR is a static test while the Clegg Impact Test is a dynamic test. Some other differences include the portability of the tests, time, costs and degree of skill required to perform the test. The Clegg offer advantages in all of these aspects (Clegg, 1980). The correlation between the CIV and the CBR is given by the following equation (Clegg, 1980):

$$CBR = (0.24(CIV) + 1)^2 \qquad R^2 = 0.92 \qquad (2.3)$$

The manner in which this linear relationship was derived should be noted. The correlation is based on data compiled from 200 tests performed in both the lab and the field, throughout several different countries on a wide range of soils and pavement materials.

### 2.2.4 Soil Stiffness Gauge

The SSG was developed as part of a joint investigation sponsored by the Federal Highway Administration (FHWA) and the United States Department of Defense. Currently the SSG is the subject of a twenty-two state pool funded investigation. The SSG is being considered as an alternative to the nuclear density gauge in controlling the compaction of soils during roadway construction (TR News, 2001). The SSG measures the in-place stiffness of compacted soil at a rate of about one test per minute (Fielder et al, 1998). A schematic of the SSG is shown in Figure 2.10.

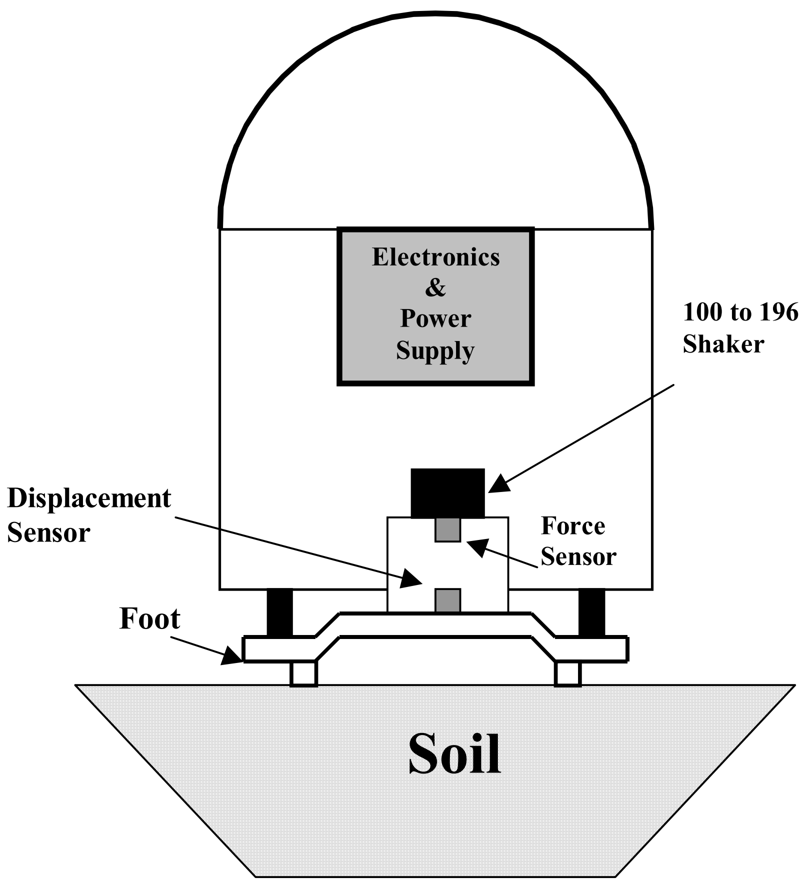


Figure 2.10 Schematic of the Soil Stiffness Gauge (Model H-4140)

The SSG weigh about 25 lbs (11.4 kg), is 11 inches (28 cm) in diameter, and stands about 10 inches (25.4 cm) tall. It rests on the soil surface through a ring shaped foot. The foot bears directly on the soil and supports the weight of the SSG using several rubber isolators. Also attached to the foot is the shaker that drives the foot and sensors that record the force and displacement measurements (Fielder et al, 1998).

The principle of operation of the SSG is to generate a force (P) and to measure the corresponding displacement (δ). The SSG measures the force imparted to the surface and the resulting surface velocity as a function of time. Stiffness, which is force over deflection, is directly related to the impedance. The SSG imparts very small displacements to the soil less than 5 x $10^{-5}$ inches (1.27 x $10^{-6}$ m) at 25 steady state frequencies between 100 and 196 Hertz (Hz). These displacements are measured by a geophone within the body of the gauge. The stiffness is determined at each frequency and the average is displayed (Fielder et al, 1998). The frequency generated by highway traffic is approximately 30 Hz, and the operating-equipment frequency is well below 30 Hz therefore, the SSG measurement will not affected by noise generated by these events (Chen et al, 2001). This stiffness can be related to shear or Young's modulus if a Poisson's ratio is assumed using the following equations (Fielder et al, 1998).

$$E = \frac{K(1-\upsilon)^2}{1.77R} \qquad (2.4)$$

$$G = \frac{K(1-\upsilon)}{3.54R} \qquad (2.5)$$

Where K is the SSG stiffness, ν is Poisson's ratio and R is the foot radius.

The SSG test is performed by seating the device on the soil and gently rotating it back and forth to obtain the 60% required minimum contact area between the SSG foot and the soil. Once this is completed, the measure key (denoted as "Meas") is depressed and the SSG measures site noise and stiffness as a function of frequency. The gauge will display average stiffness, lb/in (Mn/m) or modulus, psi (MPa). The SSG can store 500 measurements while working in operational mode. It has a stiffness measurement range from 17,000 lb/in to 126,000 lb/in (3 to 22.1 MN/m) and a Young's Modulus measurement range of 3,800 to 28,000 psi (26.2 to 193 MPa). The depth of influence is between four and six inches from the surface (Fielder et al, 1998). The SSG simulates soil stress levels (4 psi or 28 kPa) common for pavement, bedding, and foundation applications (Fielder et al, 1998).

### 2.2.5 Limerock Bearing Ratio

Limerock Bearing Ratio tests have long been used for flexible pavement design in Florida. The LBR test is a modified CBR test, which has become one of the most widely, used and recognized soil strength parameters. 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 plunging a 3 $in^2$ circular piston at a specified rate and measuring the load required to force the piston into a soil specimen 0.1 inch, divided by the load in psi required to force the same piston 0.1inch into a crushed limerock sample. The standard penetration load for crushed limerock in Florida is 800 psi. This ratio is multiplied by 100 and the percent sign is omitted thus given the LBR value (Ping and Yu, 1994). Field LBR testing was performed according to ASTM D 4429-93 (*Standard Test Method for CBR (California Bearing Ratio) of Soils in Place)*. The CBR values were converted to LBR values by multiplying them by 1.25. The 1.25-multiplier results when the standard CBR load at 1000 psi is divided by the standard LBR load at 800 psi for the Florida Department of Transportation test method (Florida Method of Test for Limerock Bearing Ratio FM-5-515).

Rodriquez (2001) conducted a field study to analyze the construction and performance of RAP in the field. RAP used in the study classified as a well-graded sand (SW) according to the Unified Soil Classification System (USCS). Among the conclusions Rodriquez (2001) formulated was that, according to field LBR theory RAP is not a feasible material for use as a base because it does not sustain the FDOT minimum requirements for base material (LBR = 100). However, RAP did sustain a minimum LBR of 40 for approximately 80% of the tests and therefore has potential to be utilized as a subbase and/or subgrade.

The Florida Department of Transportation conducted a study to evaluate the use of UNRAP (untreated RAP) as a base course material in the construction of road shoulders. Limerock was used as a control material. The UNRAP classified as a GW (well-graded gravel) based on the USCS. Laboratory LBR's were conducted on both soaked and unsoaked samples. The LBR values ranged from 25 to 30 for the soaked and 29 to 38 for the unsoaked (Sayed, et al., 1993). Field LBR's were also conducted during the study. The average field LBR attained for the UNRAP was 29, with values ranging from 15 to 54. The average field LBR on the limerock was 77 (Sayed, et al., 1993).

## 2.3 Relative Humidity

Relative humidity is the most common way of describing atmospheric moisture. The relative humidity (RH) is an indicator of how close the air is to being saturated. RH is the ratio of the amount of water vapor actually in the air to the maximum amount of water vapor required for saturation at that particular temperature (Ahrens, 2001). This relationship is shown below in equation format.

$$RH = \frac{water\ vapor\ content}{water\ vapor\ capacity} \times 100 \qquad (2.6)$$

Relative humidity is usually expressed as a percent. For example air with a 50% RH contains one-half the amount required for saturation. Air with 100% RH is said to be saturated, and air with relative humidity greater than 100% is said to be supersaturated. Relative humidity can be changed by changing the air's water vapor content or by changing the air temperature (Ahrens, 2001). RH is inversely related to air temperature. With constant water vapor content, increasing air temperature lowers the relative humidity, while decreasing air temperature will increase the relative humidity. Therefore relative humidity will be the highest during the morning hours and decrease as the air temperature warms up during the day (Ahrens, 2001).

## 2.4 Previous Environmental Lab Testing

Townsend and Brantley (1998) investigated the leaching characteristics of RAP by conducting both batch-scale and leaching columns tests. The primary leachable pollutants investigated were volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and selected heavy metals (Ba, Ca, Cr, Cu, Pb, Ni, and Zn).

The batch-scale tests were EPA TCLP and SPLP that were performed to determine if the RAP tested was a hazardous waste. Both TCLP and SPLP results showed that none of the compounds analyzed in the study were detected in the leachate, indicating that the RAP tested was not a hazardous waste.

In the column leaching tests, approximately 60 lbs of RAP material were used to fill a three-foot column. Duplicate columns were subjected to saturated and unsaturated conditions. Leachate samples collected from tested columns continued for a total of 42 days and were analyzed for the same parameters as the batch-scale tests. Concentrations of selected heavy metals, except lead (Pb), in column leachate were below detection limits. Lead was detected at the level slightly above the groundwater guidance concentration, i.e., 15 ppb, but decreased over time. The study found that one unsaturated column and three saturated columns exceeded the 15-ppb groundwater guidance concentrations for lead. However, all but one column dropped to below 1 ppb by the end of the study. Townsend and Brantley (1998) reported lead was observed in the greatest concentrations in the oldest RAP samples and suggested that the lead was not a result of the leaching of the aggregate or asphalt cement, but rather a result of vehicle traffic and emissions.

The study concluded that, overall RAP poses minimal risk to groundwater as a result of pollutant leaching under normal land disposal or beneficial reuse. Conditions of possible concern would be RAP used in saturated environments where little dilution occurred.

# 3. Methodology

## 3.1 Material Sampling for Field Site Construction

RAP samples were obtained from the hammermill post-milling processed stockpile at the APAC-Florida, Inc. asphalt plant located in Melbourne, Florida. Several hundred pounds of this material were taken, in accordance with ASTM D75 “Standard Practice for Sampling Aggregates”, to insure that a thorough laboratory-testing program could be completed to aid in the construction of the field site. The hammermill grinder separates the larger RAP material with a screen before it is fed into a swing-hammer impact crusher. The swing-hammer impact crusher reduces material to sizes of ½ an inch or smaller. The processing of RAP is most commonly performed throughout the United States with the hammermill grinder. Limerock from the Mazak Mine (FDOT mine# 18-522) located in Webster, Florida was also sampled following ASTM D75 standards.

### 3.1.1 Grain Size Distribution

Sieve analyses were performed following ASTM C136-93, *Standard Test Method for Sieve Analysis of Fine and Course Aggregates*. RAP and limerock samples were dried at room temperature before performing the sieve analyses. The sieve sizes used during the sieve analysis were 1.5 inch, 0.75 inch, 0.375 inch, #4, #8, #16, #30, #60, #100, and #200.

Three samples of approximately 1500 grams each were tested to produce an average gradation curve for each material. From the gradation curves the $D_{10}$, $D_{30}$, and $D_{60}$, gradation parameters were determined. These parameters represent the grain diameter (in millimeters) at 10, 30, and 60 percent passing by weight (Holtz and Kovacs, 1981). The coefficient of curvature ($C_c$) and uniformity ($C_u$) were also calculated. Classification of the materials was made using the United Soil Classification System (USCS) and the American Association for State Highway Transportation Officials (AASHTO).

### 3.1.2 Asphalt Content

Asphalt content tests were performed on RAP samples using test method FM 5-563 (*Quantitative Determination of Asphalt Content from Asphalt paving Mixtures by the Ignition Method*) of the 2000 Florida Sampling and Testing Methods Manual. Four samples of approximately 1550 grams were tested, to determine an average asphalt content value. The FDOT, District 5 Materials and Research Division, located in Deland, Florida conducted the tests.

## 3.2 Field Site Development and Layout

A field site has been chosen for construction at the APAC-Florida, Central Florida Division – Melbourne Branch asphalt plant. The site was approximately 60 feet by 120 feet. It was divided into two major sections, one was constructed of RAP and the other was constructed from limerock. Each section included a 5 foot by 5 foot collection system for the collection of the runoff and leachate to be studied as part of FDOT research contract "*Developing Specifications for Using*

*Recycled Asphalt Pavement as Base, Subbase, or General Fill Materials: Phase II*". A drawing of the field site layout is presented in Figure 3.1.

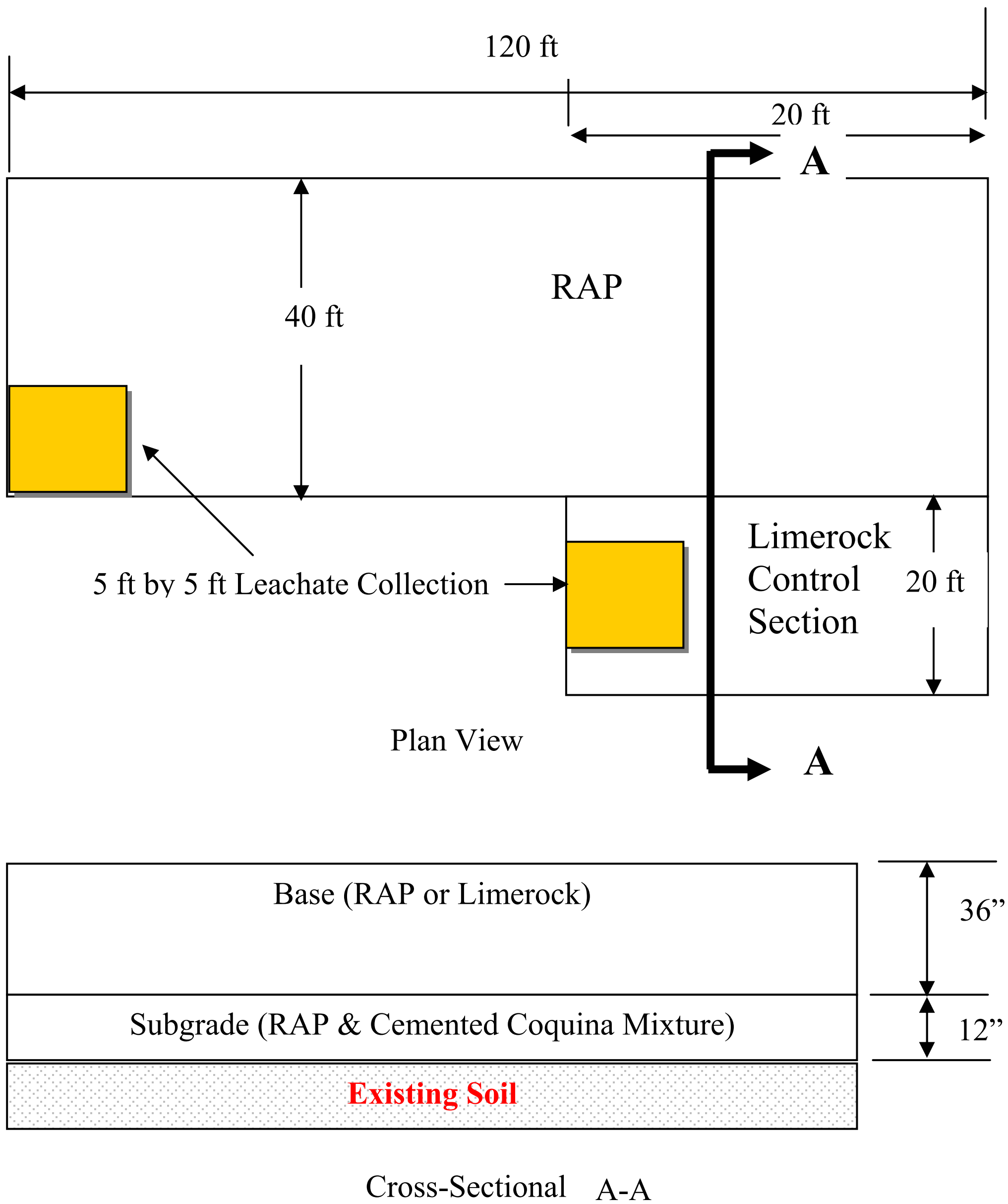


Figure 3.1 Field Site Layout (Not to Scale)

## 3.3 Field Site Construction

Construction of the field test site began on Monday, April 16, 2001 and required approximately six days to complete. No rain occurred during construction and temperatures averaged 78°F. The material used at the Phase I field site of this project was removed to a depth of 12-inches below the surface. The materials removed consisted of RAP and cemented coquina. They were remixed with a tiller and compacted with ten passes from a smooth drum vibratory roller, to form a subgrade for the new site. Figure 3.2 shows the mixing of the materials to create the uniform subgrade.

Figure 3.2 Mixing of RAP and Cemented Coquina from Phase I to form uniform subgrade for Phase II

After the subgrade was constructed the first lifts of RAP and limerock control were placed. In order to achieve a compacted lift thickness of 6-inches, material was placed in 8-inch loose lifts. Each lift of RAP and limerock was compacted using a smooth drum vibratory compactor at ten passes as shown in Figure 3.3.


Figure 3.3 Vibratory Compaction of 1st Lift

Nuclear density readings and Calcium Carbide Gas Pressure Moisture tests, also known as speedy moisture tests, were performed after each lift installation. The corresponding densities and moisture contents recorded during construction are given in Appendix A. Six-inch lifts were placed until a total thickness of 36 inches was achieved. The constructed field site is shown in Figure 3.4.


Figure 3.4 Completed Highway Materials Test Field Site

## 3.4 Testing Cycles

Table 3.1 shows the type of tests and the number of tests per cycle that were conducted at the field site. The tests were performed during the first, second, fourth, sixth, and eighth week following construction. The testing program started on April 25, 2001 and concluded on June 14, 2001.

Table 3.1 Test Index

| Test Name | Tests Per Cycle RAP | Tests Per Cycle Limerock | Avg. Test Time (minutes) |
|---|---|---|---|
| **Falling Weight Deflectometer** | 21 | 4 | < 5 |
| **Clegg Impact Test** | 24 | 9 | < 5 |
| **Soil Stiffness Gauge** | 24 | 9 | < 5 |
| **Limerock Bearing Ratio** | 8 | 3 | < 30 |
| **Nuclear Densometer** | 8 | 3 | < 5 |
| **Calcium Carbide Gas Pressure Moisture Test** | 5 | 3 | < 5 |
| **Temperature and Humidity** | Continuous | N/A | N/A |

A testing grid was developed to maximize the number of tests performed per cycle space. One of the major criteria for determining the test grid layout was to establish a layout that accounts for the influence zone produced by the destructive tests. It was assumed that destructive tests influence five feet of surrounding soil in any direction; therefore adequate spacing was required to minimally skew subsequent tests. Figure 3.5 shows a schematic of the testing grid layout. The grid layout is divided into two main sections, one for RAP and one for limerock. The numbers 1.01 through 4.04 represent FWD test locations. FWD tests were conducted in four rows. The rows are numbered 1 through 4, with each row being subdivided into locations labeled .01, .02, .03 etc. The numbers 1 through 11 represent Limerock Bearing Ratio (LBR), Clegg Impact Test, Soil Stiffness Gauge (SSG), and Nuclear Densometer test locations.

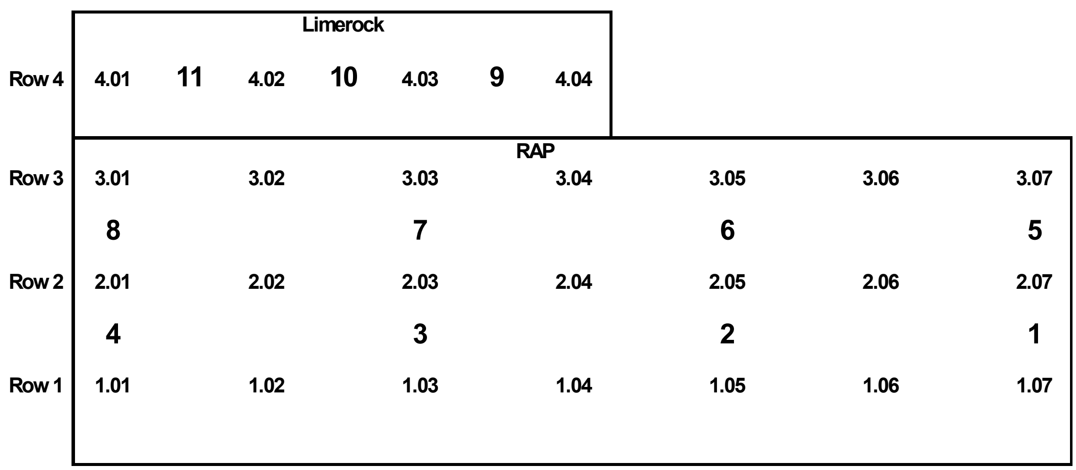


Figure 3.5 Testing Grid Layout

## 3.5 Testing Procedures

### 3.5.1 Falling Weight Deflectometer

No specifications were found for conducting the FWD test. Twenty-five tests were performed per test cycle, twenty-one on RAP and four on limerock. Each test took approximately two minutes to complete. For each test location three load levels were targeted, 6000, 9000, and 12000 lbf. Deflections from seven geophones spaced at 0, 8, 12, 18, 24, 36, and 60 inches from the load plate were recorded. Temperature data was also recorded. All data was obtained in both hardcopy and 3.5-inch floppy disk format.

### 3.5.2 Clegg Impact Test

Tests were performed according to ASTM D 5874 (*Determination of the Impact Value (IV) of a Soil*). Thirty-three tests were performed per testing cycle, twenty-four on the RAP and nine on the limerock. Similarly to the FWD, the Clegg test took about one minute to complete. At each test location three Clegg tests were performed, the tests were centered around the location of the Nuclear Densometer tests. The Clegg hammer was dropped four times on the same location, with the highest value of the four used for data analysis (Clegg, 1980).

### 3.5.3 Soil Stiffness Gauge

Standard specifications governing how to perform this test have not yet been developed since this device is relatively new. Thirty-three tests were performed per testing cycle, twenty-four on the RAP and nine on the limerock. At each test location three SSG tests were performed, the tests were centered around the location of the Nuclear Densometer tests. Each test was completed in about two minutes. The average of all three tests were taken to establish a stiffness value for each location.

### 3.5.4 Limerock Bearing Ratio

LBR values were calculated by performing field CBR tests according to ASTM D 4429-93 (*Standard Test Method for CBR (California Bearing Ratio) of Soils in Place)*. Eleven tests were performed per testing cycle, eight on the RAP and three on the limerock. Field CBR tests required approximately 25 minutes to complete. At each test location one field CBR was performed, the tests were averaged to generate one field CBR value for RAP and one field CBR value for limerock per testing cycle. These values were then converted to field LBR values using the following equation (Florida Method of Test for Limerock Bearing Ratio FM-5-515), as described in Section 2.2.5:

$$LBR = 1.25CBR \qquad (3.1)$$

### 3.5.5 Calcium Carbide Gas Pressure Moisture Tester

Calcium Carbide Gas Pressure Moisture tests were performed according to FM 5-507 (*Determination of Moisture Content by Means of a Calcium Carbide Gas Pressure Moisture Tester*) of the 1994 Florida Sampling and Testing Methods Manual. These tests were performed at the site by FDOT personnel to determine in-situ moisture contents.

Three tests were performed on each material per testing cycle. The tests were averaged to obtain a moisture content for each material. The average test time for Calcium Carbide Gas Pressure Moisture tests was about five minutes.

### 3.5.6 Nuclear Densometer

Wet Density testing was performed according to FM 1-T 238 (*Density of Soils and Bituminous Concrete Mixtures In Place By the Nuclear Method*) of the 1994 Florida Sampling and Testing Methods Manual. FDOT personnel performed the tests and each test required about two minutes to perform.

Eleven tests were performed per testing cycle, eight on the RAP and three on the limerock. At each test location two nuclear density tests were performed, one at six inches and one at twelve inches. The wet density for each location was recorded. Moisture contents taken from the Calcium Carbide Gas Pressure Moisture Tester were used to calculate dry densities. The nuclear densometer equipment records moisture contents for materials approved by the state, such as cemented coquina and limerock. RAP is not an approved material; therefore moisture contents were obtained using a Calcium Carbide Gas Pressure Moisture Tester. The tests were averaged giving an average dry density for RAP and one for limerock per testing cycle.

### 3.5.7 Temperature and Humidity Loggers

Data loggers were used to monitor air and ground temperature as well as humidity over the course of this investigation. Air temperature and humidity were monitored using HOBO® H8 Pro RH/Temperature Loggers. A photograph of the HOBO logger can be viewed in Figure 3.6.


Figure 3.6 HOBO® H8 Pro RH/Temperature Loggers

The logger was fastened to a stake using Velcro strips and placed on top of a soil stockpile adjacent to the field site.  A plastic disc was stapled to the stake to serve as a rain shield, protecting the logger from direct rainfall.   The logger was set to take readings every hour for the duration of the investigation.  BoxCar 3.6 for Windows® was used to upload data from the loggers periodically.

Vemco® mini-log temperature probes were used to collect ground temperatures within the RAP.  The Minilogs are data loggers that record temperature at a user programmed time interval.  The minilog temperature probe is shown in Figure 3.7.


Figure 3.7 Vemco® Minilog Temperature Probe

Five probes were placed within a ¾ inch PVC pipe and spaced at 0, 6, 12, 18, and 30 inches below the surface. PVC tubing was chosen instead of metal tubing because metal tubing absorbs larger amounts of heat that adversely affect the temperatures. Spacing between the probes was controlled using half inch caulking rod. The caulking rod also served as an insulation device, controlling the heat transfer between each test zone. A schematic showing the testing layout is shown in Figure 3.8.

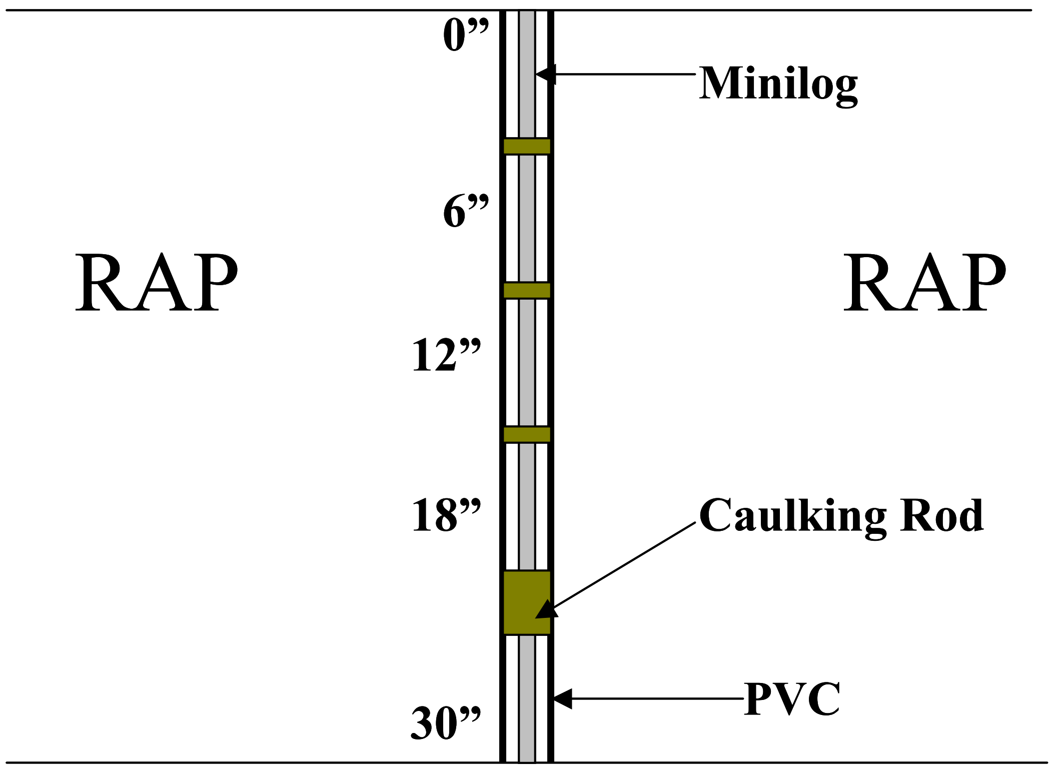


Figure 3.8 Ground Temperature Testing Layout

Temperatures were recorded every hour for the duration of the investigation. The probes were removed periodically and uploaded to a computer via the Minilog-Windows-PC® interface.

## 3.6 RAP-Soil Mixtures Methodology & Test Procedures

### 3.6.1 Introduction

RAP was mixed with a soil at various percentages by weight. The soil selected for mixing with RAP was a fine sand-trace of organics that was processed from muck obtained from a local dredging project and is referred to as fine sand for this investigation. Sieve analysis, Atterberg limits, specific gravity, asphalt content, and organic content tests were performed to characterize the RAP, fine sand, and RAP-soil mixtures. The engineering properties of the RAP and RAP-soil mixtures were evaluated by performing dry rodded unit weight, moisture-density, permeability, Limerock Bearing Ratio, static triaxial compression, and resilient modulus tests.

Dry rodded unit weight results were used to make initial decisions on the selection of RAP-soil mixtures to be used for further testing. Moisture-density curves were then developed to identify the optimum moisture contents and maximum dry unit weights of the selected mixtures. The remaining tests were conducted on RAP-soil mixtures compacted at their respective optimum moisture contents using modified Proctor compaction effort. Strength parameters of the mixtures were determined by the LBR, static triaxial compression, and resilient modulus tests. Drainage characteristics of the mixtures were evaluated through permeability tests.

### 3.6.2 Selection of RAP-Soil Mixtures

The RAP-soil mixtures used in this investigation were based on dry rodded unit weight tests performed on mixtures with varying RAP percentages. The results to be presented in Chapter 4, show a distinct peak dry rodded unit weight for a mixture containing 80% RAP. The dry rodded unit weight increased as the RAP percentage increased from 60 to 80, and then decreased as the RAP percentage increased from 80 to 100. Therefore, mixtures of RAP with a fine sand at the following proportions by weight were selected for further testing: 100% RAP, 80% RAP – 20% soil, and 60% RAP – 40% soil.

### 3.6.3 Material Sampling

RAP samples were collected from the top 12-inch lift of the field site (Section 3.2) following the FDOT *Manual of Florida Sampling and Testing Methods 1994*, procedure FM 1-T 002, “Sampling Coarse and Fine Aggregate.” The RAP used in the construction of the field site was obtained from a stockpile of hammermill post-milling processed RAP at the APAC-Florida, Central Florida Division – Melbourne Branch asphalt plant.

The fine sand used for mixing with RAP was processed from muck obtained from a spoil storage/dewatering area located at the intersection of US1 and Conlan Blvd. in Melbourne, Florida. The material was dredged from the mouth of Turkey Creek by the Saint Johns River Water Management District and transported to the spoil area. The spoil area serves as a large settling pond to separate the sediments and water (BCI, 1996). After the solids settle to the bottom, the clear liquid is drained and the solids allowed to dry by evaporation. To improve the drying process, solids were removed from the bottom of the settling pond and spread on an open field around the spoil area, increasing the surface area and thus allowing for quicker evaporation to take place. Samples for this study were collected over a period of 12 months at different locations of the spread material. The choice of location for sampling depended on the visual characteristics of the soil. Typically the dryer material displayed a lighter color than wet material. Dry material was preferred for ease of handling and reduced drying time.

### 3.6.4 Sample Preparation

All the RAP used for testing was air dried at room temperature and modified in size according to procedures outlined in section 3.2 of FM 5-521 and FM 5-515. The RAP obtained from the field was air dried for 4 to 5 days on flat metal trays at room temperature (approximately 75$^{o}$F). RAP was air dried rather than oven dried to prevent changes in its behavior due to the presence of asphalt binder. The size modification follows the sample preparation procedure for the Modified Proctor Compaction and Limerock Bearing Ratio tests, and was maintained for the remaining tests to allow for a relatively constant grain size distribution throughout the testing program. Material passing the 2 inch sieve and retained on the ¾ inch sieve was weighed and replaced by an equal weight of material passing the ¾ inch sieve and retained on the # 4 sieve. Material retained on the 2 inch sieve was discarded. The modified RAP was reduced for laboratory mixing and testing by the quartering method outlined in FM 1-T 248, "Reducing Field Samples of Aggregate to Testing Size."

The material obtained from the spoil storage/dewatering area was oven-dried at 60$^{o}$C. Dry solid particles larger than 1 inch were reduced in size using a 10 pound hammer with an 18 inch drop height. The particles were further reduced in size using a soil grinder. The ground material passing the #40 sieve was used in the RAP-soil mixtures and the remaining material retained on the #40 sieve discarded.

### 3.6.5 Test Procedures

Physical and engineering properties of the RAP, fine sand, and RAP-soil mixtures were determined following either the FDOT *Manual of Florida Sampling and Testing Methods 1994* (Florida Methods) or ASTM standards where applicable.

#### *3.6.5.1 Physical Properties*

A summary of the laboratory tests conducted to characterize the RAP, fine sand, and RAP-soil mixtures is presented in Table 3.2.

Table 3.2. Summary of laboratory tests and procedures for physical properties.

| Laboratory Test | Procedure | Description |
|---|---|---|
| Sieve Analysis | FM 1-T 027 / AASHTO T27 | Sieve Analysis of Fine and Coarse Aggregates |
| Atterberg Limits | FM 1-T 089 / AASHTO T89 | Determining the Liquid Limit of Soils |
| | FM 1-T 090 / AASHTO T90 | Determining the Plastic Limit and Plasticity Index of Soils |
| Specific Gravity | FM 1-T 100 / AASHTO T100 | Specific Gravity of Soils |
| | FM 1-T 085 | Specific Gravity and Absorption of Coarse Aggregates |
| Asphalt Content | FM 5-563 | Quantitative Determination of Asphalt Content from Asphalt Paving Mixtures by the Ignition Method |
| Organic Content | FM 1-T 267 | Determination of Organic Content in Soils by Loss on Ignition |

The grain-size distributions of RAP, fine sand, and RAP-soil mixtures were determined by performing sieve analyses following FM 1-T 027. U.S. standard sieve sizes of 1.5 inch, 0.75 inch, 0.375 inch, #4, #8, #16, #30, #60, #100, and #200 were used for the RAP and RAP-soil mixtures. Air-dried samples weighing approximately 10 pounds were used for each sieve analysis. For the fine sand, a 1½ pound sample and the U.S. standard sieve sizes #40, #60, #140, #200, and #270 were used. The sieve analyses conducted were based on dry sieving. Atterberg limits of the fine sand were also determined for soil classification purposes according to FM 1-T 089 and FM 1-T 090.

Specific gravity of RAP and RAP-soil mixtures was determined following FM 1-T 100 for material passing the #4 (4.75 mm) sieve, and FM 1-T 085 for material retained on the #4 (4.75 mm) sieve. A weighted average specific gravity was calculated from the percent material and specific gravity of the material passing and retained on the #4 sieve. The specific gravity of the fine sand was determined by FM 1-T 100.

The asphalt content of RAP was determined following FM 5-563. Two samples weighing approximately 1200 grams were tested and an average asphalt content calculated. The tests were conducted by FDOT personnel at the State Materials Office in Gainesville, Florida.

The organic content of the fine sand was determined following FM 1-T 267. Three samples weighing approximately 40 grams were oven-dried for 24 hours at 110$^{o}$C and then placed in a furnace for 6 hours at a temperature of 445$^{o}$C. An average organic content was calculated from the three samples.

*3.6.5.2 Engineering Properties*

A summary of the laboratory tests performed to evaluate the engineering properties of the RAP and RAP-soil mixtures is presented in Table 3.3.

Table 3.3. Summary of laboratory tests and procedures for engineering properties.

| Laboratory Test | Procedure | Description |
|---|---|---|
| Dry Rodded Unit Weight | ASTM C 29 / C 29 M | Standard Test Method for Unit Weight and Voids in Aggregate |
| Moisture - Density | FM 5-521 [FM 1-T 180] | Moisture Density Relations of Soils Using 10-lb. [4.54 kg] Rammer and an 18-in. [457 mm] Drop* |
| Permeability | FM 1-T 215 / AASHTO T215 | Permeability of Granular Soils (Constant Head) |
| | FM 5-513 | Coefficient of Permeability - Falling Head Method |
| | ASTM D 5084 | Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter |
| LBR | FM 5-515 | Limerock Bearing Ratio |
| Static Triaxial Compression | ASTM D 4767 | Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils ** |
| | Procedure by Head (1986) | Manual of Soil Laboratory Testing: Volume 3 by Head (1986) ** |
| Resilient Modulus | LTTP Protocol P46 | Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils |

*This compaction procedure is a modification of AASHTO T 180-74, Method D

**The sample preparation and testing procedures presented in ASTM D 4767 and the Manual of Soil Laboratory Testing: Volume 3 were adopted in performing the consolidated-drained (CD) triaxial tests

*3.6.5.2.1 Dry Rodded Unit Weight*

Dry rodded unit weight tests were conducted on RAP-soil mixtures following ASTM C29 / C29 M (ASTM, 1994). A 6 inch diameter, 9 inch high compaction mold (mold + collar) was used, yielding a volume of 0.147 $ft^3$. The material was compacted with a tamping rod in 3 equal layers and 25 strokes evenly distributed over the surface area per layer. The tamping rod was 24 inches long and 5/8 inch in diameter with a hemispherical tip. Two separate samples were prepared for testing. Tests were conducted starting with a 100% RAP sample and incrementally adding the required amount of fine sand (i.e. material passing the #40 sieve size) to obtain the desired mix proportions. The first series of tests were conducted at mixtures containing 100, 90, 80, 70, and 60% RAP. A second series was performed at mixtures of 100, 90, 85, 80, 75, 70, 65, and 60 % RAP. An average dry rodded unit weight was calculated from the two trials.

*3.6.5.2.2 Moisture-Density*

The relationship between dry density and moisture content of the RAP-soil mixtures was determined according to FM 5-521 (FM 1-T 180). Samples were compacted in 5 equal layers with 56 blows per layer using a 10 pound hammer and an 18 inch drop height, yielding a compactive effort of 56,000 ft-lb/ft$^3$. Compaction was done with a mechanical compaction machine manufactured by Ploog Engineering Company, Inc. Standard 6 inch diameter compaction molds with volumes of 0.075 ft$^3$ were used. Samples were prepared at moisture contents ranging from 3 to 11% and allowed to hydrate overnight prior to compaction.

*3.6.5.2.3 Permeability*

Permeability of the 100% RAP specimens was determined by constant and falling head tests according to FM 1-T 215 and FM 5-513 respectively. Samples were compacted in a standard 4 inch diameter compaction mold with a ¼ inch spacer disk. The spacer disk was used to provide the necessary spacing for the placement of the porous stone at the top of the specimen in the rigid wall permeameter. After compaction, the specimens were prepared in the rigid wall permeameter and left to permeate overnight with the constant head setup to ensure proper saturation prior to testing. Samples were tested first using the constant head setup and upon completion the same sample was tested using the falling head setup. Tap water was used as the permeant for testing.

The permeability of the 80 and 60% RAP samples were expected to be lower than 100% RAP and were determined using a flexible wall permeameter according to ASTM D 5084, Method C – Falling Head, rising tailwater elevation (ASTM, 2002). Samples were compacted in a 4 inch diameter mold (similar mold as for 100% RAP samples), weighed, and extruded with a hydraulic jack. The diameter and length were recorded prior to placement of the specimen in the permeability cell. The sample was placed on a porous stone at the base pedestal of the cell, followed by a porous stone and top cap at the top of the sample. Filter paper was placed at the top and bottom specimen-porous stone interfaces. A latex membrane was placed around the sample and sealed with rubber O-rings. The chamber was filled with water and the drainage lines saturated. The test samples were saturated using back-pressure saturation and the degree of saturation was monitored by calculating the B-coefficient. The cell and backpressure were increased incrementally until a value of 0.95 or higher was obtained for the B-coefficient. A pressure difference of 5 psi was maintained between the cell and backpressure system during saturation and testing. Proper saturation of permeability samples using back-pressure typically took 4 to 5 days at cell pressures ranging from 80 to 90 psi. Deaired tap water was used as the permeant for testing.

Permeability tests for all samples were conducted at hydraulic gradients of 1, 2.5, 4.5, and 6. Three samples were prepared for the 100% RAP and 80% RAP-soil mixtures and three trials were performed at each gradient per sample. Due to long testing durations, only two 60% RAP-soil samples were tested, with two trials per gradient. The direction of flow through the samples was from bottom to top. All the permeability samples were compacted manually. A summary of the compaction characteristics of the permeability samples and a comparison to AASHTO T 180-74 Method D is presented in Table 3.4.

Table 3.4. Compaction characteristics of permeability samples.

| Compaction | Method D - modified Moisture-density & LBR | 100% RAP | 80% RAP Soil mixture | 60% RAP Soil mixture |
|---|---|---|---|---|
| Mold: | | | | |
| Volume ($ft^3$) | 0.075 | 0.0317 | 0.0333 | 0.0333 |
| Diameter (in) | 6 | 4 | 4 | 4 |
| Weight of hammer (lb) | 10 | 10 | 10 | 10 |
| Height of drop of hammer (in) | 18 | 18 | 18 | 18 |
| Number of layers of soil | 5 | 5 | 5 | 5 |
| Number of blows per layer | 56 | 24 | 25 | 25 |
| Compactive effort (ft-lb/$ft^3$) | 56000 | 56702 | 56246 | 56246 |
| % difference | - | 1.3 | 0.4 | 0.4 |

*3.6.5.2.4 Limerock Bearing Ratio*

The bearing capacity of the RAP and RAP-soil mixtures was evaluated using LBR tests following FM 5-515. The LBR samples were compacted in a similar fashion as the moisture-density samples, with 5 equal layers and 56 blows per layer using a 10 pound hammer and an 18 inch drop height. Compaction was done with a mechanical compaction machine manufactured by Ploog Engineering Company, Inc. Standard 6 inch diameter compaction molds with perforated base plates were used. Samples were prepared at their respective optimum moisture contents and allowed to hydrate overnight prior to compaction. After compaction the samples were soaked in a water bath for two days prior to testing. LBR samples were tested as base and subgrade material. Samples tested as subgrade material were subjected to a surcharge of 15 pounds during testing. A total of four samples were tested for each RAP and RAP-soil mixture tested as base and subgrade material.

*3.6.5.2.5 Static Triaxial Compression*

The elastic modulus, maximum stress at failure, and shear strength of the RAP and RAP-soil mixtures was determined by consolidated-drained (CD) triaxial compression tests. The sample preparation and testing procedures followed in conducting the triaxial tests were adopted from ASTM D 4767, "Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils" (ASTM, 2002) and the "Manual of Soil Laboratory Testing: Volume 3" by Head (1986). Samples were prepared at their respective optimum moisture contents and allowed to hydrate overnight prior to compaction. A 4 inch diameter, 8.375 inch high mold was used for compaction. The material was manually compacted in 6 equal layers with 38 blows per layer using a 10 pound hammer and an 18 inch drop height, yielding a compactive effort of 56,153 ft-lb/ft$^3$. The sample was weighed after compaction and then extruded with a hydraulic jack from the mold. The diameter and length were recorded prior to placement of the specimen in the triaxial cell. A porous stone and filter paper were placed on the base pedestal of the cell, after which eight ¾ inch wide filter paper strips were spaced radially on the circular filter paper placed on the porous stone. After placement of the sample, the filter paper strips were folded and attached vertically to the side of the specimen and folded on top. Another circular filter paper and porous stone was placed on top with a top cap. A latex membrane was placed around the sample and sealed with rubber O-rings. The chamber was filled with water and the drainage lines were left open to atmosphere. A triaxial sample is shown in Figure 3.9.

Figure 3.9. Triaxial sample of RAP-soil mixture on base pedestal

In drained triaxial compression tests water is allowed to enter or leave the sample while being compressed to reduce any excess pore water pressure build-up. For this to occur, compression must take place at a very slow rate. Most procedures for drained triaxial tests specify drainage only from the bottom of the sample. In order to reduce the time required for consolidation and compression, drainage was allowed to take place from the top and bottom of the sample. The addition of side drains (vertical filter paper strips) to drainage from both ends further reduces the time required for the consolidation and compression phase. By providing more drainage paths, any excess pore water pressure that might develop is able to dissipate more rapidly during the test. Because of the extensive time (4 to 5 days) required for proper saturation of the specimens, the triaxial compression tests were performed on partly saturated samples. After compaction the samples were consolidated until no major volume change was observed. Volume change was measured with burettes open to atmosphere that were connected to the top and bottom drainage lines of the triaxial cell. The rate of loading during compression was estimated from consolidation results. A 60% RAP permeability sample was consolidated following procedures outlined by Head (1986). The maximum loading rate for samples with side drains was estimated to be 0.002 inch / minute. However, due to limitations of the loading machine, the slowest possible loading rate of 0.005 inch / minute was selected. Two samples were tested at effective consolidation pressures of 5 and 15 psi for each RAP and RAP-soil sample.

*3.6.5.2.6 Resilient Modulus*

Resilient modulus tests of the RAP and RAP-soil mixtures were conducted by FDOT personnel at the State Materials Office in Gainesville, Florida. The Long-Term Pavement Performance (LTPP) Protocol P46 test procedure for "Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils" as described by Alavi et al. (1997) was followed. The RAP obtained from the field was modified in size for testing by passing the entire sample through a jaw crusher set at a maximum opening of ¾ inch. The RAP and RAP-soil mixtures were prepared at their respective optimum moisture contents and allowed to hydrate overnight prior to compaction. The samples were compacted in 4 inch diameter, 8 inch high compaction molds using a mechanical compaction machine. Samples were compacted in 6 equal layers with 38 blows per layer using a 10 pound hammer and an 18 inch drop height, yielding a compactive effort of 58,785 ft-lb/ft$^3$. After compaction the samples were extruded from the mold and placed on the triaxial base pedestal. A porous stone was placed at the top and bottom of the sample with filter paper placed between the sample and porous stones. A top cap was positioned on the top of the specimen followed by the placement of a latex membrane around the sample. The membrane was sealed to the base pedestal and top cap with rubber O-rings. The RAP and RAP-soil mixtures were tested as base and subgrade material. Samples tested as base material were subjected to a confining pressure of 15 psi and conditioned by applying 500 repetitions of an axial load equivalent to a stress of 15 psi. The subgrade samples were subjected to a confining pressure of 6 psi and conditioned by applying 500 repetitions of an axial load equivalent to a stress of 4 psi. Conditioning eliminates the effects of specimen disturbances due to sampling, compaction, and specimen preparation procedures, and also aids in minimizing the effects of imperfect contacts between end platens and the specimen (Mohammad et al., 1994). Samples tested as base material were loaded following the sequence in Table 3.5. After conditioning (sequence # 0), the confining pressure and the maximum applied axial stress were adjusted to 3 psi and the sample loaded for 100 repetitions. The average deformation of the last five load repetitions were recorded. The test continued following the remaining sequences. A contact stress (seating load) of 10% of the maximum applied axial stress of each sequence was maintained on the sample during all the load repetitions. Samples tested as subgrade material were loaded following the sequence in Table 3.6. A closed-loop servo-hydraulic system was used for testing. Displacements were measured by externally mounted LVDT's and load cells were used for load measurements. The load repetitions used for sample conditioning and testing of the base and subgrade samples were applied using a haversine shaped load pulse with 0.1 seconds of loading and 0.9 seconds of rest. The top and bottom drainage lines were open to atmosphere prior and during the tests. Two tests were conducted for each RAP and RAP-soil mixture.

Table 3.5 Resilient modulus loading sequence for base materials.

| Sequence # | Confining Pressure | | Max. Axial Stress | | Cyclic Stress | | Contact Stress | | Number of Load Repetitions |
|---|---|---|---|---|---|---|---|---|---|
| | (kPa) | (psi) | (kPa) | (psi) | (kPa) | (psi) | (kPa) | (psi) | |
| 0 | 103.4 | 15 | 103.4 | 15 | 93.1 | 13.5 | 10.3 | 1.5 | 500 - 1000 |
| 1 | 20.7 | 3 | 20.7 | 3 | 18.6 | 2.7 | 2.1 | 3.0 | 100 |
| 2 | 20.7 | 3 | 41.4 | 6 | 37.3 | 5.4 | 4.1 | 0.6 | 100 |
| 3 | 20.7 | 3 | 62.1 | 9 | 55.9 | 8.1 | 6.2 | 0.9 | 100 |
| 4 | 34.5 | 5 | 34.5 | 5 | 31.1 | 4.5 | 3.5 | 0.5 | 100 |
| 5 | 34.5 | 5 | 68.9 | 10 | 62.0 | 9.0 | 6.9 | 1.0 | 100 |
| 6 | 34.5 | 5 | 103.4 | 15 | 93.1 | 13.5 | 10.3 | 1.5 | 100 |
| 7 | 68.9 | 10 | 68.9 | 10 | 62.0 | 9.0 | 6.9 | 1.0 | 100 |
| 8 | 68.9 | 10 | 137.9 | 20 | 124.1 | 18.0 | 13.8 | 2.0 | 100 |
| 9 | 68.9 | 10 | 206.8 | 30 | 186.1 | 27.0 | 20.7 | 3.0 | 100 |
| 10 | 103.4 | 15 | 68.9 | 10 | 62.0 | 9.0 | 6.9 | 1.0 | 100 |
| 11 | 103.4 | 15 | 103.4 | 15 | 93.1 | 13.5 | 10.3 | 1.5 | 100 |
| 12 | 103.4 | 15 | 206.8 | 30 | 186.1 | 27.0 | 20.7 | 3.0 | 100 |
| 13 | 137.9 | 20 | 103.4 | 15 | 93.1 | 13.5 | 10.3 | 1.5 | 100 |
| 14 | 137.9 | 20 | 137.9 | 20 | 124.1 | 18.0 | 13.8 | 2.0 | 100 |
| 15 | 137.9 | 20 | 275.8 | 40 | 248.2 | 36.0 | 27.6 | 4.0 | 100 |

Table 3.6 Resilient modulus loading sequence for subgrade materials.

| Sequence # | Confining Pressure | | Max. Axial Stress | | Cyclic Stress | | Contact Stress | | Number of Load Repetitions |
|---|---|---|---|---|---|---|---|---|---|
| | (kPa) | (psi) | (kPa) | (psi) | (kPa) | (psi) | (kPa) | (psi) | |
| 0 | 41.4 | 6 | 27.6 | 4 | 24.8 | 3.6 | 2.8 | 0.4 | 500 - 1000 |
| 1 | 41.4 | 6 | 13.8 | 2 | 12.4 | 1.8 | 1.4 | 0.2 | 100 |
| 2 | 41.4 | 6 | 27.6 | 4 | 24.8 | 3.6 | 2.8 | 0.4 | 100 |
| 3 | 41.4 | 6 | 41.4 | 6 | 37.3 | 5.4 | 4.1 | 0.6 | 100 |
| 4 | 41.4 | 6 | 55.2 | 8 | 49.7 | 7.2 | 5.5 | 0.8 | 100 |
| 5 | 41.4 | 6 | 68.9 | 10 | 62.0 | 9.0 | 6.9 | 1.0 | 100 |
| 6 | 27.6 | 4 | 13.8 | 2 | 12.4 | 1.8 | 1.4 | 0.2 | 100 |
| 7 | 27.6 | 4 | 27.6 | 4 | 24.8 | 3.6 | 2.8 | 0.4 | 100 |
| 8 | 27.6 | 4 | 41.4 | 6 | 37.3 | 5.4 | 4.1 | 0.6 | 100 |
| 9 | 27.6 | 4 | 55.2 | 8 | 49.7 | 7.2 | 5.5 | 0.8 | 100 |
| 10 | 27.6 | 4 | 68.9 | 10 | 62.0 | 9.0 | 6.9 | 1.0 | 100 |
| 11 | 13.8 | 2 | 13.8 | 2 | 12.4 | 1.8 | 1.4 | 0.2 | 100 |
| 12 | 13.8 | 2 | 27.6 | 4 | 24.8 | 3.6 | 2.8 | 0.4 | 100 |
| 13 | 13.8 | 2 | 41.4 | 6 | 37.3 | 5.4 | 4.1 | 0.6 | 100 |
| 14 | 13.8 | 2 | 55.2 | 8 | 49.7 | 7.2 | 5.5 | 0.8 | 100 |
| 15 | 13.8 | 2 | 68.9 | 10 | 62.0 | 9.0 | 6.9 | 1.0 | 100 |

# 3.7 Preliminary Creep Testing Methodology

## 3.7.1 Typical Creep Behavior of Soils

Creep, or slow shear movements, begins to occur when shear stresses in soils increase as a function of the total shear strength. Generally sandy and gravelly soils can sustain shear stresses very close to their shear strength for long periods without failing, and is one of the reasons that these soils are superior materials for many applications. Although RAP is classified as an A-1-a soil, indicating that it is typically a gravel/sand mixture, it is still necessary to determine whether creep is a concern due to the asphalt content that the RAP possesses.

Creep behavior of soils under a constant stress may vary depending upon the level of the stress being applied. Under relatively low shearing stresses, creep movements may be small and cease after some period of time. Under higher stresses, creep movements may continue indefinitely. In some soils, continued application of stress may result in acceleration of the creep rate followed by complete rupture.

These time-dependent responses of soils may take on a variety of forms depending on such factors as soil type, soil structure, stress history, drainage conditions, type of loading, and other factors. It is necessary to determine into what pattern of long-term creep behavior RAP falls.

### 3.7.2 Development of Creep Testing Methodology

Although many studies have been performed on cohesive soils to determine creep behavior, very few have been completed with the focus on non-cohesive soils. As a result, no procedural guidelines were found for the testing of creep in a granular material such as RAP. Consequently, a preliminary testing method was derived by FIT from the basic underlying concepts and procedures applied for creep testing in cohesive soils, as well as LBR testing that has been performed on RAP.

Three factors were measured to evaluate the creep characteristics of RAP; stress, deflection, and time. The testing was conducted by using a *Brainard-Kilman Terraload Consolidation Load Frame.* Three samples were prepared for separate testing in 6-inch diameter proctor molds according to ASTM-1557 Method D with a moisture content of 10%, which is slightly wet of optimum. The three materials tested were 100% RAP, a RAP-soil mixture of 80% RAP and 20% soil, as well as for A-3 soil, which was used as the control. The general setup of the testing apparatus can be seen in Figure 3.10.

By evaluating several Load Penetration Curves from previous LBR testing, an ultimate strength of RAP was determined. With an estimated 800psi as the 100% ultimate strength level, various percentages of this strength were chosen for the application loads. The sample was loaded with a 1.95-inch diameter ($3in^2$) piston, which is traditionally used for LBR testing. Loads were maintained for a minimum of 4000 minutes, provided that sample failure did not occur prior to this point. The samples were incrementally loaded with 33.5psi, 67psi, 134psi, and 268psi, which respectively correspond to 4.2%, 8.4%, 16.7% and 33.5% of the ultimate strength.

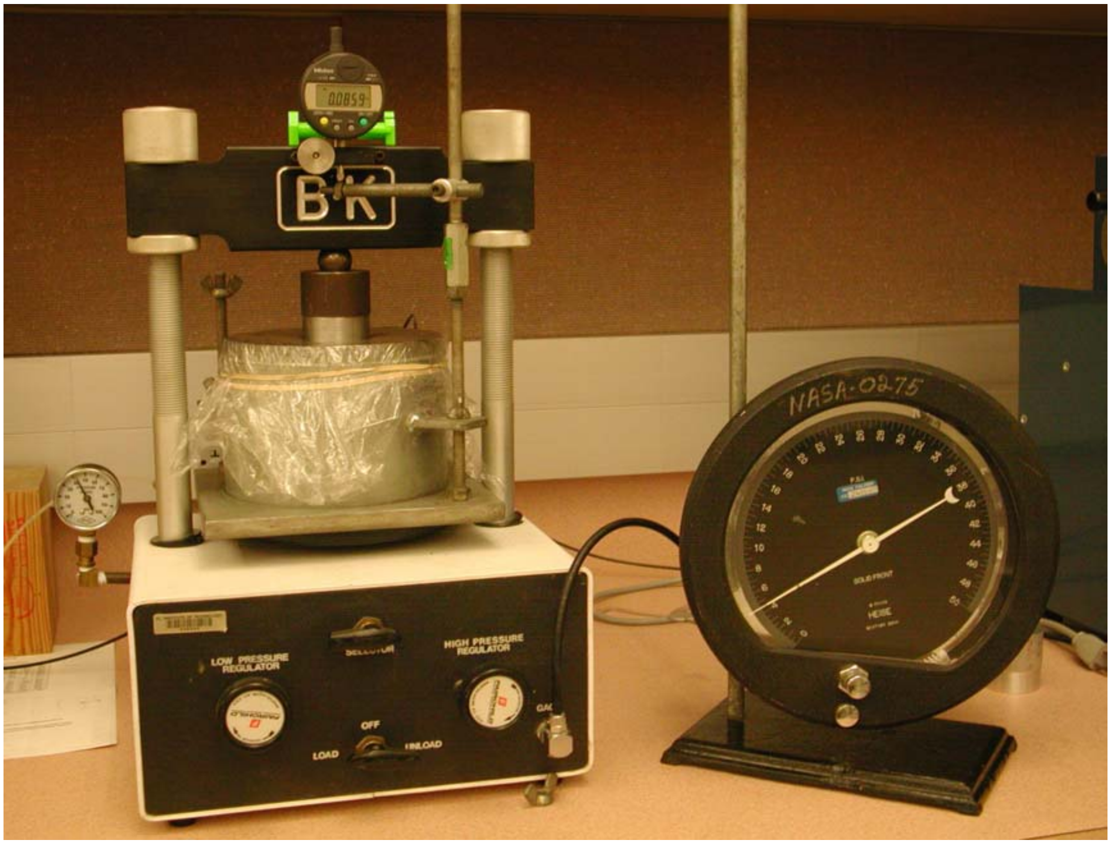


Figure 3.10  Setup of Creep Testing Apparatus

# 3.8 Environmental Testing Methodologies

## 3.8.1 Site Construction

The 5-foot by 5-foot runoff and leachate collection systems constructed as part of the field site were situated so as not to be disturbed by engineering evaluation on the site (See Figure 3.1). Perforated PVC piping (4-inch diameter) was included near the surface to collect surface waters and on the geomembrane to collect the leachate waters. The surface slopes, graded to approximately 2 %, were sufficient to cause water that contacted these areas to flow towards the collection system. The infiltrated water was prevented from passing through the RAP or limerock layer due to an impermeable 40-mil geomembrane that was placed beneath it. The perforated PVC pipes were wrapped in geotextile fabric designed to allow water to pass through but prevent clogging by the RAP or limerock particles. These pipes were sloped toward the outer edges of the collection system to 2-inch diameter pipes that were sloped towards the collection drums (See Figure 3.11). Two 55-gallon plastic drums were connected to the collection systems for both the surface runoff and leachate (See Figure 3.11). Following construction of the drainage system, both the RAP and Limerock sites were backfilled to final grade, by placing 8-inch loose lifts of material and compacting them with a vibratory compactor to 6-inch lifts. The density of the materials in these sections was not equivalent, because the compaction equipment (Figure 3.3) could not be used in these confined areas.


Figure 3.11 Photograph of Limerock Collection Systems prior to backfilling with Limerock

### 3.8.2 <u>Environmental Field Monitoring</u>

Figure 3.12 shows the completed RAP and Limerock collection systems. Depending on the rainfall events, environmental monitoring and sampling were performed monthly for the first three months and bi-monthly thereafter. Both surface runoff and leachate were collected for analysis of cadmium (Cd), chromium (Cr), lead (Pb), selenium (Se), and silver (Ag).

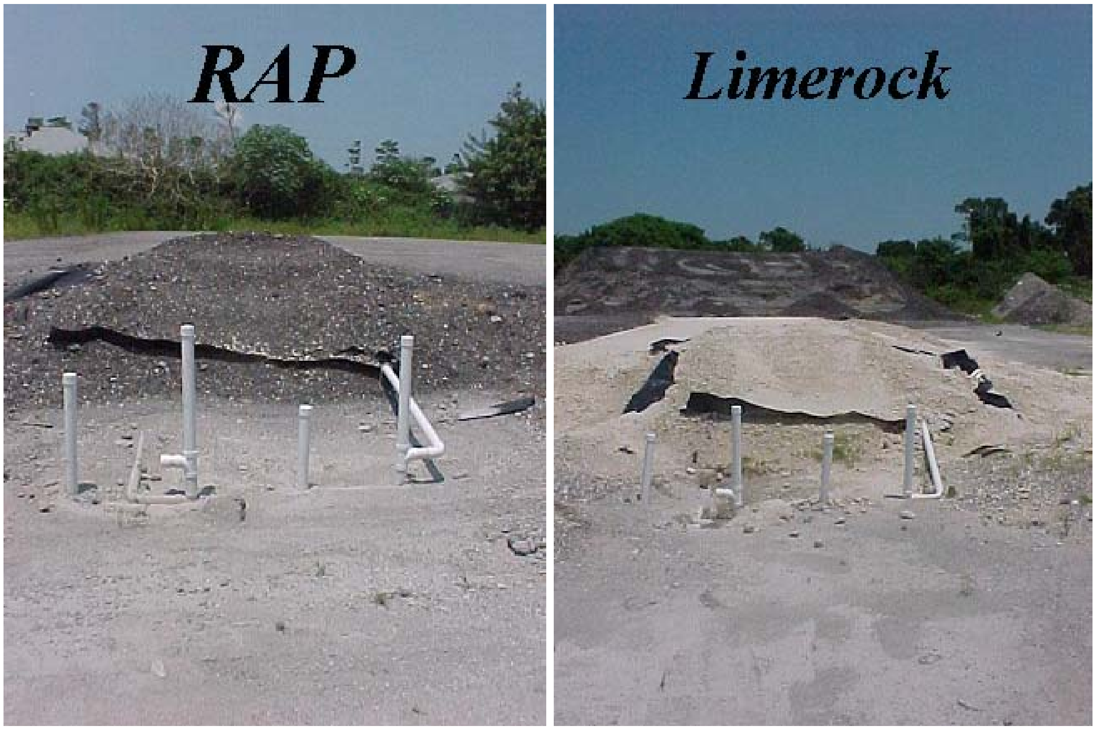


Figure 3.12  Completed RAP and Limerock Collection Systems

*3.8.2.1 Sampling*

Both surface and leachate water samples were collected from the RAP and limerock sites for chemical analysis. Samples were only collected when at least 2-inches of liquid had accumulated in the collection drums. Samples were collected immediately after a rainfall event and preserved immediately by acidifying to below pH 2 prior to exporting them back to the laboratory for analysis. Quantities of accumulated liquid samples in the collection drums were recorded to enable assessment of leaching characteristics of the RAP and the control limestone sites.

*3.8.2.2 Chemical and Instrumental Analysis*

A Perkin-Elmer Model 5100 Atomic Absorption Spectrophotometer (AAS) equipped with Zeeman background correction was used for leachate analysis. Analyses of trace metals were performed by using graphite furnace AAS. Different matrix modifier solutions were used for different elements to stabilize the analyte for analysis by the furnace AAS (Table 3.7).

Table 3.7 Modifier solutions used for graphite furnace AAS with Zeeman background correction

| Element | Modifier Solution |
|---|---|
| Ag | 3 % $(NH_4)2HPO_4$ + 10 % $NH_4NO_3$ |
| Cd | 10 % $NH_4NO_3$ |
| Cr | 3 % $(NH_4)_2HPO_4$ + 10 % $NH_4NO_3$ |
| Pb | 3 % $(NH_4)_2HPO_4$ + 10 % $NH_4NO_3$ |
| Se | $Mg(NO_3)_2$ |

### 3.8.3 Laboratory Test Procedures

#### *3.8.3.1 Toxicity Characteristic Leaching Procedure (TCLP)*

RAP and Limerock were crushed using a mortar and pestle to reduce particle size less than 9.5 mm (3/8-inch) diameter. Three 40 g crushed samples of each material were quantitatively transferred to a 1 liter acid-cleaned polypropylene bottle. Extraction was carried out at a 20:1 liquid to solid ratio using diluted acetic acid. An 800 ml solution was added to each replicate. It was prepared by diluting 5.7 ml of glacial acetic (99.7%) with distilled-deionized water (DDW) followed by adding 64.3 ml of 1 N NaOH to a volume of 1 liter, pH 4.93 ± 0.05.

The mixture was shaken mechanically for 18 hours. Within 2 hours of the mixing, separation of the material into its component liquid and solid phases was performed by filtering through a 0.4 μm Millipore® membrane filter. The filtrate was acidified with Ultrix® nitric acid to pH below 2 and was stored in acid-cleaned polypropylene bottles under refrigeration (4°C), until AAS analysis. Figure 3.13 is a flow chart that summarizes the TCLP test procedure.

#### *3.8.3.2 Synthetic Precipitation Leaching Procedure (SPLP)*

The leaching experiment for SPLP was similar to the TCLP procedure. In the SPLP test, a pH 4.2 synthetic acid rain solution was prepared according to EPA Method 1312 (draft) (U.S. EPA, 1994) by adding of a 60/40 weight percent mixture of sulfuric and nitric acids to DDW until pH 4.2 ± 0.05 was achieved (Table 3.8). A 1 N NaOH solution may be prepared to maintain pH to approximately 4.2. Figure 3.14 is a flow chart that summarizes the SPLP test procedure.

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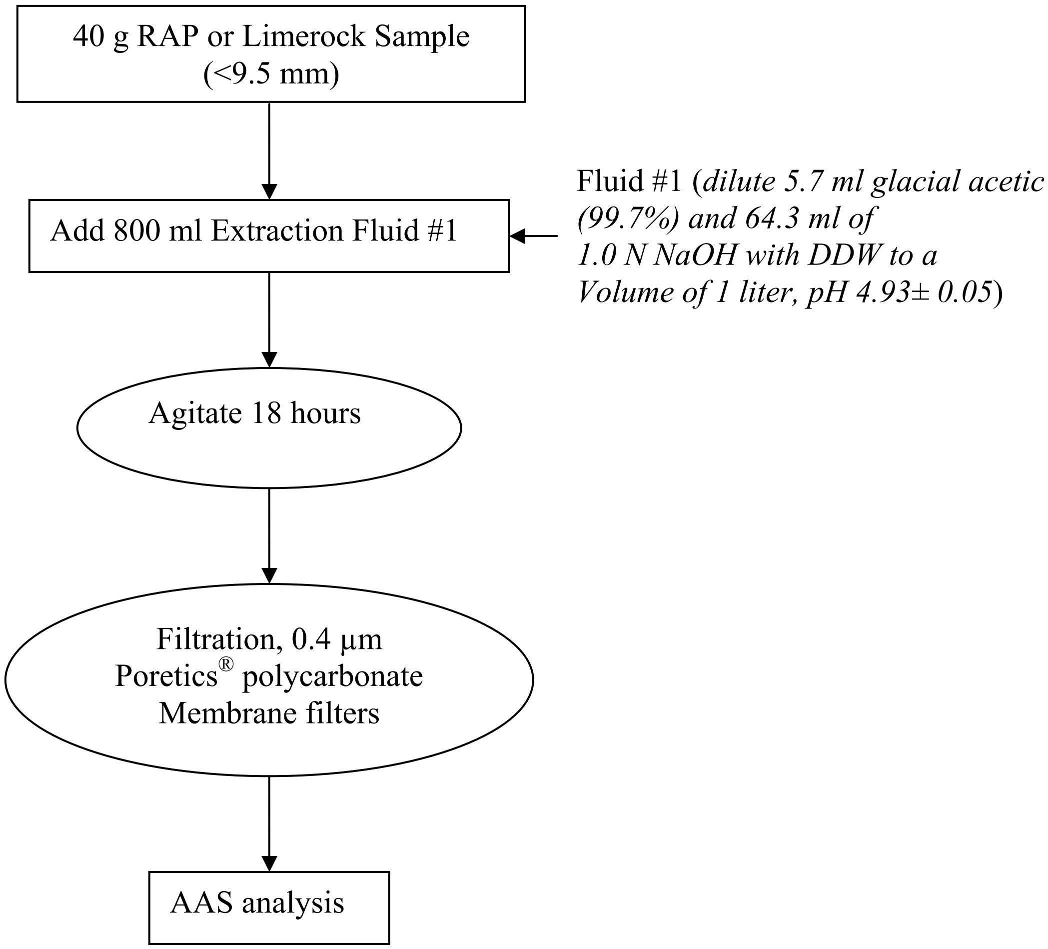



Figure 3.13 Flow chart shows the procedure of TCLP Test

Table 3.8 Chemicals used to prepare a primary solution for a 4-liter Synthetic Acid Rain

| Chemical | Weight (g) |
| --- | --- |
| $NaNO_3$ | 0.1150 |
| $KNO_3$ | 0.2196 |
| $NH_4NO_3$ | 0.6480 |
| $MgCl_2$ | 0.0821 |
| $H_2SO_4$ | 0.1755 |
| $CaSO_4$ | 0.1057 |

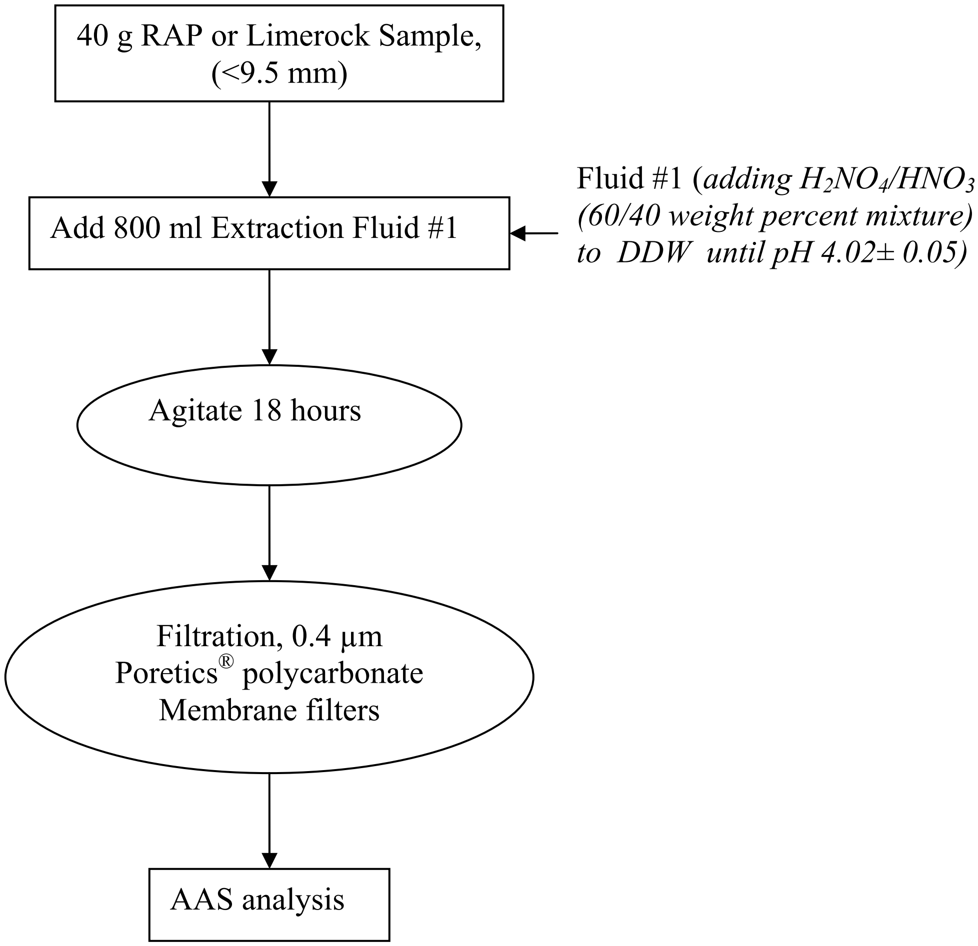



Figure 3.14 Flow chart shows the procedure of SPLP Test

#### *3.8.3.3 Column Leaching Test*

The column-leaching test was designed to determine the environmental impact of RAP being used as a subsurface highway material. Five columns were constructed to investigate leaching characteristics of RAP and limerock under controlled situations in laboratory.

The column-leaching test, modified from ASTM D2434-68 Standard Test Method for Permeability of Granular Soils (Constant Head) and ASTM D4874-95 Standard Test Method for Leaching Solid Material in a Column Apparatus, was conducted to investigate the leaching of RAP in controlled solution. The column was made of PVC, which had a diameter of 10.2 cm (4 in) and a height of 76.2 cm (30 in). The column was mounted on a platform and a screen and drainage tube was installed in the bottom of the column. Leachate from the column was collected over different time intervals. A schematic of the column is depicted in Figure 3.15. The rainfall simulation nozzle was installed on the top of the column, as shown in Figure 3.16, to simulate average rate of rainfall in the adjacent areas of the field site. The Standard Proctor Compaction technique (ASTM D-698) was used to compact the RAP and Limerock samples. Leaching column samples used in this study were compacted by using 2.5 kg (5.5 lb) PVC hammer and 12-inch (304.8 mm) drop that was the compaction technique according to the Standard Proctor compaction test (Das, 1989) modified for environmental concerns.

The construction of the column was carried out to simulate field conditions, including test material, thickness and compaction techniques. Leaching media for column tests were DDW and synthetic acid rain that was prepared according to the National Atmosphere Deposition Program (NADP) quality reference to simulate acid rain common to the Northeastern United States (U.S. EPA, 1990). Column leaching samples were collected for analysis of cadmium, chromium, lead, selenium, and silver. Analytical data generated in the laboratory study were correlated to the results of field study.

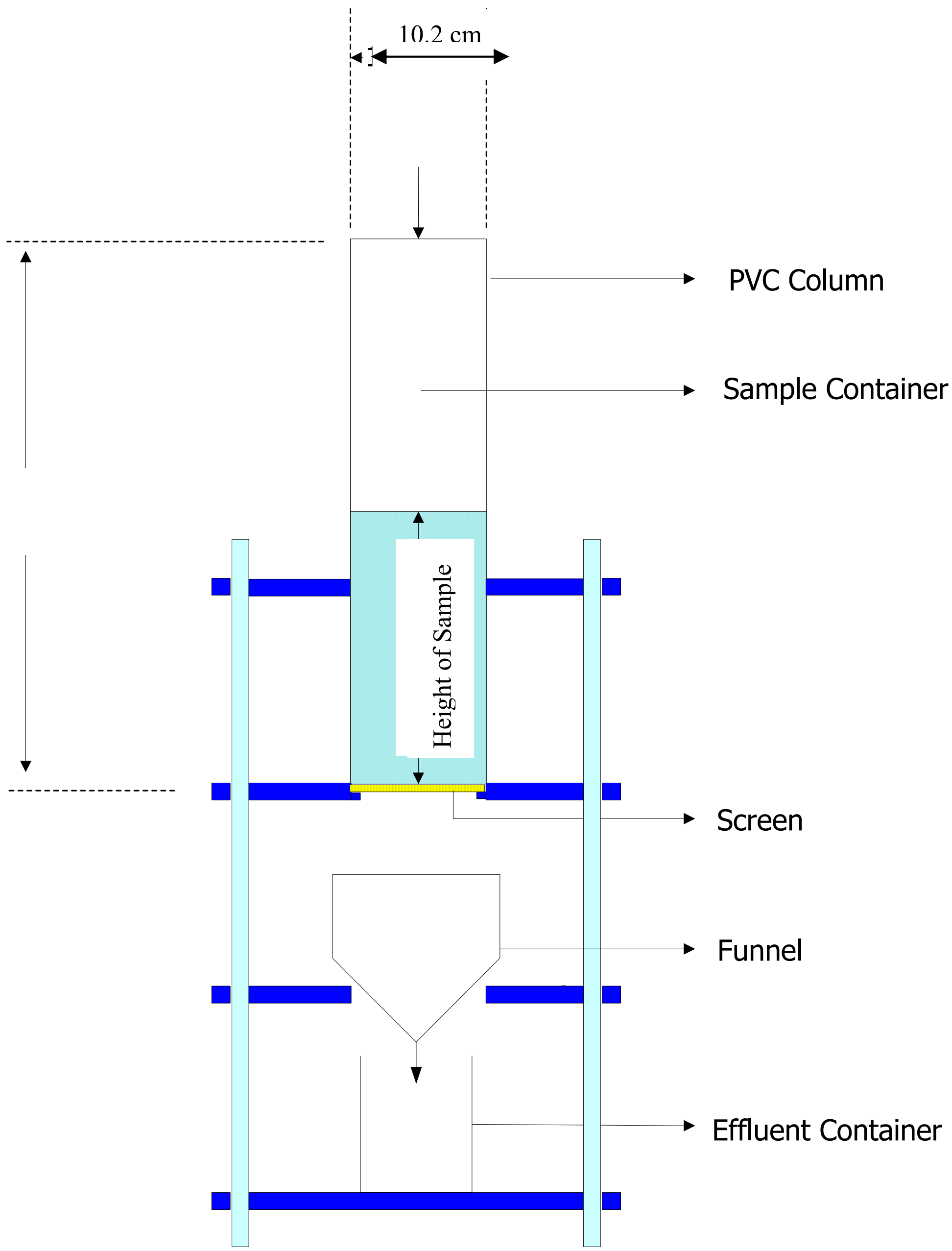



Figure 3.15 Schematic for column leaching test on RAP and Limerock

Figure 3.16 Photo of nozzle for distributing leaching media into column leaching test apparatus.

# 4. Presentation and Discussion of Results

## 4.1 Grain Size Distribution

The gradation curves for the RAP and limerock, using the average of three tests samples, are shown in Figure 4.1. RAP was classified as well-graded gravel (GW) and limerock classified as well graded sand (SW) using the Unified Soil Classification System (USCS). Based on the American Association for State Highway and Transportation Officials (AASHTO) standards, RAP was classified as an A-1-a and limerock classified as an A-1-b.

Table 4.1 shows a summary of the gradation parameters, $D_{10}$, $D_{30}$, and $D_{60}$. The coefficient of curvature ($C_c$) and coefficient of uniformity ($C_u$) are also presented in Table 4.1. The RAP being used compares well to the RAP used in the previous studies. The major difference is that the newest material was classified as gravel and the RAP samples from previous investigations were classified as both sand and gravel. The effective grain size ($D_{10}$) has an important influence on permeability (Holtz and Kovacs, 1981). It is proportional to permeability, meaning the larger the $D_{10}$ the more permeable the material. RAP and limerock used in this investigation had effective grain sizes of 0.43 and 0.25 mm respectively. Based on its $D_{10}$ –value, RAP would be expected to have better drainage characteristics than limerock.

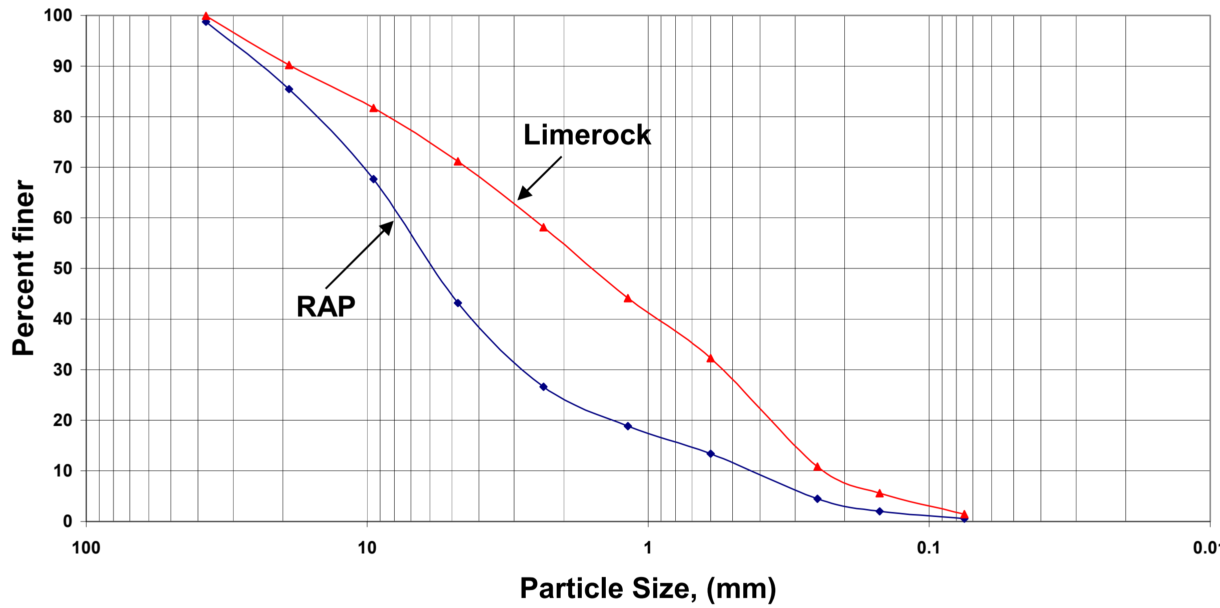



Figure 4.1 Particle Size Distributions for RAP and Limerock

Table 4.1 Gradation Parameters and Classification of RAP and Limerock

| | Present Study RAP | Present Study Limerock | Doig (2000) RAP | Montemayor (1998) RAP |
|---|---|---|---|---|
| $D_{10}$ (mm) | 0.43 | 0.25 | 0.35 | 0.28 to 0.32 |
| $D_{30}$ (mm) | 2.8 | 0.55 | 1.9 | 1.3 to 2.0 |
| $D_{60}$ (mm) | 7.6 | 2.6 | 3.7 to 5.0 | 5.1 to 6.0 |
| $C_u$ | 17.7 | 10.4 | 10 to 14.3 | 17.1 |
| $C_c$ | 2.4 | 0.47 | 1.5 to 2.1 | 1.2 to 2.2 |
| USCS | GW | SW | SW | GW/SW |
| AASHTO | A-1-a | A-1-b | A-1-a | A-1-a |

## 4.2 Asphalt Content

The average asphalt content was 6.04 ± 0.01 percent for the RAP used in this investigation. Rodriquez (2001) and Montemayor (1998) reported asphalt contents of 6.73 and 5.67 percent respectively. The expected range for asphalt content is 4 to 8 percent by weight, for structural asphalt concrete mixtures used in Florida (Montemayor, 1998).

## 4.3 Falling Weight Deflectometer

Calculations done using MODULUS 5.1 indicated that very slight changes in layer thickness caused large changes in elastic moduli; the tolerance for layer thickness required by this program was not met at this field site. For this reason typical back calculations of elastic moduli were not performed. FWD data was used to calculate Impulse Stiffness Modulus (ISM) values according to equation 4.1 (Bush, 1990). The ISM is defined as the load in kips divided by the center plate deflection in mils and is an indication of the overall pavement system stiffness. The ISMs developed for comparison purposes was an average of twenty-one tests in RAP and four tests in limerock at three different load levels, per testing cycle. Raw ISM data is shown in Appendix B. A plot of ISM for RAP and limerock versus time is shown in Figures 4.2 for the 9000-lbf tests. Also included in the plot are one standard deviation error bars. Plots for the 6000-lbf and 12000-lbf tests are shown in Appendix C.

$$ISM = \frac{Load\,(kips)}{Center\ Plate\ Deflection\,(mils)} \qquad (4.1)$$

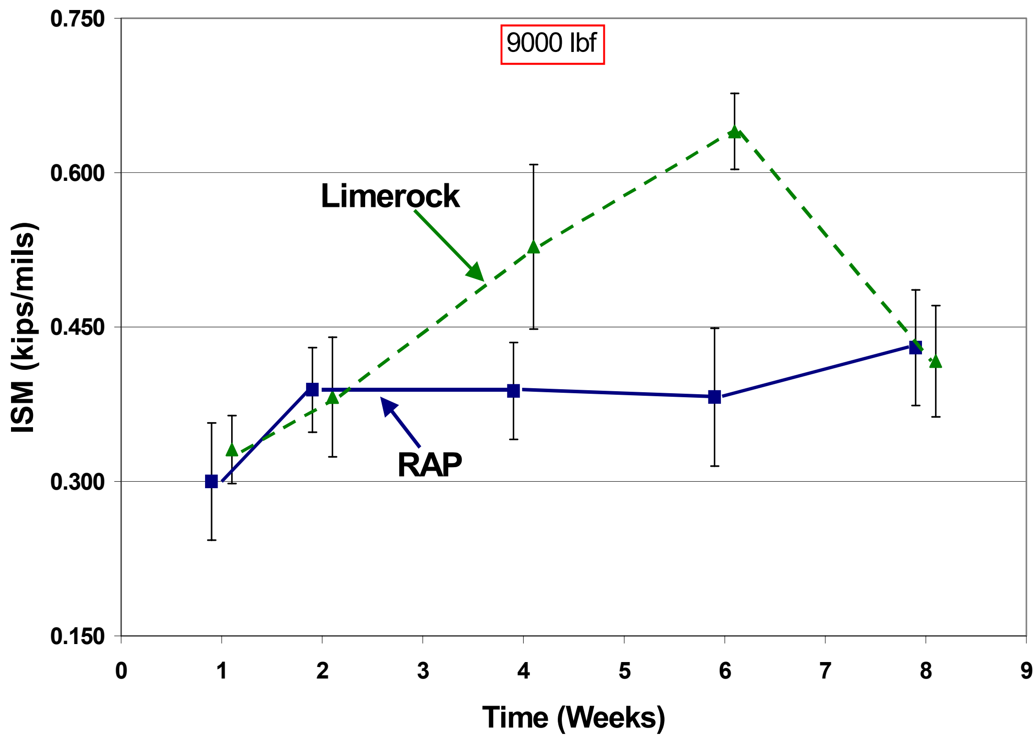



Figure 4.2 ISM vs. Time for RAP and Limerock (9000-lbf)

The ISM values obtained in the limerock were nearly identical to those obtained in RAP during the first and second week of testing. The fourth and sixth week ISM's showed RAP to be about 67% as stiff as limerock. Between the sixth and eighth testing interval the limerock's strength decreased by 42%, which made its ISM approximately equal to that of the RAP. Based on the ISM the strength gains for the RAP and limerock after eight weeks were 49% and 15% respectively.

Based on moisture content changes from week six to week eight, RAP proved to be less susceptible to moisture than limerock.

## 4.4 Clegg Impact Test

Twenty-four Clegg impact tests were conducted on RAP and nine were conducted on limerock per testing cycle. Each test consists of four drops of a 10-lb hammer over 18 inches. The Clegg Impact Value (CIV), which is the peak deceleration rate in tens of gravities, is obtained. All the CIV data collected during this investigation can be viewed in Appendix D. The graph of CIV versus time is shown in Figure 4.3. One standard deviation error bars are also included.

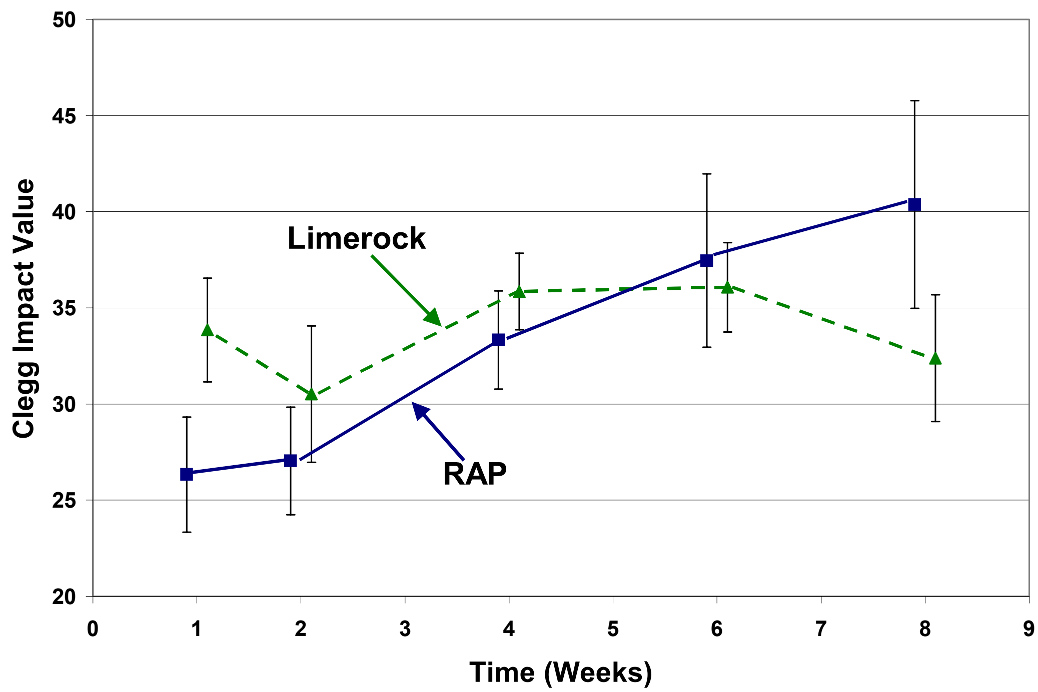



Figure 4.3 CIV vs. Time for RAP and Limerock

The CIV for limerock is higher than the CIV for RAP for four out of the five test intervals. The strength of RAP is steadily increasing over time based on the CIV. Again it can be seen that the strength of the limerock decreases between the sixth and eighth week. The limerock undergoes a 4% loss of CIV between during this period. Week one testing showed that the limerock was 28% stiffer than the RAP. Week two, week four and week six tests show the limerock as being 18%, 13%, and 4% stronger than RAP respectively. As time passes RAP's strength nears that of limerock, finally surpassing it during week eight. Using the CIV as an indicator, after eight weeks the RAP has become 55% stronger whereas the limerock has become 4% weaker. RAP has a large strength gain compared to relatively small strength gains seen in the limerock over the eight-week period. Based on the error bars it can be concluded that there is no change in the CIVs for limerock however, there is a definite increase in RAP CIVs over eight weeks. This research indicates that RAP is again less susceptible to moisture than limerock.

## 4.5 Soil Stiffness Gauge

Thirty-three Soil Stiffness Gauge tests were completed each test cycle, twenty-four on RAP and nine on limerock. At each test location three SSG tests were performed, the tests were centered around the location of the Nuclear Densometer tests. The average of all three tests were taken to establish a stiffness value for each location. Figure 4.4 presents the trends in stiffness values throughout the eight-week testing cycle. Included in the plot are one standard deviation error bars.

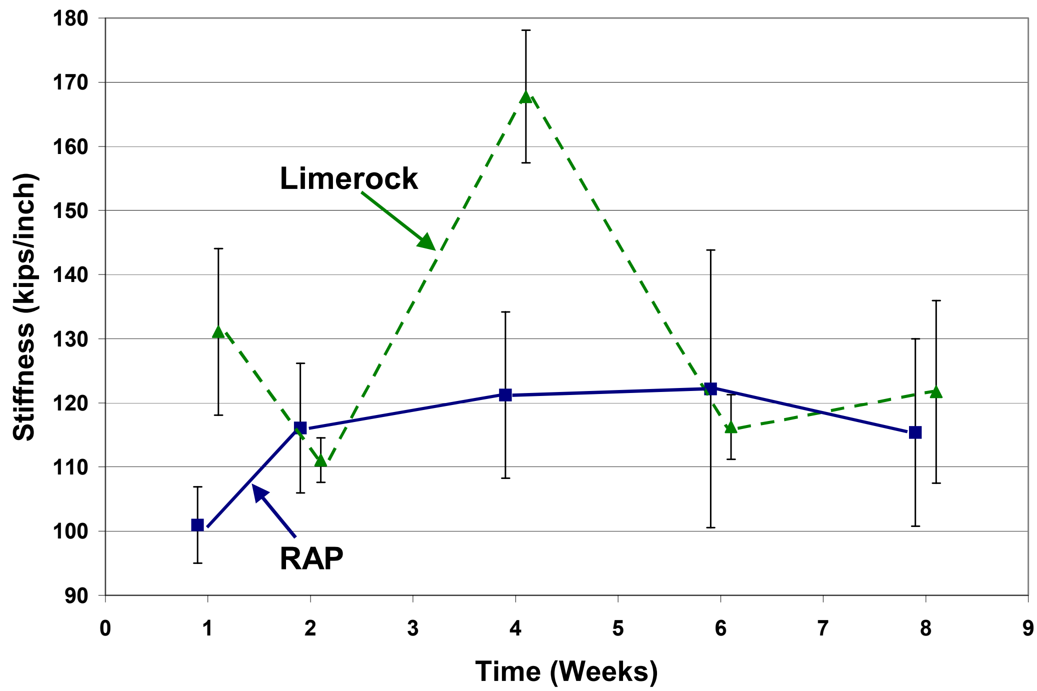



Figure 4.4 Stiffness vs. Time for RAP and Limerock

From week one to week two the stiffness of the RAP increased by 15% while the stiffness of the limerock decreased by 15%. The stiffness of the RAP continued to increase throughout week six and decreased slightly between weeks six and eight. Limerock had a more erratic behavior, decreasing and increasing between test intervals. During weeks two, six, and eight the RAP and limerock displayed approximately the same stiffness. At eight weeks the stiffness of RAP increased by 15% and the stiffness of the limerock decreased by 7% as compared to values at week one. A complete set of SSG data collected during this project is presented in Appendix E.

## 4.6 Field Limerock Bearing Ratio

Eight Limerock Bearing Ratio (LBR) tests were conducted on the RAP and three were conducted on the limerock each test interval. Figure 4.5 depicts the trends in LBR values throughout the first eight weeks following construction. Following construction the LBR values for RAP and limerock were 22 and 87 respectively. Throughout the eight weeks RAP never achieved an LBR value greater than 43. Limerock attained LBR values slightly greater than 100 during the week four and week six testing intervals. Following this peak period the LBR for limerock decreased by 38% due to moisture variations. From week one to week eight the LBR values of the RAP increased 55% as compared to a 31% decrease for the limerock, again indicating that RAP is less susceptible to moisture variations than limerock. Field LBR data is shown in Appendix F.

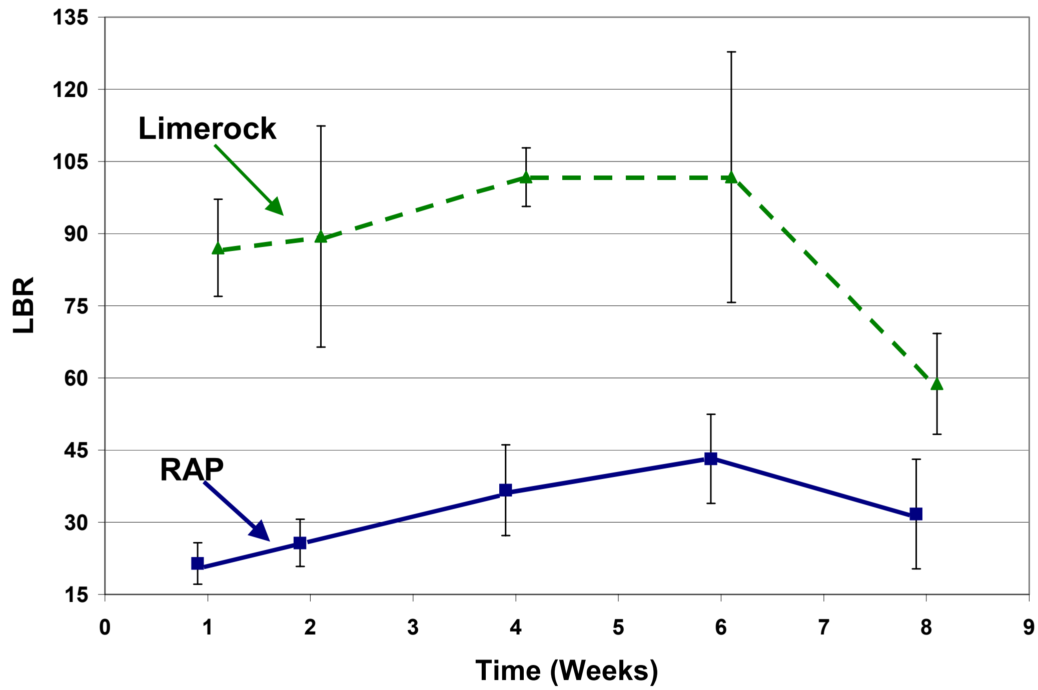



Figure 4.5 LBR vs. Time for RAP and Limerock

## 4.7 Comparisons Between Test Results

The previous sections showed the initial strength gains in RAP and limerock based on the FWD, Clegg, SSG, and LBR tests. In order to draw further conclusions from this data it was plotted as total percent increase versus test type, with the total increase being from week 1 to week 8. Figure 4.6 summarizes the strength variations from the field-testing at week eight.

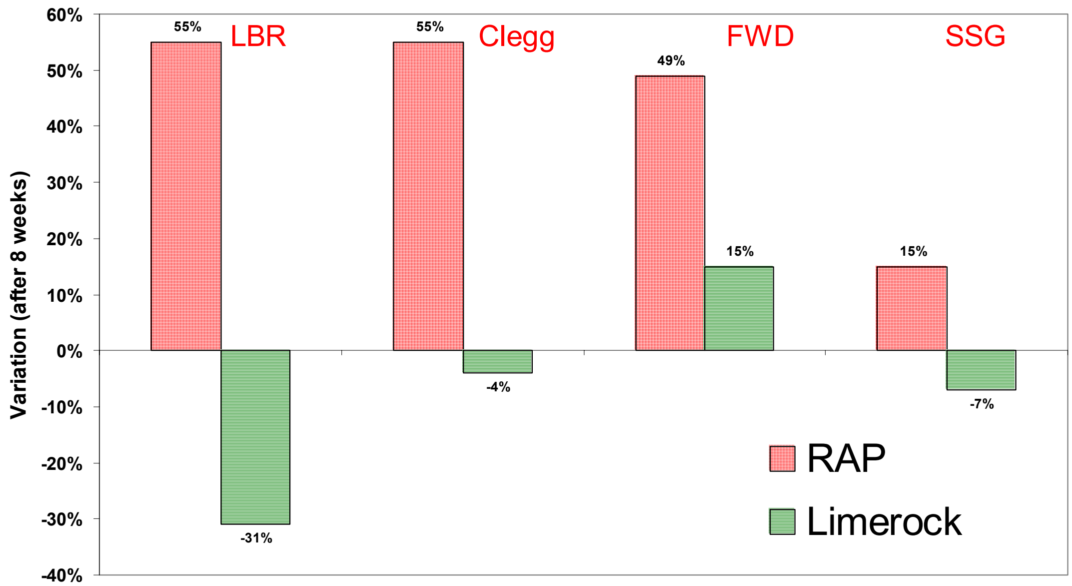



Figure 4.6 Strength and Stiffness Variations at Week 8 for RAP and Limerock

The LBR, Clegg, and FWD showed similar eight-week strength gains of 49 to 55 % in the RAP. SSG tests showed a 15% strength gain for RAP, which is nearly three times lower than the other tests. This may be due to the low strain levels of the SSG tests. The average strain level for the SSG tests performed over the eight weeks was 0.00032. The LBR, Clegg, and FWD tests produce higher strain levels.

As was the case when the individual plots were analyzed, the eight-week strength gains from limerock did not display the same consistency as the RAP data. The LBR, Clegg, and SSG tests showed strength decrease in the limerock of 31%, 3%, and 7% respectively, whereas, the FWD showed a strength increase of 15%.

In order to compare tests on the RAP material a ratio between the RAP and limerock test values was developed. The test value obtained for RAP was divided by the test value obtained for limerock. This ratio is plotted versus time in Figure 4.7.

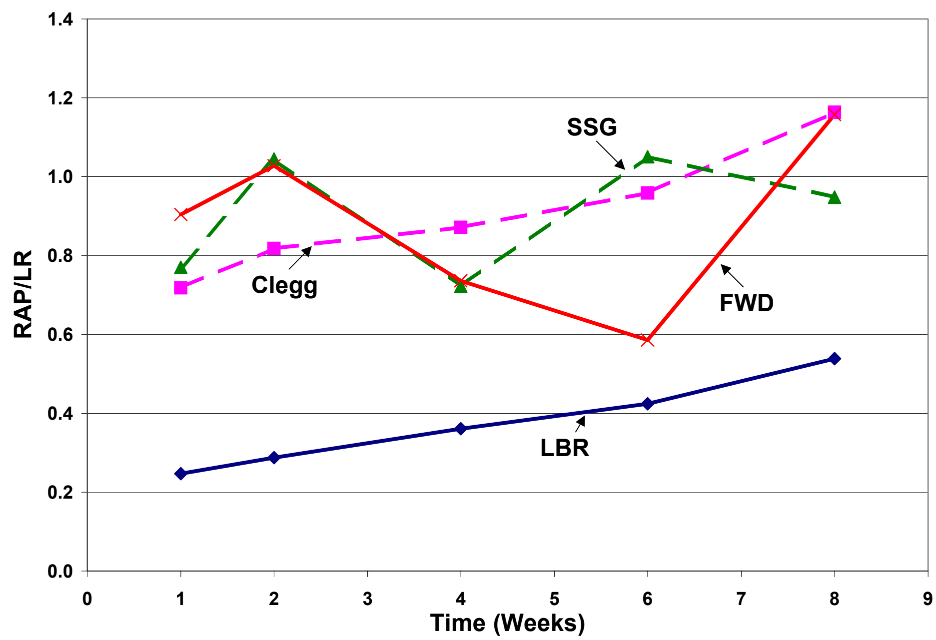



Figure 4.7 Ratio of Behavior in RAP to Behavior in Limerock

This field strength ratio showed that the LBR when compared to the Clegg, FWD, and SSG tests might not be properly representing the strength of the RAP. For instance, during week one, according to the LBR the RAP has 25% the strength of the limerock, whereas, the Clegg, FWD, and SSG are showing that the RAP is about 80% as strong as the limerock. This trend continues over the entire eight-week testing cycle. During week eight the LBR showed that the RAP is about 55% as strong as the limerock. Based on the FWD and Clegg tests during this same period the RAP is 18% stronger than the limerock while SSG tests show that the RAP and limerock are approximately equal in strength. Based on this ratio it can be concluded that the LBR tests underestimates the strength of RAP by a factor of three when compared to the Clegg, FWD, and SSG tests.

## 4.8 Density and Moisture Tests

Densities and moisture contents were determined by test methods FM 1-T 238 and FM 5-507 respectively. Upon completion of the field site the dry density of RAP was 118 pcf (1.89 g/cm$^3$) and the dry density of limerock was 114 pcf (1.83 g/cm$^3$). The RAP achieved higher densities than the limerock throughout the testing cycle. Subsequent tests showed little change in the density of RAP or limerock. Density can be depicted in terms of relative compaction. Relative compaction is defined as the ratio of the field dry density to the laboratory maximum dry density according to a specified standard test such as the standard or modified Proctor (Holtz and Kovacs, 1981). Maximum laboratory dry densities of 117 pcf (1.87 g/cm$^3$) for the RAP (Doig, 2000) and 116 pcf (1.86 g/cm$^3$s) for the limerock (Central Testing Laboratory, 2001) were reported. The relationship between relative compaction and time is shown in Figure 4.8.

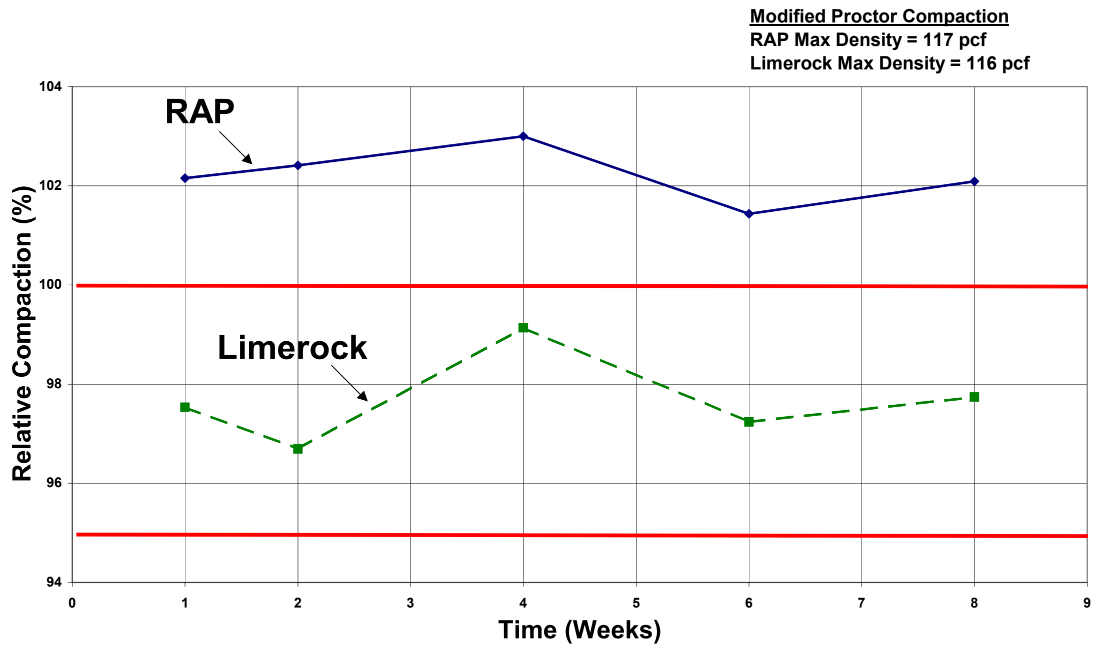



Figure 4.8 Relative Field Compaction vs. Time for RAP and Limerock

Relative compaction for RAP ranged from 101% to 103%. Limerock had an average relative compaction of 98% throughout the testing cycle. There were no noticeable changes in density over the eight-week testing cycle. It can be concluded that the same compaction effort will result in about 102% and 98% relative compaction for RAP and limerock respectively.

Moisture contents were taken each test cycle using the calcium carbide gas pressure moisture tester. Figure 4.9 shows the moisture contents versus time for the eight-week testing period.

The moisture content for RAP and limerock are based on an average of three tests. RAP's moisture content ranged between 3% and 4% and limerock's was between 7% and 9%. Density and moisture data collected throughout this investigation can be viewed in Appendix A.

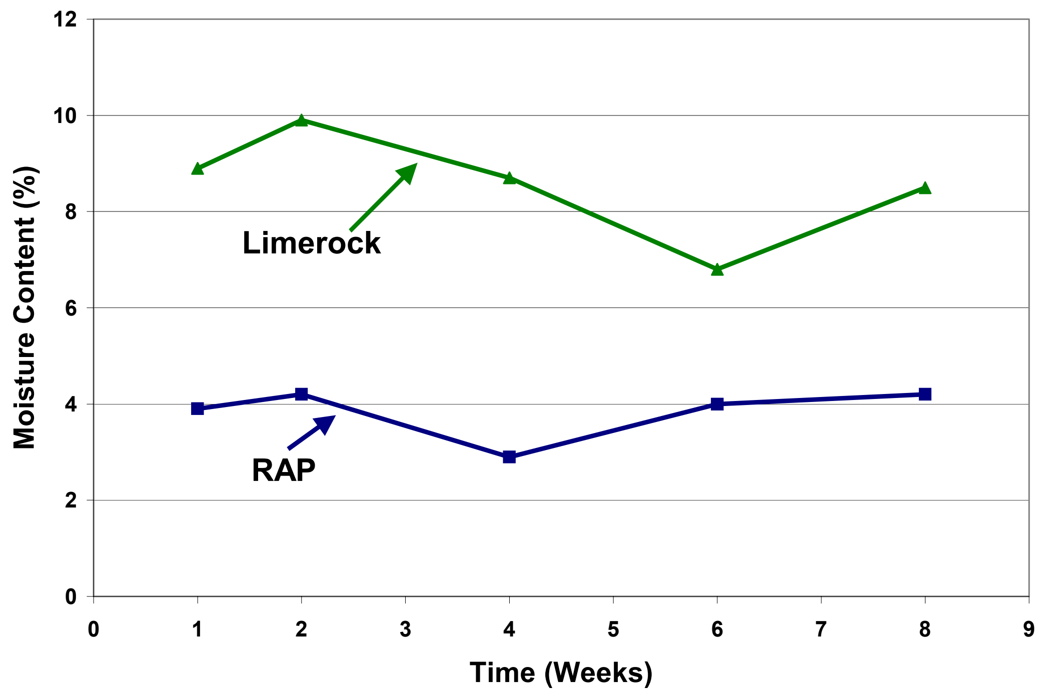



**Figure 4.9 Moisture Content vs. Time for RAP and Limerock**

# 4.9 Environmental Conditions

Air temperature and humidity were monitored throughout the eight-week testing cycle. Figure 4.10 displays this data. Between weeks one and six there was a steady increase in the daily high temperature, which is due to the transition between the spring and summer seasons. As expected the relative humidity also increased from spring to summer. The warmest period occurred between weeks six and eight. This period experienced average daily highs of 95$^{o}$F and lows around 70$^{o}$F. Relative humidity daily highs were slightly above 100% with lows in the mid 40% range. Daily high RAP surface and 6-inch depth temperatures are also included. Both data sets follow the same trend as the daily high ambient temperatures. Surface and 6-inch depth temperatures were consistently about 10$^{o}$F and 3$^{o}$F higher than the ambient temperature throughout the eight-week period.

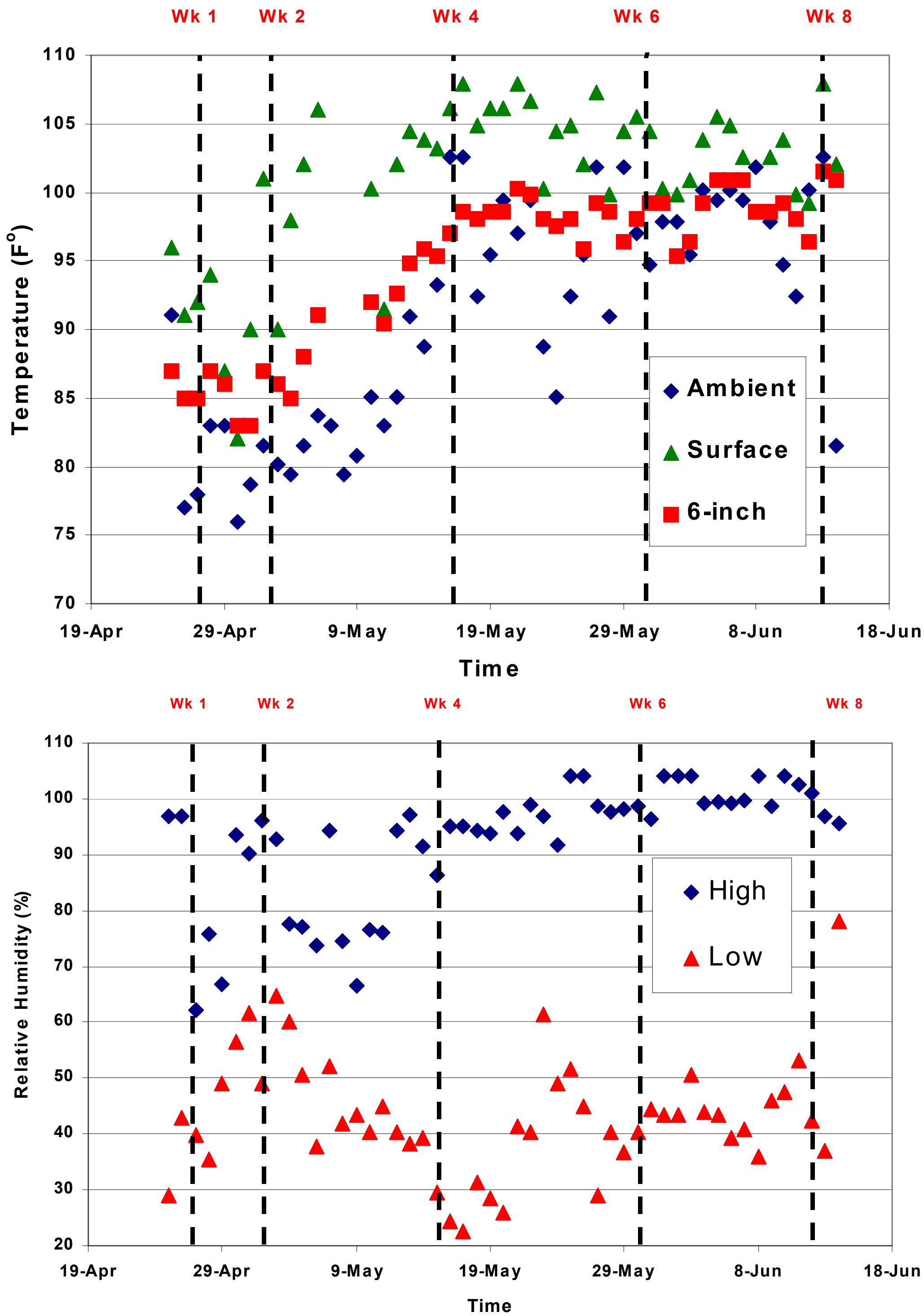



Figure 4.10 Daily High Temperatures and Relative Humidity vs. Time

# 4.10 Temperature Profiles

Previous research by Rodriquez (2001), Doig (2000) and Montemayor (1998) suggest that a relationship exists between temperature and the behavior of RAP. In-situ temperature monitoring took place over the course of this investigation using VEMCO mini-log temperature probes. Temperature profiles for the RAP were developed using this data by averaging the data over the initial eight-week study period. The average temperature profile is shown in Figure 4.11. One standard deviation error bars are also included in the plot. The temperature gradient (ΔT/ ΔZ) decreases linearly. The average temperature of the RAP decreases from 95°F at the surface to 89°F at a depth of 30 inches.

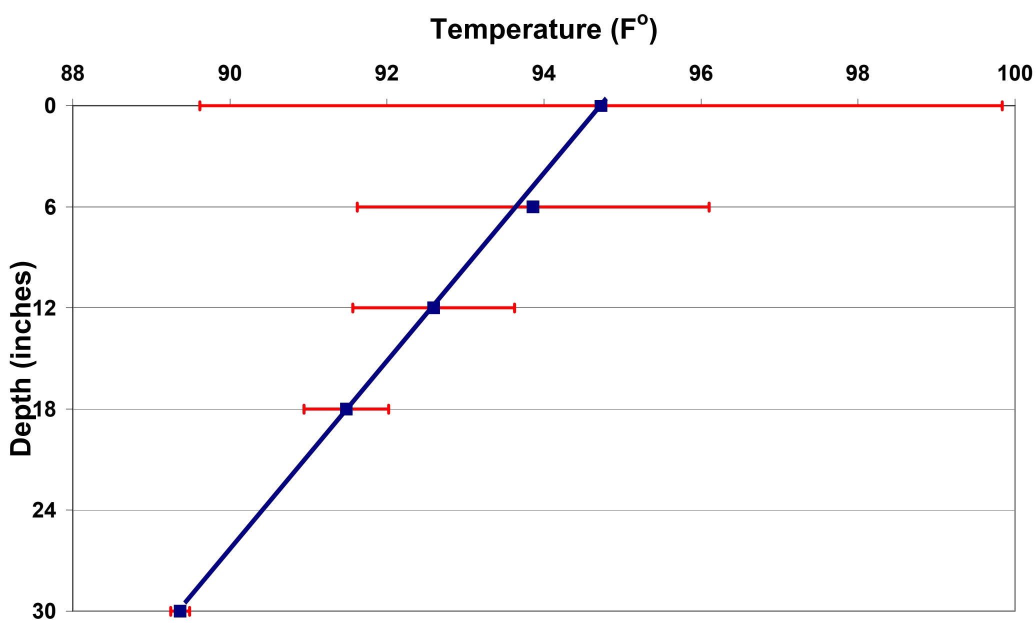
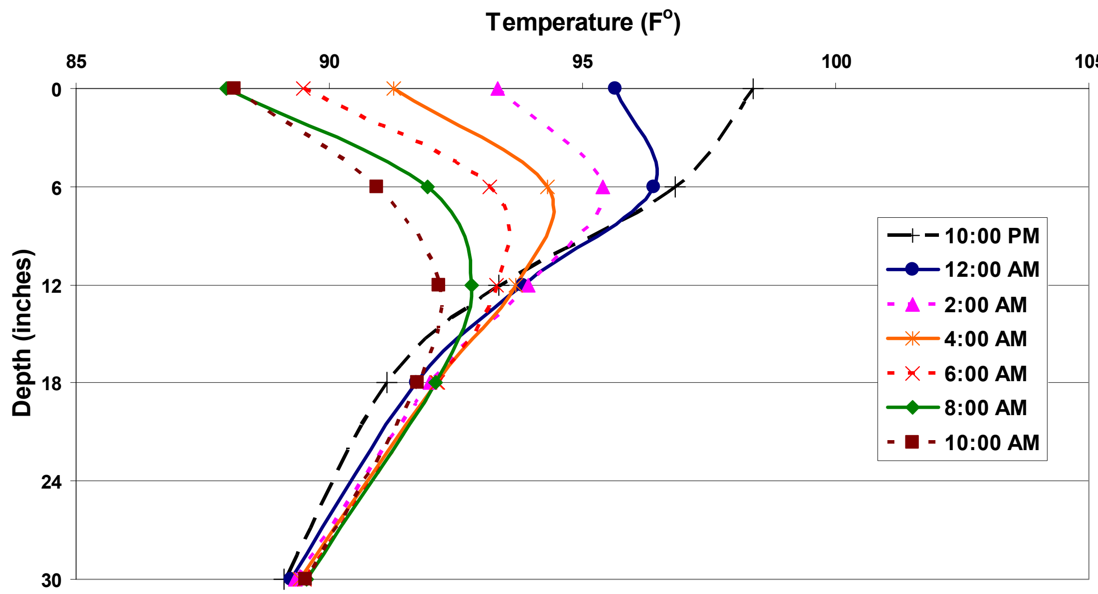



Figure 4.11 Average Temperature Profile for RAP (April 25 – June 14, 2001)

To gain a better understanding of the effects of temperature on RAP's behavior, one-day temperature profiles were developed. An average of the data taken over the eight-week period was used to construct these profiles. Figure 4.12 represents the temperature profile of the RAP from 10:00 pm to 8:00 pm. The upper plot shows the temperature profiles during the nighttime and morning hours (10:00 pm to 10:00 am). The lower plot shows the temperature profile during the afternoon and evening hours (12:00 pm to 8:00 pm). During the night and morning hours the surface temperature lags the temperatures taken at 6-inch and 12-inch depths by 3 to 4 degrees. Once the day begins to heat up the reverse of this phenomena takes place. The afternoon and evening hours show the surface temperature higher by 5 to 6 degrees than the 6-inch and 12-inch depth temperatures. This effect can be seen by looking at the directional change of the curves in the upper and lower plots. Below 18-inches of depth the profiles are nearly identical. The conclusion can be made that the effects of diurnal temperature changes are minimal below a depth of 18 inches.

Correlations between surface temperature and strength data from the Clegg, FWD, LBR, and SSG tests results produced correlation coefficients ($r^2$) of 0.83, 0.78, 0.67, and 0.42 respectively. These plots are presented in Appendix G. This behavior may be attributed to the properties of asphalt binder. During the eight week testing cycle surface temperatures increased from 85$^{o}$F to 105$^{o}$F during testing. The asphalt binder used in hot mix asphalt production is highly dependent on temperature. At temperatures between 160 to 300$^{o}$F, asphalt behaves as a viscous liquid. Below 160$^{o}$F, the behavior can be described as linearly viscoelastic (Somayaji, 2001). This means that RAP strength should decrease with temperature, however, an increase in RAP strength occurred. The temperatures experienced at the field site may not be high enough to cause a dramatic weakening of the RAP. This strengthening of the material may be a function of time as well as temperature. Asphalt is a polymer, which means it has a high coefficient of thermal expansion. The cyclic nature of the temperature, heating and cooling between daytime and nighttime, may be causing strain hardening in the material. As the asphalt is expanding, strain is being exerted on the surrounding material, causing it to both stiffen and strengthen. Another phenomenon that may be taking place is age hardening. When a sample of asphalt is heated and then allowed to cool, its molecules will be rearranged to form a gel-like structure, causing it to harden with time (Somayaji, 2001). This may be the reason that the strength of RAP is increasing with temperature as opposed to decreasing.



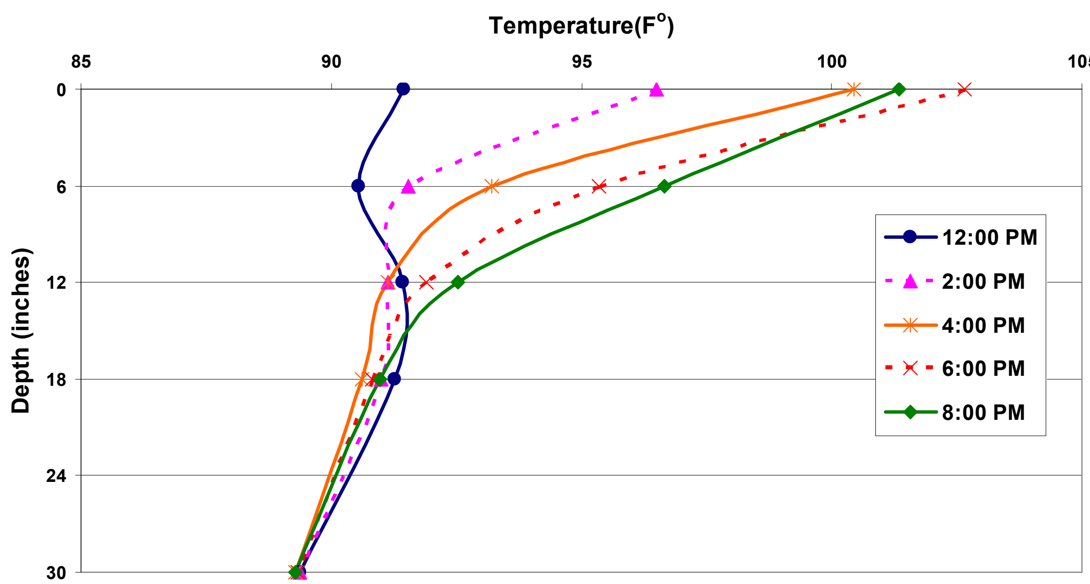




Figure 4.12 Bi-hourly Temperature Profiles for RAP (April 25–June 14, 2001)

## 4.11 Dry Rodded Unit Weight of RAP-Soil Mixtures

The relationship between unit weight and RAP-soil mixtures was initially evaluated through dry rodded unit weight tests. The objective of these tests was to characterize the effects of soil mixtures on the unit weight and use the results to aid in the selection of mixtures to be used for further investigation. This test was relatively quick and consumed less material as compared to standard compaction procedures. Tests were conducted starting with a sample of 100% RAP and incrementally adding the required amount of fine sand (i.e. material passing the #40 sieve size) to obtain the desired mix proportions. The results are shown in Figure 4.13. A maximum unit weight was achieved for a mixture of 80% RAP - 20% soil. The unit weight was improved by approximately 7 lb/ft$^3$ or 7.5% from a 100 to an 80% RAP sample, and 3.4 lb/ft$^3$ from a 60 to 80% RAP sample. The largest changes in unit weight occurred for samples containing 60 to 70 and 100 to 85 percent RAP, while minimal changes in unit weight occurred for mixtures containing 70 to 85 percent RAP. Based on these findings, RAP-soil mixtures containing 60, 80, and 100% RAP were selected for further investigation. A mixture yielding a maximum density was achieved for an 80% RAP mixture and the 60% RAP mixture was selected to investigate the behavior of RAP-soil mixtures over a broader range. Additional investigation of mixtures from 0 to 60% RAP were considered to be unnecessary as a secondary objective was to utilize the maximum amount of RAP. The sample preparation procedure for the fine sand also proved to be very time consuming and labor intensive.

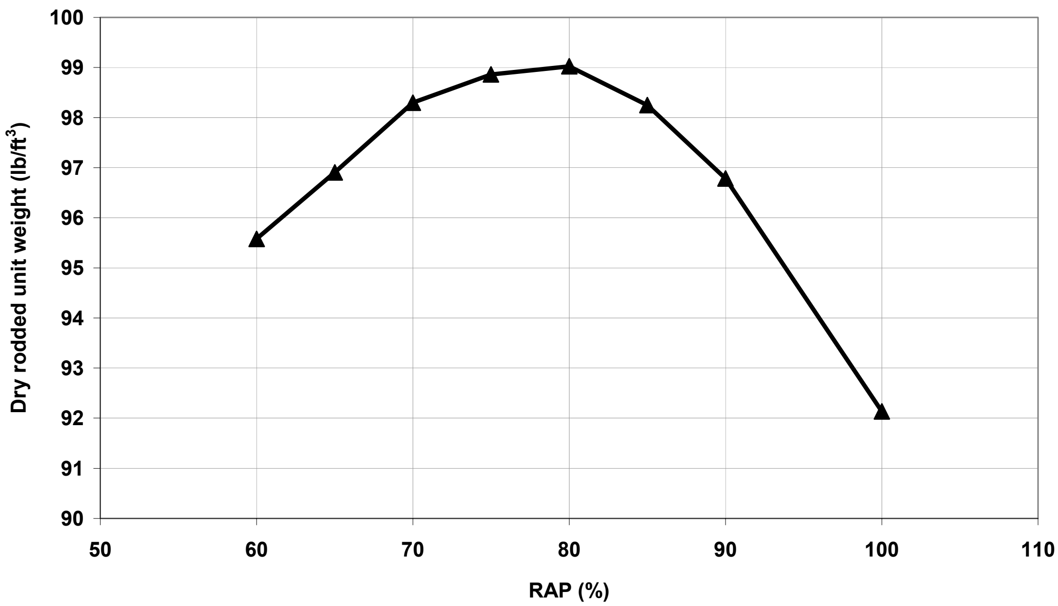


Figure 4.13 Dry rodded unit weight of RAP-soil mixtures

## 4.12 Physical Properties of RAP-soil Mixtures

The grain-size distributions of the RAP obtained from the field and the fine sand are shown in Figure 4.14. The RAP field material classified as an A-1-a and GW soil according to the American Association for State Highway and Transportation Officials (AASHTO) and Unified Soil Classification System (USCS) respectively. The fine sand classified as an A-2-6 soil according to AASHTO classification standards and as an SP-SC according to USCS. The gradation curve of the RAP field material falls within the ranges specified for graded aggregate (GA) base material (Figure 4.14) in section 204-2 of the *Standard Specifications for Road and Bridge Construction* (FDOT 2000).

The RAP-field material shows characteristics of a gap-graded soil, lacking particles in the 2.36 to 0.60 mm and 0.25 to .075 mm range. A set of RAP gradation data of various investigations were collected and combined to show the variations in RAP gradation. The upper and lower ranges are presented in Figure 4.15. The upper range corresponds to the investigation conducted by Chesner et al. (1998) and the lower range was a combination of work by Sayed et al. (1993) and Taha et al. (1999). In general, the gradation curves presented by various investigations show the RAP to have characteristics of a gap-graded material.

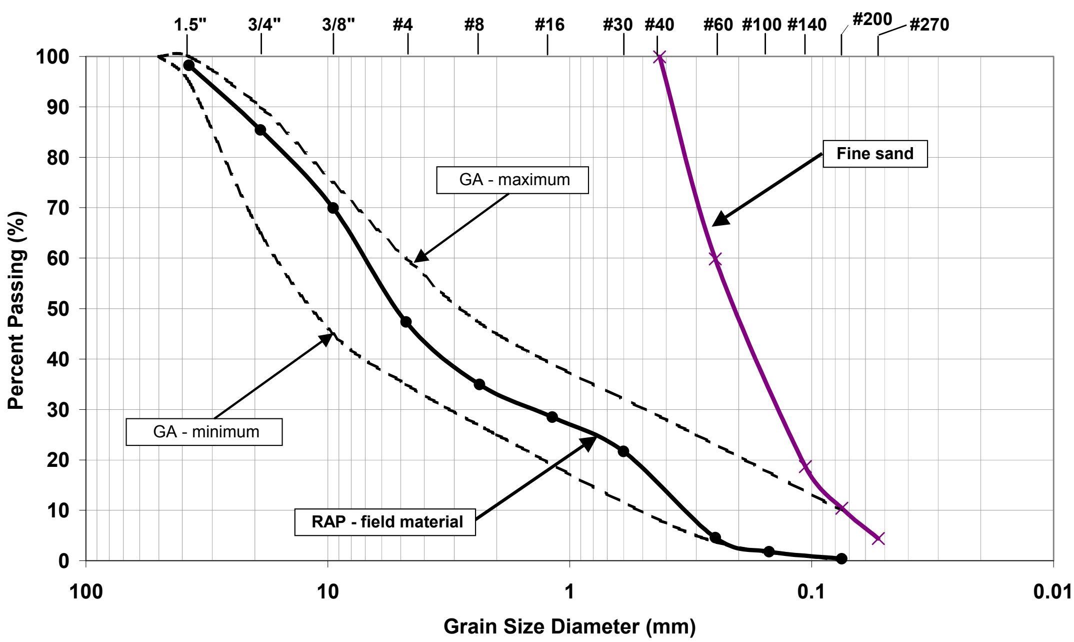



Figure 4.14 Grain-size distribution of RAP field material and fine sand (GA – graded aggregate base material)

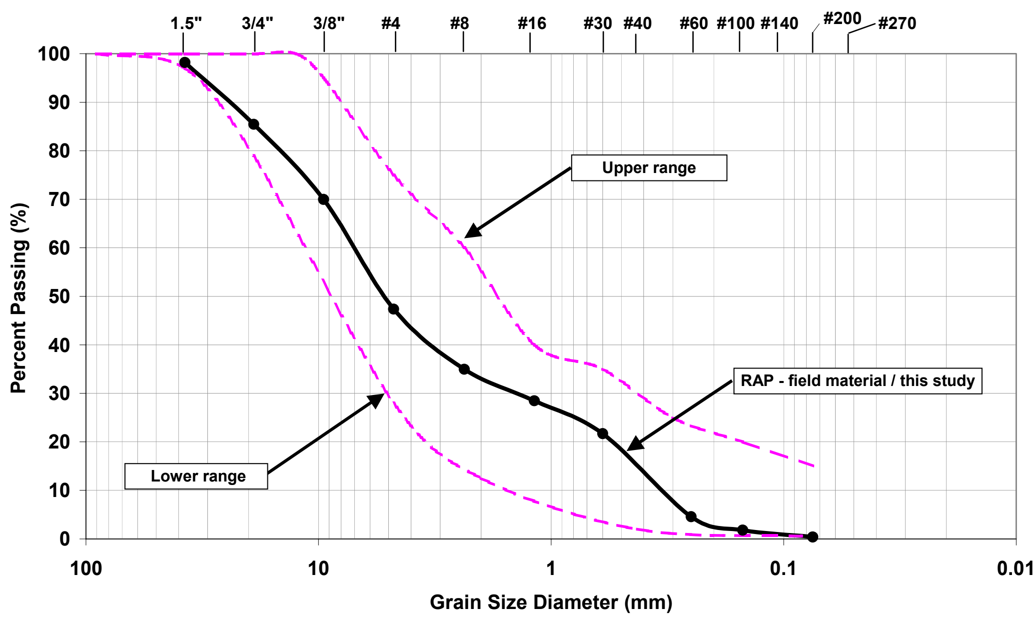



Figure 4.15 Variations in grain-size distribution of RAP from several investigations

Composite grain size distribution curves representing 60 and 80% RAP mixtures were developed from RAP field material and fine sand gradation results using a combination of analytical and graphical procedures. This was done because no sieve analyses were performed on mixtures containing actual RAP field material. The results are presented in Figure 4.16. Most of the 80% RAP mixture falls within the specified range except between the grain sizes from 0.35 to 3 mm that have a slightly higher percent passing. The 60% RAP mixture falls outside the range except for the larger (25 – 37.5 mm) and smaller (0.2 – 0.075 mm) particle sizes.

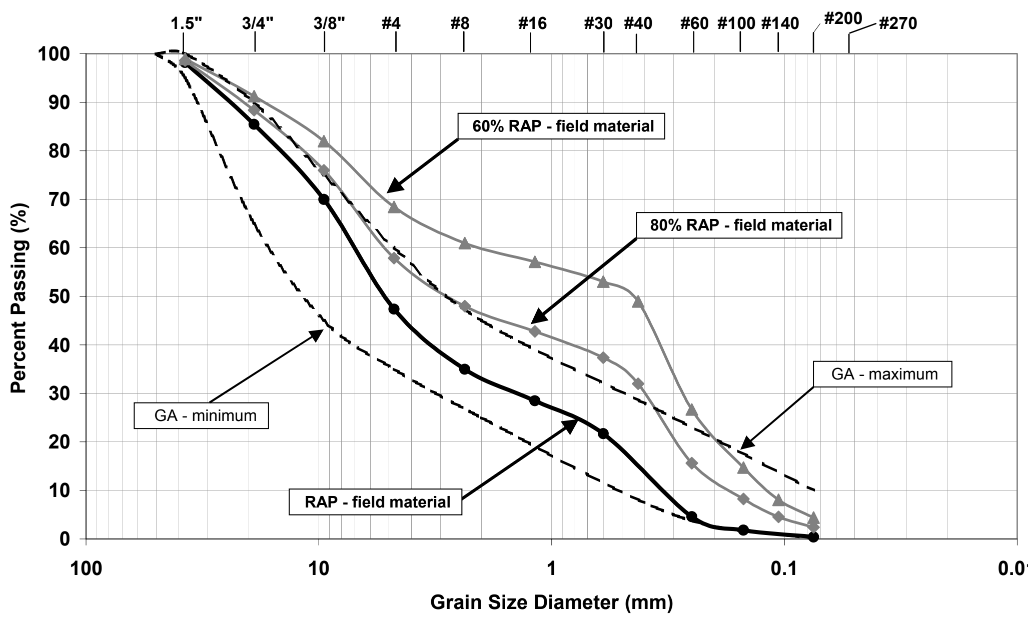



Figure 4.16 Composite gradation of RAP-soil mixtures developed using a combination of analytical and graphical procedure (GA – graded aggregate base material)

The RAP and RAP-soil mixtures used for laboratory testing consist of material passing the ¾ inch sieve (modified for testing) and do not represent field conditions. Their gradation curves are shown in Figure 4.17. The percent material passing the #40 sieve for the 60 and 80% RAP mixtures increased by 28 and 14% respectively relative to the 100% RAP. The addition of the fine sand increased the overall percent passing of the 100% RAP and changed the AASHTO classification from an A-1-a to an A-1-b for the RAP-soil mixtures. A summary of the gradation characteristics of RAP, RAP-soil mixtures, and fine sand based on dry sieve analysis are presented in Table 4.2.

Results pertaining to the specific gravity, asphalt content, and organic content are listed in Table 4.3. The RAP used in this study had a specific gravity of 2.19, which is slightly lower than results obtained from other studies.

Montemayor (1998) and Clary et al. (1997) reported specific gravity values of 2.27 and 2.38 respectively. The specific gravity of the mixtures increased with the addition of fine sand. The asphalt content of RAP falls within the range of most old pavements comprising of approximately 3 to 7 percent by weight (Chesner, et al. 1998). The fine sand had a dark grayish color and an organic content of 3.19%. The fine sand samples used for determining the organic content had a white color after completion of the organic content test.

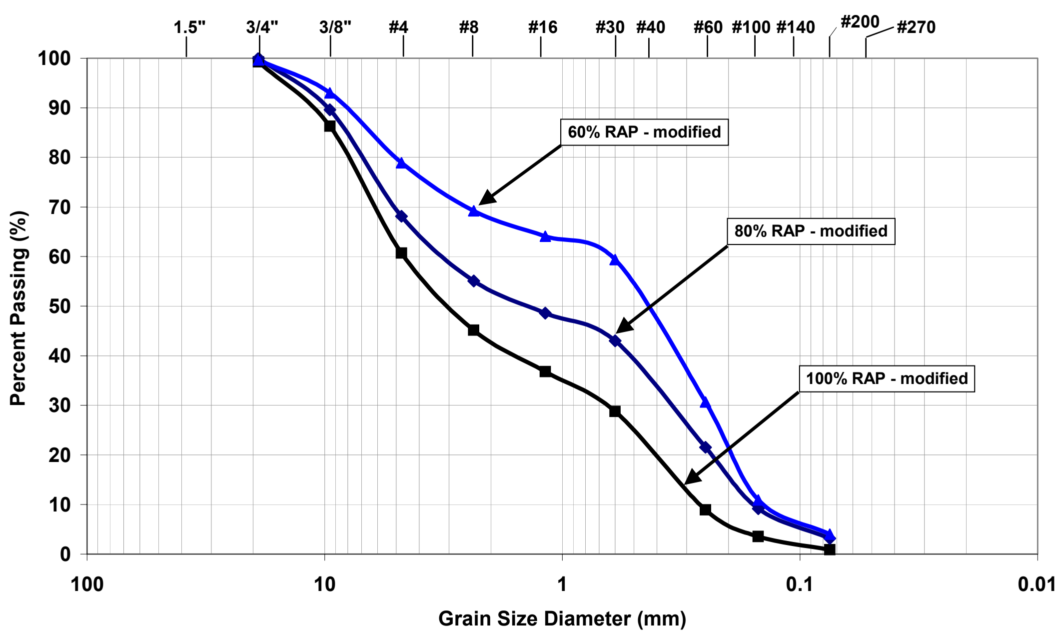



Figure 4.17 Grain-size distribution of the RAP and RAP-soil mixtures used for laboratory testing

Table 4.2 Summary of gradation parameters based on dry sieve analysis

| | RAP field material[a] | 100% RAP modified[b] | 80% RAP modified[b] | 60% RAP modified[b] | Fine sand[c] |
|---|---|---|---|---|---|
| $D_{10}$ (mm) | 0.33 | 0.27 | 0.17 | 0.15 | 0.074 |
| $D_{30}$ (mm) | 1.5 | 0.65 | 0.35 | 0.25 | 0.15 |
| $D_{60}$ (mm) | 7 | 4.7 | 3.3 | 0.62 | 0.26 |
| Cu | 21 | 17 | 19 | 4.1 | 3.5 |
| Cc | 1.0 | 0.3 | 0.2 | 0.7 | 1.2 |
| LL | - | - | - | - | 39 |
| PI | - | - | - | - | 15 |
| % passing #40 sieve size | 15.0 | 21.0 | 35.0 | 49.0 | 99.9 |
| % passing #200 sieve size | 0.4 | 0.9 | 3.1 | 4.0 | 10.4 |
| USCS classification | GW | SP | SP | SP | SP-SC |
| AASHTO classification | A-1-a | A-1-a | A-1-b | A-1-b | A-2-6 |

[a] : material having a 1.5 inch maximum size
[b] : material having a 3/4 inch maximum size
[c] : material passing the #40 sieve
- : not determined

Table 4.3 Specific gravity, asphalt content, and organic content results

| | 100% RAP modified[b] | 80% RAP modified[b] | 60% RAP modified[b] | Fine sand[c] |
|---|---|---|---|---|
| Specific Gravity | 2.19 | 2.25 | 2.37 | 2.64 |
| Asphalt Content (%) | 5.24 | - | - | - |
| Organic Content (%) | - | - | - | 3.19 |

[b] : material having a 3/4 inch maximum size

[c] : material passing the #40 sieve

- : not determined

# 4.13 Engineering Properties of RAP-Soil Mixtures

## 4.13.1 Moisture-Density

The moisture-density relationships of the RAP-soil mixtures obtained using modified Proctor compaction effort are presented in Figures 4.18 through 4.21. The 100% RAP material achieved a maximum density of 117.8 lb/ft$^3$ at an optimum moisture content of 8.0%. Montemayor (1998) reported an average maximum density of 111.5 lb/ft$^3$ at an approximate moisture content of 7.0%. He also reported that no well-defined peak was obtained from the moisture-density results, which agrees with the findings from this investigation. Chesner et al. (1998) reported compacted unit weights of RAP in the range of 100 to 125 lb/ft$^3$ and maximum moisture contents in the range of 7 to 8%.

For the 80% RAP mixture, a maximum dry density of 121.7 lb/ft$^3$ was achieved at an optimum water content of 6.0%. This corresponds to an increase of approximately 4 lb/ft$^3$ or 3.3%. The 60% RAP mixture yielded a maximum density of 121.2 lb/ft$^3$ at an optimum water content of 7.8%. It can be observed that the compaction curves had a better defined peak as more fine sand was added to the RAP. The change in characteristics of the RAP-soil compaction curves is best observed in Figure 4.21.

The specific gravity results (Table 4.3) were used in an attempt to plot the zero air voids curve of the RAP and RAP-soil mixtures, however, the zero air voids curve of the RAP and 80% RAP mixture intersected their respective compaction curves. Only for the 60% RAP mixture was the zero air voids curve to the right of its corresponding compaction curve. As the percentage of RAP in the mixtures decreased, the zero air voids curve shifted to the right in relation to their corresponding compaction curves. The specific gravity of the RAP and RAP-soil mixtures were determined based on testing procedures for aggregates and soils. Air trapped in the asphalt and between the asphalt-aggregate interface could have increased the overall volume, resulting in lower specific gravity values. It is recommended that procedures for determining the specific gravity of bituminous materials be followed in order to obtain accurate results.

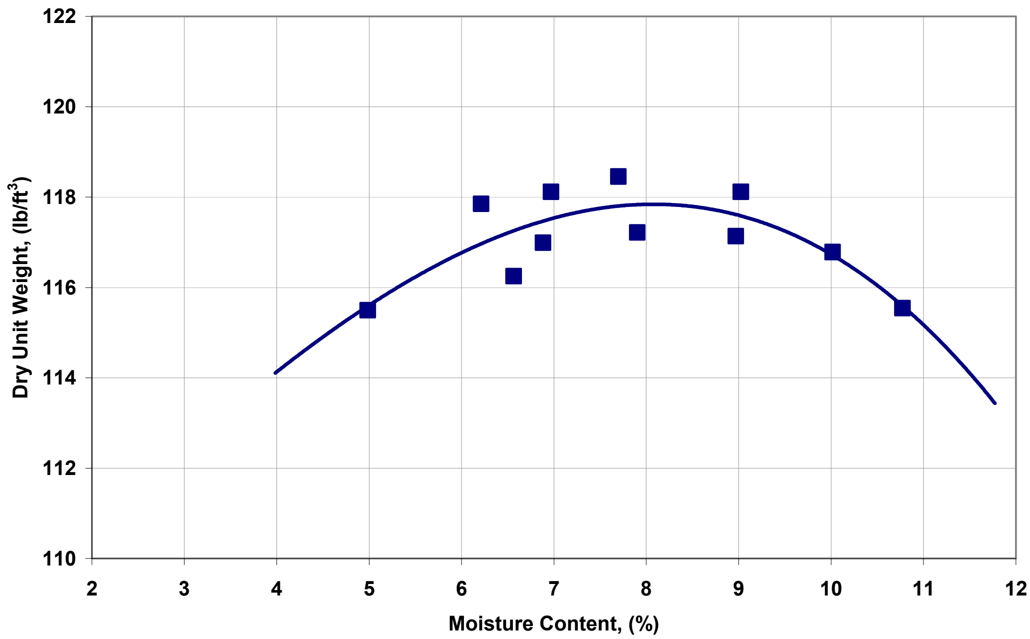



Figure 4.18. Moisture-Density curve of 100% RAP

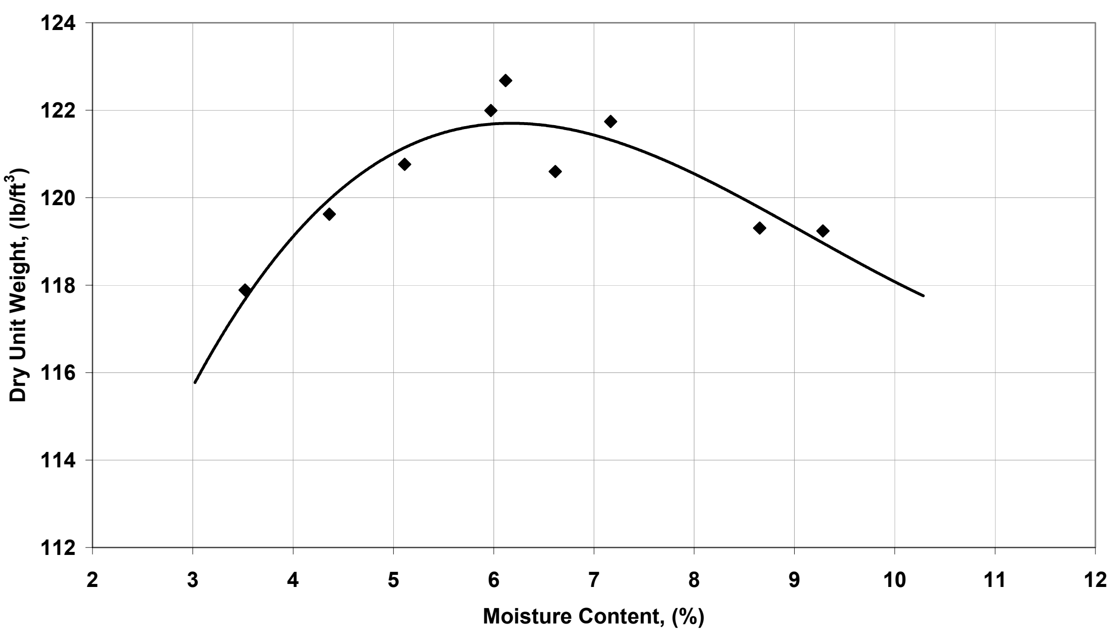



Figure 4.19. Moisture-Density curve of 80% RAP

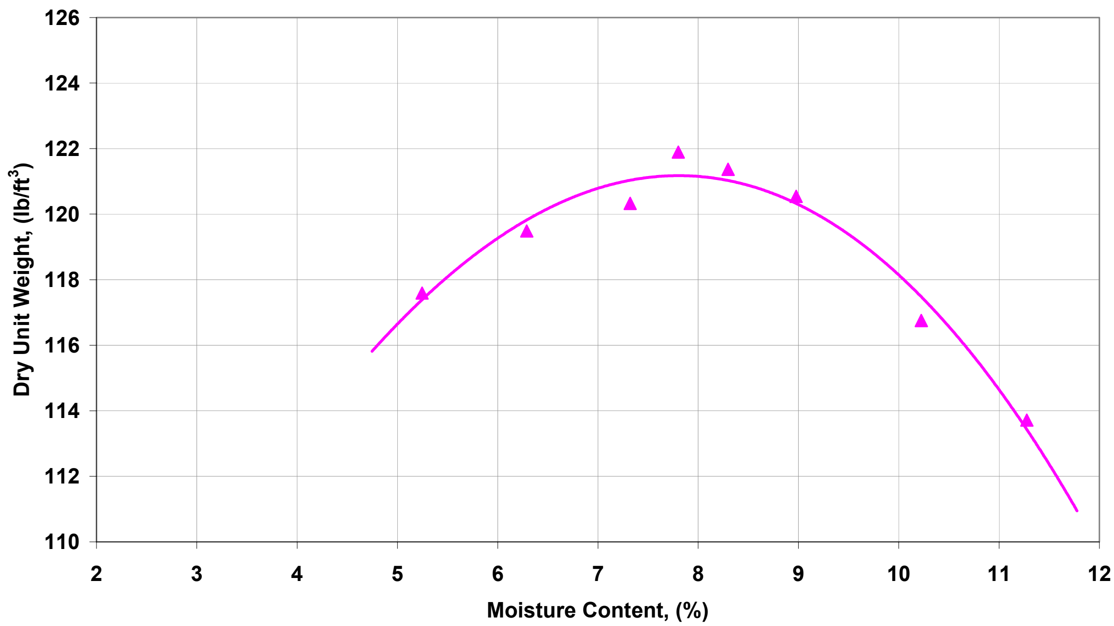



Figure 4.20. Moisture-Density curve of 60% RAP

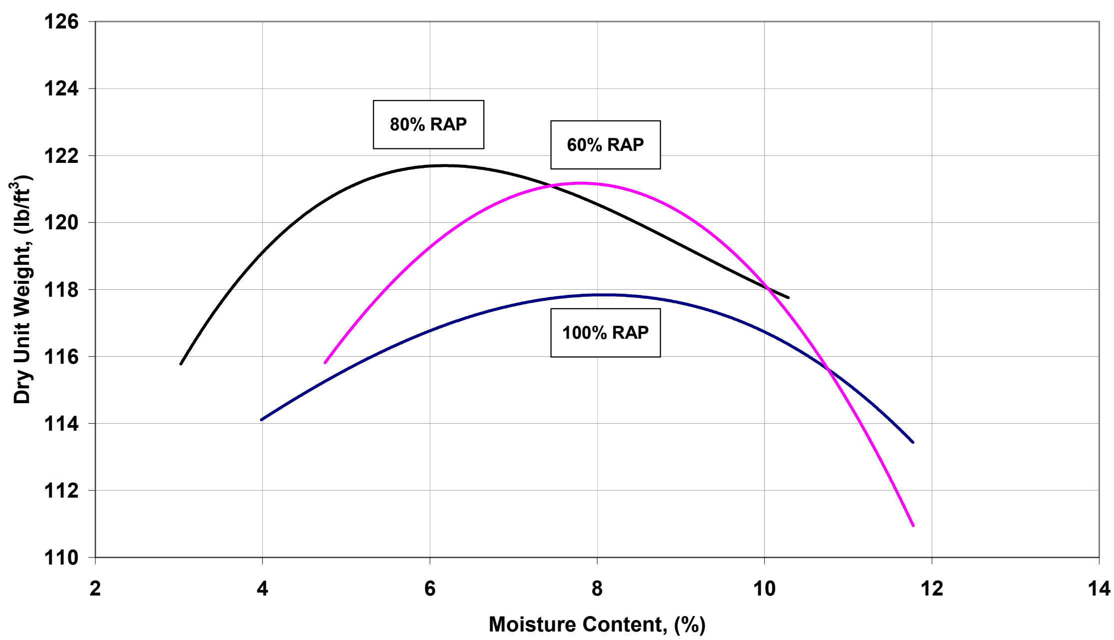



Figure 4.21. Moisture-Density curves of the RAP-soil mixtures

The maximum densities achieved for each mixture follow a similar trend as reported for the results obtained from the dry rodded unit weight tests (Figure 4.13). The 80% RAP mixture yielded the maximum density, followed by the 60% RAP mixture and the 100% RAP respectively.

The relationship between maximum dry unit weight and the percent material passing the #40 sieve size present in the RAP-soil mixtures is presented in Figure 4.22. Since the RAP-soil mixtures attained a maximum dry unit weight at 80% RAP, the optimal percent passing to achieve maximum density for the mixtures tested is about 35% for the #40 sieve size. An increase in the material passing the #40 sieve size increased the density until an optimal level was achieved; further increase caused a slight decrease in density. Changes in density were more pronounced below the optimal percent passing (i.e. 35%) the #40 sieve size.

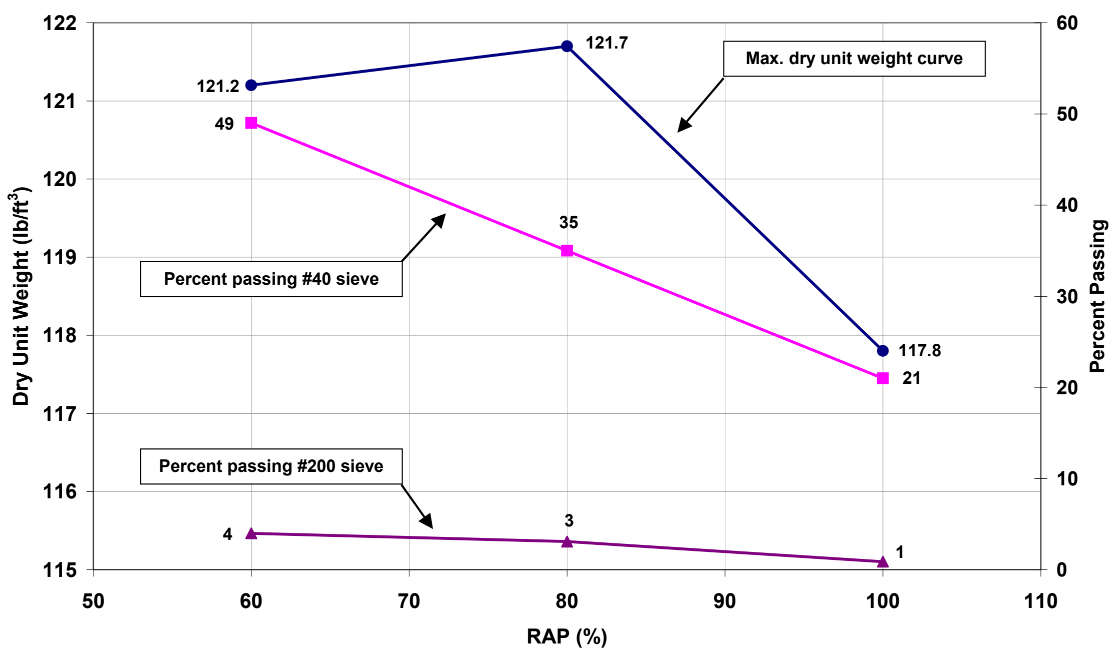



Figure 4.22. Dry unit weight – gradation relationship of RAP-soil mixtures

### 4.13.2 Permeability

The permeability test results for the RAP and RAP-soil mixtures are presented in Figure 4.23. Permeability of the RAP and RAP-soil mixtures remained relatively constant with changes in hydraulic gradient. The average permeability of the 100, 80, and 60% RAP mixtures were $2.0 \times 10^{-4}$, $3.1 \times 10^{-5}$, and $1.8 \times 10^{-6}$ cm/s respectively. Figure 4.24 shows the average permeability in relation to the RAP percentage in the mixtures. For the range examined, the permeability decreased approximately by one order of magnitude for each increment of added fine sand.

Casagrande and Fadum (1940) report a permeability of $1 \times 10^{-4}$ cm/s as an approximate boundary between soils providing good and poor drainage under low hydraulic gradients. Based on this, RAP is classified as a material providing good drainage while the RAP-soil mixtures classify as a poorly drained soil. The amount of fines (material passing the #200 sieve) present affects the drainage characteristics of a material. Added fines fill the intergranular voids; reducing the effective pore size, thereby increasing friction and restricting flow through a material. The RAP and RAP-soil mixtures had between 1 to 4% material passing the #200 sieve as determined by dry sieve analysis. According to Barksdale (1991) a base material is not free draining if the amount of material passing the #200 sieve is more than about 2%. Investigation by Blanco et al. (2003) on the laboratory and in-situ permeability of base materials in Missouri revealed that the average permeability of the base materials were 1000 times lower than typically required for good drainage. The laboratory permeabilities ranged from $9 \times 10^{-2}$ to $3 \times 10^{-7}$ cm/s and the in-situ permeabilities ranged from $2 \times 10^{-3}$ to $4 \times 10^{-5}$ cm/s. Average values for the percent fines (material passing the #200 sieve) determined by the dry sieve method and by the wet sieve method were found to be 4 and 15 percent respectively (Blanco et al. 2003).

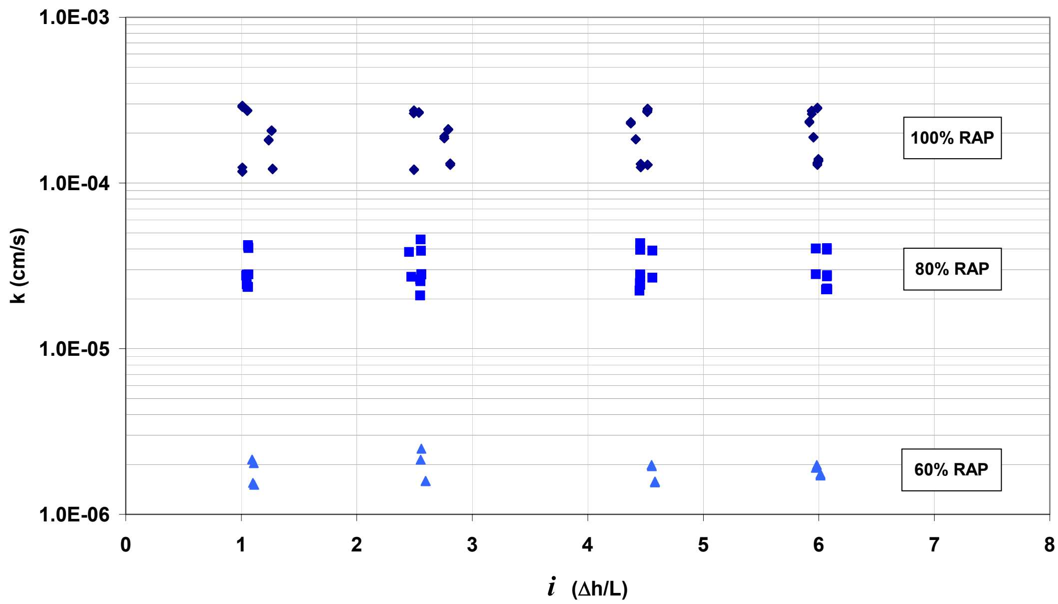



Figure 4.23 Permeability vs. hydraulic gradient of RAP and RAP-soil mixtures

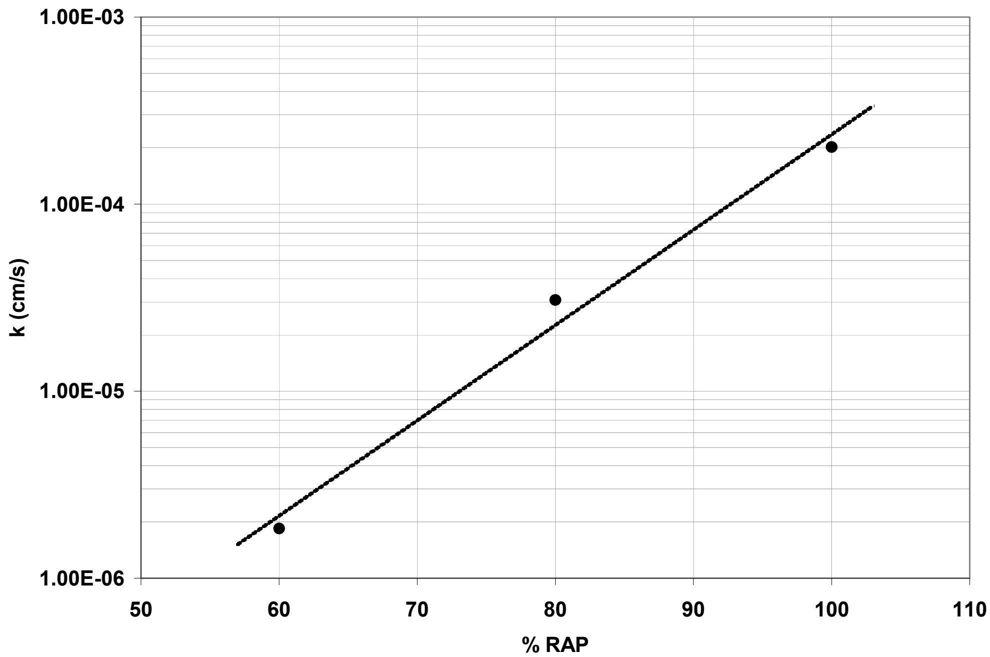



Figure 4.24 Permeability vs. percent RAP for RAP-soil mixtures

### 4.13.3 Limerock Bearing Ratio

Density is usually an indicator of the strength and stability of granular soil material. Densely compacted materials demonstrate higher strengths with less deformation than the same loosely compacted materials. The strength of the RAP-soil mixtures as measured by the LBR test are presented in Figures 4.25 and 4.26. LBR results of samples tested as base material are shown in Figure 4.25. All the samples tested were below the minimum LBR requirement of 100 for base material. The relative compaction of all base samples for LBR testing were close to 100 percent. The average density, LBR, and relative compaction are summarized in Table 4.4. The addition of fine sand resulted in an increase in density, but the most significant improvement was obtained in the LBR. The addition of 20% fine sand yielded an increase in density of 3.7% while the LBR improved by 111% relative to 100% RAP. Additions of 40% fine sand resulted in a 1.8% increase in density and a 54% improvement in LBR relative to 100% RAP.

To investigate whether the increases were due to either density or grain size distribution, additional tests were conducted on three 100% RAP samples compacted at twice the modified Proctor compaction effort (double-modified Proctor). The samples compacted using double-modified Proctor energy displayed densities comparable to the 60% RAP samples, however, the LBR increased only 17%. From these additional tests it can be concluded that the major improvements in LBR are due to the added fine sand, and not because of slight increases in density. This demonstrates that the LBR can be improved more significantly by the addition of fine sand (i.e. material passing the #40 sieve size) rather than by increases in density due to doubling the compaction effort.

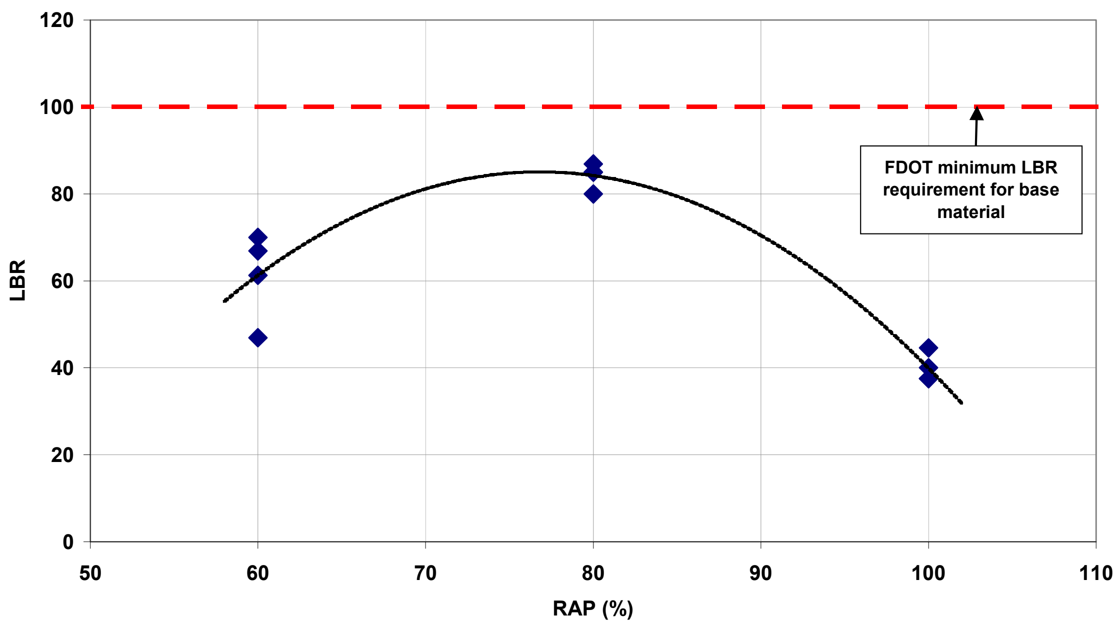



Figure 4.25 LBR vs. percent RAP of RAP-soil mixtures tested as base material

Table 4.4 Density, LBR, and relative compaction of RAP-soil mixtures tested as base material

| | Compactive Effort (ft-lb/ft$^3$) | Moisture content (%) | | Density (lb/ft$^3$) | | | LBR | | | R.C. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ave. | stdv. | ave. | stdv. | % improvement | ave. | stdv. | % improvement | |
| 100% RAP | 56,000 | 7.8 | 0.43 | 117.6 | 0.75 | - | 39.9 | 3.35 | - | 99.8 |
| 80% RAP | 56,000 | 6 | 0.08 | 121.9 | 0.77 | 3.7 | 84.2 | 2.96 | 111 | 100.2 |
| 60% RAP | 56,000 | 8 | 0.17 | 119.7 | 1.49 | 1.8 | 61.3 | 10.24 | 54 | 98.8 |
| 100% RAP | 112,000 | 8 | 0.18 | 120.0 | 0.32 | 2.0 | 46.7 | 6.06 | 17 | na |

ave. : average
stdv. : standard deviation
- : % improvement was determined relative to the 100% RAP results
R.C. : Relative Compaction
na : not available

LBR results of RAP and RAP-soil mixtures tested as subgrade material are shown in Figure 4.26. All the samples were at or above the minimum LBR requirement of 40 for subgrade material. The relative compaction of all subgrade samples for LBR testing was close to 100 percent. The average density, LBR, and relative compaction are summarized in Table 4.5. The behavior of the RAP and RAP-soil mixtures tested as subgrade materials were similar to the base material and a similar trend was observed in the improvement of density and LBR. The addition of 20% fine sand increased the density by 3.4% and improved the LBR by 99% relative to 100% RAP. Additions of 40% fine sand yielded a 1.2% increase in density and a 36% improvement in LBR relative to 100% RAP. The addition of minus #40 sieve size particles (i.e. fine sand) resulted in significant increases in LBR, similar to increases of the RAP and RAP-soil mixtures tested as base material.

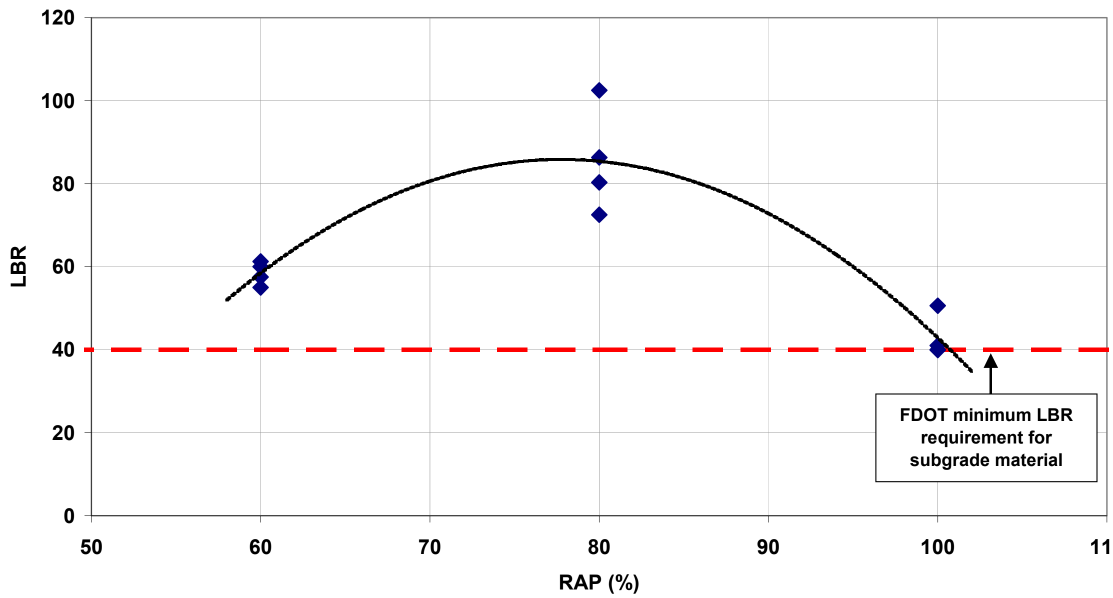



Figure 4.26 LBR vs. percent RAP of RAP-soil mixtures tested as subgrade material

Table 4.5 Density, LBR, and relative compaction of RAP-soil mixtures tested as subgrade material

| | Moisture content (%) | | Density ($lb/ft^3$) | | | LBR | | | R.C. |
|---|---|---|---|---|---|---|---|---|---|
| | ave. | stdv. | ave. | stdv. | % improvement | ave. | stdv. | % improvement | (%) |
| 100% RAP | 8 | 0.33 | 117.7 | 0.26 | - | 42.9 | 5.17 | - | 99.9 |
| 80% RAP | 6.4 | 0.7 | 121.7 | 1.87 | 3.4 | 85.4 | 12.72 | 99 | 100.0 |
| 60% RAP | 8 | 0.31 | 119.1 | 2.02 | 1.2 | 58.4 | 2.77 | 36 | 98.3 |

ave. : average
stdv. : standard deviation
- : % improvement was determined relative to the 100% RAP results
R.C. : Relative Compaction

### 4.13.4 Static Triaxial Compression

The strength of the RAP and RAP-soil mixtures was also measured by triaxial compression tests. Stress-strain curves were developed for each sample to determine the initial elastic modulus, secant elastic modulus, and maximum stress at failure. The initial modulus consists of the initial slope of the stress-strain curve and the secant modulus was determined from the slope of a straight line from the origin to 50% of the maximum stress level. The stress-strain characteristics of the RAP and RAP-soil mixtures are presented in Figures 4.27 and 4.28.

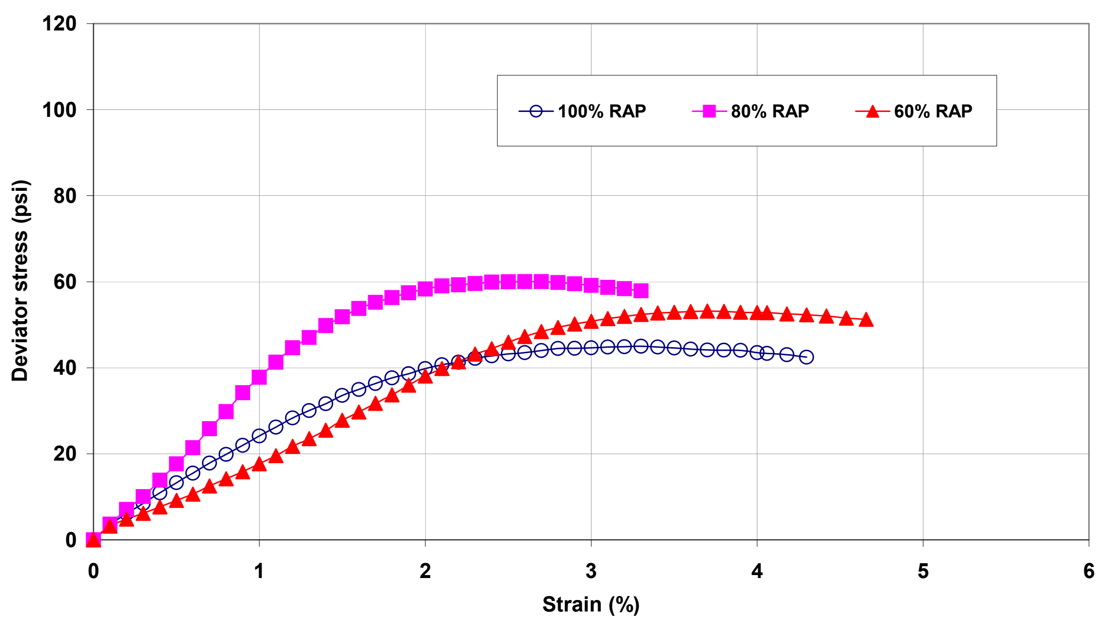



Figure 4.27 Stress-strain characteristics of RAP-soil mixtures at effective confining pressures of 5 psi

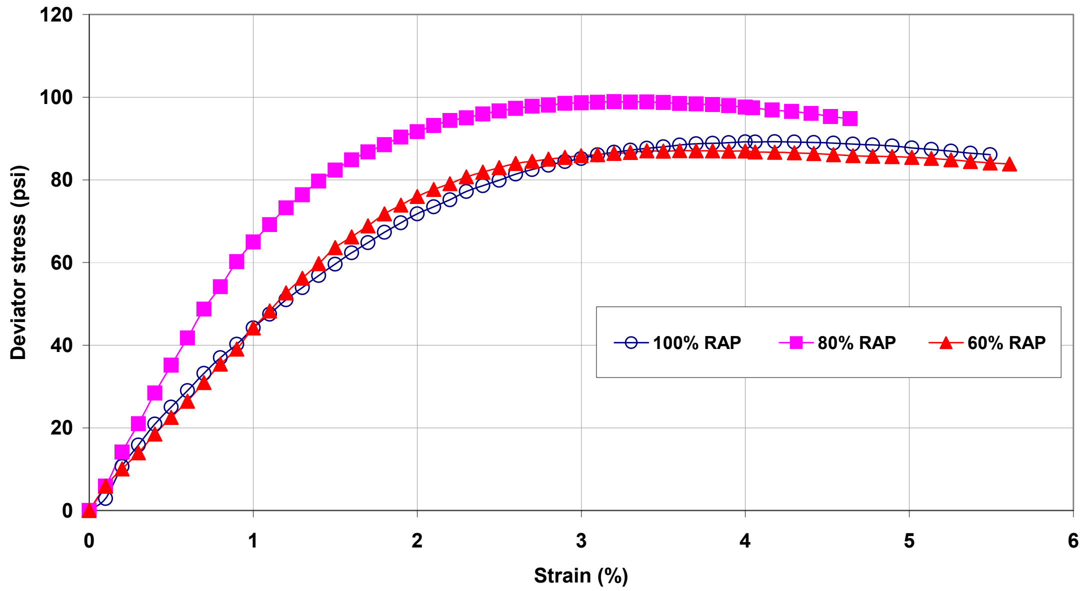



Figure 4.28 Stress-strain characteristics of RAP-soil mixtures at effective confining pressures of 15 psi

The maximum stress at failure was the highest for the 80% RAP mixture, and was 30% and 9.2% higher at respective confining pressures of 5 and 15 psi relative to 100% RAP. For the 60% RAP mixture, the maximum stress at failure was 16% higher than the 100% RAP at the lower confining pressure (Figure 4.27). At the higher confining pressure the changes were minimal (Figure 4.28). In general, the changes in maximum stress at failure were greater at lower confining pressures.

The 80% RAP mixture yielded the highest secant moduli, and were approximately 57% higher relative to 100% RAP at confining pressures of 5 and 15 psi. The secant modulus of 60% RAP was lower than 100% RAP at the lower confining pressure. At the higher confining pressure, the secant elastic modulus obtained for the 60% RAP mixture yielded comparable results to the 100% RAP sample. The initial and secant modulus of all samples tested were generally very similar. The results for 100% RAP agree with values reported by Doig (2000). Bennert et al. (2000) reported a secant modulus of 3384 psi for RAP at a confining pressure of 15 psi. A plot of the secant modulus of elasticity versus percent RAP is presented in Figure 4.29. The modulus of soils is a function of stress level and tends to increase with an increase in confining pressure ($\sigma_3$). This behavior was also evident for the RAP and RAP-soil mixtures. The triaxial compression results demonstrate that the 80% RAP - 20% soil mixture has a higher stiffness than the 100 and 60% RAP, which support the findings from LBR testing. The 80% RAP yielded the highest LBR values, thus demonstrating higher strength and stiffness.

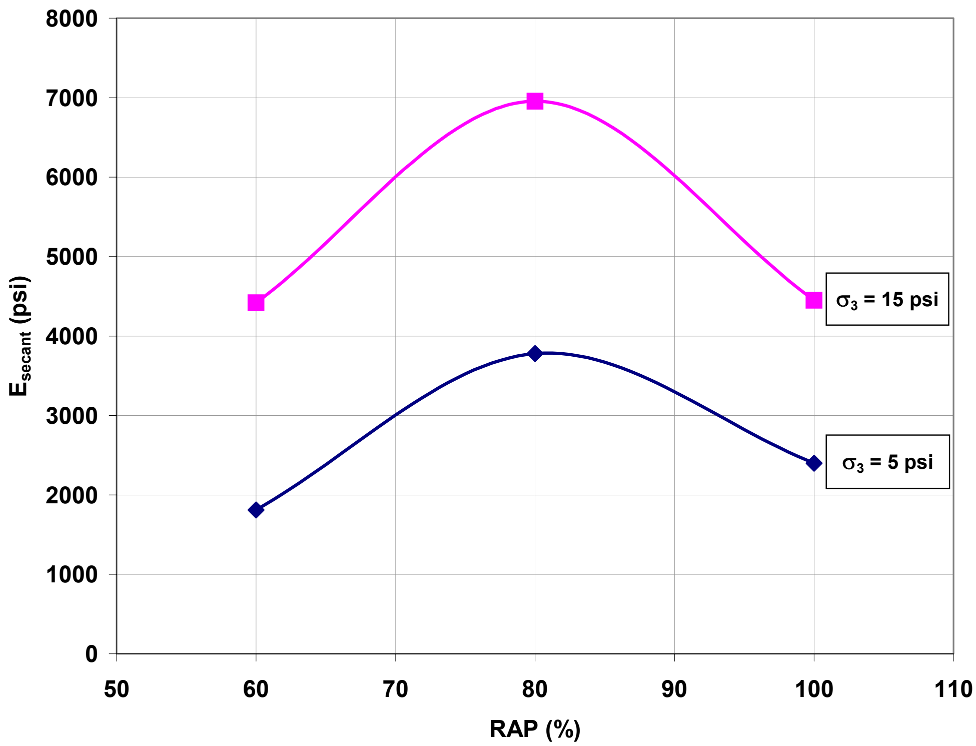



Figure 4.29 Secant modulus of elasticity vs. percent RAP at effective confining pressures of 5 and 15 psi

The maximum deviator stresses at failure were used to develop Mohr-Coulomb failure envelopes (Appendix I) in order to determine the cohesion intercept and friction angle of the RAP and RAP-soil mixtures. The highest friction angle obtained was for 100% RAP, and decreased as the percentage of fine sand increased. The addition of fine sand may have reduced the grain-to-grain contact causing the larger particles to float within the soil matrix. This would have created planes in which the particles can slip and dislocate when a load is applied, resulting in a reduction of the friction angle. The 80 and 60% RAP mixtures demonstrated higher cohesion values than the 100% RAP. The cohesion obtained for RAP may be attributed to the presence of asphalt binder that would cause the particles to adhere to each other when forced together. The increase in cohesion as the percentage of fine sand increased may be due to capillary pressures caused by the attraction of the pore water menisci on the fine sand particles, resulting in an apparent cohesion. This behavior is described by Terzaghi and Peck (1948). Changes in cohesion were more pronounced from 100 to 80% RAP. The results are presented in Figure 4.30. Doig (2000) reported a friction angle of 44 degrees and a cohesion of 2.3 psi for Hammermill processed RAP tested at room temperature for zero storage days. Investigation by Bennert et al. (2000) also yielded a friction angle of 44 degrees and a cohesion of 2.3 psi, and Garg and Thompson (1996) reported a friction angle of 45 degrees and a cohesion of 19 psi for RAP. Friction angles for limerock and cemented coquina of 44 and 41 degrees respectively were reported by Bosso (1995). A summary of the triaxial results is presented in Table 4.6.

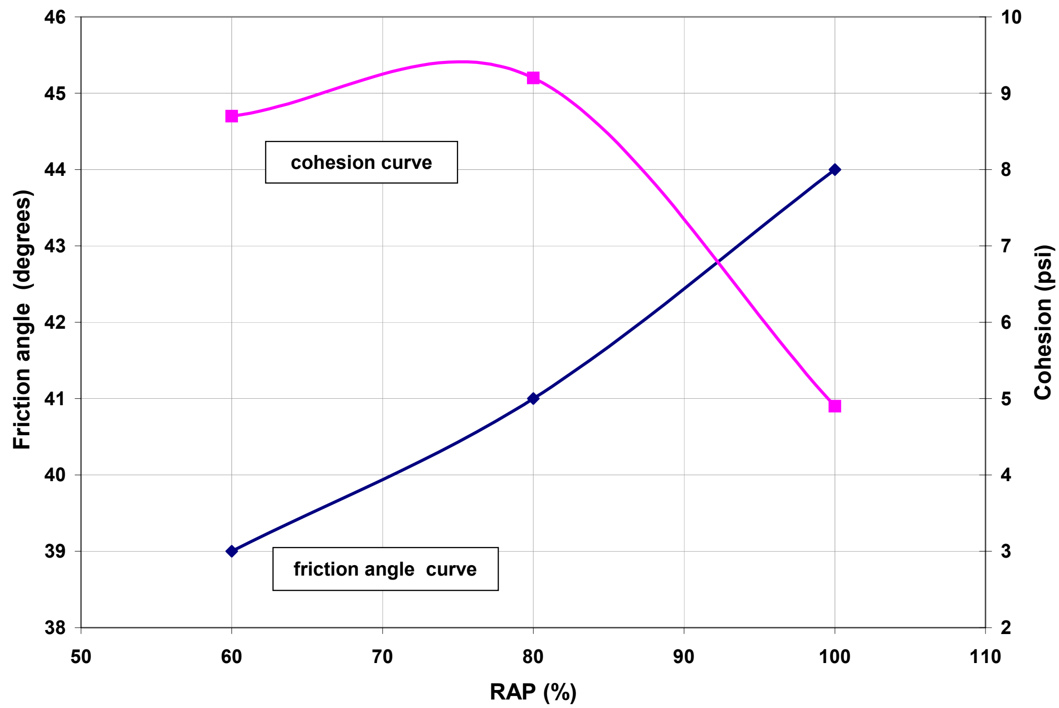



Figure 4.30 Cohesion and friction angle vs. percent RAP

Table 4.6 Summary of triaxial compression results of RAP-soil mixtures

| | 100% RAP | | 80% RAP | | 60% RAP | |
|---|---|---|---|---|---|---|
| | $\sigma_3$ = 5 psi | $\sigma_3$ = 15 psi | $\sigma_3$ = 5 psi | $\sigma_3$ = 15 psi | $\sigma_3$ = 5 psi | $\sigma_3$ = 15 psi |
| $\sigma_1$ @ failure, (psi) | 50.0 | 104.3 | 65.0 | 113.9 | 58.2 | 102.1 |
| $E_{initial}$, (psi) | 2357 | 4400 | 3780 | 6957 | 1470 | 4245 |
| $E_{secant}$ @ 50% failure, (psi) | 2400 | 4450 | 3780 | 6957 | 1810 | 4420 |
| Friction angle, (degrees) | 44 | | 41 | | 39 | |
| Cohesion, (psi) | 4.9 | | 9.2 | | 8.7 | |

$\sigma_1$ : deviator stress
$\sigma_3$ : confining pressure

### 4.13.5 Resilient Modulus

The resilient modulus results of the RAP and RAP-soil mixtures tested as base and subgrade materials are presented in a logarithmic format in Figures 4.31 and 4.32 respectively. The results show that the 100% RAP specimens yielded the highest resilient modulus for the ranges of bulk stresses (θ) tested, followed by the 80 and 60% RAP mixtures. This behavior coincides with findings from Clary et al. (1997), Maher et al. (1997), and Bennert et al. (2000), where the resilient modulus increased as the percentage of RAP in the mixture increased. The resilient modulus also increased with an increase in bulk stress, which is typical of granular soils. The samples tested as base material showed very consistent results, with regression coefficients ($r^2$) ranging from 0.85 to 0.98. However, the results of samples tested as subgrade material were less consistent, with regression coefficients as low as 0.47 and 0.50 for the 80 and 100% RAP samples. The 60% RAP sample had a regression coefficient of 0.79, but the results were obtained by testing only one specimen due to material shortage. All the remaining results were obtained by performing 2 tests for each RAP and RAP-soil mixture tested as base and subgrade material. The regression constants, $k_1$ and $k_2$, derived from the test results fall within the ranges of typical values for base materials specified in the AASHTO *Guide for Design of Pavement Structures* (1993).

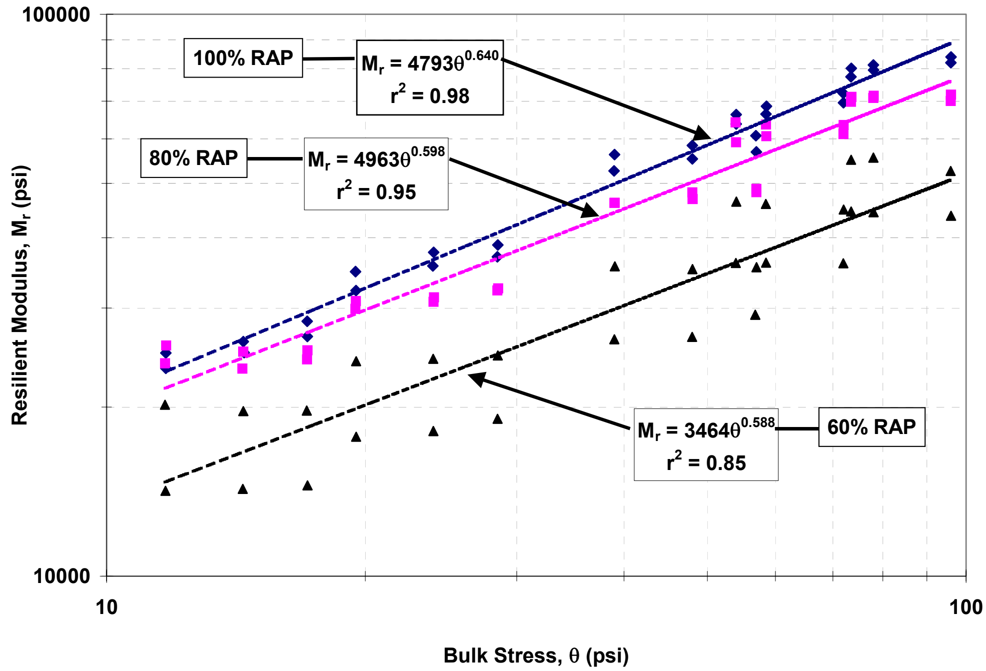



Figure 4.31 Resilient modulus results for RAP and RAP-soil mixtures tested as base material, $M_r = k_1\, \theta^{\,k_2}$ (psi)

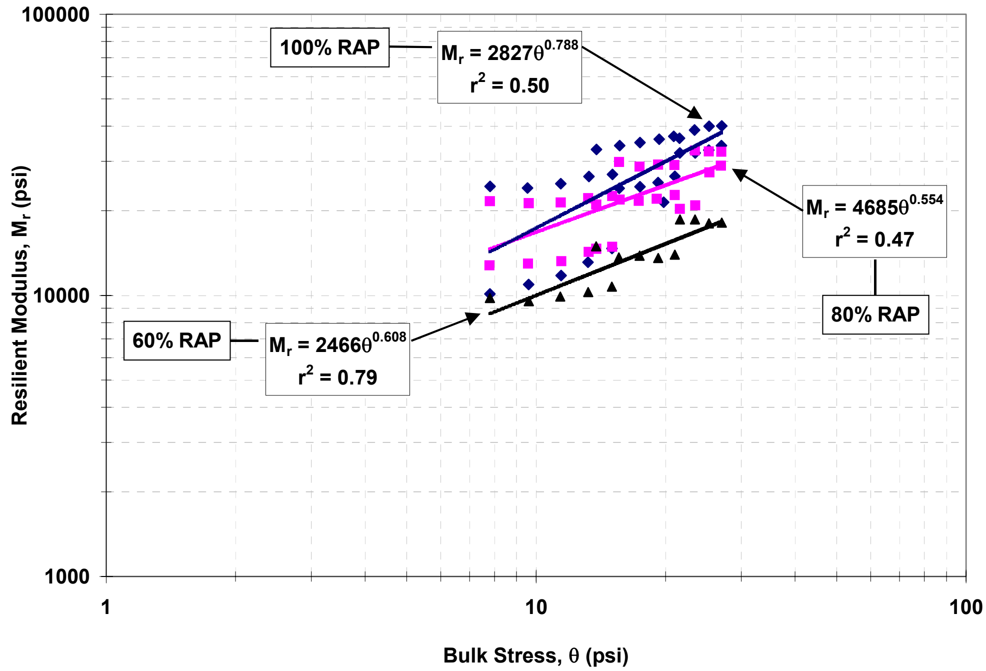



Figure 4.32 Resilient modulus results for RAP and RAP-soil mixtures tested as subgrade material, $M_r = k_1\ \theta^{\ k2}$ (psi)

The investigations by Clary et al. (1997), Maher et al. (1997), and Bennert et al. (2000) were conducted on mixtures of RAP and materials commonly used for base and subbase applications. RAP yielded higher resilient moduli than the base and subbase course materials used in these investigations, and the resilient modulus of the RAP mixtures increased as the RAP percentage increased. Ping and Ge (1996) reported resilient modulus of limerock for displacements measured over the entire specimen and at the middle one-third of the specimen. Resilient moduli of limerock and coquina were reported by McClellan et al. (2001). To provide a basis for comparison, resilient moduli tests performed on limerock samples from the field site were compared to the RAP and RAP-soil mixtures results. These test results produced stiffness values very similar to RAP and the regression coefficients for the log-log data were all above 0.92. Comparisons of all the data at bulk stresses of 21 and 50 psi are presented in Table 4.7. It should be noted that the test procedures followed in each study differ, and the results were presented for comparisons of their behavior. The test procedures vary slightly from each other in loading sequences, applied confining pressures, amount of load repetitions, and location of displacement measuring devices (LVDT's). LTTP Protocol P46 is the latest test procedure implemented to ensure repeatable, reliable, and quality resilient modulus results.

Table 4.7 Comparison of resilient modulus results, $M_r = k_1\,\theta^{\,k2}$ (psi)

| Reference | Application | Procedure | Material | $k_1$ | $k_2$ | $r^2$ | $M_r$ at θ = 21 psi (psi) | $M_r$ at θ = 50 psi (psi) |
|---|---|---|---|---|---|---|---|---|
| This study - RAP Mixture with processed organic soil | Base | LTTP Protocol P46 | 100% RAP | 4793 | 0.640 | 0.980 | 33,583 | 58,486 |
| | | | 80% RAP | 4963 | 0.598 | 0.950 | 30,648 | 51,488 |
| | | | 60% RAP | 3464 | 0.588 | 0.850 | 20,747 | 34,549 |
| This study - RAP Mixture with processed organic soil | Subgrade | LTTP Protocol P46 | 100% RAP | 2827 | 0.788 | 0.500 | 31,134 | * |
| | | | 80% RAP | 4685 | 0.554 | 0.470 | 25,306 | * |
| | | | 60% RAP | 2466 | 0.608 | 0.790 | 15,700 | * |
| This study - Limerock | Base | LTTP Protocol P46 | LIMEROCK[b] | 2258 | 0.781 | 0.977 | 24,302 | 47835 |
| | | | LIMEROCK[c] | 5544 | 0.574 | 0.927 | 31,215 | 51272 |
| Clary et al. (1997) - Mixture with dense graded crushed stone | Base | AASHTO T 294 - 94 | 100% RAP | 6180 | 0.505 | 0.930 | 28,755 | 44,562 |
| | | | 50% RAP | 3604 | 0.597 | 0.970 | 22,190 | 37,245 |
| | | | 30% RAP | 2870 | 0.647 | 0.970 | 20,576 | 36,067 |
| | | | 10% RAP | 2252 | 0.654 | 0.970 | 16,493 | 29,087 |
| | | | 0% RAP | 2410 | 0.661 | 0.880 | 18,030 | 31,992 |
| Clary et al. (1997) - Mixture with gravel | Subbase | AASHTO T 294 - 94 | 100% RAP | 6180 | 0.505 | 0.930 | 28,755 | 44,562 |
| | | | 50% RAP | 3610 | 0.586 | 0.960 | 21,495 | 35,736 |
| | | | 30% RAP | 2976 | 0.625 | 0.960 | 19,954 | 34,315 |
| | | | 10% RAP | 2821 | 0.611 | 0.930 | 18,125 | 30,795 |
| | | | 0% RAP | 2610 | 0.631 | 0.900 | 17,822 | 30,810 |
| Maher et al. (1997) | Base | AASHTO T 294 - 92 | RAP | - | - | - | 37,745 | 52,567 |
| | | | DGABC[a] | - | - | - | 20,750 | 31,513 |
| Bennert et al. (2000) - Mixture with DGABC[a] | Base | AASHTO TP46 - 94 | 100% RAP | - | - | - | 38,173 | 52,342 |
| | | | 75% RAP | - | - | - | 27,397 | 40,740 |
| | | | 50% RAP | - | - | - | 25,830 | 40,537 |
| | | | 25% RAP | - | - | - | 23,075 | 33,967 |
| | | | 0% RAP | - | - | - | 16,838 | 26,033 |
| Ping and Ge (1996) | Base | AASHTO T 292 -91 | LIMEROCK[b] | 3366 | 0.662 | 0.871 | 25,259 | 44,857 |
| | | | LIMEROCK[c] | 4665 | 0.635 | 0.806 | 32,245 | 55,937 |
| McClellan et al. (2001) | Base | AASHTO T 294 - 92 | LIMEROCK | 5925 | 0.592 | 0.986 | 35,884 | 59,949 |
| | | | COQUINA | 7310 | 0.596 | 0.990 | 44,927 | 75,370 |

* : Bulk stresses (θ) during laboratory tests range from 7 - 27 psi for subgrade material

\- : not available

a : Dense Graded Aggregate Base Coarse

b : mean values of $k_1$, $k_2$, and $r^2$ were calculated from samples tested in the optimum moisture content range (10.2 to 12.6%) for deformation readings measured over the entire length of the specimen

c : mean values of $k_1$, $k_2$, and $r^2$ were calculated from samples tested in the optimum moisture content range (10.2 to 12.6%) for deformation readings measured at the middle third of the specimen

The equation specified by AASHTO (1993) to estimate the layer coefficient ($a_2$) of base materials was used to determine $a_2$-values of the RAP, RAP-soil mixtures and the limerock from the field site. The layer coefficient is a function of the resilient modulus and increases with an increase in resilient modulus. The $a_2$-values, calculated based on a bulk stress ($\theta$) of 20 psi, are presented in Table 4.8. They represent the strength immediately after placement and exclude any long-term strength gains that the materials may display. Typical layer coefficients for Florida aggregates specified by the FDOT are listed in Table 4.9. These typical values were developed through the comprehensive laboratory and field-testing program described in Chapter 2.1 of the FDOT Materials Manual (2000), which account for long-term strength gain.

As was the case with the resilient moduli, the 100% RAP had the highest layer coefficient, followed by the 80 and 60% RAP. The difference in layer coefficient between the 100 and 80% RAP is quite small, and the values compare well with the layer coefficient specified by the FDOT for graded aggregate base material. Results from the field studies in both Phase I and II of this investigation indicate that RAP undergoes a strength gain, but it has the advantage of not being adversely affected by moisture. Additional work needs to be performed to evaluate this long-term strength gain.

Based on the layer coefficients and resilient moduli values, which were determined from small strains, RAP and RAP-soil mixtures warrant additional evaluations. These evaluations should be on samples placed in a controlled test pit subjected to both small and large strains. Testing should be conducted according to the procedures outlined in the FDOT Materials Manual (2000).

Table 4.8 Layer coefficient ($a_2$) of RAP, RAP-soil mixtures and Limerock for base application (excludes long-term strength gain)

| Material | $k_1$ | $k_2$ | $M_r$ at $\theta$ = 20 psi (psi) | $a_2$* | LBR |
|---|---|---|---|---|---|
| 100% RAP | 4793 | 0.640 | 32551 | 0.15 | 40 |
| 80% RAP | 4963 | 0.598 | 29767 | 0.14 | 84 |
| 60% RAP | 3464 | 0.588 | 20160 | 0.09 | 61 |
| Limerock | 2258 | 0.781 | 23394 | 0.11 | 100 |

* : $a_2 = 0.249*(\log_{10} M_r) - 0.977$ (AASHTO 1993)

Table 4.9 Layer coefficient ($a_2$) of typical aggregates used in Florida for base application (includes long-term strength gain)

| Material | Application | Minimum LBR | $a_2$ | Specification Section |
|---|---|---|---|---|
| Limerock[a] | Base | 100 | 0.18 | 200 |
| Cemented Coquina[a] | Base | 100 | 0.18 | 250 |
| Graded Aggregate[a] | Base | 100 | 0.15 | 204 |
| Sand Clay[b] | Base | 75 | 0.12 | 240 |

[a] : general use
[b] : limited use

The 100% RAP yielded the highest resilient modulus, however, the resilient modulus results differ from the LBR and triaxial compression results in which the 100% RAP produced a lower strength and stiffness as compared to the 60 and especially the 80% RAP mixture. Bennert et al. (2000) suggested that this type of behavior of RAP may be attributed to the resilient modulus test procedure itself. For the load sequences used in the test procedure, the average deformation of the last five load cycles is used from the total 100 load cycles applied. The strains that might develop during the first 95 load cycles are not accounted for. From the permanent deformation tests conducted on RAP, recycled concrete aggregate (RCA), and a dense-graded aggregate coarse (DGABC) by the Bennert et al. (2000), RAP obtained the highest permanent strain. The respective permanent strains of the RCA and DGABC were 6.9 and 12.0% the strain of RAP. Recall that the resilient modulus is defined as the deviator stress divided by the recoverable (resilient) strain. During the load sequences, RAP might experience larger plastic deformations and smaller resilient strains, while conventional material might undergo smaller plastic deformations with larger resilient strains. This would result in higher resilient modulus for RAP and lower resilient modulus for conventional materials. Despite the higher resilient modulus obtained for RAP, it is likely that based on the findings by Bennert et al. (2000), RAP would experience larger plastic deformations, showing potential for rutting and possible creep behavior.

### 4.13.6 Compaction Characteristics

A summary of the compaction characteristics of all the tests is presented in Appendix L. An effort was made to maintain the compactive effort as close as possible to modified Proctor energy (56,000 ft-lb/ft$^3$) and to perform compaction at the optimum moisture content for each RAP-soil mixture. The number of layers and the number of blows per layer for the static triaxial compression, resilient modulus, and permeability tests were modified to achieve a compactive effort as close as possible to 56,000 ft-lb/ft$^3$.

The relative compaction of the LBR RAP-soil mixtures was very consistent with values close to 100 percent. The decrease in sample size for the static triaxial compression, resilient modulus, and permeability tests, resulted in variations in the relative compaction values of the RAP-soil mixtures.

## 4.14 Preliminary Creep Investigation Results

The load-deflection versus time data was reduced to the plot shown in Figure 4.33. The data indicate all three materials experienced a rapid initial deflection increase followed by a leveling trend that was either horizontal or very close to horizontal. When comparing the 100% RAP to the 80/20 RAP-soil mixture, it is definite that the 80/20 RAP-Soil mix produced lower deflections. Both the RAP and RAP-soil mixture samples demonstrated a similar characteristic, in that they each displayed continuous deformation as shown in Figure 4.33. The A-3 soil, which was used as the control, stopped showing significant deformations after approximately 4000 minutes with an application of 33.5psi and after approximately 1000 minutes with an application of 67 psi. It should be noted that the A-3 soil sample exhibited a bearing capacity failure during the first minute of the 134 psi loading and it is therefore not possible to analyze the increments of 134 psi and 268 psi. When comparing the deformation patterns of the RAP samples to the A-3 soil, it is evident that the RAP samples exhibit much smaller initial deformations with continuous deformations. On the other hand, the A-3 soil exhibits much larger initial deformations, which quickly level off and nearly stop deforming.

To normalize the vertical axis of Figure 4.33, it was converted from deflection to an axial strain. This is a result of making assumptions in order to calculate the strain of each sample. This experiment was based on the LBR methodology where the mold diameter was 6 inches and the piston diameter was 1.95 inches. As a result, the strains are not one-dimensional. and strain cannot be calculated with exact certainty. In order to calculate a strain, it was assumed that the original height ($h_o$) for the strain ($\varepsilon = \Delta h / h_o$) was the height of the sample located directly underneath the piston. It was also assumed that all of the deformation ($\Delta h$) occurred in the column of soil located directly beneath the 1.95-inch piston.

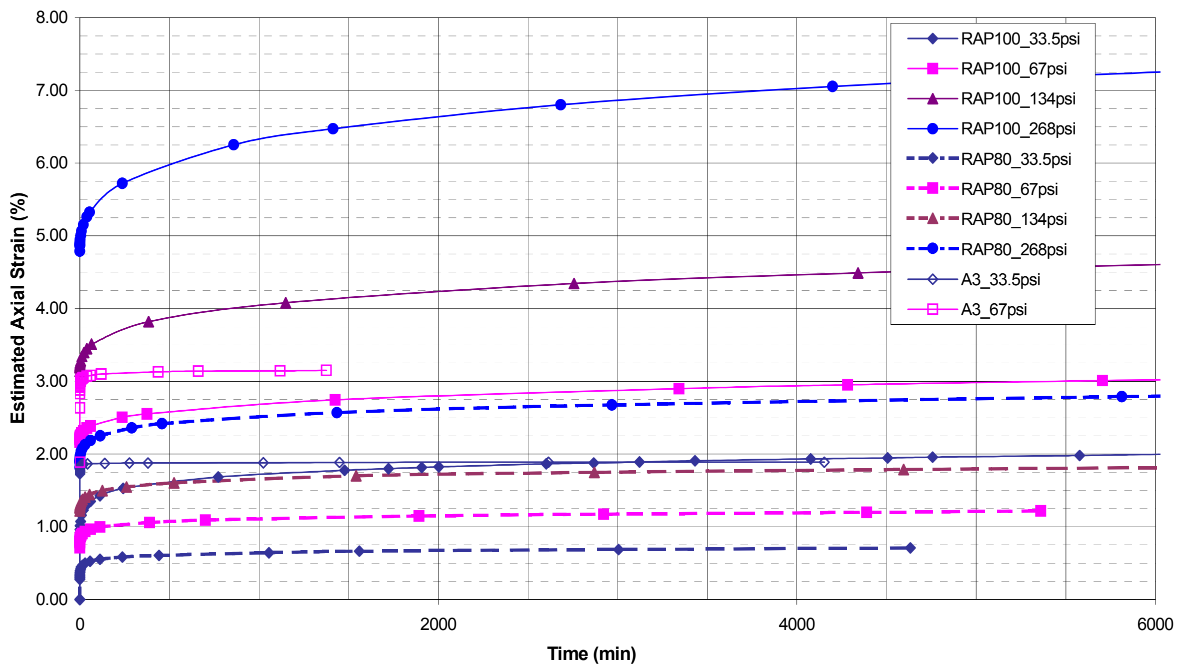



Figure 4.33  Results from creep testing of 100% RAP, 80/20 RAP-Soil Mixes, and 100% A-3 Soils.

The long-term characteristics were evaluated by calculating the slope of each curve between 1000 minutes and 4000 minutes, and the results are exhibited in Table 4.10.  The slopes of the curves in terms of strain versus time, or percent per minute, are presented in the table.  Since the A-3 sample failed during the application of 134 psi, no data exists for 134 psi or 268 psi for this sample.

Table 4.10 Slopes of Estimated Axial Strain versus Time (between 1000 and 4000 minutes)

| Stress Level (psi) | Soil Tested | Slope of Curve (%/min) |
|---|---|---|
| 33.5 | 100%RAP | 7.2E-05 |
| | 80%RAP | 2.1E-05 |
| | A-3 Soil | 2.2E-06 |
| 67 | 100%RAP | 9.0E-05 |
| | 80%RAP | 1.4E-05 |
| | A-3 Soil | 2.0E-06 |
| 134 | 100%RAP | 1.4E-04 |
| | 80%RAP | 4.2E-05 |
| | A-3 Soil | N/A |
| 268 | 100%RAP | 2.4E-04 |
| | 80%RAP | 7.1E-05 |
| | A-3 Soil | N/A |

N/A - no data available because these stresses exceeded the bearing capacity of the soil.

As expected, as the applied pressures increased, the rate at which the samples deformed also increased. Therefore, increases in pressure resulted in larger amounts of creep.

The results were also analyzed by isolating each of the pressures. The strain rate decreases significantly from the 100% RAP to the 80% RAP to the A-3 soil, implying that less RAP results in lower creep values. For each of the loading applications, there is at least an estimated half an order of magnitude difference in the slopes between the 100% RAP and 80% RAP samples. There is approximately one order of magnitude difference between the 80% RAP and A-3 soil samples in each case, which was possible to analyze.

These results show that there is a decrease in the strain rates when comparing 100% RAP to 80% RAP. However, the rate at which the 80% RAP strains is still well above the values for the A-3 control soil. The performance of RAP, in terms of creep, is significantly improved by mixing with soil.

To estimate a total settlement of a typical 20-foot high MSE wall with a life of 20 years, the sum of the strains for various time intervals were calculated, and then summed. The time intervals began with 1000-minute increments and increased as the curve approached zero. The settlement associated with each time interval was calculated by multiplying the strain in percent by the total height of the MSE wall, which was assumed to be 20 feet.

By performing these calculations, the total creep movement for a 20-foot high MSE wall with a 20-year design life and constructed of 100% RAP is estimated to be 0.275 feet (3.3 inches). Performing the same analysis with 80% RAP yields a total secondary settlement of approximately 0.105 feet (1.25 inches). By decreasing the amount of RAP by 20%, the total secondary settlement was reduced by more than 60%.

Although the results for the 80/20 RAP-soil indicate that it does not perform as well as the A-3 control soil, there is a possibility that other mixtures might. This preliminary testing indicates that RAP and RAP-soil mixtures need to be further tested for their long-term behavior.

# 4.15 Environmental Results and Discussion

## 4.15.1 Field Study

Using the surface water and leachate water sampled from the field site over a 10-month period, Silver, Cadmium, Chromium, Lead, and Selenium concentrations were determined versus time. Typically, eight metals are analyzed to determine their "*leachability*" into the environment; this includes the five above plus, Mercury, Arsenic and Barium. Mercury was not evaluated as it is a fairly volatile substance and most probably volatilized prior to the milling operation for RAP. Arsenic and Barium have historically not been present in the by-products from the asphalt industry and were not investigated by other researchers who evaluated RAP (Townsend and Brantley, 1998). Therefore, neither of these metals were included in this study.

The format used to present the results is consistent throughout this section. Both tables and figures are used for each element. The first column of the data tables shows the time-of-exposure, (i.e. the number of days after construction when aqueous samples were collected). The figures are semi-log plots that show the EPA Standards and the lowest detectable concentration for each of the five metals. The lowest detectable concentration was determined based on the range of concentrations expected for each metal. Statistical data from 3 standard tests were used to develop an expected range within which the AAS yields reliable data. Data above and below this range are not near a regression line developed based on the standards. During this research, only values below the detection limit occurred. These concentrations are shown so readers can visualize the total number of samples tested, along with those below the AAS detection limit.

#### *4.15.1.1 Sampling Protocol*

The sampling protocol for the surface water collection was slightly different than the protocol for the leachate collection. Following severe rainfall events, surface water samples were collected in two separate collection tanks (Figure 3.11). These samples were collected, analyzed and are reported in two separate columns within these tables. On many sampling days, there was insufficient quantity in the second collection tank for analyses. During sample collection, it was noted that the volume of surface runoff from the RAP collection system was larger than the volume produced by the limerock control site. This is probably attributed to more surface runoff in RAP than limerock.

As expected, the leachate sample volumes were lower than the surface water volumes, therefore, no single rainfall event, during the 10-months, generated enough leachate to require the $2^{nd}$ tank shown in Figure 3.11 for collection. Subsequently, only one column of the data table is presented for the leachate results.

Data shown in the tables represent the mean value of each analysis, which includes three replicates with less than 5% variation. Since all standard deviations were much less than the 5 % limit they were not displayed in the following tables. Data was also presented in graphical format, in Figures 4.34 – 4.38, to determine if there were any trends in the concentration changes over time during the study period. US EPA standards are also shown in each figure for comparison purposes. In many instances the data from the testing was below the detectable limit of the testing equipment for the particular chemical being analyzed. This value is also shown in the tables and on the plots.

*4.15.1.2 Silver (Ag) Concentration in Runoff and Leachate Samples*

Appendix Table J.1 shows the concentration of silver in surface runoff and leachate samples collected from both the RAP and Limerock collection systems. There were 14 sampling periods over 165 days that produced 50 adequate samples out of a possible 84. There were insufficient quantities retrieved for testing in the remaining 34 samples. Three tests were conducted on each of the 50 adequate samples and 25 sets of three, or 50 percent, produced results that were below the detectable limit of 1 µg/l for silver. The three tests conducted on each of the 27 adequate RAP samples produced 15 sets of three, or 56 percent, below the detectable limit. There were 23 adequate samples collected from the Limerock collection system, of which 10 sets of three, or 44 percent, were below the detectable limit.

The initial surface runoff samples from RAP site were collected after 38 days of exposure, and displayed a concentration below detection limit. The next sample was collected one week later with a concentration slightly above the detection limit. Detectable concentrations of silver from RAP surface runoff samples were found for those collected within 100 days of exposure. After 100 days of exposure, surface runoff samples from the RAP site showed no detectable concentrations of silver. As shown in Figure 4.32, concentrations of detectable silver in surface runoff samples from the RAP site were far below the EPA standards of 5,000 µg/l and just barely above the detectable limit. No change in concentration over time was observed during the sampling period. The results indicated that, with regard to silver, RAP possessed no threat to the environment through surface runoff.

The first detectable Ag concentration in the leachate from RAP was not found until 58 days of exposure, while the last detectable concentration was found in the samples collected after 134 days. While detectable, these samples produced very low Ag concentrations, which were slightly above detection limit and similar to the range of surface runoff samples. The Ag concentrations also decreased over time. After 140 days of exposure, leachate from the RAP site showed no detectable concentrations of silver. (Appendix Table J.1 and Figure 4.34). Overall, concentrations of detectable silver in leachate samples from RAP site were far below the EPA standards. The results indicated that RAP does not pose a threat to the environment from silver contamination.

Findings from the limerock control site were quite similar to those found from RAP, (Appendix Table J.1 and Figure 4.34). None of the silver concentrations were near the EPA Standard of 5000 μg/l and were just barely above detectable limits, as shown in Figure 4.34. The results indicated that, with regard to silver, Limerock poses no threat to the environment through either surface runoff or leachate.

Limerock is a naturally occurring material, used in a large amount of highway construction. Since the findings for RAP are similar to those for Limerock, environmentally it can be concluded that, concerning silver, RAP is acceptable.

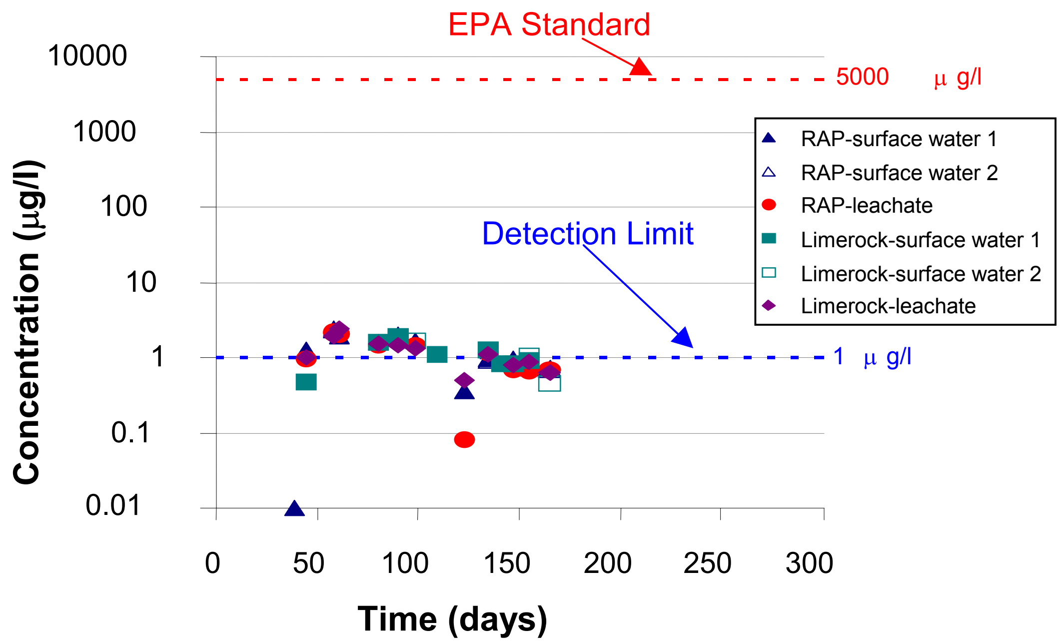



Figure 4.34. Silver (Ag) Concentration versus Time in Surface Runoff and Leachate Collected from the RAP and Limerock Collection Systems.

*4.15.1.3 Cadmium (Cd) Concentrations in Runoff and Leachate Samples*

Appendix Table J.2 and Figure 4.35 show the concentration of cadmium in surface runoff and leachate samples collected from both the RAP and Limerock collection systems. There were 14 sampling periods over 165 days, yielding data for 50 adequate samples out of a possible 84. There were insufficient quantities retrieved for testing in the remaining 34 samples. Three tests were conducted on each of the 50 samples and 47, or 94 percent, produced results below the detectable limit of 1 µg/l for cadmium. The three tests conducted on each of the 27 adequate RAP samples produced 26, or 91 percent, below the detectable limit. There were 23 adequate samples collected from the Limerock collection system, of which 21, or 91 percent, were below the detectable limit.

Appendix Table J.2 shows the concentration of cadmium in surface runoff and leachate samples collected on site. The first surface runoff samples from the

RAP site were collected after 38 days of exposure and produced a Cd concentration of 2.78 µg/l, which is slightly above the detection limit and far below EPA standards of 1,000 µg/l. The first sample collected was the only one that had detectable concentrations of dissolved cadmium in surface runoff throughout the period of the study. No detectable concentrations of cadmium occurred in leachate from the 11 RAP samples evaluated. The results indicated that RAP does not pose a threat to the environment from cadmium contamination.

Findings from the limerock control site were very similar to those found from the RAP, (Appendix Table J.2 and Figure 4.35), which showed that the first detectable cadmium surface runoff concentration, of 2.21 µg/l, in occurred after 44 days of exposure. A second detectable concentration of 3.28 µg/l, much less than the 1000µg/l EPA standard, was found in the Limerock surface water samples at 141 exposure days. Leachate from Limerock site had no detectable concentrations of cadmium throughout the period of the study. The results indicated that Limerock does not pose a threat to the environment from silver contamination.

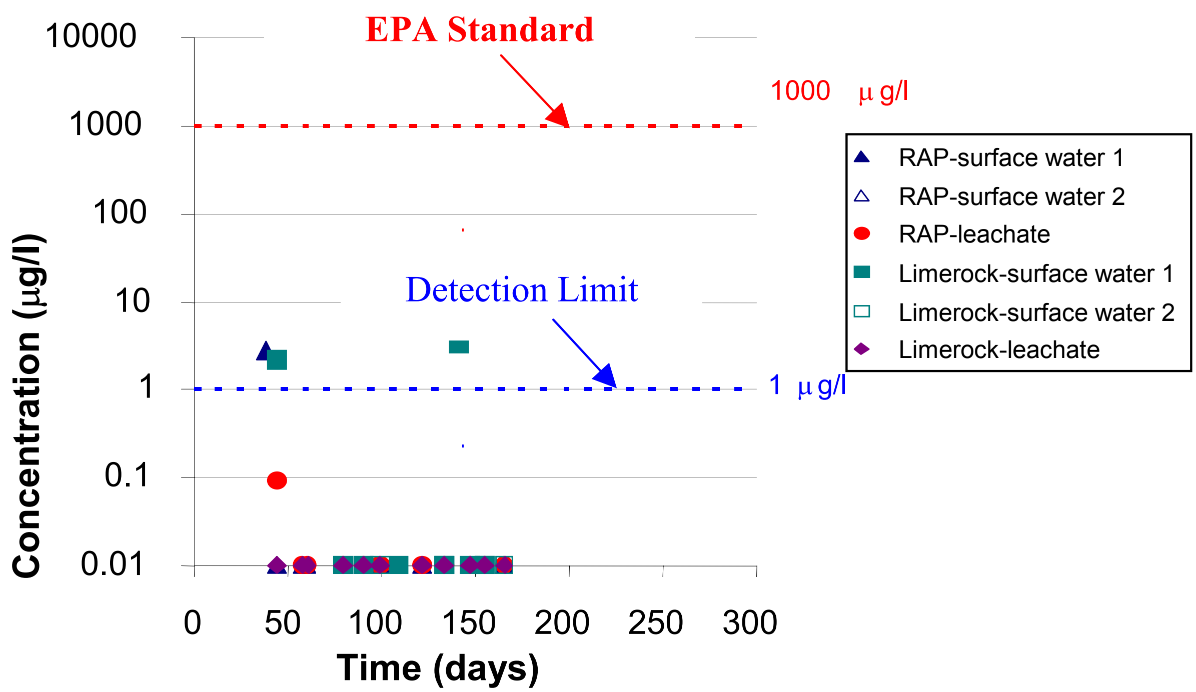



Figure 4.35 Cadmium (Cd) Concentration versus Time in Surface Runoff and Leachate Collected from the RAP and Limerock Collection Systems.

*4.15.1.4 Chromium (Cr) Concentrations in Runoff and Leachate Samples*

Appendix Table J.3 and Figure 4.36 show the concentration of chromium in surface runoff and leachate samples collected on site. There were 14 sampling periods over 165 days, yielding data for 50 adequate samples out of a possible 84. There were insufficient quantities retrieved for testing in the remaining 34 samples. Three tests were conducted on each of the 50 samples and 49, or 98 percent, produced results below the detectable limit of 5 µg/l for chromium. There were 27 adequate samples collected from the RAP collection system and all were below the detectable limit. There were 23 adequate samples collected from the Limerock collection system, of which 22, or 96 percent, were below the detectable limit.

None of the surface runoff and leachate samples collected from the RAP site produced detectable concentrations of chromium. Similar results were found for the limerock site, except that the first surface runoff sample had a chromium concentration of about 9 µg/l. It was assumed that this spike in concentration resulted from an unknown external source. Note this data represents only for four percent of the total chromium samples in the Limerock. The results indicate that neither RAP nor Limerock pose a threat to the environment from chromium contamination.

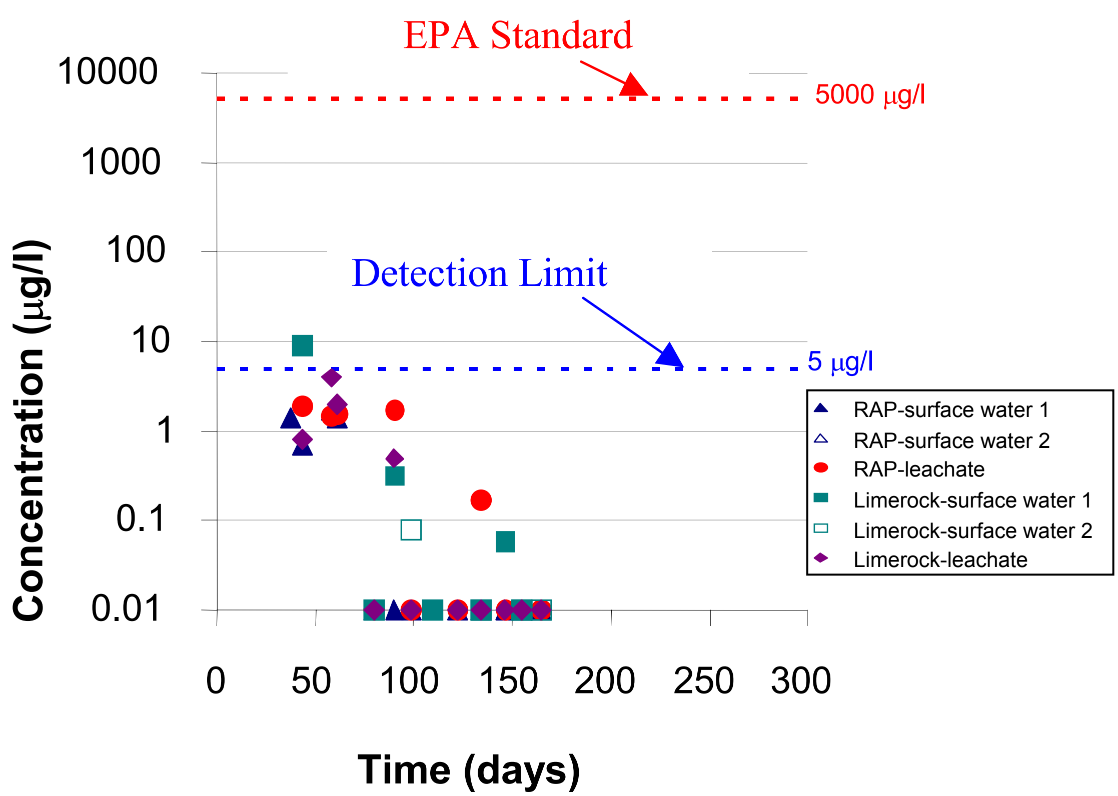



Figure 4.36 Chromium (Cr) Concentration versus Time in Surface Runoff and Leachate Collected from the RAP and Limerock Collection Systems.

*4.15.1.5 Lead (Pb) Concentrations in Runoff and Leachate Samples*

Appendix Table J.4 and Figure 4.37 show the concentrations of lead in surface runoff and leachate samples collected on site. There were 17 sampling periods over 290 days, yielding data for 65 adequate samples out of a possible 102. There were insufficient quantities retrieved for testing in the remaining 37 samples. Three tests were conducted on each of the 65 samples and 54, or 83 percent, produced results that were below the detectable limit of 5 μg/l for lead. The three tests conducted on each of the 36 adequate RAP samples produced 32 sets, or 89 percent, below the detectable limit. There were 29 adequate samples collected from the Limerock collection system, of which 22 sets, or 76 percent, were below the detectable limit.

The first surface runoff samples from the RAP site were collected after 38 days of exposure and displayed a concentration of about 39 μg/l. The second detectable concentration of lead was found in the sample on the 61$^{st}$ exposure day displaying a concentration about 335 μg/l. It was not until 165-day of exposure when a third detectable concentration of lead (21 μg/l) was again found in the surface runoff sample. Concentrations above the detectable limit were only found in samples obtained from the 1$^{st}$ tank of the surface runoff collection system. It was concluded that the three spikes in the lead concentrations within the RAP resulted from external sources. Possible sources could be the vehicular traffic on the pavement prior to recycling such as a wheel balance weight or could be naturally occurring in the aggregate used in the asphalt mix from which the RAP comes.

The only detectable concentration of lead in leachate from the RAP site was found from the sample obtained on the 58$^{th}$ exposure day which displayed a concentration of 7.76 μg/l, slightly above the detection limit of 5 μg/l, and far below EPA lead standard of 5,000 μg/l. The remaining leachate samples showed no detectable concentrations of lead.

Data from the surface runoff at the limerock site indicated several concentrations of lead, slightly above the detection limit (Appendix Table J.4 and Figure 4.37). Limerock leachate samples had only two instances where detectable lead concentrations were produced.

The results indicate that neither RAP nor Limerock pose a threat to the environment from lead contamination.

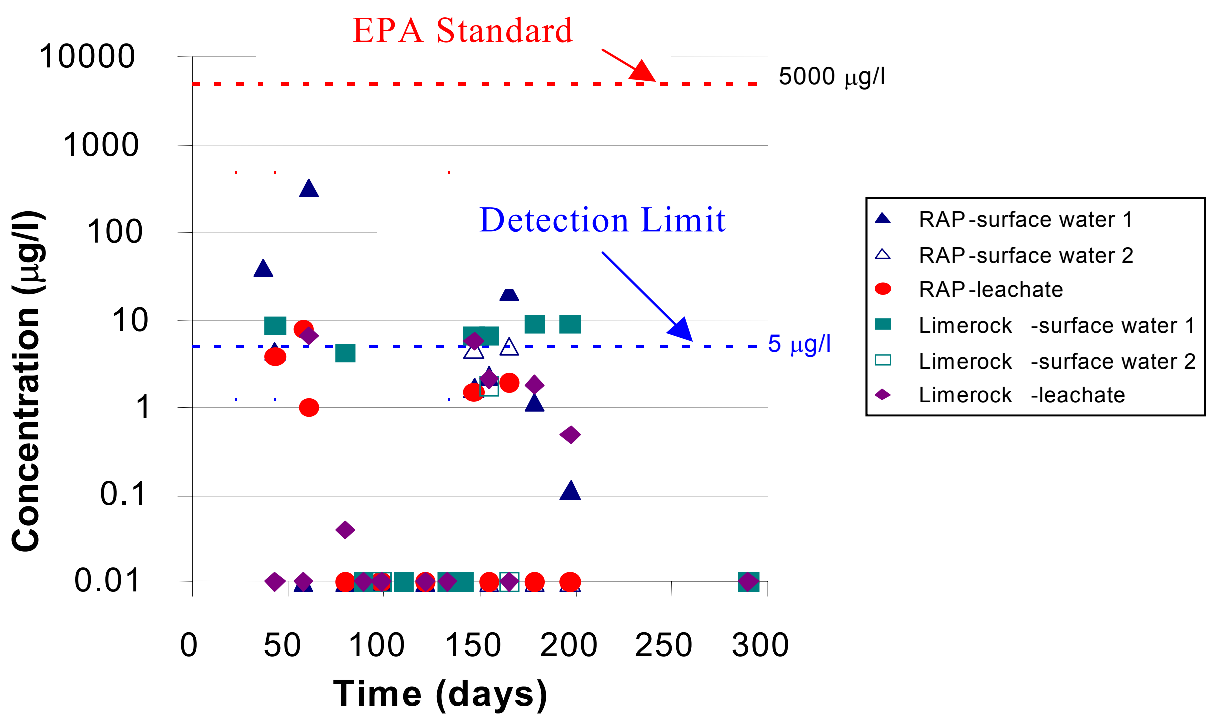



Figure 4.37 Lead (Pb) Concentration versus Time in Surface Runoff and Leachate Collected from the RAP and Limerock Collection Systems.

*4.15.1.6 Selenium (Se) Concentrations in Runoff and Leachate Samples*

Appendix Table J.5 and Figure 4.38 show the concentration of selenium in surface runoff and leachate samples collected on site. There were 14 sampling periods over 165 days, yielding data for 50 adequate samples out of a possible 84. There were insufficient quantities retrieved for testing in the remaining 34 samples. Three tests were conducted on each of the 50 samples and 9, or 18 percent, produced results that were below the detectable limit of 1 μg/l for selenium. Three tests were conducted on each of the 27 RAP samples and 9, or 33 percent, produced results that were below the detectable limit of 1 μg/l for selenium. All 23 samples obtained from the Limerock collection system produced results above detectable limit of 1 μg/l for selenium.

Several RAP surface runoff samples produced selenium concentrations just above the detection limit of 1 μg/l. Samples were retrieved from both the 1st and 2nd tanks for the 134th exposure day. Samples from the 2nd surface runoff tank had detectable concentrations, while samples from the 1st tank had no detectable concentration. This anomaly was assumed to be the result of some unknown source of selenium, which was present in the 2nd tank.

Leachate samples from the RAP site produced one slightly elevated selenium concentration. This outlier occurred for the sample retrieved at day 44. All remaining data, except one, showed detectable concentrations slightly higher or near to the detection limit. The high value of 85 μg/l at day 44, was still well below the EPA standard of 1000 μg/l. It was assumed to be the result of an unknown source of selenium.

Limerock surface runoff samples produced an average selenium concentration of 19.37 mg/l, which is well below the EPA Standard of. Samples were retrieved from both the 1st and 2nd surface runoff tanks.

Leachate samples from the RAP site produced elevated selenium concentrations. Although the average throughout the study was 426.53 μg/l, a sudden spike in the concentrations occurred on after the 90th sampling day. Two values slightly above the 1000 μg/l EPA Standard occurred on the 90th and 99th sampling days, and the concentrations generally decreased with time until the sampling operation was completed. It was assumed that this peak was the result of an unknown source of selenium, which might have occurred from a change in the pH or temperature of the liquid.

The presence of selenium in both the surface and leachate waters is not surprising because this chemical exists naturally in the soil, surface water and groundwater. Weathering of rocks and soils transports selenium into the environment (U.S. Department of Interior Bureau of Reclamation, 2001)

The results from both the surface water and leachate water analyses indicate that RAP does not pose a threat to the environment from selenium contamination. Limerock displayed concentrations near the EPA Standard which can be expected from materials formed through sedimentary deposits.

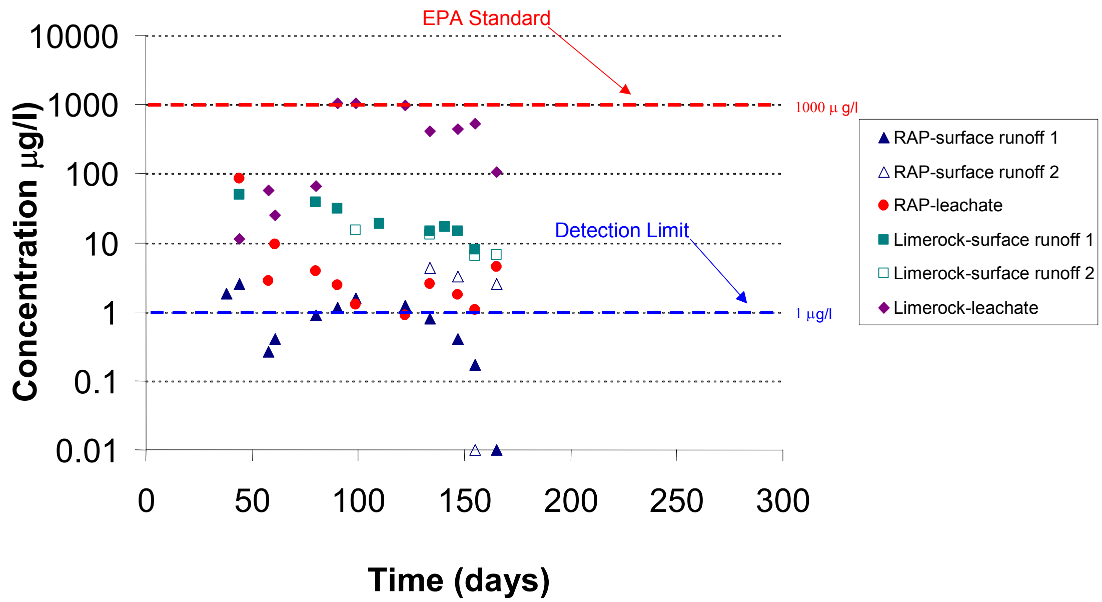



Figure 4.38 Selenium (Se) Concentration versus Time in Surface Runoff and Leachate Collected from the RAP and Limerock Collection Systems.

## 4.15.2 Laboratory Studies

### *4.15.2.1 TCLP and SPLP Tests*

Laboratory TCLP tests conducted on RAP and limerock according to EPA methods showed that concentrations of silver (Ag), cadmium (Cd), and chromium (Cr) were not detectable (Table 4.11). As was the case for all environmental testing, three trials were performed on each sample and an average was determined. This process yielded a total of 30 trials on the RAP and Limerock samples. Of the 30 trials, 22 or 73 percent yielded results below the detectable limit. All of the TCLP and SPLP results above the detectable limit were well below the EPA Standards

(Tables 4.11 and 4.12). Lead was detected in one of the three replicates of the limerock sample; while selenium was detected in all three replicates of the limerock sample (Table 4.11). For RAP, lead was found in all three replicates at a concentration close to the detection limit, while selenium was only found in one of the three replicates at a concentration just above the detection limit.

Laboratory SPLP tests conducted on RAP and limerock according to EPA methods showed that concentrations of silver (Ag), cadmium (Cd), chromium (Cr), and lead (Pb) were not detectable (Table 4.12). Of the 30 total trials, 27 or 90 percent produced results below the detectable limit. Selenium was found in all three replicates of limerock samples with a mean concentration of 9.83 μg/l, which again is well below the EPA standard of 1000 μg/l. For RAP, no detectable selenium concentrations were found.

Concentrations of selenium in both TCLP and SPLP were very low (10 μg/l), about two orders of magnitude lower than EPA standards. The detectable concentrations of selenium can be attributed to the leachable fraction of selenium in limerock, introduced from surrounding soils during its process (U.S. Department of Interior Bureau of Reclamation, 2001). No records were available about the source, process, and storage of limerock used in the study, therefore, it was not possible to investigate their possible inputs to the limerock matrix. Further studies would need to be conducted to determine the leachable fraction of selenium.

Table 4.11 Results of TCLP test on limerock and RAP

| | Concentrations (μg/l) | | | | |
|---|---|---|---|---|---|
| | Ag | Cd | Cr | Pb | Se |
| Limerock | | | | | |
| 1 | BDL | BDL | BDL | 34.84 | 10.95 |
| 2 | BDL | BDL | BDL | BDL | 8.99 |
| 3 | BDL | BDL | BDL | BDL | 9.54 |
| Mean | BDL | BDL | BDL | 11.61 | 9.83 |
| RAP | | | | | |
| 1 | BDL | BDL | BDL | 7.96 | BDL |
| 2 | BDL | BDL | BDL | 5.99 | BDL |
| 3 | BDL | BDL | BDL | 5.57 | 1.06 |
| Mean | BDL | BDL | BDL | 6.51 | 0.35 |
| EPA standards | 5,000 | 1,000 | 5,000 | 5,000 | 1,000 |

BDL = below detection limit (Ag < 1 μg/l, Cd < 1 μg/l, Cr < 5 μg/l, Pb < 5 μg/l, Se < 1 μg/l)

Table 4.12 Results of SPLP tests on limerock and RAP

| | Concentrations (µg/l) | | | | |
|---|---|---|---|---|---|
| | Ag | Cd | Cr | Pb | Se |
| Limerock | | | | | |
| 1 | BDL | BDL | BDL | BDL | 11.66 |
| 2 | BDL | BDL | BDL | BDL | 9.53 |
| 3 | BDL | BDL | BDL | BDL | 10.71 |
| mean | BDL | BDL | BDL | BDL | 10.63 |
| RAP | | | | | |
| 1 | BDL | BDL | BDL | BDL | BDL |
| 2 | BDL | BDL | BDL | BDL | BDL |
| 3 | BDL | BDL | BDL | BDL | BDL |
| mean | BDL | BDL | BDL | BDL | BDL |
| EPA SPLP standards | 5,000 | 1,000 | 5,000 | 5,000 | 1,000 |

BDL = Below detection limit (Ag < 1 µg/l, Cd < 1 µg/l, Cr < 5 µg/l, Pb < 5 µg/l, Se < 1 µg/l)

*4.15.2.2 Column Leaching Results*

Results of column leaching tests using DDW and synthetic acid rain (SAR) produced no detectable concentrations of silver and chromium from RAP or limerock and are not discussed in further detail. Appendix Tables J.6 – J.8 and Figures 4.39 – 4.41 show the detectable concentrations of cadmium, lead, and selenium, respectively.

*4.15.2.3 Cadmium*

Column leaching tests conducted with DDW showed no leachable cadmium from either RAP or limerock (Appendix Table J.6 and Figure 4.39). When SAR was introduced to the RAP column, leachable cadmium was released in a decreasing trend over time. The concentration of cadmium in the leachate was far below the EPA regulatory standard of 1,000 µg/l. After 300 minutes of contact time, no detectable cadmium concentrations were found. The results indicate that cadmium leachate from RAP, when in contact with aqueous solutions of either DDW or SAR, has no significant effect on the environment.

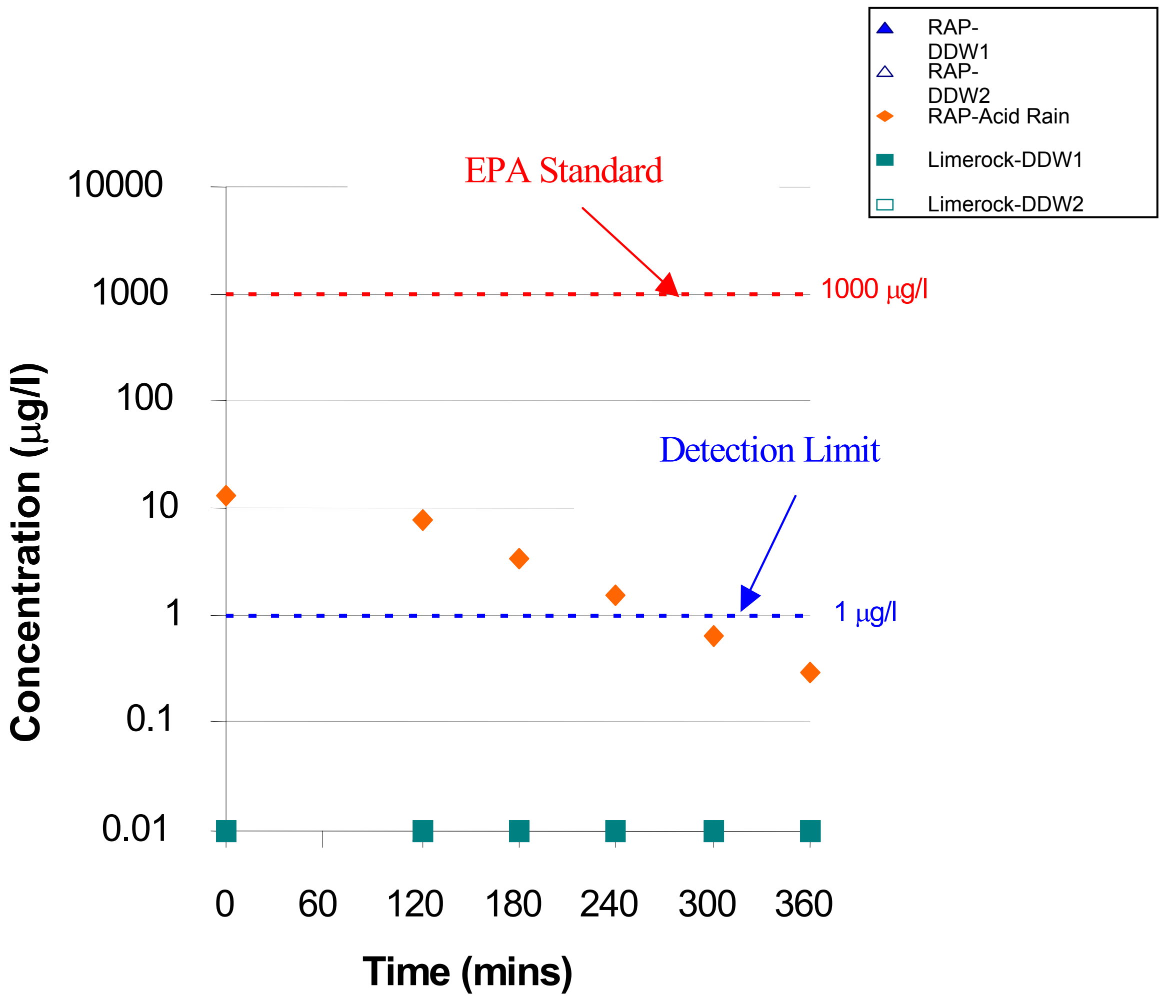



Figure 4.39 Concentration of Cadmium versus time in Leachate from Column Leaching Tests

*4.15.2.4 Lead*

Appendix Table J.7 and Figure 4.40 show the concentration of lead from column leaching tests. No detectable lead concentrations were produced from RAP columns exposed to either the DDW or SAR leaching media. For Limerock, detectable concentrations well below the EPA Standard of 5000 μg/l were found at 120 minutes and 180 minutes, respectively. After 240 minutes of contact time, no detectable lead concentrations were found. The results indicate that lead leachate from RAP, when in contact with aqueous solutions or either DDW or SAR, has no significant effect on the environment.

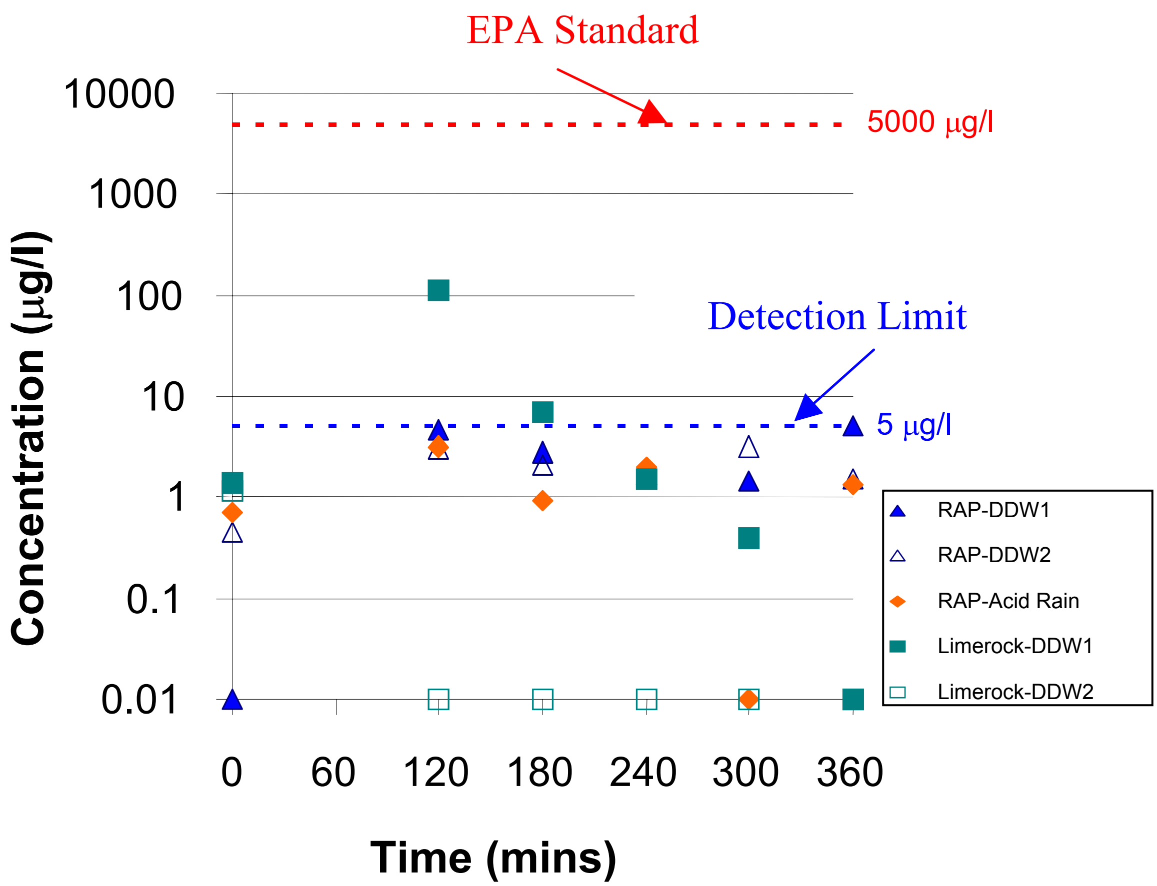



Figure 4.40 Concentration of Lead versus time in Leachate from Column Leaching Tests

#### *4.15.2.5 Selenium*

Appendix Table J.8 and Figure 4.41 show the concentrations of selenium in column leaching tests. When DDW was introduced to the RAP columns, two detectable concentrations were found in each of the duplicated columns near the detection limit. When SAR was introduced, no detectable concentrations were found. The results indicate that selenium leachate from RAP, when in contact with aqueous solutions of either DDW or SAR, has no significant effect on the environment.

When DDW was introduced to the Limerock columns, concentrations in excess of the EPA Standard were found. These concentrations generally decreased with time of exposure (Appendix Table J.8). As was stated previously, Selenium occurs naturally in sedimentary deposits. Because there was no information available on the source, storage and process of the Limerock used in this study, it is not possible to determine the cause of these high concentrations. Determination of this value was beyond the scope of the project.

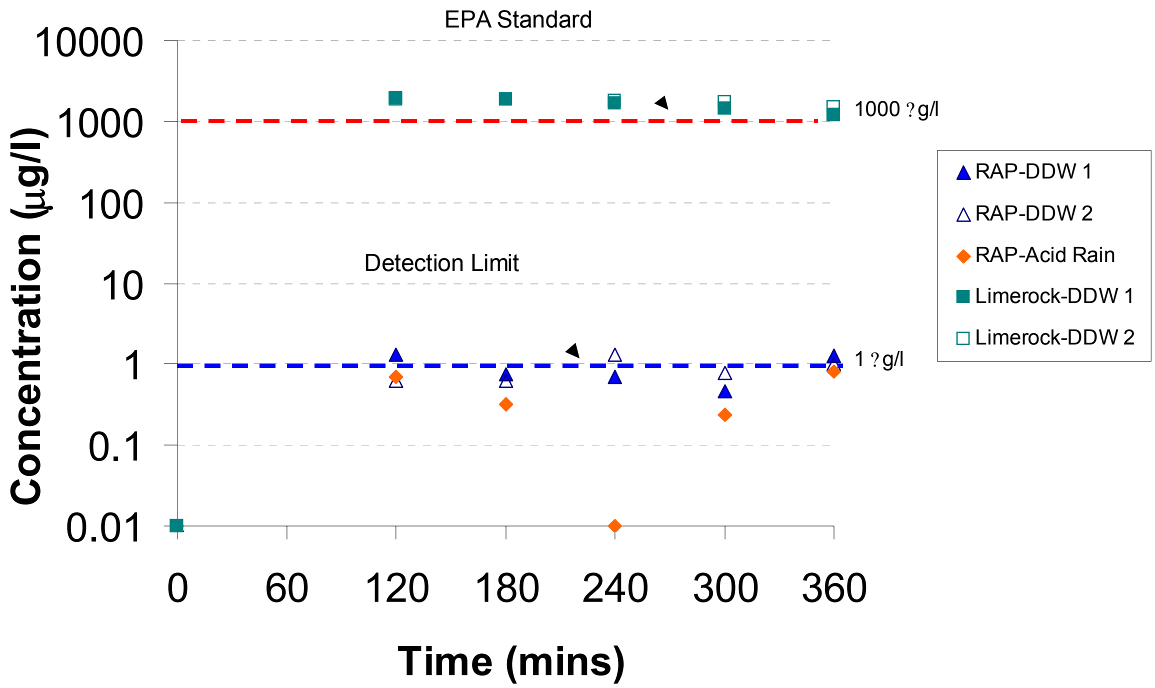



Figure 4.41 Concentration of Selenium in Leachate from Column Leaching Tests

### 4.15.3 Environmental Summary

Tables 4.13 and 4.14 present a summary of the testing for both RAP and Limerock, respectively. The data presented in the tables are the average concentrations for the data above the detection limit along with the percent of samples that produced data below the detectable limit of the lab equipment. Evaluation of the data in these tables indicates that RAP does not pose any threat to the environment, and that most of the data even falls below the detection limit of the equipment used. Concentrations as high as 10 µg/l were rarely observed showing how safe these materials are from an environmental standpoint.

Data in Table 4.13 indicates shows that none of the chemicals leach into the environment from RAP at significant levels regardless of the type of test conducted. Samples were evaluated using four different testing protocols and none of the results are near the EPA Standards. As stated previously, the anomaly in the lead testing is most likely due to an external source of contamination, as it only occurs in one test protocol

Data in Table 4.14 indicates that limerock contains about the same concentrations of the five metals as RAP. Again none of the concentrations are near the EPA standards and lead displayed a slightly elevated concentration.

Table 4.13 Environmental Testing Summary for RAP

| | Silver | Cadmium | Chromium | Lead | Selenium |
|---|---|---|---|---|---|
| Field Surface Runoff Ave > BDL (μg/l) | 1.79 | 2.78 | < 5 | 131.31 | 2.29 |
| % BDL | 62 | 94 | 100 | 86 | 50 |
| Field Leachate Water Ave > BDL (μg/l) | 1.65 | < 1 | < 5 | 7.76 | 11.46 |
| % BDL | 45 | 100 | 100 | 93 | 9 |
| Lab Column Leaching with DDW Ave > BDL (μg/l) | < 1 | < 1 | < 5 | < 5 | 1.22 |
| % BDL | 100 | 100 | 100 | 100 | 67 |
| Lab Column Leaching with SAR Ave > BDL (μg/l) | < 1 | 6.33 | < 5 | < 5 | < 1 |
| % BDL | 100 | 33 | 100 | 100 | 100 |
| Detection Limit (μg/l) | 1 | 1 | 5 | 5 | 1 |
| EPA Standard (μg/l) | 5000 | 1000 | 5000 | 5000 | 1000 |

Table 4.14 Environmental Testing Summary on Limerock

| | Silver | Cadmium | Chromium | Lead | Selenium |
|---|---|---|---|---|---|
| Field Surface Runoff Ave > BDL (μg/l) | 1.41 | 2.75 | 9.14 | 7.80 | 19.37 |
| % BDL | 42 | 83 | 92 | 67 | - |
| Field Leachate Water Ave > BDL (μg/l) | 1.54 | < 1 | < 5 | 6.03 | 426.53 |
| % BDL | 36 | 100 | 100 | 86 | - |
| Lab Column Leaching with DDW Ave > BDL (μg/l) | < 1 | < 1 | < 5 | 59.94 | 1693.85 |
| % BDL | 100 | 100 | 100 | 67 | 0 |
| Detection Limit (μg/l) | 1 | 1 | 5 | 5 | 1 |
| EPA Standard (μg/l) | 5000 | 1000 | 5000 | 5000 | 1000 |

# 5. Conclusions

## 5.1 Initial Strength Gain Conclusions

Field testing to document the initial change in the engineering behavior of RAP based on strength and stiffness characteristics from the LBR, Clegg, FWD and SSG tests yielded the following conclusions.

1. FWD, Clegg, and SSG results consistently modeled the initial strength gains at lower strain levels, while the LBR values determined from field CBR's reflect its strength at higher strains.
2. The strength-deformation characteristics of RAP increased with time after placement over the eight-week testing period while the limerock strength-deformation characteristics varied due to moisture changes, therefore, RAP was less susceptible to moisture than limerock.
    a) LBR, Clegg, and FWD test results showed a 50% increase in the engineering properties of RAP at week eight.
    b) SSG test results indicate a 15% increase in the stiffness of RAP at week eight.
3. The LBR testing procedure yields strength-deformation characteristics of RAP that are one-third those produced by the Clegg, FWD, and SSG.
4. Based on the small strain stiffness results of the Clegg, FWD, and SSG testing, RAP performed in a manner similar to limerock.

Therefore, RAP usage should be limited to subgrade applications or to sub-base applications below rigid pavements once the concerns over creep potential, or large strain, are clarified

5. Comparisons of RAP to limerock behavior using the Clegg, FWD, and SSG show that RAP achieved 80 to 115 % the stiffness of limerock during the eight-week testing intervals. Thus, the Clegg, FWD and SSG tests indicate that RAP is equivalent in stiffness to limerock.

## 5.2 RAP-Soil Mixing Conclusions

Laboratory testing to document the strength and drainage characteristics of RAP-soil mixtures lead to the following conclusions.

1. The addition of fine sand (i.e. material passing the #40 sieve) to RAP provided an improvement in density, bearing strength, and stiffness.
    a. The density and LBR improved with the addition of material passing the #40 sieve over the ranges examined in this study. The 80% RAP – 20% soil mixture provided significant improvements in density and strength characteristics. The 60% RAP – 40% soil mixture yielded better density and strength characteristics than 100% RAP.
    b. The major improvements in LBR are due to the added material passing the #40 sieve size, and not because of slight increases in density.
    c. Significant increase in the secant modulus was only achieved for the 80% RAP- 20% soil mixture.

d. The angle of internal friction decreased while the cohesion increased with the addition of material passing the #40 sieve.
e. The RAP-soil mixtures were classified as an A-1-b soil according to the AASHTO classification.

2. The permeability of RAP and RAP-soil mixtures compacted to FM 5-521 classified as material providing good drainage and as a poorly drained material respectively. Permeability of the RAP-soil mixtures decreased with the addition of material passing the #40 sieve.
3. RAP yielded higher resilient moduli than the RAP-soil mixtures. The higher resilient modulus of RAP might be attributed to the resilient modulus test procedure. The resilient modulus decreased with the addition of material passing the #40 sieve.
4. The fine sand used in this study was a very difficult material to process and is not recommended for RAP-soil mixtures. A fine, non-organic sand with similar grain-size distribution is recommended for mixing with RAP.
5. RAP and RAP-soil mixtures met the minimum LBR requirement of 40 for subgrade material, indicating that RAP is acceptable as a stabilizer for subgrade construction.
6. RAP and RAP-soil mixtures did not meet the minimum LBR requirement of 100 for base application in highway construction.
7. The estimated layer coefficients for base material ($a_2$) of the RAP and 80% RAP – 20% soil mixture compare well with values specified by the FDOT for graded aggregate base material. The base layer coefficients decreased with the addition of material passing the #40 sieve.
8. In general, the 80% RAP – 20% soil mixture provided the best strength properties while maintaining a reasonable permeability coefficient.

## 5.3 Environmental Conclusions

Both the laboratory and field investigations indicate that the use of RAP as a highway fill poses no environmental concerns. Concentrations reported for the heavy metals evaluated in RAP (i.e., Silver, Cadmium, Chromium, Lead and Selenium) are well below all EPA Standards.

The testing protocol, which included four types of environmental evaluations, resulted in similar conclusions indicating these tests were properly conducted. With the exception of Selenium in Limerock, all metals evaluated yielded similar environmental properties in both the RAP and the limerock control. Selenium occurs naturally in many geologic deposits and influences the concentration in limerock.

# 6. Recommendations

RAP has proven to be a very useful highway fill material. The following recommendations address the several areas of concern that still exist.

1. The long-term strength deformation (i.e., creep or large strain) behavior of RAP and RAP-soil mixes should be investigated. Soils selected for mixing with RAP should increase the percentage of material passing the #40 sieve. Both laboratory and field tests should be conducted. To evaluate the long-term behavior, the FDOT Materials Office test pits in Gainesville, Florida should be used and the testing protocol outlined in the FDOT Materials Manual (2000) should be followed.
2. The correlations between LBR and dynamic tests such as the Clegg, FWD, or SSG should be developed from several field sites around the state. Based on results to date it is believed that the Clegg test best represents the strength-deformation characteristics of RAP and would be the recommended choice. Static and dynamic plate testing could be performed in conjunction with the Clegg tests at FDOT's Materials Office to develop correlations between the CIV and the modulus of subgrade reaction.
3. Following the research on the long-term strength-deformation characteristics, a full-scale highway study using RAP in sub-base, subgrade and general fill applications should be conducted. The study site should be at least ½ mile long. RAP should be compared to the other FDOT approved materials.

4. Field compaction of RAP has been successfully performed, by flooding the area to be compacted prior to using vibratory compaction on 6-inch lifts. This is contrary to the conventional Proctor moisture-density approach. The effects of moisture on field compaction of RAP must be understood so it can be specified in the FDOT Specifications.

# 7. Field Specifications

The following specifications, presented in the Phase I report in the format currently used in the FDOT Specifications for Road and Bridge Construction, were modified to reflect the results from the Phase II findings. They are to be considered preliminary or developmental at this point and will be refined further during future research that will focus on the field and creep behavior of RAP and RAP-Soil mixes.

*Special comments are included in this section to substantiate the reasons for the specifications. All comments are shown in italics. These specifications are presented for inclusion in two sections of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction. One portion will be included in the section in Division II, under Construction Details for Base Courses as Section 283 and the other portion will be specified under the section in Division III, under Flexible Pavement Materials in Section 918.*

**SECTION 283**

**RECLAIMED ASPHALT PAVEMENT SUB-BASE**

*RAP is limited to sub-base applications below rigid pavements because of its excellent drainage characteristics, low LBR values, and potential for creep.*

**283-1 Description.**

Construct a sub-base course comprised of reclaimed asphalt pavement (RAP) material below rigid pavement.

*The post-milling processes that reduce the size of RAP with tubgrinder or hammermill crushers, produced a uniform material with desirable highway engineering properties. RAP stockpiles form a hard crust when exposed to summer temperatures, therefore, samples should be obtained from material below this crust, which is typically six to10 inches thick. Special care should be taken for stockpiles of RAP obtained from residential construction; these stockpiles often include large slabs that are unsuitable for FDOT applications.*

**283-2 Materials.**

The contractor may use RAP material, obtained by either milling or crushing an existing asphalt pavement, meeting the following gradation requirements:

| Sieve Size | Percent By Weight Passing |
|---|---|
| 1.5-inch | 90 to 100 |
| 3/8 -inch | 50 to 90 |
| # 10 | 25 to 60 |
| #200 | Less than 5 |

Gradation analyses shall conform to FM 1-T 027 with the following exceptions:

(1) Air-dry samples to surface dry condition (2% or less moisture).

(2) If using mechanical shakers, use a sieving time of 15 minutes minimum.

When the RAP material is stockpiled from a previous Department project and the composition of the existing pavement is known, the Engineer may approve the material on the basis of composition. When the composition of stockpiled RAP is not known, use the following procedure for approval:

(1) Conduct a minimum of six extraction gradation analyses of the RAP material. Take samples at random locations in the stockpile.

(2) Request the Engineer to make a visual inspection of the stockpile of the RAP material. Based on this visual inspection of the stockpiled material and the results of the gradation analyses, the Engineer will determine the suitability of the materials.

(3) The Engineer may require crushing of stockpiled material to meet gradation criterion.

*Preliminary compaction based on dry rodded unit weight testing quickly and accurately yielded the variations in density of RAP-Soil mixes results. The dry rodded densities are to be used only as an indicator of which mixtures provide the desired density. Proctor testing should be used to further validate the moisture-density relationships.*

*The addition of an A-2-6 soil, increased the percentage of material passing the number 40 sieve resulting in an increase in the maximum dry Proctor density and LBR, without adversely affecting the permeability. It is expected that fine aggregates in the A-2 and A-3 categories would yield similar results for RAP-Soil mixes. These properties were acceptable for 60/40 and 80/20 ratios of RAP to soil, however, the engineering properties were optimal at the 80/20 level. For ratios with more than 40 percent soil the permeability of the mix would adversely affect the drainage characteristics.*

**283-2.1 Mixtures of RAP and Fine Aggregate.**

When RAP is mixed with a fine aggregate, the maximum allowable percentage of the soil is limited to 40 percent by weight. The soil added must meet the gradation requirements of Section 283-2 Materials.

**283-3 Spreading RAP Material.**

**283-3.1 Method of Spreading:** Spread the RAP with a blade or device, which strikes off the material uniformly to laying thickness and produces an even distribution of the RAP.

**283-3.2 Number of Courses:** When the specified compacted thickness of the sub-base is greater than 6-inches, construct the base in multiple courses. Place the first course to a thickness of approximately one-half the total thickness of the finished base, or sufficient additional thickness to bear the weight of the construction equipment without disturbing the subgrade. The compacted thickness of any course shall not exceed 6-inches.

**283-4 Compacting and Finishing Base.**

*Although laboratory compaction tests have shown that RAP is insensitive to moisture content, flooding the area to be compacted and immediately using vibratory roller to achieve the required densities, most readily resulted in proper field compaction of RAP.*

*Field moisture contents obtained from nuclear density equipment must be carefully correlated to moisture contents from oven-dried samples.*

**283-4.1 General.**

*201-4.1.1 Single-Course Base:* Construct as specified in 200-6.1.1.

*201-4.1.2 Multiple-Course Base:* Construct as specified in 200-6.1.2.

**283-4.2 Moisture Content:** Meet the requirements of 200-6.2. Ensure that the moisture content at the time of compaction is 3% wet of optimum.

**283-4.3 Density Requirements:** After attaining the proper moisture content, compact the material to a density of not less than 98% of maximum density as determined by FM 5-521. Perform sub-base compaction using standard base compaction equipment, vibratory compactors, trench rollers, or other special equipment that will provide the density requirements specified herein.

**283-4.4 Density Tests:** Meet the requirements of 200-6.4.

**283-5 Testing Surface.**

In the testing of the surface, do not take measurements in small holes caused by the grader pulling out individual pieces of aggregate.

**SECTION 918**

**RECLAIMED ASPHALT PAVEMENT**

**MATERIAL FOR SUB-BASE**

**918-1 General.**

This section governs the material requirements for the construction of a sub-base course using RAP or stabilized with RAP below rigid pavements.

*Although lab compaction research has shown RAP to be insensitive to moisture content, flooding the area to be compacted and immediately using vibratory roller to achieve the required densities most readily resulted in proper field compaction of RAP.*

**918-2 Furnishing of Material.**

Except as might be specifically shown otherwise, all RAP material and the sources thereof shall be furnished by the Contractor. Approval of RAP sources shall be in accordance with 6-3.3. Any RAP material occurring in State-furnished borrow areas shall not be used by the Contractor in constructing the sub-base, unless permitted by the plans or other contract documents.

*The post-milling processes that reduce the size of RAP with tubgrinder or hammermill crushers produced a uniform material with desirable highway engineering properties.*

**918-3 Composition.**

The material used shall be reclaimed asphalt pavement (RAP).

**918-4 Liquid Limit and Plasticity Requirements.**

None required.

**918-5 Mechanical Requirements.**

**918-5.1 Deleterious Material:** RAP material shall contain not more than five percent of any lumps, balls or pockets of foreign material in sufficient quantity as to be detrimental to the proper bonding, finishing, or strength of the RAP base.

**918-5.2 Gradation and Size Requirements:** Meet the requirements of 283-2. All crushing or breaking-up, which might be necessary in order to meet such size requirements, shall be done before the material is placed on the road.

**918-6 Alternative Acceptance Means.**

*Field-testing of RAP indicated RAP had similar stiffness to the Limerock used in a control section at small strains. Field-testing was performed with Field CBR's, Falling Weight Deflectometers, Clegg Impact Hammers and the Soil Stiffness Gauge.*

**918-6.1 Field LBR:** Field CBR (ASTM D4429) values shall be taken at the following time intervals and converted to LBR values, and shall be performed directly on the sub-base. At each testing interval the corresponding minimum average LBR values shall be met:

| *Testing Interval* | *Minimum Average LBR Value* |
|---|---|
| Finished Construction | 15 |
| 2-months | 35 |

**918-6.2 Falling Weight Deflectometer:** Impulse Stiffness Moduli (ISM) values shall be determined at the following time intervals based on FWD tests conducted using a falling weight height that produces a 9000 pound impulse loading directly on the sub-base. The ISM will be determined by dividing the maximum impulse load by the deflection of the geophone directly under the loading plate, and reported in units of kips per mil. At each testing interval the corresponding minimum average ISM values shall be met:

| *Testing Interval* | *Minimum Average ISM Value* |
|---|---|
| Finished Construction | 0.30 |
| 2-months | 0.40 |

**918-6.3 Clegg Impact Test:** Clegg Impact Values (CIV) shall be taken at the following time intervals. A minimum of four, Clegg Impact tests should be performed directly on the sub-base at each specified location on the RAP. At each testing interval the corresponding minimum average CIV values shall be met:

| *Testing Interval* | *Minimum Average CIV Value* |
|---|---|
| Finished Construction | 26 |
| 2-months | 40 |

**918-6.4 Soil Stiffness Gauge:** Soil Stiffness Gauge (SSG) values, reported in units of kips per inch, shall be taken at the following time intervals directly on the sub-base. At each testing interval the corresponding minimum average SSG values shall be met:

| *Testing Interval* | *Minimum Average SSG Value* |
|---|---|
| Finished Construction | 100 |
| 2-months | 120 |

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# Appendix A

# Field Moisture and Density Data

| WEEK 1 | | | |
|---|---|---|---|
| Test Depth | Wet Density (pcf) | Speedy Moisture | Dry Density (pcf) |
| **1** | | | |
| *12 -inch* | 123.5 | 3.6 | 119.2 |
| *6-inch* | 122.1 | 3.6 | 117.9 |
| **2** | | | |
| *12-inch* | 124.4 | 3.6 | 120.1 |
| *6-inch* | 124 | 3.6 | 119.7 |
| **3** | | | |
| *12 -inch* | 123.9 | 3.5 | 119.7 |
| *6-inch* | 122.9 | 3.5 | 118.7 |
| **4** | | | |
| *12-inch* | 126.1 | 5.4 | 119.6 |
| *6-inch* | 125.1 | 5.4 | 118.7 |
| **5** | | | |
| *12 -inch* | 122.9 | 3.5 | 118.7 |
| *6-inch* | 123.7 | 3.5 | 119.5 |
| **6** | | | |
| *12-inch* | 125.7 | 3.8 | 121.1 |
| *6-inch* | 124.9 | 3.8 | 120.3 |
| **7** | | | |
| *12 -inch* | 125.4 | 3.7 | 120.9 |
| *6-inch* | 125 | 3.7 | 120.5 |
| **8** | | | |
| *12-inch* | 125.6 | 3.9 | 120.9 |
| *6-inch* | 125.5 | 3.9 | 120.8 |
| **9** | | | |
| *12 -inch* | 123.6 | 8.5 | 113.9 |
| *6-inch* | 123.7 | 8.5 | 114.0 |
| **10** | | | |
| *12-inch* | 122.6 | 8.5 | 113.0 |
| *6-inch* | 122.2 | 8.5 | 112.6 |
| **11** | | | |
| *12 -inch* | 124.2 | 9.6 | 113.3 |
| *6-inch* | 123.6 | 9.6 | 112.8 |

| WEEK 2 | | | |
|---|---|---|---|
| Test Depth | Wet Density (pcf) | Speedy Moisture | Dry Density (pcf) |
| **1** | | | |
| *12 -inch* | 124 | 3.5 | 119.8 |
| *6-inch* | 123.9 | 3.5 | 119.7 |
| **2** | | | |
| *12-inch* | 123.2 | 4 | 118.5 |
| *6-inch* | 124.8 | 4 | 120.0 |
| **3** | | | |
| *12 -inch* | 126.4 | 3.8 | 121.8 |
| *6-inch* | 124.6 | 3.8 | 120.0 |
| **4** | | | |
| *12-inch* | 126.1 | 3.3 | 122.1 |
| *6-inch* | 124.4 | 3.3 | 120.4 |
| **5** | | | |
| *12 -inch* | 126.4 | 5 | 120.4 |
| *6-inch* | 125.4 | 5 | 119.4 |
| **6** | | | |
| *12-inch* | 125.8 | 4.1 | 120.8 |
| *6-inch* | 125.3 | 4.1 | 120.4 |
| **7** | | | |
| *12 -inch* | 125.6 | 5 | 119.6 |
| *6-inch* | 125.4 | 5 | 119.4 |
| **8** | | | |
| *12-inch* | 126 | 4.9 | 120.1 |
| *6-inch* | 125 | 4.9 | 119.2 |
| **9** | | | |
| *12 -inch* | 125.1 | 9.2 | 114.6 |
| *6-inch* | 124.1 | 9.2 | 113.6 |
| **10** | | | |
| *12-inch* | 122.7 | 10.6 | 110.9 |
| *6-inch* | 122.5 | 10.6 | 110.8 |
| **11** | | | |
| *12 -inch* | 122.8 | 10 | 111.6 |
| *6-inch* | 123.3 | 10 | 112.1 |

| WEEK 4 | | | |
|---|---|---|---|
| Test Depth | Wet Density | Speedy Moisture | Dry Density |
| | **1** | | |
| *12 -inch* | 123.9 | 2.9 | 120.4 |
| *6-inch* | 122.4 | 2.9 | 119.0 |
| | **2** | | |
| *12-inch* | 125.9 | 2.9 | 122.4 |
| *6-inch* | 125.8 | 2.9 | 122.3 |
| | **3** | | |
| *12 -inch* | 125.4 | 2.9 | 121.9 |
| *6-inch* | 124.4 | 2.9 | 120.9 |
| | **4** | | |
| *12-inch* | 124.1 | 2.9 | 120.6 |
| *6-inch* | 123.1 | 2.9 | 119.6 |
| | **5** | | |
| *12 -inch* | 125.2 | 2.9 | 121.7 |
| *6-inch* | 124 | 2.9 | 120.5 |
| | **6** | | |
| *12-inch* | 124.9 | 2.9 | 121.4 |
| *6-inch* | 124.9 | 2.9 | 121.4 |
| | **7** | | |
| *12 -inch* | 124.6 | 2.9 | 121.1 |
| *6-inch* | 123.8 | 2.9 | 120.3 |
| | **8** | | |
| *12-inch* | 124.5 | 2.9 | 121.0 |
| *6-inch* | 123.6 | 2.9 | 120.1 |
| | **9** | | |
| *12 -inch* | 123.2 | 6.7 | 115.5 |
| *6-inch* | 124.7 | 6.7 | 116.9 |
| | **10** | | |
| *12-inch* | 123.4 | 6.7 | 115.7 |
| *6-inch* | 122.2 | 6.7 | 114.5 |
| | **11** | | |
| *12 -inch* | 122.9 | 6.7 | 115.2 |
| *6-inch* | 121.2 | 6.7 | 113.6 |

| WEEK 6 | | | |
|---|---|---|---|
| Test Depth | Wet Density | Speedy Moisture | Dry Density |
| **1** | | | |
| *12 -inch* | 126 | 4 | 121.2 |
| *6-inch* | 123.8 | 4 | 119.0 |
| **2** | | | |
| *12-inch* | 125.4 | 4 | 120.6 |
| *6-inch* | 122.9 | 4 | 118.2 |
| **3** | | | |
| *12 -inch* | 123.3 | 4 | 118.6 |
| *6-inch* | 123.1 | 4 | 118.4 |
| **4** | | | |
| *12-inch* | 121.8 | 4 | 117.1 |
| *6-inch* | 123.6 | 4 | 118.8 |
| **5** | | | |
| *12 -inch* | 124.8 | 4 | 120.0 |
| *6-inch* | 123.8 | 4 | 119.0 |
| **6** | | | |
| *12-inch* | 124.5 | 4 | 119.7 |
| *6-inch* | 123.2 | 4 | 118.5 |
| **7** | | | |
| *12 -inch* | 124.1 | 4 | 119.3 |
| *6-inch* | 124.5 | 4 | 119.7 |
| **8** | | | |
| *12-inch* | 123.5 | 4 | 118.8 |
| *6-inch* | 122.5 | 4 | 117.8 |
| **9** | | | |
| *12 -inch* | 121.1 | 6.4 | 113.8 |
| *6-inch* | 122.2 | 6.6 | 114.6 |
| **10** | | | |
| *12-inch* | 117.6 | 6.8 | 110.1 |
| *6-inch* | 120.8 | 6.8 | 113.1 |
| **11** | | | |
| *12 -inch* | 119.8 | 7.1 | 111.9 |
| *6-inch* | 118.5 | 7.1 | 110.6 |

| WEEK 8 | | | |
|---|---|---|---|
| Test Depth | Wet Density | Speedy Moisture | Dry Density |
| **1** | | | |
| *12 -inch* | 126.2 | 4.2 | 121.1 |
| *6-inch* | 125.2 | 4.2 | 120.2 |
| **2** | | | |
| *12-inch* | 126.01 | 4.2 | 120.9 |
| *6-inch* | 124.2 | 4.2 | 119.2 |
| **3** | | | |
| *12 -inch* | 126.5 | 4.2 | 121.4 |
| *6-inch* | 123.8 | 4.2 | 118.8 |
| **4** | | | |
| *12-inch* | 125.2 | 4.2 | 120.2 |
| *6-inch* | 124 | 4.2 | 119.0 |
| **5** | | | |
| *12 -inch* | 126.3 | 4.2 | 121.2 |
| *6-inch* | 125.1 | 4.2 | 120.1 |
| **6** | | | |
| *12-inch* | 125.4 | 4.2 | 120.3 |
| *6-inch* | 123.9 | 4.2 | 118.9 |
| **7** | | | |
| *12 -inch* | 126.2 | 4.2 | 121.1 |
| *6-inch* | 124 | 4.2 | 119.0 |
| **8** | | | |
| *12-inch* | 126.5 | 4.2 | 121.4 |
| *6-inch* | 125.5 | 4.2 | 120.4 |
| **9** | | | |
| *12 -inch* | 124.3 | 7 | 116.2 |
| *6-inch* | 124.4 | 7.3 | 115.9 |
| **10** | | | |
| *12-inch* | 121.6 | 8.6 | 112.0 |
| *6-inch* | 121 | 8.6 | 111.4 |
| **11** | | | |
| *12 -inch* | 123.7 | 9.4 | 113.1 |
| *6-inch* | 123.5 | 9.5 | 112.8 |

**Appendix B**

**Falling Weight Deflectometer Data**

```
R80     137   010426FIT_1    36F10
700023008002-0310          03111  8
150 0    203 305 457 610 914 1524 5.9    0      8      12     18     24     36     60

RAP
*
S1.0100   WB   44               I41114111          Heights ..........................
 418 377 142  54   30   30   28  21   6640 14.82  5.60  2.12   1.19   1.19   1.12   0.81
 576 517 202  77   25   43   38  30   9152 20.34  7.94  3.01   0.99   1.68   1.49   1.17
 760 684 271 103   44   52   49  39 12080 26.93 10.67  4.07   1.73   2.05   1.95   1.54
S1.0200   WB   44               I41115111          Heights ..........................
 388 678 153  31   17   21   24  16   6168 26.68  6.04  1.22   0.66   0.82   0.95   0.65
 554 818 221  50   17   26   33  25   8808 32.20  8.69  1.95   0.66   1.03   1.28   0.97
 760 995 305  73   19   30   40  33 12080 39.17 12.00  2.89   0.74   1.19   1.57   1.29
S1.03     WB   44               I41116111          Heights ..........................
 403 479 162  59   24   31   28  22   6408 18.87  6.40  2.32   0.95   1.23   1.12   0.85
 569 634 225  84   32   43   40  30   9032 24.97  8.87  3.30   1.28   1.68   1.57   1.17
 774 809 300 112   43   53   52  40 12296 31.86 11.82  4.40   1.69   2.09   2.03   1.58
S1.04     WB   44               I41117111          Heights ..........................
 394 565 188  65   26   35   34  27   6256 22.26  7.41  2.57   1.03   1.40   1.33   1.05
 560 753 264  94   36   48   46  37   8888 29.65 10.41  3.71   1.40   1.89   1.82   1.46
 765 960 352 129   50   60   61  49 12152 37.79 13.85  5.09   1.98   2.38   2.40   1.94
S1.05     WB   44               I41118111          Heights ..........................
 391 613 213  67   18   30   34  26   6208 24.14  8.38  2.65   0.70   1.19   1.33   1.01
 550 812 288  95   25   39   46  37   8736 31.99 11.34  3.75   0.99   1.52   1.82   1.46
 7571050 382 130   36   46   61  48 12032 41.34 15.04  5.13   1.40   1.81   2.40   1.90
S1.06     WB   44               I41118111          Heights ..........................
 391 650 218  69   22   32   37  29   6208 25.60  8.60  2.73   0.87   1.27   1.45   1.13
 556 835 298  99   35   43   52  40   8840 32.86 11.73  3.91   1.36   1.68   2.03   1.58
 7671049 391 139   51   54   66  54 12184 41.30 15.39  5.46   2.02   2.13   2.61   2.14
S1.07     WB   44               I41119111          Heights ..........................
 393 591 189  67   28   41   38  28   6240 23.26  7.45  2.65   1.11   1.60   1.49   1.09
 556 774 268 100   47   56   54  39   8840 30.48 10.54  3.95   1.85   2.22   2.11   1.54
 764 982 360 140   59   72   72  51 12144 38.67 14.16  5.50   2.31   2.83   2.82   2.02
S2.01     WB   44               I41125111          Heights ..........................
 386 581 179  47   44   33   34  23   6136 22.88  7.06  1.83   1.73   1.31   1.33   0.89
 548 737 248  73   33   46   45  35   8712 29.02  9.75  2.89   1.32   1.81   1.78   1.37
 751 919 328 107   53   61   62  47 11928 36.16 12.92  4.19   2.10   2.42   2.44   1.86
S2.02     WB   44               I41150111          Heights ..........................
 413 395 165  73   31   44   39  29   6568 15.53  6.48  2.89   1.24   1.72   1.53   1.13
 574 529 225 103   50   60   54  41   9128 20.84  8.87  4.07   1.98   2.38   2.11   1.62
 777 727 305 135   68   79   72  54 12352 28.60 12.00  5.33   2.68   3.12   2.82   2.14
S2.03     WB   44               I41151111          Heights ..........................
 387 713 235  59   15   27   39  31   6152 28.06  9.26  2.32   0.58   1.07   1.53   1.21
 552 915 320  91   23   33   54  44   8768 36.04 12.62  3.58   0.91   1.31   2.11   1.74
 7591134 424 133   36   41   68  59 12072 44.64 16.67  5.25   1.40   1.60   2.69   2.30
S2.04     WB   44               I41151111          Heights ..........................
 389 643 187  56   23   33   40  31   6192 25.31  7.37  2.20   0.91   1.31   1.57   1.21
 553 830 262  85   32   44   55  43   8784 32.70 10.32  3.34   1.28   1.72   2.15   1.70
 7631046 353 121   45   55   73  58 12128 41.17 13.89  4.76   1.77   2.17   2.86   2.26
S2.05     WB   44               I41152111          Heights ..........................
 393 528 188  55   24   36   37  27   6248 20.80  7.41  2.16   0.95   1.44   1.45   1.05
 560 714 262  77   27   47   53  38   8888 28.10 10.32  3.01   1.07   1.85   2.07   1.50
 768 932 351 108   40   55   73  51 12208 36.71 13.81  4.23   1.57   2.17   2.86   2.02
S2.06     WB   44               I41154111          Heights ..........................
 386 534 168  55   26   39   38  29   6136 21.00  6.62  2.16   1.03   1.52   1.49   1.13
 547 732 236  80   38   51   53  41   8688 28.81  9.31  3.14   1.48   2.01   2.07   1.62
 750 958 319 109   50   65   71  54 11912 37.71 12.57  4.28   1.98   2.54   2.78   2.14
S2.07     WB   44               I41155111          Heights ..........................
 390 692 231  64   18   29   37  29   6192 27.23  9.09  2.52   0.70   1.15   1.45   1.13
 548 865 311  96   27   38   51  40   8712 34.07 12.26  3.79   1.07   1.48   1.99   1.58
 7621088 413 141   40   45   65  53 12104 42.84 16.28  5.54   1.57   1.76   2.57   2.10
S3.01     WB   44               I41157111          Heights ..........................
 375 737 173  22    5   17   27  21   5968 29.02  6.79  0.86   0.21   0.66   1.08   0.81
 538 912 248  44   15   22   39  30   8552 35.91  9.75  1.75   0.58   0.86   1.53   1.17
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 7451109 332  70  16  25   52  40 11840 43.68 13.06  2.77  0.62  0.98  2.03  1.58
S3.02      WB  44              I41158111        Heights ..........................
 377 632 189  59  20  29   27  23  6000 24.89  7.45  2.32  0.78  1.15  1.08  0.89
 541 824 257  87  23  40   41  30  8600 32.45 10.10  3.42  0.91  1.56  1.62  1.17
 7451030 338 121  35  51   56  40 11840 40.55 13.32  4.76  1.36  2.01  2.20  1.58
S3.03      WB  44              I41158111        Heights ..........................
 368 771 194  37  12  23   27  21  5848 30.36  7.63  1.47  0.45  0.90  1.08  0.81
 526 938 263  63  21  28   39  30  8368 36.91 10.37  2.48  0.82  1.11  1.53  1.17
 7311122 347  90  24  34   52  40 11616 44.18 13.67  3.54  0.95  1.35  2.03  1.58
S3.04      WB  44              I41159111        Heights ..........................
 394 510 164  39   7  24   28  20  6256 20.09  6.44  1.55  0.29  0.94  1.12  0.77
 552 676 230  64  16  31   40  29  8776 26.60  9.04  2.52  0.62  1.23  1.57  1.13
 768 881 313  97  25  39   53  39 12208 34.70 12.31  3.83  0.99  1.52  2.07  1.54
S3.05      WB  44              I41159111        Heights ..........................
 393 535 164  51  15  28   27  20  6256 21.05  6.44  2.00  0.58  1.11  1.08  0.77
 557 719 233  77  22  38   39  29  8840 28.31  9.17  3.01  0.87  1.48  1.53  1.13
 768 934 318 110  31  46   52  39 12208 36.79 12.53  4.32  1.24  1.81  2.03  1.54
S3.06      WB  44              I41200111        Heights ..........................
 388 581 168  42  27  31   29  21  6160 22.88  6.62  1.67  1.07  1.23  1.16  0.81
 548 757 233  63  40  43   42  30  8712 29.82  9.17  2.48  1.57  1.68  1.66  1.17
 759 973 314  90  44  54   57  41 12056 38.29 12.35  3.54  1.73  2.13  2.24  1.62
S3.07      WB  44              I41201111        Heights ..........................
 388 562 189  56  23  34   31  24  6168 22.13  7.45  2.20  0.91  1.35  1.20  0.93
 549 769 262  80  30  44   43  33  8728 30.27 10.32  3.14  1.19  1.72  1.70  1.29
 759 996 352 109  40  55   58  45 12056 39.21 13.85  4.28  1.57  2.17  2.28  1.78
S4.01      WB  44              I41203111        Heights ..........................
 390 630 300 122  36  35   29  24  6200 24.80 11.82  4.80  1.40  1.40  1.16  0.93
 551 789 388 176  62  53   41  34  8760 31.07 15.26  6.92  2.43  2.09  1.62  1.33
 759 957 482 232  92  73   56  45 12064 37.67 18.97  9.12  3.63  2.87  2.20  1.78
S4.02      WB  44              I41207111        Heights ..........................
 409 483 232 114  46  42   31  25  6496 19.00  9.13  4.48  1.81  1.64  1.20  0.97
 581 660 322 167  73  60   43  35  9232 25.97 12.66  6.56  2.88  2.38  1.70  1.37
 779 820 403 216 102  82   57  44 12376 32.28 15.88  8.51  4.00  3.24  2.24  1.74
S4.03      WB  44              I41211111        Heights ..........................
 404 538 240 122  48  43   28  24  6424 21.17  9.44  4.80  1.90  1.68  1.12  0.93
 568 677 316 169  72  61   39  33  9032 26.64 12.44  6.64  2.84  2.42  1.53  1.29
 774 833 402 224 102  85   57  44 12304 32.78 15.84  8.84  4.00  3.36  2.24  1.74
S4.04      WB  44              I41212111        Heights ..........................
 459 579 283 140  54  32   17  17  7296 22.80 11.16  5.50  2.14  1.27  0.66  0.69
 613 714 357 182  78  52   28  26  9736 28.10 14.07  7.17  3.09  2.05  1.12  1.01
 757 834 450 239 108  76   43  37 12032 32.82 17.73  9.41  4.24  3.00  1.70  1.46
EOF
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```
R80      137010503FIT_2    36F20
7000    08002-175    694200       .
 150    0 203 305 457 610 9141524   5.9    0.0    8.0  12.0  18.0  24.0  36.0  60.0
A:\                         .FWD
Rap

.............................................................
TODD    Standard Setup
*0000
S   1.010WB  -17.8    26 25D70928  -0  79  77
 389 361 158  68  37  36  31  24  6178 14.22  6.23  2.66  1.44  1.43  1.22  0.96
 567 512 226  96  50  46  44  36  9010 20.17  8.88  3.79  1.96  1.83  1.74  1.42
 760 637 287 118  55  53  50  37 12069 25.07 11.30  4.65  2.17  2.08  1.98  1.47
S   1.020WB  -17.8    26 23D70929  -0  79  73
 390 304 126  47  32  25  23  15  6189 11.97  4.98  1.85  1.26  0.97  0.89  0.60
 557 511 185  66  45  38  35  24  8859 20.12  7.27  2.60  1.76  1.50  1.36  0.95
 726 655 234  77  54  48  45  33 11533 25.78  9.22  3.05  2.11  1.90  1.78  1.30
S   1.030WB  -17.8    29 23D70931  -0  84  74
 378 433 148  50  27  27  23  18  6006 17.06  5.83  1.97  1.07  1.06  0.90  0.70
 568 597 219  73  36  35  37  28  9018 23.52  8.61  2.87  1.43  1.39  1.47  1.12
 757 728 281  99  45  44  48  38 12026 28.64 11.08  3.89  1.78  1.73  1.90  1.50
S   1.040WB  -17.8    29 23D70932  -0  85  73
 379 427 176  77  34  33  29  21  6027 16.82  6.91  3.02  1.33  1.29  1.15  0.82
 569 569 239 110  55  46  46  35  9046 22.40  9.40  4.33  2.17  1.82  1.82  1.37
 760 729 310 146  73  62  62  47 12069 28.72 12.22  5.74  2.86  2.45  2.45  1.85
S   1.050WB  -17.8    30 23D70934  -0  85  74
 373 517 175  66  35  33  30  22  5924 20.35  6.89  2.59  1.39  1.30  1.19  0.85
 567 644 241 100  53  46  46  34  9002 25.34  9.49  3.94  2.08  1.83  1.79  1.32
 756 806 317 136  69  60  62  46 12013 31.74 12.47  5.36  2.74  2.36  2.44  1.81
S   1.060WB  -17.8    29 23D70935  -0  85  74
 371 443 161  69  42  38  34  26  5892 17.45  6.33  2.70  1.66  1.52  1.34  1.02
 555 646 235 100  56  54  48  36  8824 25.42  9.26  3.93  2.19  2.13  1.91  1.41
 741 806 314 136  74  73  66  51 11779 31.74 12.35  5.37  2.93  2.87  2.59  2.00
S   1.070WB  -17.8    30 23D70936  -0  85  73
 380 402 159  74  48  44  35  25  6038 15.82  6.27  2.93  1.89  1.73  1.38  0.97
 564 584 233 111  70  61  53  39  8962 22.99  9.18  4.37  2.76  2.41  2.09  1.54
 753 757 309 149  93  79  73  55 11965 29.82 12.15  5.85  3.67  3.11  2.85  2.18
S   2.010WB  -17.8    29 23D70938  -0  84  74
 376 422 149  54  35  33  30  22  5975 16.60  5.87  2.13  1.39  1.30  1.19  0.87
 560 590 215  81  49  47  45  33  8898 23.24  8.48  3.17  1.93  1.85  1.78  1.30
 751 747 287 111  63  61  59  44 11934 29.41 11.29  4.38  2.50  2.38  2.32  1.74
S   2.020WB  -17.8    29 23D70939  -0  85  73
 379 392 164  69  41  38  36  26  6022 15.41  6.47  2.73  1.61  1.50  1.41  1.01
 564 553 238 105  60  59  53  40  8959 21.79  9.37  4.14  2.36  2.31  2.07  1.56
 756 717 313 142  78  75  71  54 12005 28.23 12.34  5.57  3.08  2.97  2.79  2.11
S   2.030WB  -17.8    29 23D70940  -0  84  73
 372 422 191  81  47  44  37  28  5908 16.63  7.54  3.19  1.83  1.73  1.47  1.10
 560 605 275 120  68  61  55  42  8891 23.80 10.84  4.71  2.67  2.39  2.18  1.65
 753 773 360 161  91  79  75  57 11962 30.42 14.15  6.36  3.58  3.12  2.96  2.25
S   2.040WB  -17.8    29 24D70941  -0  85  74
 377 392 162  75  44  41  37  26  5991 15.45  6.36  2.96  1.74  1.63  1.44  1.01
 566 558 240 114  65  60  55  40  8999 21.97  9.44  4.48  2.56  2.36  2.18  1.57
 761 720 318 154  85  79  76  55 12097 28.36 12.51  6.06  3.36  3.11  2.98  2.15
S   2.050WB  -17.8    29 23D70942  -0  84  74
 382 390 143  66  46  41  34  24  6070 15.34  5.64  2.61  1.80  1.61  1.33  0.93
 568 553 214 102  68  61  52  36  9030 21.76  8.44  4.01  2.67  2.40  2.03  1.41
 763 694 288 138  89  80  71  49 12121 27.34 11.34  5.45  3.52  3.14  2.78  1.93
S   2.060WB  -17.8    30 23D70943  -0  85  74
 360 529 175  62  43  43  34  26  5725 20.82  6.87  2.45  1.69  1.67  1.35  1.01
 548 738 254  89  59  58  52  39  8705 29.07 10.02  3.51  2.32  2.28  2.04  1.52
 750 800 317 133  83  80  70  53 11914 31.48 12.47  5.24  3.28  3.15  2.76  2.08
S   2.070WB  -17.8    30 23D70944  -0  85  74
 368 444 157  76  51  45  35  25  5852 17.50  6.19  3.00  1.99  1.78  1.39  0.96
 557 649 232 112  73  64  54  37  8859 25.55  9.14  4.40  2.86  2.52  2.13  1.46
 752 833 310 149  96  84  73  51 11941 32.80 12.19  5.87  3.76  3.31  2.86  2.00
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S   3.010WB  -17.8    25 22D71042   -0  76  71
 369 611 136  43  33  29  28  21   5868 24.05   5.35  1.70  1.28  1.15  1.11  0.82
 565 672 200  75  50  45  41  29   8983 26.44   7.88  2.96  1.96  1.77  1.63  1.16
 749 878 269  96  62  59  54  40 11894 34.57 10.60  3.78  2.42  2.32  2.14  1.56
S   3.020WB  -17.8    23 22D71043   -0  74  71
 380 367 168  63  29  27  27  19   6035 14.46   6.63  2.49  1.16  1.06  1.07  0.76
 571 525 235  96  45  41  40  29   9073 20.65   9.25  3.78  1.77  1.60  1.59  1.14
 759 664 300 129  62  53  55  40 12065 26.15 11.82  5.08  2.45  2.09  2.16  1.58
S   3.030WB  -17.8    37 27D71204   -0  98  80
 383 332 137  68  44  36  29  20   6078 13.07   5.41  2.69  1.72  1.43  1.15  0.77
 571 497 205 102  65  54  45  31   9078 19.58   8.06  4.04  2.55  2.13  1.76  1.22
 761 657 267 133  81  71  58  40 12092 25.85 10.50  5.22  3.20  2.78  2.30  1.59
S   3.040WB  -17.8    36 26D71205   -0  97  79
 379 425 126  61  39  33  24  16   6030 16.74   4.98  2.42  1.53  1.31  0.95  0.62
 572 579 190  97  66  53  44  32   9086 22.80   7.49  3.82  2.59  2.08  1.75  1.27
 765 731 255 136  94  78  67  50 12156 28.77 10.04  5.35  3.72  3.07  2.64  1.98
S   3.050WB  -17.8    36 26D71206   -0  97  79
 379 395 146  68  42  33  25  18   6019 15.54   5.76  2.66  1.64  1.32  1.00  0.70
 572 560 219 101  63  50  40  28   9081 22.04   8.61  3.97  2.49  1.96  1.58  1.11
 761 712 286 132  81  64  53  37 12100 28.05 11.25  5.20  3.19  2.53  2.11  1.46
S   3.060WB  -17.8    37 26D71207   -0  99  79
 377 401 144  65  42  35  27  19   5991 15.79   5.67  2.57  1.66  1.40  1.07  0.76
 569 584 208  95  61  50  42  28   9034 23.00   8.20  3.73  2.42  1.97  1.65  1.11
 762 754 272 123  78  67  56  39 12113 29.70 10.70  4.85  3.06  2.62  2.19  1.52
S   3.070WB  -17.8    36 25D71208   -0  97  78
 373 458 154  76  47  39  32  22   5927 18.03   6.05  2.99  1.86  1.53  1.26  0.88
 555 659 231 114  68  58  47  33   8816 25.93   9.09  4.49  2.67  2.28  1.87  1.30
 749 841 308 153  89  77  64  45 11902 33.09 12.15  6.03  3.50  3.01  2.52  1.78
S   4.010WB  -17.8    26 26D71213   -0  79  80
 379 476 215 102  60  45  35  25   6022 18.72   8.46  4.04  2.35  1.79  1.37  0.98
 564 622 298 153  90  70  51  37   8967 24.48 11.75  6.03  3.55  2.74  2.02  1.45
 756 750 374 202 123  94  69  49 12010 29.52 14.74  7.94  4.85  3.69  2.73  1.95
S   4.020WB  -17.8    27 25D71215   -0  80  77
 362 534 260 108  51  44  36  23   5752 21.02 10.22  4.24  2.02  1.72  1.40  0.92
 550 702 347 161  85  65  54  36   8736 27.64 13.65  6.34  3.34  2.56  2.13  1.40
 745 840 429 214 119  88  71  48 11838 33.07 16.90  8.42  4.70  3.45  2.81  1.88
S   4.030WB  -17.8    26 25D71217   -0  79  78
 378 433 201 103  52  37  26  21   6003 17.06   7.92  4.07  2.03  1.44  1.01  0.84
 560 578 284 152  81  55  39  31   8903 22.76 11.20  5.98  3.19  2.15  1.54  1.21
 762 712 363 199 111  76  54  43 12113 28.04 14.28  7.84  4.35  3.00  2.13  1.68
S   4.040WB  -17.8    27 25D71218   -0  81  78
 381 368 192  95  50  34  25  19   6054 14.50   7.57  3.75  1.97  1.32  0.98  0.74
 564 501 270 141  78  52  38  28   8967 19.72 10.62  5.54  3.09  2.06  1.50  1.11
 754 634 346 188 108  75  52  38 11989 24.94 13.61  7.41  4.27  2.94  2.04  1.48
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R80        137010516FIT-3    36F20
7000    08002-175    694200        .
 150    0 203 305 457 610 9141524    5.9    0.0    8.0  12.0  18.0  24.0  36.0  60.0
A:\                         .FWD
RAP-3

*0000
S   1.010NBTL-17.8    40 29D71123   -0 104   85
 392 376 155  67  36  31  25  19  6229 14.81  6.10  2.64  1.40  1.22  0.98  0.76
 588 535 224  99  53  45  38  29  9348 21.08  8.80  3.91  2.11  1.77  1.49  1.16
 778 701 291 129  71  58  50  38 12359 27.59 11.47  5.09  2.78  2.27  1.96  1.50
S   1.020NBTL-17.8    40 30D71124   -0 103   86
 385 389 139  51  28  24  21  15  6118 15.31  5.46  2.02  1.11  0.96  0.81  0.60
 574 618 214  73  35  34  31  23  9113 24.33  8.42  2.89  1.37  1.33  1.21  0.91
 761 795 280  93  42  41  40  31 12085 31.30 11.02  3.68  1.65  1.61  1.56  1.21
S   1.030NBTL-17.8    40 30D71125   -0 104   87
 390 354 151  68  40  32  25  18  6202 13.94  5.93  2.69  1.56  1.24  0.98  0.70
 574 523 222 104  59  47  38  28  9121 20.60  8.74  4.08  2.32  1.86  1.49  1.08
 760 668 290 136  77  62  50  37 12069 26.32 11.42  5.36  3.02  2.44  1.96  1.44
S   1.040NBTL-17.8    43 31D71126   -0 109   87
 387 412 151  74  45  38  30  22  6146 16.23  5.93  2.91  1.78  1.49  1.16  0.87
 574 611 229 111  69  56  46  34  9129 24.06  9.00  4.37  2.72  2.20  1.81  1.35
 757 776 303 147  91  74  61  46 12029 30.56 11.92  5.78  3.57  2.91  2.42  1.81
S   1.050NBTL-17.8    42 30D71126   -0 107   85
 379 428 169  82  48  39  32  22  6022 16.83  6.66  3.22  1.87  1.55  1.26  0.86
 572 653 255 124  70  56  48  34  9094 25.69 10.06  4.87  2.74  2.22  1.90  1.33
 761 822 333 163  91  73  64  45 12085 32.37 13.10  6.41  3.57  2.85  2.50  1.79
S   1.060NBTL-17.8    40 32D71142   -0 104   89
 385 385 155  78  47  38  32  23  6115 15.17  6.09  3.06  1.87  1.49  1.26  0.92
 582 611 245 120  71  59  50  37  9253 24.04  9.64  4.72  2.80  2.32  1.97  1.47
 764 789 322 158  93  77  66  50 12137 31.08 12.69  6.21  3.65  3.03  2.59  1.96
S   1.070NBTL-17.8    38 31D71143   -0 101   88
 381 476 156  78  49  43  34  25  6051 18.75  6.15  3.06  1.94  1.70  1.33  0.96
 566 674 233 117  75  63  52  37  8999 26.54  9.18  4.62  2.95  2.50  2.05  1.46
 756 853 311 158 100  84  71  51 12013 33.59 12.23  6.22  3.96  3.30  2.78  2.00
S   2.010NBTL-17.8    46 31D71149   -0 114   87
 371 405 130  61  43  37  30  19  5900 15.94  5.12  2.40  1.70  1.45  1.20  0.76
 567 618 207  96  65  58  47  34  9014 24.34  8.14  3.78  2.54  2.27  1.86  1.35
 755 792 278 128  86  75  63  45 11994 31.17 10.94  5.04  3.38  2.96  2.48  1.76
S   2.020NBTL-17.8    43 31D71153   -0 109   88
 372 395 146  68  46  40  33  24  5908 15.55  5.76  2.67  1.82  1.57  1.30  0.95
 560 588 229 104  70  60  51  38  8891 23.15  9.02  4.11  2.74  2.37  2.00  1.48
 750 750 304 140  92  81  67  49 11918 29.52 11.99  5.50  3.62  3.18  2.64  1.94
S   2.030NBTL-17.8    43 32D71203   -0 109   89
 377 431 164  84  56  48  38  28  5995 16.95  6.46  3.29  2.20  1.89  1.48  1.11
 579 634 247 129  87  72  58  43  9200 24.97  9.74  5.09  3.42  2.84  2.28  1.69
 768 792 319 170 114  96  76  57 12208 31.17 12.56  6.71  4.50  3.78  3.00  2.25
S   2.040NBTL-17.8    42 33D71205   -0 107   91
 381 390 172  87  54  47  38  27  6051 15.35  6.78  3.43  2.14  1.87  1.50  1.06
 580 584 259 134  83  70  57  40  9216 22.98 10.20  5.26  3.28  2.75  2.26  1.59
 772 743 336 175 111  93  77  54 12275 29.23 13.22  6.90  4.39  3.67  3.02  2.13
S   2.050NBTL-17.8    45 30D71205   -0 113   85
 389 323 141  77  51  45  34  24  6181 12.71  5.56  3.04  2.00  1.77  1.35  0.94
 585 484 213 119  78  69  52  36  9293 19.06  8.38  4.67  3.06  2.70  2.06  1.42
 769 632 280 158 104  89  70  48 12216 24.88 11.03  6.20  4.09  3.49  2.75  1.91
S   2.060NBTL-17.8    46 31D71208   -0 115   87
 369 421 136  74  50  44  34  24  5868 16.59  5.35  2.91  1.96  1.72  1.32  0.96
 573 604 221 118  79  68  54  39  9110 23.76  8.68  4.64  3.11  2.67  2.12  1.52
 766 764 298 159 104  89  71  52 12169 30.08 11.75  6.25  4.09  3.52  2.80  2.04
S   2.070NBTL-17.8    45 30D71210   -0 113   86
 364 487 145  73  50  45  33  25  5789 19.17  5.72  2.89  1.96  1.78  1.32  0.97
 566 727 238 117  77  67  55  39  8994 28.62  9.37  4.60  3.02  2.63  2.17  1.52
 758 897 322 159 101  88  73  52 12042 35.33 12.68  6.24  3.99  3.48  2.89  2.04
S   3.010NBTL-17.8    48 29D71217   -0 119   85
 355 492 111  62  40  32  25  17  5646 19.36  4.38  2.44  1.59  1.26  0.97  0.67
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 554 729 187 101  64  51  40  28  8803 28.71  7.37  3.98  2.52  2.02  1.56  1.09
 748 903 260 137  85  67  53  38 11878 35.54 10.25  5.38  3.35  2.64  2.11  1.48
S   3.020NBTL-17.8    43 32D71232   -0 110  89
 384 368 154  70  39  32  25  18  6107 14.49  6.07  2.75  1.55  1.27  0.98  0.70
 569 547 229 109  63  49  40  28  9041 21.52  9.00  4.30  2.46  1.94  1.57  1.11
 753 682 292 144  83  65  54  38 11965 26.84 11.49  5.66  3.27  2.57  2.14  1.48
S   3.030NBTL-17.8    43 33D71232   -0 109  92
 375 391 148  72  40  38  24  18  5963 15.41  5.84  2.83  1.57  1.52  0.95  0.70
 574 568 224 110  66  55  42  29  9126 22.35  8.82  4.35  2.61  2.18  1.67  1.15
 760 720 289 143  88  70  56  38 12073 28.35 11.37  5.65  3.46  2.77  2.22  1.52
S   3.040NBTL-17.8    49 32D71233   -0 120  90
 384 359 130  65  42  35  25  16  6107 14.12  5.11  2.58  1.65  1.36  0.99  0.63
 577 512 197 102  65  52  40  27  9169 20.16  7.77  4.02  2.58  2.06  1.57  1.07
 770 653 261 138  86  70  54  36 12243 25.69 10.27  5.41  3.40  2.75  2.11  1.42
S   3.050NBTL-17.8    49 31D71234   -0 120  88
 371 405 144  71  45  35  25  17  5887 15.93  5.67  2.79  1.77  1.40  1.00  0.67
 574 589 221 111  70  55  41  27  9121 23.17  8.71  4.36  2.74  2.17  1.60  1.07
 764 743 289 146  91  73  54  37 12145 29.27 11.38  5.75  3.60  2.86  2.13  1.44
S   3.060NBTL-17.8    49 31D71235   -0 121  87
 375 388 149  72  46  36  27  18  5956 15.30  5.87  2.83  1.80  1.41  1.04  0.69
 576 569 226 111  71  56  42  28  9150 22.42  8.89  4.36  2.78  2.21  1.65  1.12
 765 730 293 144  92  73  56  38 12156 28.72 11.53  5.69  3.62  2.88  2.19  1.49
S   3.070NBTL-17.8    49 31D71236   -0 120  88
 363 463 159  70  43  37  27  19  5776 18.23  6.25  2.74  1.68  1.44  1.06  0.76
 565 712 256 111  67  55  44  31  8983 28.04 10.07  4.39  2.65  2.16  1.74  1.24
 751 882 335 148  88  72  59  43 11938 34.70 13.19  5.83  3.45  2.84  2.31  1.68
S   4.010NBTL-17.8    30 36D71348   -0  85  97
 367 395 150  67  43  38  31  23  5824 15.54  5.89  2.64  1.68  1.49  1.20  0.90
 566 559 240 112  67  59  48  35  8991 22.01  9.43  4.40  2.62  2.33  1.90  1.36
 748 653 305 150  88  78  65  47 11891 25.71 12.00  5.91  3.48  3.07  2.58  1.85
S   4.020NBTL-17.8    35 33D71352   -0  95  92
 377 274 122  71  48  38  31  20  5995 10.80  4.81  2.80  1.90  1.50  1.22  0.79
 576 399 195 119  81  64  49  33  9150 15.69  7.69  4.67  3.17  2.51  1.93  1.31
 762 490 253 157 107  86  66  44 12108 19.30  9.95  6.19  4.22  3.37  2.58  1.72
S   4.030NBTL-17.8    32 35D71358   -0  89  95
 377 291 133  76  53  49  38  29  5995 11.44  5.25  2.99  2.07  1.91  1.51  1.15
 573 415 200 111  71  62  47  32  9105 16.34  7.89  4.36  2.80  2.43  1.83  1.27
 767 513 260 149  95  79  62  42 12192 20.19 10.23  5.85  3.72  3.10  2.45  1.64
S   4.040NBTL-17.8    32 36D71411   -0  89  97
 379 296 118  63  42  34  26  19  6030 11.64  4.65  2.47  1.65  1.34  1.02  0.74
 582 417 186 104  68  55  42  30  9240 16.43  7.32  4.09  2.69  2.17  1.65  1.19
 778 511 242 142  94  75  57  41 12367 20.11  9.53  5.59  3.69  2.96  2.25  1.60
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RAP..................
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S  1.0100WB  44.5              I41025112            Heights .........................
 423 388 147  72  45  37   25  21   6728 15.28  5.80  2.82  1.78  1.47  0.99  0.81
 622 568 205 107  69  57   38  30   9888 22.36  8.08  4.20  2.72  2.25  1.49  1.18
 784 698 275 133  83  68   49  41  12464 27.48 10.81  5.22  3.28  2.66  1.94  1.63
S  1.0200WB  44.5              I41027112            Heights .........................
 384 445 169  60  36  29   24  19   6096 17.53  6.63  2.37  1.42  1.15  0.95  0.73
 597 668 250  92  54  42   35  27   9496 26.31  9.84  3.63  2.13  1.64  1.36  1.06
 736 808 306 114  63  51   43  34  11696 31.81 12.04  4.49  2.49  2.00  1.69  1.34
S  1.0300WB  44.5              I41028112            Heights .........................
 366 435 156  65  40  34   28  22   5808 17.11  6.15  2.57  1.58  1.35  1.12  0.85
 572 615 228  98  59  52   44  34   9096 24.23  8.96  3.88  2.33  2.05  1.74  1.34
 767 812 301 132  77  65   57  43  12184 31.98 11.86  5.18  3.04  2.58  2.23  1.71
S  1.0400WB  44.5              I41030112            Heights .........................
 392 355 176  92  58  46   39  31   6224 13.99  6.94  3.63  2.29  1.80  1.53  1.22
 578 522 250 129  77  58   45  34   9192 20.57  9.84  5.06  3.04  2.29  1.78  1.34
 766 714 343 177 105  82   67  53  12176 28.10 13.49  6.98  4.15  3.23  2.64  2.07
S  1.0500WB  44.5              I41031112            Heights .........................
 384 434 185  86  55  42   34  23   6112 17.07  7.29  3.39  2.17  1.64  1.32  0.89
 568 638 276 129  79  61   50  34   9024 25.11 10.85  5.06  3.12  2.41  1.98  1.34
 763 877 364 173 104  80   65  45  12120 34.52 14.32  6.81  4.11  3.15  2.56  1.79
S  1.0600WB  44.5              I41032112            Heights .........................
 392 333 173  86  54  43   36  28   6232 13.11  6.81  3.39  2.13  1.68  1.40  1.10
 579 510 240 127  80  64   51  40   9192 20.07  9.45  5.02  3.16  2.54  2.02  1.59
 769 712 326 172 105  84   68  54  12224 28.02 12.83  6.77  4.15  3.31  2.69  2.12
S  1.0700WB  44.5              I41034112            Heights .........................
 406 419 179  91  59  48   38  27   6456 16.49  7.03  3.59  2.33  1.88  1.49  1.06
 579 588 253 131  85  69   54  38   9192 23.15  9.97  5.14  3.36  2.70  2.11  1.51
 767 789 338 177 113  92   73  52  12192 31.06 13.31  6.98  4.46  3.64  2.89  2.03
S  2.0100WB  44.5              I41036112            Heights .........................
 446 410 234  88  47  35   39  22   7088 16.15  9.23  3.47  1.86  1.39  1.53  0.85
 610 594 228 102  68  56   45  31   9688 23.40  8.96  4.00  2.69  2.21  1.78  1.22
 761 785 288 138  91  75   59  45  12104 30.89 11.34  5.43  3.59  2.95  2.31  1.79
S  2.0200WB  44.5              I41036112            Heights .........................
 412 398 169  81  58  48   40  29   6552 15.65  6.63  3.18  2.29  1.88  1.57  1.14
 566 559 203 118  84  68   54  41   9000 22.02  8.00  4.65  3.32  2.66  2.11  1.63
 755 754 292 160 112  92   73  56  11992 29.69 11.51  6.28  4.42  3.64  2.89  2.20
S  2.0300WB  44.5              I41038112            Heights .........................
 415 390 173  93  64  53   42  32   6600 15.36  6.81  3.67  2.53  2.09  1.65  1.26
 585 559 249 134  90  74   60  45   9296 22.02  9.80  5.26  3.55  2.90  2.36  1.79
 777 762 326 181 121  99   81  61  12344 30.02 12.83  7.14  4.78  3.89  3.18  2.40
S  2.0400WB  44.5              I41051112            Heights .........................
 401 483 174  85  56  48   41  30   6376 19.03  6.85  3.35  2.21  1.88  1.61  1.18
 573 646 247 125  81  69   58  42   9104 25.44  9.71  4.94  3.20  2.70  2.27  1.67
 767 827 333 171 110  91   77  57  12184 32.56 13.09  6.73  4.34  3.60  3.02  2.24
S  2.0500WB  44.5              I41052112            Heights .........................
 431 318 143  82  59  48   38  28   6840 12.53  5.62  3.22  2.33  1.88  1.49  1.10
 585 465 193 117  83  69   52  38   9288 18.32  7.60  4.61  3.28  2.70  2.07  1.51
 771 630 261 155 111  91   70  52  12248 24.81 10.28  6.12  4.38  3.60  2.77  2.03
S  2.0600WB  44.5              I41052112            Heights .........................
 427 378 162  86  58  48   39  28   6784 14.86  6.37  3.39  2.29  1.88  1.53  1.10
 577 566 231 122  80  67   55  40   9160 22.27  9.09  4.81  3.16  2.62  2.15  1.59
 762 742 299 163 106  88   72  54  12104 29.23 11.77  6.41  4.19  3.48  2.85  2.12
S  2.0700WB  44.5              I41053112            Heights .........................
 415 375 193  83  55  49   39  29   6600 14.78  7.60  3.26  2.17  1.92  1.53  1.14
 582 544 249 117  78  67   54  40   9256 21.40  9.80  4.61  3.08  2.62  2.11  1.59
 775 735 326 155 103  88   71  53  12320 28.94 12.83  6.12  4.07  3.48  2.81  2.07
S  3.0100WB  44.5              I41059112            Heights .........................
 408 428 146  74  47  38   29  21   6488 16.86  5.76  2.90  1.86  1.51  1.16  0.81
 564 604 206 105  67  53   41  29   8960 23.77  8.13  4.12  2.65  2.09  1.61  1.14
 751 805 272 142  89  72   55  39  11936 31.68 10.72  5.59  3.51  2.82  2.15  1.55
S  3.0200WB  44.5              I41100112            Heights .........................
```

3.02

```
 408 435 158  73  41  36  29  19  6488 17.11  6.24  2.86  1.62  1.43  1.16  0.73
 574 611 206 106  62  52  41  29  9120 24.06  8.13  4.16  2.45  2.05  1.61  1.14
 766 809 295 142  81  70  54  39 12176 31.85 11.60  5.59  3.20  2.74  2.11  1.55
S  3.0300WB  44.5            I41101112        Heights .........................
 449 332 179  74  47  37  28  21  7128 13.07  7.03  2.90  1.86  1.47  1.12  0.81
 607 476 251 104  64  51  40  29  9648 18.74  9.89  4.08  2.53  2.00  1.57  1.14
 766 654 326 138  85  67  52  38 12168 25.73 12.83  5.43  3.36  2.62  2.07  1.51
S  3.0400WB  44.5            I41101112        Heights .........................
 455 319 152  78  48  35  23  18  7232 12.57  5.98  3.06  1.90  1.39  0.91  0.69
 599 471 219 114  66  53  43  28  9520 18.53  8.61  4.49  2.61  2.09  1.69  1.10
 765 650 283 148  88  70  56  38 12160 25.61 11.16  5.83  3.47  2.74  2.19  1.51
S  3.0500WB  44.5            I41102112        Heights .........................
 423 295 153  81  49  37  28  21  6720 11.62  6.02  3.18  1.93  1.47  1.12  0.81
 592 434 227 118  69  54  41  29  9400 17.07  8.92  4.65  2.72  2.13  1.61  1.14
 786 596 304 156  92  71  55  38 12496 23.48 11.95  6.16  3.63  2.78  2.15  1.51
S  3.0600WB  44.5            I41103112        Heights .........................
 413 361 138  73  50  39  29  21  6568 14.20  5.45  2.86  1.97  1.55  1.16  0.81
 582 520 201 106  70  56  43  30  9248 20.48  7.91  4.16  2.76  2.21  1.69  1.18
 776 698 270 142  93  74  57  40 12336 27.48 10.63  5.59  3.67  2.90  2.23  1.59
S  3.0700WB  44.5            I41104112        Heights .........................
 409 354 152  83  55  43  31  23  6496 13.95  5.98  3.26  2.17  1.68  1.24  0.89
 578 517 231 121  78  60  45  32  9184 20.36  9.09  4.77  3.08  2.37  1.78  1.26
 769 699 314 165 104  80  62  42 12224 27.52 12.35  6.49  4.11  3.15  2.44  1.67
S  4.0100WB  44.5            I41120112        Heights .........................
 387 631 161  50  44  41  31  24  6152 24.86  6.33  1.96  1.74  1.60  1.24  0.94
 578 631 235 104  80  65  49  36  9184 24.86  9.27  4.08  3.16  2.58  1.94  1.42
 756 731 312 146 115  92  73  48 12008 28.77 12.30  5.75  4.54  3.64  2.89  1.87
S  4.0200WB  44.5            I41122112        Heights .........................
 410 383 154  73  43  35  29  21  6512 15.07  6.06  2.86  1.70  1.39  1.16  0.81
 608 509 219 113  71  56  44  33  9656 20.03  8.61  4.45  2.80  2.21  1.74  1.30
 789 681 293 153  96  75  58  43 12528 26.81 11.56  6.04  3.79  2.95  2.27  1.71
S  4.0300WB  44.5            I41125112        Heights .........................
 3951092 319  79  23  22  25  19  6272 43.01 12.57  3.10  0.91  0.86  0.99  0.73
 597 642 288 107  49  44  41  31  9496 25.27 11.34  4.20  1.93  1.72  1.61  1.22
 788 674 344 145  72  60  55  41 12520 26.52 13.53  5.71  2.84  2.37  2.15  1.63
S  4.0400WB  44.5            I41126112        Heights .........................
 411 463 270 112  48  25  25  19  6536 18.24 10.63  4.41  1.90  0.98  0.99  0.73
 604 551 301 137  70  45  39  29  9592 21.69 11.86  5.39  2.76  1.76  1.53  1.14
 768 743 355 173  96  61  54  39 12200 29.27 13.97  6.81  3.79  2.41  2.11  1.55
EOF
```

TODD Standard Setup
*0000

| | | | | | | | | BLF | DF1 | DF2 | DF3 | DF4 | DF5 | DF6 | DF7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 1.010[redacted] | | | | | | | | | | | | | | |
| 410 | 577 | 154 | 66 | 41 | 34 | 27 | 19 | 6515 | 22.70 | 6.05 | 2.61 | 1.63 | 1.35 | 1.07 | 0.75 |
| 591 | 772 | 231 | 98 | 58 | 49 | 39 | 29 | 9391 | 30.39 | 9.09 | 3.85 | 2.27 | 1.94 | 1.54 | 1.15 |
| 767 | 914 | 299 | 127 | 72 | 63 | 50 | 37 | 12192 | 36.00 | 11.79 | 5.00 | 2.85 | 2.48 | 1.98 | 1.46 |
| S | 1.020SBTL-17.8 | 49 | 32D71458 | -0 | 120 | 90 | | | | | | | | | |
| 381 | 394 | 157 | 56 | 33 | 28 | 21 | 16 | 6054 | 15.50 | 6.17 | 2.19 | 1.30 | 1.09 | 0.83 | 0.62 |
| 569 | 596 | 234 | 81 | 47 | 39 | 33 | 23 | 9050 | 23.46 | 9.22 | 3.18 | 1.83 | 1.52 | 1.31 | 0.89 |
| 773 | 793 | 317 | 108 | 56 | 49 | 44 | 31 | 12280 | 31.24 | 12.48 | 4.26 | 2.19 | 1.93 | 1.72 | 1.21 |
| S | 1.030SBTL-17.8 | 51 | 32D71459 | -0 | 124 | 89 | | | | | | | | | |
| 378 | 401 | 178 | 85 | 40 | 33 | 22 | 16 | 6003 | 15.78 | 7.02 | 3.33 | 1.59 | 1.30 | 0.87 | 0.65 |
| 565 | 588 | 256 | 124 | 62 | 48 | 36 | 27 | 8970 | 23.16 | 10.10 | 4.89 | 2.44 | 1.88 | 1.42 | 1.07 |
| 772 | 777 | 335 | 161 | 81 | 65 | 48 | 37 | 12264 | 30.59 | 13.17 | 6.34 | 3.17 | 2.54 | 1.90 | 1.44 |
| S | 1.040SBTL-17.8 | 52 | 32D71500 | -0 | 126 | 89 | | | | | | | | | |
| 363 | 555 | 147 | 63 | 41 | 33 | 29 | 20 | 5773 | 21.86 | 5.80 | 2.46 | 1.62 | 1.30 | 1.15 | 0.81 |
| 558 | 770 | 232 | 102 | 61 | 52 | 44 | 33 | 8872 | 30.32 | 9.13 | 4.01 | 2.38 | 2.05 | 1.75 | 1.28 |
| 764 | 971 | 318 | 140 | 81 | 69 | 61 | 45 | 12137 | 38.24 | 12.52 | 5.49 | 3.19 | 2.72 | 2.39 | 1.77 |
| S | 1.050SBTL-17.8 | 51 | 32D71501 | -0 | 124 | 89 | | | | | | | | | |
| 371 | 405 | 160 | 84 | 52 | 39 | 30 | 21 | 5887 | 15.96 | 6.30 | 3.30 | 2.06 | 1.54 | 1.18 | 0.83 |
| 560 | 630 | 252 | 128 | 78 | 58 | 46 | 33 | 8903 | 24.81 | 9.93 | 5.06 | 3.07 | 2.29 | 1.82 | 1.30 |
| 766 | 848 | 349 | 175 | 104 | 78 | 63 | 45 | 12172 | 33.39 | 13.76 | 6.91 | 4.09 | 3.09 | 2.46 | 1.77 |
| S | 1.060SBTL-17.8 | 51 | 32D71502 | -0 | 123 | 89 | | | | | | | | | |
| 361 | 414 | 168 | 84 | 49 | 39 | 32 | 24 | 5733 | 16.31 | 6.61 | 3.30 | 1.94 | 1.54 | 1.25 | 0.95 |
| 553 | 656 | 259 | 128 | 76 | 61 | 49 | 35 | 8779 | 25.84 | 10.20 | 5.04 | 2.99 | 2.39 | 1.92 | 1.39 |
| 763 | 856 | 359 | 177 | 103 | 82 | 67 | 49 | 12116 | 33.69 | 14.12 | 6.95 | 4.06 | 3.24 | 2.65 | 1.95 |
| S | 1.070SBTL-17.8 | 51 | 32D71503 | -0 | 124 | 89 | | | | | | | | | |
| 360 | 542 | 168 | 82 | 53 | 43 | 34 | 24 | 5713 | 21.33 | 6.63 | 3.23 | 2.08 | 1.70 | 1.33 | 0.96 |
| 551 | 754 | 259 | 129 | 81 | 63 | 52 | 38 | 8748 | 29.70 | 10.21 | 5.06 | 3.19 | 2.47 | 2.06 | 1.50 |
| 756 | 956 | 351 | 176 | 111 | 83 | 73 | 55 | 12013 | 37.65 | 13.82 | 6.93 | 4.38 | 3.27 | 2.85 | 2.15 |
| S | 2.010SBTL-17.8 | 53 | 32D71505 | -0 | 126 | 90 | | | | | | | | | |
| 361 | 424 | 132 | 63 | 43 | 35 | 29 | 20 | 5741 | 16.67 | 5.20 | 2.49 | 1.69 | 1.38 | 1.15 | 0.78 |
| 559 | 658 | 216 | 100 | 65 | 52 | 46 | 32 | 8879 | 25.92 | 8.49 | 3.94 | 2.56 | 2.06 | 1.80 | 1.25 |
| 759 | 877 | 302 | 138 | 86 | 70 | 61 | 44 | 12061 | 34.52 | 11.90 | 5.44 | 3.40 | 2.74 | 2.41 | 1.72 |
| S | 2.020SBTL-17.8 | 49 | 32D71507 | -0 | 120 | 90 | | | | | | | | | |
| 364 | 396 | 155 | 83 | 55 | 45 | 33 | 24 | 5789 | 15.59 | 6.10 | 3.28 | 2.18 | 1.76 | 1.32 | 0.94 |
| 558 | 600 | 239 | 129 | 85 | 69 | 53 | 38 | 8864 | 23.61 | 9.42 | 5.09 | 3.34 | 2.74 | 2.07 | 1.49 |
| 767 | 805 | 326 | 176 | 115 | 95 | 72 | 53 | 12180 | 31.68 | 12.83 | 6.92 | 4.54 | 3.74 | 2.85 | 2.07 |
| S | 2.030SBTL-17.8 | 49 | 31D71509 | -0 | 121 | 89 | | | | | | | | | |
| 372 | 303 | 149 | 86 | 57 | 47 | 37 | 27 | 5903 | 11.94 | 5.85 | 3.37 | 2.26 | 1.87 | 1.44 | 1.04 |
| 567 | 500 | 236 | 133 | 88 | 72 | 57 | 41 | 9007 | 19.67 | 9.28 | 5.22 | 3.48 | 2.85 | 2.23 | 1.61 |
| 774 | 696 | 326 | 183 | 120 | 99 | 77 | 57 | 12296 | 27.39 | 12.83 | 7.19 | 4.71 | 3.90 | 3.05 | 2.25 |
| S | 2.040SBTL-17.8 | 46 | 34D71527 | -0 | 116 | 93 | | | | | | | | | |
| 368 | 402 | 145 | 78 | 53 | 46 | 37 | 26 | 5844 | 15.83 | 5.72 | 3.08 | 2.10 | 1.81 | 1.46 | 1.03 |
| 569 | 614 | 227 | 121 | 81 | 69 | 57 | 40 | 9050 | 24.19 | 8.95 | 4.76 | 3.17 | 2.70 | 2.24 | 1.57 |
| 772 | 811 | 310 | 164 | 109 | 92 | 77 | 55 | 12264 | 31.92 | 12.19 | 6.44 | 4.30 | 3.62 | 3.04 | 2.16 |
| S | 2.050SBTL-17.8 | 47 | 33D71528 | -0 | 117 | 91 | | | | | | | | | |
| 374 | 273 | 138 | 77 | 52 | 44 | 31 | 22 | 5940 | 10.74 | 5.43 | 3.04 | 2.06 | 1.72 | 1.23 | 0.87 |
| 564 | 434 | 214 | 120 | 82 | 67 | 50 | 35 | 8967 | 17.10 | 8.43 | 4.72 | 3.21 | 2.65 | 1.95 | 1.37 |
| 770 | 606 | 292 | 163 | 111 | 92 | 69 | 48 | 12243 | 23.87 | 11.51 | 6.43 | 4.38 | 3.62 | 2.72 | 1.89 |
| S | 2.060SBTL-17.8 | 50 | 32D71529 | -0 | 122 | 90 | | | | | | | | | |
| 362 | 343 | 143 | 81 | 52 | 43 | 34 | 24 | 5752 | 13.49 | 5.63 | 3.17 | 2.06 | 1.69 | 1.34 | 0.94 |
| 559 | 528 | 223 | 123 | 80 | 64 | 53 | 37 | 8883 | 20.78 | 8.77 | 4.85 | 3.14 | 2.52 | 2.07 | 1.46 |
| 765 | 717 | 304 | 168 | 108 | 87 | 72 | 51 | 12153 | 28.21 | 11.96 | 6.60 | 4.24 | 3.44 | 2.82 | 2.01 |
| S | 2.070SBTL-17.8 | 49 | 32D71529 | -0 | 121 | 90 | | | | | | | | | |
| 362 | 370 | 154 | 78 | 51 | 44 | 34 | 23 | 5749 | 14.55 | 6.06 | 3.06 | 1.99 | 1.75 | 1.32 | 0.90 |
| 560 | 589 | 248 | 124 | 80 | 67 | 54 | 37 | 8903 | 23.20 | 9.76 | 4.88 | 3.14 | 2.63 | 2.11 | 1.46 |
| 766 | 795 | 344 | 171 | 108 | 89 | 73 | 50 | 12164 | 31.29 | 13.53 | 6.73 | 4.24 | 3.52 | 2.89 | 1.98 |
| S | 3.010SBTL-17.8 | 51 | 31D71617 | -0 | 123 | 87 | | | | | | | | | |
| 350 | 464 | 147 | 67 | 38 | 32 | 24 | 16 | 5562 | 18.26 | 5.77 | 2.64 | 1.48 | 1.25 | 0.95 | 0.64 |
| 544 | 687 | 226 | 102 | 59 | 48 | 37 | 26 | 8652 | 27.06 | 8.91 | 4.02 | 2.31 | 1.89 | 1.46 | 1.01 |
| 754 | 899 | 305 | 138 | 80 | 65 | 51 | 35 | 11981 | 35.40 | 11.99 | 5.42 | 3.15 | 2.56 | 2.00 | 1.39 |

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S   3.020SBTL-17.8   47 35D71611   -0 116  94
 360 611 151  64  36  32  24  18  5717 24.05  5.94  2.52  1.43  1.27  0.95  0.71
 550 816 230  99  57  48  40  28  8740 32.14  9.05  3.90  2.24  1.89  1.57  1.09
 7551008 313 137  78  65  53  38 11997 39.68 12.33  5.41  3.06  2.58  2.11  1.52
S   3.030SBTL-17.8   45 33D71612   -0 113  91
 368 322 150  71  40  34  24  16  5844 12.66  5.93  2.78  1.58  1.32  0.95  0.64
 564 507 227 106  66  50  39  26  8962 19.94  8.94  4.19  2.61  1.96  1.55  1.02
 770 705 310 145  88  67  53  36 12228 27.76 12.21  5.69  3.48  2.62  2.10  1.42
S   3.040SBTL-17.8   44 32D71612   -0 112  89
 360 347 134  61  38  36  24  16  5725 13.66  5.28  2.41  1.50  1.40  0.94  0.65
 555 523 207  96  59  52  38  26  8819 20.59  8.15  3.77  2.31  2.04  1.50  1.03
 765 698 279 131  80  67  52  36 12161 27.49 11.00  5.17  3.16  2.63  2.06  1.41
S   3.050SBTL-17.8   47 32D71613   -0 116  89
 374 314 131  68  42  32  24  16  5935 12.37  5.16  2.66  1.66  1.26  0.93  0.62
 570 486 206 106  63  50  38  26  9062 19.14  8.13  4.18  2.50  1.98  1.51  1.03
 778 667 282 145  86  68  52  36 12363 26.28 11.09  5.69  3.40  2.68  2.05  1.41
S   3.060SBTL-17.8   50 32D71614   -0 123  89
 363 311 126  64  41  33  24  15  5760 12.24  4.98  2.51  1.61  1.29  0.93  0.61
 566 504 204 103  66  51  39  26  8991 19.82  8.04  4.04  2.59  2.00  1.53  1.02
 774 687 281 141  89  69  53  35 12299 27.04 11.06  5.55  3.50  2.71  2.09  1.39
S   3.070SBTL-17.8   52 31D71615   -0 126  88
 353 379 141  68  39  32  23  16  5614 14.94  5.55  2.66  1.55  1.25  0.89  0.64
 554 603 234 109  64  48  39  27  8800 23.74  9.21  4.29  2.54  1.87  1.53  1.06
 765 809 324 149  84  63  53  37 12161 31.85 12.76  5.86  3.30  2.48  2.07  1.45
S   4.010SBTL-17.8   32 31D71620   -0  90  87
 377 226 112  62  39  34  29  22  5991  8.89  4.43  2.45  1.55  1.33  1.15  0.86
 573 337 176 101  63  54  46  34  9102 13.27  6.94  3.98  2.50  2.11  1.82  1.35
 772 432 233 139  89  74  64  47 12275 17.00  9.17  5.46  3.52  2.92  2.52  1.84
S   4.020SBTL-17.8   33 31D71621   -0  91  87
 377 249  97  52  37  35  28  20  5995  9.79  3.82  2.05  1.46  1.40  1.08  0.78
 576 389 160  85  62  55  45  32  9153 15.32  6.31  3.35  2.46  2.17  1.78  1.27
 765 468 214 120  88  76  63  45 12161 18.43  8.41  4.71  3.44  3.00  2.47  1.76
S   4.030SBTL-17.8   32 32D71624   -0  90  89
 367 235 129  63  36  30  25  19  5829  9.23  5.09  2.46  1.41  1.16  1.00  0.75
 570 367 212 108  59  46  43  31  9062 14.45  8.36  4.24  2.34  1.83  1.67  1.20
 768 451 273 149  84  65  58  42 12204 17.76 10.74  5.85  3.31  2.55  2.30  1.66
S   4.040SBTL-17.8   31 31D71628   -0  87  88
 389 235 142  65  39  30  28  20  6181  9.24  5.61  2.56  1.55  1.17  1.09  0.77
 578 359 217 103  60  44  43  29  9181 14.14  8.54  4.07  2.36  1.74  1.68  1.16
 774 457 272 140  85  61  60  42 12304 17.97 10.69  5.52  3.36  2.41  2.35  1.67
EOF
```

# Appendix C

# 6000-lbf and 12000-lbf

# ISM vs. Time Plots

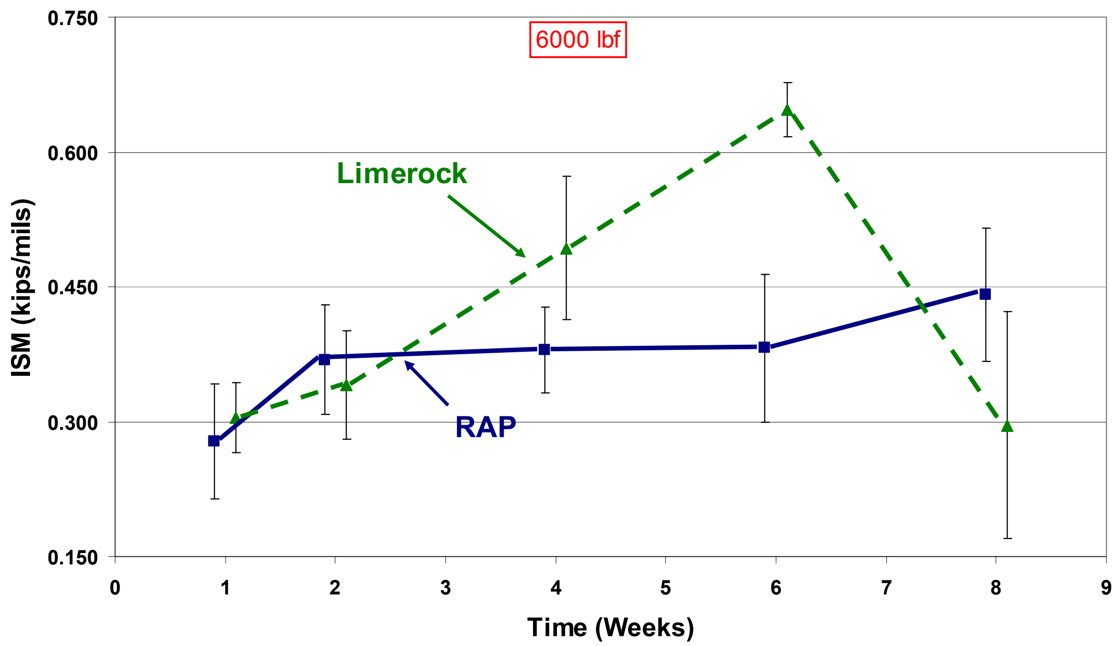



**Figure B-1 ISM vs. Time for RAP and Limerock (6000-lbf)**

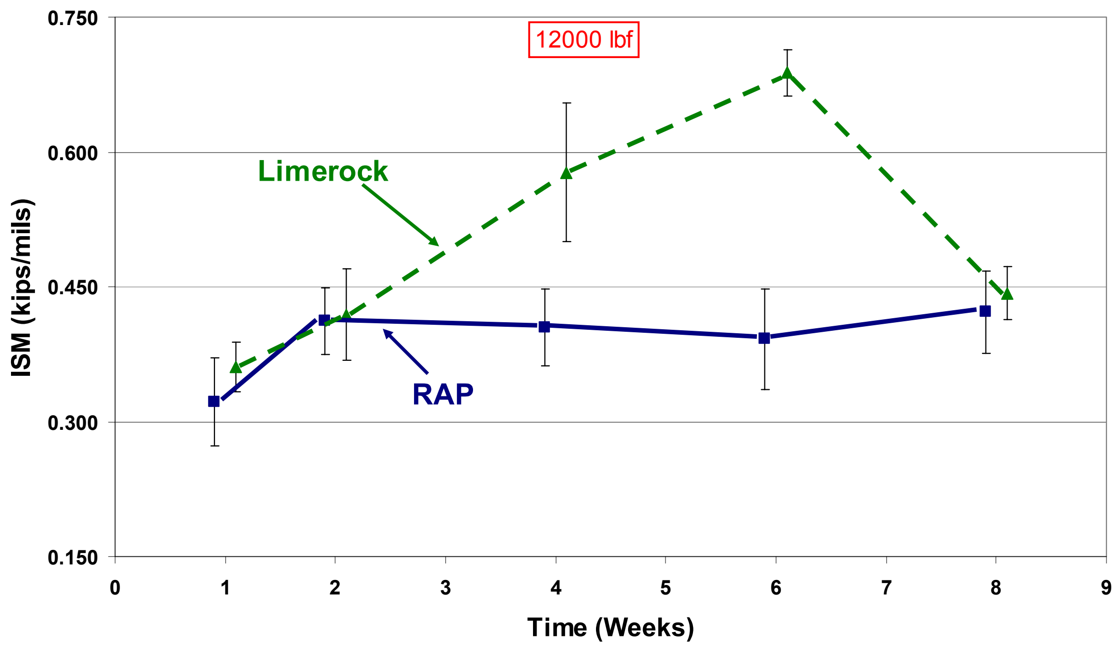



**Figure B-2 ISM vs. Time for RAP and Limerock (12000-lbf)**

## Appendix D

## Clegg Impact Test Data

| WEEK 1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Test Site | Material | Clegg Impact Values (IV) | | | | Max | Max (Avg) |
| | | 1 | 2 | 3 | 4 | | |
| 1 | RAP | 16 | 21 | 21 | 22 | 22 | 23 |
| 1 | | 16 | 22 | 23 | 24 | 24 | |
| 1 | | 14 | 18 | 22 | 21 | 22 | |
| 2 | RAP | 21 | 30 | 29 | 29 | 30 | 26 |
| 2 | | 18 | 22 | 24 | 24 | 24 | |
| 2 | | 16 | 21 | 22 | 24 | 24 | |
| 3 | RAP | 21 | 26 | 29 | 27 | 29 | 27 |
| 3 | | 17 | 23 | 25 | 27 | 27 | |
| 3 | | 19 | 23 | 25 | 24 | 25 | |
| 4 | RAP | 15 | 21 | 25 | 26 | 26 | 22 |
| 4 | | 10 | 14 | 15 | 16 | 16 | |
| 4 | | 13 | 18 | 21 | 23 | 23 | |
| 5 | RAP | 23 | 31 | 33 | 32 | 33 | 30 |
| 5 | | 18 | 24 | 26 | 26 | 26 | |
| 5 | | | 24 | 25 | 26 | 26 | |
| 6 | RAP | 23 | 30 | 28 | 32 | 32 | 30 |
| 6 | | 21 | 28 | 31 | 29 | 31 | |
| 6 | | 19 | 22 | 26 | 26 | 26 | |
| 7 | RAP | 21 | 26 | 28 | 28 | 28 | 28 |
| 7 | | 22 | 26 | 29 | 30 | 30 | |
| 7 | | 21 | 24 | 25 | 27 | 27 | |
| 8 | RAP | 21 | 26 | 25 | 28 | 28 | 26 |
| 8 | | 14 | 21 | 22 | 23 | 23 | |
| 8 | | 14 | 22 | 25 | 26 | 26 | |
| 9 | Limerock | 25 | 35 | 37 | 38 | 38 | 35 |
| 9 | | 13 | 22 | 27 | 29 | 29 | |
| 9 | | 17 | 27 | 31 | 37 | 37 | |
| 10 | Limerock | 29 | 38 | 41 | 42 | 42 | 39 |
| 10 | | 25 | 33 | 36 | 39 | 39 | |
| 10 | | 22 | 30 | 36 | 36 | 36 | |
| 11 | Limerock | 25 | 32 | 35 | 38 | 38 | 36 |
| 11 | | 19 | 29 | 31 | 35 | 35 | |
| 11 | | 22 | 32 | 33 | 35 | 35 | |

| WEEK 2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Test Site | Material | Clegg Impact Values (IV) | | | | Max | Max (Avg) |
| | | 1 | 2 | 3 | 4 | | |
| 1 | RAP | 19 | 19 | 20 | 21 | 21 | 29 |
| 1 | | 27 | 32 | 34 | 33 | 34 | |
| 1 | | 22 | 29 | 33 | 31 | 33 | |
| 2 | RAP | 24 | 29 | 30 | 29 | 30 | 29 |
| 2 | | 20 | 23 | 25 | 25 | 25 | |
| 2 | | 24 | 28 | 30 | 31 | 31 | |
| 3 | RAP | 21 | 26 | 28 | 29 | 29 | 28 |
| 3 | | 18 | 25 | 24 | 26 | 26 | |
| 3 | | 20 | 28 | 27 | 30 | 30 | |
| 4 | RAP | 17 | 21 | 23 | 23 | 23 | 24 |
| 4 | | 18 | 25 | 25 | 27 | 27 | |
| 4 | | 16 | 22 | 22 | 23 | 23 | |
| 5 | RAP | 22 | 25 | 27 | 26 | 27 | 29 |
| 5 | | 18 | 23 | 25 | 24 | 25 | |
| 5 | | 17 | 20 | 21 | 23 | 23 | |
| 6 | RAP | 23 | 28 | 28 | 31 | 31 | 29 |
| 6 | | 19 | 23 | 25 | 26 | 26 | |
| 6 | | 21 | 25 | 25 | 30 | 30 | |
| 7 | RAP | 19 | 24 | 25 | 26 | 26 | 26 |
| 7 | | 20 | 27 | 28 | 29 | 29 | |
| 7 | | 17 | 21 | 23 | 22 | 23 | |
| 8 | RAP | 16 | 19 | 21 | 21 | 21 | 22 |
| 8 | | 18 | 23 | 23 | 23 | 23 | |
| 8 | | 16 | 20 | 21 | 21 | 21 | |
| 9 | Limerock | 27 | 33 | 34 | 35 | 35 | 32 |
| 9 | | 14 | 21 | 24 | 27 | 27 | |
| 9 | | 19 | 28 | 31 | 33 | 33 | |
| 10 | Limerock | 20 | 30 | 32 | 35 | 35 | 38 |
| 10 | | 24 | 31 | 34 | 38 | 38 | |
| 10 | | 20 | 34 | 36 | 40 | 40 | |
| 11 | Limerock | 18 | 26 | 29 | 32 | 32 | 30 |
| 11 | | 18 | 25 | 29 | 30 | 30 | |
| 11 | | 17 | 24 | 26 | 27 | 27 | |

| WEEK 4 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Test Site | Material | Clegg Impact Values (IV) | | | | Max | Max (Avg) |
| | | 1 | 2 | 3 | 4 | | |
| 1 | RAP | 27 | 36 | 42 | 44 | 44 | 36 |
| 1 | | 24 | 30 | 34 | 32 | 34 | |
| 1 | | 22 | 26 | 28 | 29 | 29 | |
| 2 | RAP | 30 | 35 | 40 | 43 | 43 | 37 |
| 2 | | 21 | 28 | 31 | 30 | 31 | |
| 2 | | 27 | 34 | 34 | 37 | 37 | |
| 3 | RAP | 25 | 30 | 31 | 30 | 31 | 35 |
| 3 | | 21 | 30 | 35 | 36 | 36 | |
| 3 | | 25 | 32 | 34 | 37 | 37 | |
| 4 | RAP | 22 | 27 | 28 | 28 | 28 | 29 |
| 4 | | 21 | 28 | 29 | 29 | 29 | |
| 4 | | 23 | 28 | 30 | 30 | 30 | |
| 5 | RAP | 30 | 35 | 36 | 37 | 37 | 33 |
| 5 | | 23 | 28 | 29 | 30 | 30 | |
| 5 | | 26 | 33 | 37 | 35 | 37 | |
| 6 | RAP | 24 | 30 | 33 | 36 | 36 | 33 |
| 6 | | 27 | 31 | 32 | 32 | 32 | |
| 6 | | 24 | 30 | 32 | 32 | 32 | |
| 7 | RAP | 25 | 28 | 30 | 31 | 31 | 31 |
| 7 | | 27 | 28 | 29 | 31 | 31 | |
| 7 | | 25 | 29 | 30 | 31 | 31 | |
| 8 | RAP | 23 | 26 | 27 | 28 | 28 | 33 |
| 8 | | 24 | 25 | 32 | 31 | 32 | |
| 8 | | 30 | 29 | 38 | 35 | 38 | |
| 9 | Limerock | 26 | 32 | 35 | 37 | 37 | 39 |
| 9 | | 24 | 34 | 38 | 40 | 40 | |
| 9 | | 23 | 32 | 36 | 40 | 40 | |
| 10 | Limerock | 30 | 39 | 42 | 42 | 42 | 40 |
| 10 | | 33 | 31 | 35 | 37 | 37 | |
| 10 | | 30 | 36 | 38 | 40 | 40 | |
| 11 | Limerock | 23 | 28 | 31 | 33 | 33 | 36 |
| 11 | | 20 | 29 | 33 | 34 | 34 | |
| 11 | | 26 | 36 | 39 | 41 | 41 | |

| WEEK 6 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Test Site | Material | Clegg Impact Values (IV) | | | | Max | Max (Avg) |
| | | 1 | 2 | 3 | 4 | | |
| 1 | RAP | 34 | 40 | 43 | 42 | 43 | 45 |
| 1 | | 31 | 41 | 49 | 45 | 49 | |
| 1 | | 33 | 40 | 43 | 32 | 43 | |
| 2 | RAP | 26 | 31 | 31 | 37 | 37 | 39 |
| 2 | | 26 | 34 | 40 | 33 | 40 | |
| 2 | | 24 | 30 | 31 | 39 | 39 | |
| 3 | RAP | 27 | 37 | 39 | 27 | 39 | 39 |
| 3 | | 20 | 24 | 25 | 41 | 41 | |
| 3 | | 28 | 36 | 38 | 34 | 38 | |
| 4 | RAP | 27 | 36 | 36 | 30 | 36 | 34 |
| 4 | | 21 | 30 | 33 | 33 | 33 | |
| 4 | | 24 | 31 | 33 | 33 | 33 | |
| 5 | RAP | 29 | 33 | 33 | 31 | 33 | 39 |
| 5 | | 28 | 28 | 29 | 29 | 29 | |
| 5 | | 25 | 28 | 30 | 39 | 39 | |
| 6 | RAP | 31 | 38 | 41 | 33 | 41 | 39 |
| 6 | | 28 | 30 | 31 | 38 | 38 | |
| 6 | | 32 | 37 | 38 | 28 | 38 | |
| 7 | RAP | 23 | 28 | 29 | 35 | 35 | 30 |
| 7 | | 29 | 30 | 30 | 26 | 30 | |
| 7 | | 19 | 24 | 25 | | 25 | |
| 8 | RAP | 23 | 28 | 32 | 31 | 32 | 35 |
| 8 | | 23 | 29 | 34 | 33 | 34 | |
| 8 | | 28 | 36 | 35 | 38 | 38 | |
| 9 | Limerock | 18 | 27 | 30 | 32 | 32 | 42 |
| 9 | | 23 | 35 | 40 | 42 | 42 | |
| 9 | | 33 | 39 | 43 | 53 | 53 | |
| 10 | Limerock | 22 | 26 | 27 | 28 | 28 | 35 |
| 10 | | 23 | 32 | 35 | 37 | 37 | |
| 10 | | 27 | 37 | 38 | 41 | 41 | |
| 11 | Limerock | 25 | 29 | 35 | 37 | 37 | 40 |
| 11 | | 23 | 32 | 38 | 40 | 40 | |
| 11 | | 27 | 37 | 42 | 42 | 42 | |

| WEEK 8 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Test Site | Material | Clegg Impact Values (IV) | | | | Max | Max (Avg) |
| | | 1 | 2 | 3 | 4 | | |
| 1 | RAP | 31 | 43 | 40 | 44 | 44 | 45 |
| 1 | | 38 | 47 | 48 | 49 | 49 | |
| 1 | | 35 | 39 | 40 | 41 | 41 | |
| 2 | RAP | 39 | 52 | 52 | 55 | 55 | 44 |
| 2 | | 28 | 33 | 35 | 36 | 36 | |
| 2 | | 35 | 38 | 42 | 40 | 42 | |
| 3 | RAP | 33 | 43 | 46 | 54 | 54 | 47 |
| 3 | | 31 | 41 | 41 | 42 | 42 | |
| 3 | | 35 | 45 | 41 | 46 | 46 | |
| 4 | RAP | 25 | 33 | 32 | 33 | 33 | 34 |
| 4 | | 27 | 31 | 32 | 32 | 32 | |
| 4 | | 31 | 37 | 38 | 33 | 38 | |
| 5 | RAP | 30 | 36 | 40 | 39 | 40 | 42 |
| 5 | | 25 | 31 | 37 | 34 | 37 | |
| 5 | | 21 | 27 | 28 | 30 | 30 | |
| 6 | RAP | 36 | 40 | 40 | 45 | 45 | 42 |
| 6 | | 31 | 35 | 39 | 38 | 39 | |
| 6 | | | 37 | 38 | 41 | 41 | |
| 7 | RAP | 23 | 33 | 35 | 36 | 36 | 32 |
| 7 | | 27 | 28 | 28 | 28 | 28 | |
| 7 | | 28 | 31 | 32 | 31 | 32 | |
| 8 | RAP | 33 | 38 | 43 | 43 | 43 | 37 |
| 8 | | 24 | 30 | 33 | 33 | 33 | |
| 8 | | 22 | 27 | 34 | 35 | 35 | |
| 9 | Limerock | 27 | 33 | 39 | 41 | 41 | 38 |
| 9 | | 27 | 37 | 38 | 40 | 40 | |
| 9 | | 20 | 29 | 34 | 34 | 34 | |
| 10 | Limerock | 20 | 26 | 29 | 30 | 30 | 32 |
| 10 | | 25 | 30 | | 37 | 37 | |
| 10 | | 20 | 26 | 28 | 29 | 29 | |
| 11 | Limerock | 26 | 36 | 42 | 45 | 45 | 34 |
| 11 | | 19 | 23 | 27 | 29 | 29 | |
| 11 | | 18 | 24 | 27 | 28 | 28 | |

# Appendix E

# Soil Stiffness Gauge Data

| WEEK 1 | | | | | |
|---|---|---|---|---|---|
| Test Site | Material | S/D | SSG (Mn/m) | Average | Std. Deviation |
| 1 | RAP | 2.86 | 21.04 | 19.28 | 1.64 |
| 1 | | 2.42 | 19.01 | | |
| 1 | | 2.19 | 17.80 | | |
| 2 | RAP | 2.36 | 17.19 | 16.15 | 1.08 |
| 2 | | 2.28 | 15.03 | | |
| 2 | | 2.68 | 16.24 | | |
| 3 | RAP | 2.11 | 17.34 | 17.18 | 1.66 |
| 3 | | 2.91 | 15.45 | | |
| 3 | | 2.47 | 18.76 | | |
| 4 | RAP | 2.62 | 19.73 | 17.51 | 2.25 |
| 4 | | 1.84 | 15.23 | | |
| 4 | | 2.40 | 17.58 | | |
| 5 | RAP | 2.56 | 19.19 | 18.76 | 0.97 |
| 5 | | 2.26 | 17.65 | | |
| 5 | | 2.48 | 19.43 | | |
| 6 | RAP | 2.12 | 17.06 | 16.71 | 0.59 |
| 6 | | 2.32 | 16.03 | | |
| 6 | | 2.25 | 17.04 | | |
| 7 | RAP | 2.52 | 17.45 | 18.19 | 0.64 |
| 7 | | 2.39 | 18.54 | | |
| 7 | | 2.37 | 18.59 | | |
| 8 | RAP | 2.36 | 16.19 | 17.64 | 2.98 |
| 8 | | 2.81 | 21.07 | | |
| 8 | | 1.92 | 15.67 | | |
| 9 | Limerock | 3.92 | 27.84 | 25.01 | 2.77 |
| 9 | | 2.79 | 22.30 | | |
| 9 | | 3.46 | 24.90 | | |
| 10 | Limerock | 2.56 | 16.73 | 20.51 | 3.29 |
| 10 | | 3.56 | 22.69 | | |
| 10 | | 2.55 | 22.12 | | |
| 11 | Limerock | 3.00 | 23.56 | 23.34 | 1.56 |
| 11 | | 3.04 | 24.78 | | |
| 11 | | 2.65 | 21.68 | | |

| WEEK 2 | | | | | |
|---|---|---|---|---|---|
| Test Site | Material | S/D | SSG (Mn/m) | Average | Std. Deviation |
| 1 | RAP | 3.97 | 25.49 | 23.94 | 2.30 |
| 1 | | 3.81 | 25.03 | | |
| 1 | | 3.09 | 21.29 | | |
| 2 | RAP | 3.37 | 22.91 | 20.66 | 2.05 |
| 2 | | 3.59 | 20.18 | | |
| 2 | | 2.82 | 18.90 | | |
| 3 | RAP | 3.66 | 20.21 | 21.01 | 0.73 |
| 3 | | 2.69 | 21.18 | | |
| 3 | | 3.11 | 21.64 | | |
| 4 | RAP | 2.67 | 20.25 | 19.78 | 1.48 |
| 4 | | 2.45 | 18.12 | | |
| 4 | | 2.87 | 20.96 | | |
| 5 | RAP | 2.47 | 18.19 | 19.00 | 1.26 |
| 5 | | 2.51 | 18.36 | | |
| 5 | | 2.81 | 20.45 | | |
| 6 | RAP | 2.84 | 20.97 | 20.29 | 0.64 |
| 6 | | 2.68 | 20.21 | | |
| 6 | | 2.72 | 19.69 | | |
| 7 | RAP | 2.53 | 18.78 | 17.86 | 1.60 |
| 7 | | | 18.78 | | |
| 7 | | 2.76 | 16.01 | | |
| 8 | RAP | 2.49 | 19.23 | 20.07 | 0.90 |
| 8 | | 2.63 | 19.96 | | |
| 8 | | 1.51 | 21.02 | | |
| 9 | Limerock | 1.65 | 16.92 | 18.90 | 3.48 |
| 9 | | 2.81 | 22.91 | | |
| 9 | | 1.79 | 16.86 | | |
| 10 | Limerock | 2.75 | 21.31 | 20.10 | 1.92 |
| 10 | | 2.82 | 21.10 | | |
| 10 | | 1.92 | 17.88 | | |
| 11 | Limerock | 2.28 | 19.89 | 19.36 | 0.46 |
| 11 | | 1.95 | 19.08 | | |
| 11 | | 2.32 | 19.11 | | |

| WEEK 4 | | | | | |
|---|---|---|---|---|---|
| Test Site | Material | S/D | SSG (Mn/m) | Average | Std. Deviation |
| 1 | RAP | 3.98 | 24.11 | 22.69 | 2.45 |
| 1 | | 3.67 | 24.10 | | |
| 1 | | 3.15 | 19.87 | | |
| 2 | RAP | 3.43 | 17.24 | 21.62 | 3.97 |
| 2 | | 3.83 | 24.97 | | |
| 2 | | 4.27 | 22.66 | | |
| 3 | RAP | 4.74 | 29.69 | 25.31 | 4.19 |
| 3 | | 3.45 | 24.89 | | |
| 3 | | 3.08 | 21.35 | | |
| 4 | RAP | 2.90 | 19.15 | 18.39 | 1.05 |
| 4 | | 3.18 | 17.20 | | |
| 4 | | 3.13 | 18.83 | | |
| 5 | RAP | 2.77 | 18.37 | 19.44 | 2.29 |
| 5 | | 3.50 | 22.07 | | |
| 5 | | 2.56 | 17.88 | | |
| 6 | RAP | 3.15 | 21.25 | 21.61 | 1.03 |
| 6 | | 2.95 | 20.81 | | |
| 6 | | 3.30 | 22.77 | | |
| 7 | RAP | 2.77 | 17.56 | 18.92 | 1.18 |
| 7 | | 2.64 | 19.55 | | |
| 7 | | 2.76 | 19.66 | | |
| 8 | RAP | 3.72 | 19.89 | 21.84 | 2.15 |
| 8 | | 4.07 | 24.15 | | |
| 8 | | 3.31 | 21.47 | | |
| 9 | Limerock | 5.80 | 33.49 | 31.07 | 2.10 |
| 9 | | 4.55 | 29.71 | | |
| 9 | | 4.13 | 30.01 | | |
| 10 | Limerock | 4.53 | 31.00 | 29.59 | 3.63 |
| 10 | | 4.46 | 32.31 | | |
| 10 | | 4.46 | 25.47 | | |
| 11 | Limerock | 3.49 | 24.96 | 27.47 | 2.20 |
| 11 | | 3.80 | 29.08 | | |
| 11 | | 3.68 | 28.37 | | |

| WEEK 6 | | | | | |
|---|---|---|---|---|---|
| Test Site | Material | S/D | SSG (Mn/m) | Average | Std. Deviation |
| 1 | RAP | 5.76 | 30.82 | 27.17 | 3.32 |
| 1 | | 4.96 | 26.36 | | |
| 1 | | 4.51 | 24.33 | | |
| 2 | RAP | 3.08 | 16.79 | 17.93 | 1.94 |
| 2 | | 3.12 | 20.17 | | |
| 2 | | 2.35 | 16.82 | | |
| 3 | RAP | 4.32 | 27.87 | 24.19 | 6.20 |
| 3 | | 2.26 | 17.04 | | |
| 3 | | 4.17 | 27.67 | | |
| 4 | RAP | 3.85 | 25.37 | 24.26 | 3.49 |
| 4 | | 3.30 | 20.35 | | |
| 4 | | 4.37 | 27.06 | | |
| 5 | RAP | 2.50 | 11.92 | 15.79 | 3.63 |
| 5 | | 2.13 | 16.32 | | |
| 5 | | 2.95 | 19.12 | | |
| 6 | RAP | 2.92 | 19.28 | 22.55 | 3.34 |
| 6 | | 4.19 | 22.41 | | |
| 6 | | 3.83 | 25.95 | | |
| 7 | RAP | 3.11 | 20.71 | 19.29 | 1.58 |
| 7 | | 2.71 | 19.58 | | |
| 7 | | 3.26 | 17.59 | | |
| 8 | RAP | 3.56 | 19.24 | 19.99 | 0.67 |
| 8 | | 3.24 | 20.51 | | |
| 8 | | 4.67 | 20.22 | | |
| 9 | Limerock | 3.15 | 24.39 | 21.38 | 3.48 |
| 9 | | 1.31 | 17.57 | | |
| 9 | | 2.43 | 22.17 | | |
| 10 | Limerock | 3.87 | 24.34 | 19.90 | 5.58 |
| 10 | | 2.34 | 21.72 | | |
| 10 | | 2.95 | 13.64 | | |
| 11 | Limerock | 2.84 | 21.79 | 19.80 | 1.92 |
| 11 | | 5.71 | 17.97 | | |
| 11 | | 2.11 | 19.63 | | |

| WEEK 8 | | | | | |
|---|---|---|---|---|---|
| Test Site | Material | S/D | SSG (Mn/m) | Average | Std. Deviation |
| 1 | RAP | 3.81 | 24.86 | 18.80 | 5.26 |
| 1 | | 4.41 | 15.47 | | |
| 1 | | 2.41 | 16.07 | | |
| 2 | RAP | 2.54 | 17.92 | 22.38 | 4.13 |
| 2 | | 4.38 | 26.08 | | |
| 2 | | 4.29 | 23.13 | | |
| 3 | RAP | 3.58 | 22.84 | 20.83 | 2.19 |
| 3 | | 2.71 | 18.49 | | |
| 3 | | 3.86 | 21.17 | | |
| 4 | RAP | 3.29 | 21.23 | 21.11 | 1.40 |
| 4 | | 3.26 | 22.45 | | |
| 4 | | 3.53 | 19.66 | | |
| 5 | RAP | 2.91 | 19.18 | 18.22 | 0.90 |
| 5 | | 2.60 | 18.08 | | |
| 5 | | 4.08 | 17.39 | | |
| 6 | RAP | 3.72 | 24.92 | 24.83 | 0.74 |
| 6 | | 4.00 | 24.05 | | |
| 6 | | 3.92 | 25.52 | | |
| 7 | RAP | 2.47 | 17.06 | 17.39 | 0.99 |
| 7 | | 2.62 | 18.51 | | |
| 7 | | 2.67 | 16.61 | | |
| 8 | RAP | 2.91 | 17.13 | 18.06 | 3.77 |
| 8 | | 3.31 | 22.21 | | |
| 8 | | 5.75 | 14.84 | | |
| 9 | Limerock | 1.33 | 15.43 | 24.29 | 7.71 |
| 9 | | 3.72 | 28.02 | | |
| 9 | | 3.83 | 29.43 | | |
| 10 | Limerock | 2.47 | 17.83 | 19.92 | 2.20 |
| 10 | | 2.30 | 19.72 | | |
| 10 | | 2.62 | 22.22 | | |
| 11 | Limerock | 3.03 | 25.29 | 19.74 | 4.93 |
| 11 | | 1.71 | 15.87 | | |
| 11 | | 2.07 | 18.06 | | |

# Appendix F

## LBR From Field CBR Data

| WEEK 1 | | | |
|---|---|---|---|
| Test Site | Material | CBR @ 0.1 | LBR @ 0.1 |
| 1 | RAP | 20.7 | 25.9 |
| 2 | RAP | 20.8 | 26.0 |
| 3 | RAP | 13.3 | 16.6 |
| 4 | RAP | 14.2 | 17.8 |
| 5 | RAP | 16.2 | 20.3 |
| 6 | RAP | 15.2 | 19.0 |
| 7 | RAP | 22.1 | 27.6 |
| 8 | RAP | 14.8 | 18.5 |
| 9 | Limerock | 62.3 | 77.9 |
| 10 | Limerock | 78.3 | 97.9 |
| 11 | Limerock | 68.3 | 85.4 |

| WEEK 2 | | | |
|---|---|---|---|
| Test Site | Material | CBR @ 0.1 | LBR @ 0.1 |
| 1 | RAP | 17.3 | 21.6 |
| 2 | RAP | 20.5 | 25.6 |
| 3 | RAP | 13.5 | 16.9 |
| 4 | RAP | 24.8 | 31.0 |
| 5 | RAP | 19.3 | 24.1 |
| 6 | RAP | 21.7 | 27.1 |
| 7 | RAP | 25.7 | 32.1 |
| 8 | RAP | 21.8 | 27.3 |
| 9 | Limerock | 91.3 | 114.1 |
| 10 | Limerock | 55 | 68.8 |
| 11 | Limerock | 68.3 | 85.4 |

| WEEK 4 | | | |
|---|---|---|---|
| Test Site | Material | CBR @ 0.1 | LBR @ 0.1 |
| 1 | RAP | 31.2 | 39.0 |
| 2 | RAP | 20.8 | 26.0 |
| 3 | RAP | 36.8 | 46.0 |
| 4 | RAP | 37.2 | 46.5 |
| 5 | RAP | 28.3 | 35.4 |
| 6 | RAP | 36.3 | 45.4 |
| 7 | RAP | 27 | 33.8 |
| 8 | RAP | 17.2 | 21.5 |
| 9 | Limerock | 84.7 | 105.9 |
| 10 | Limerock | 75.8 | 94.8 |
| 11 | Limerock | 83.7 | 104.6 |

| Week 6 | | | |
|---|---|---|---|
| Test Site | Material | CBR @ 0.1 | LBR @ 0.1 |
| 1 | RAP | 49.7 | 62.1 |
| 2 | RAP | 37 | 46.3 |
| 3 | RAP | 36.6 | 45.8 |
| 4 | RAP | 29.7 | 37.1 |
| 5 | RAP | 26.3 | 32.9 |
| 6 | RAP | 31.7 | 39.6 |
| 7 | RAP | 37.2 | 46.5 |
| 8 | RAP | 28.3 | 35.4 |
| 9 | Limerock | 75.7 | 94.6 |
| 10 | Limerock | 104.5 | 130.6 |
| 11 | Limerock | 64 | 80.0 |

| Week 8 | | | |
|---|---|---|---|
| Test Site | Material | CBR @ 0.1 | LBR @ 0.1 |
| 1 | RAP | 29.2 | 36.5 |
| 2 | RAP | 26.7 | 33.4 |
| 3 | RAP | 28.7 | 35.9 |
| 4 | RAP | 40.8 | 51.0 |
| 5 | RAP | 8.3 | 10.4 |
| 6 | RAP | 24 | 30.0 |
| 7 | RAP | 20.7 | 25.9 |
| 8 | RAP | 24.7 | 30.9 |
| 9 | Limerock | 50.3 | 62.9 |
| 10 | Limerock | 37.5 | 46.9 |
| 11 | Limerock | 53.3 | 66.6 |

# Appendix G

## Temperature Correlations

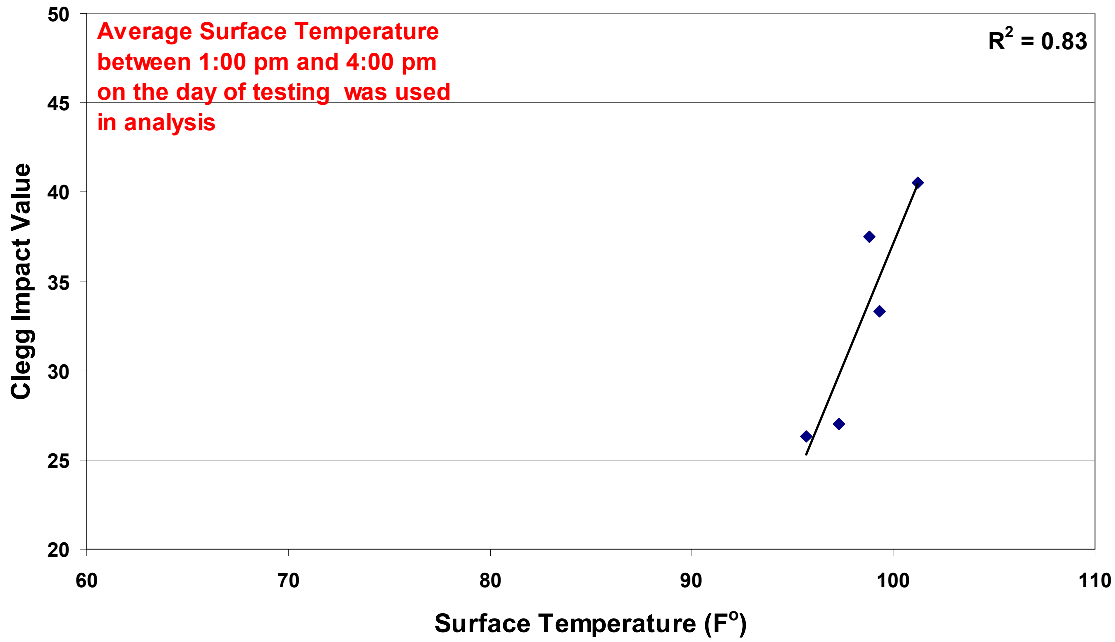



**Figure G-1 Clegg Impact Value vs. RAP Surface Temperature**

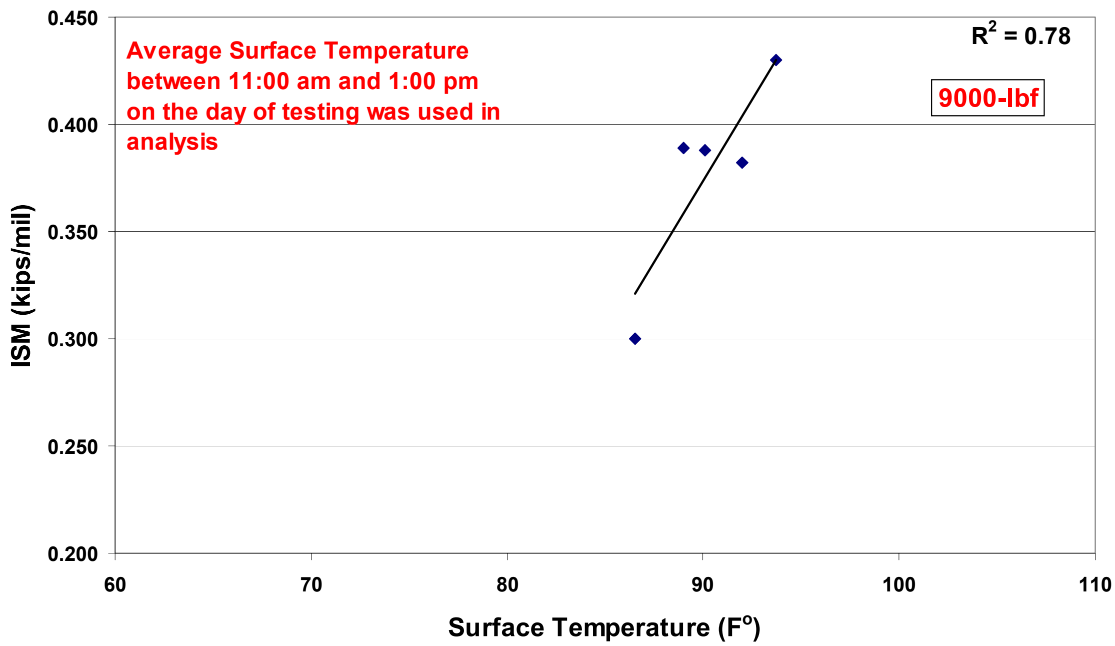



**Figure G-2 ISM vs. RAP Surface Temperature**

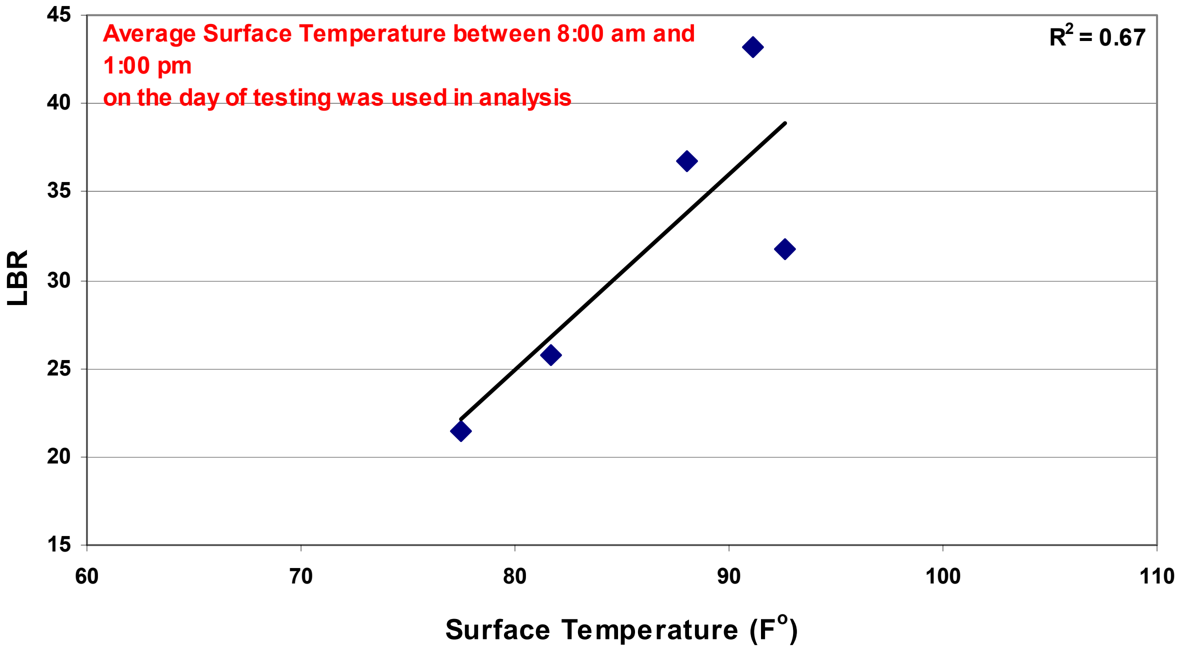



**Figure G-3 LBR vs. RAP Surface Temperature**

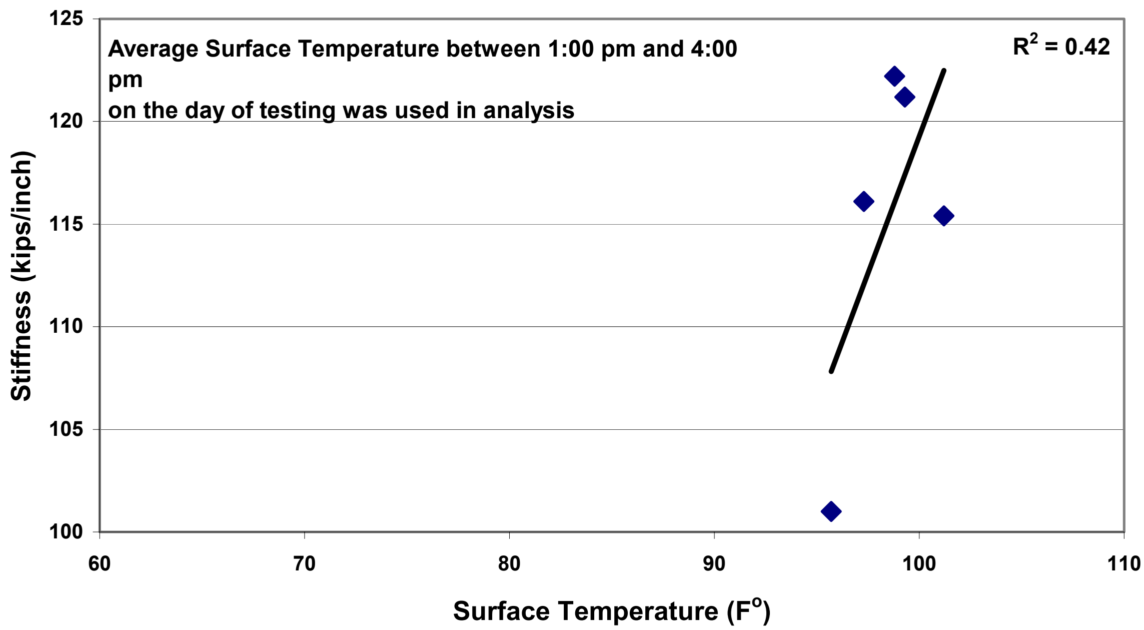



**Figure G-4 SSG vs. RAP Surface Temperature**

# Appendix H

## RAP-Soil Mixtures Laboratory LBR Data

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 100% RAP (1) @ woptimum = 8% | **Date** | 5/30/2002 (mixed) |
| | | | 5/31/2002 (compacted) |
| **Tested By** | Francis | | 6/2/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Sample was tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 7 | | 8 | |
| *Mass of Can* | 0.2792 | lb | 0.1320 | lb |
| *Mass of Wet Soil & Can* | 0.9556 | lb | 0.9576 | lb |
| *Mass of Dry Soil & Can* | 0.9036 | lb | 0.8958 | lb |
| *Mass of Dry Soil* | 0.6244 | lb | 0.7638 | lb |
| *Mass of Water* | 0.052 | lb | 0.0618 | lb |
| *w (%)* | 8.33 | | 8.09 | |
| *Average w (%)* | 8.21 | | St Dev = | 0.167 |

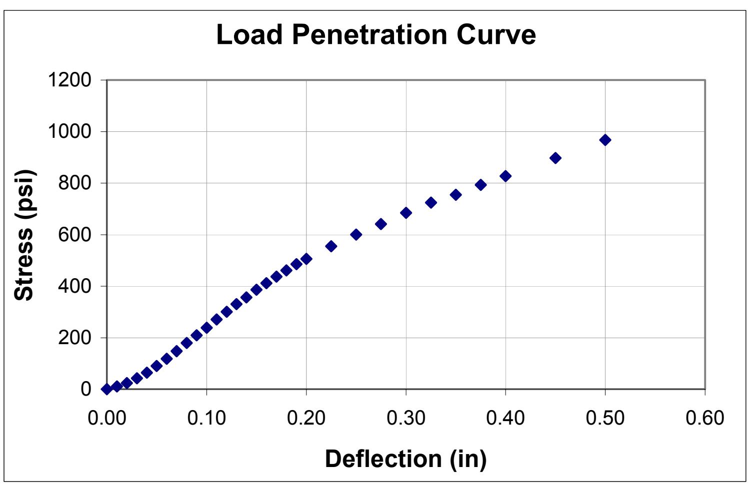
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.326 | lb |
| *Mass of Mold and Wet Soil* | 18.805 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.479 | lb |
| *Wet Density* | 126.4 | $lb/ft^3$ |
| *Dry Density* | 116.8 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 10.0 | 30 |
| 0.020 | 23.4 | 70 |
| 0.030 | 42.9 | 128 |
| 0.040 | 64.3 | 192 |
| 0.050 | 89.7 | 268 |
| 0.060 | 117.9 | 352 |
| 0.070 | 147.7 | 441 |
| 0.080 | 179.8 | 537 |
| 0.090 | 208.6 | 623 |
| 0.100 | 238.7 | 713 |
| 0.110 | 270.2 | 807 |
| 0.120 | 300.4 | 897 |
| 0.130 | 330.5 | 987 |
| 0.140 | 356.9 | 1066 |
| 0.150 | 385.7 | 1152 |
| 0.160 | 411.2 | 1228 |
| 0.170 | 436.6 | 1304 |
| 0.180 | 461.1 | 1377 |
| 0.190 | 485.5 | 1450 |
| 0.200 | 505.9 | 1511 |
| 0.225 | 555.2 | 1658 |
| 0.250 | 600.7 | 1794 |
| 0.275 | 641.6 | 1916 |
| 0.300 | 684.4 | 2044 |
| 0.325 | 724.3 | 2163 |
| 0.350 | 754.7 | 2254 |
| 0.375 | 793.6 | 2370 |
| 0.400 | 827.4 | 2471 |
| 0.450 | 897.0 | 2679 |
| 0.500 | 967.4 | 2889 |




**LBR 37.5**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 100% RAP (2) @ woptimum = 8% | **Date** | 6/4/2002 (mixed) |
| | | | 6/5/2002 (compacted) |
| **Tested By** | Francis & Eric | | 6/7/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Sample was tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 7 | | 8 | |
| *Mass of Can* | 0.2792 | lb | 0.1326 | lb |
| *Mass of Wet Soil & Can* | 1.0000 | lb | 0.8122 | lb |
| *Mass of Dry Soil & Can* | 0.9476 | lb | 0.7604 | lb |
| *Mass of Dry Soil* | 0.6684 | lb | 0.6278 | lb |
| *Mass of Water* | 0.0524 | lb | 0.0518 | lb |
| *w (%)* | 7.84 | | 8.25 | |
| *Average w (%)* | 8.05 | | St Dev = | 0.291 |

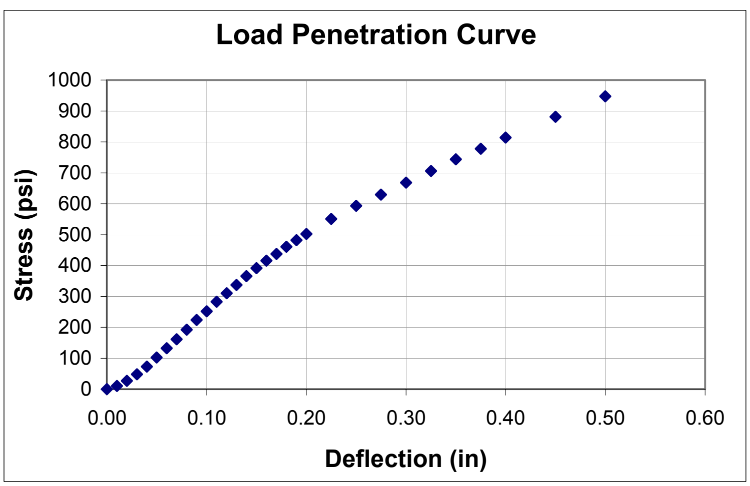
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.325 | lb |
| *Mass of Mold and Wet Soil* | 18.828 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.503 | lb |
| *Wet Density* | 126.7 | $lb/ft^3$ |
| *Dry Density* | 117.2 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 10.0 | 30 |
| 0.020 | 26.5 | 79 |
| 0.030 | 48.2 | 144 |
| 0.040 | 73.7 | 220 |
| 0.050 | 102.8 | 307 |
| 0.060 | 132.6 | 396 |
| 0.070 | 161.4 | 482 |
| 0.080 | 192.2 | 574 |
| 0.090 | 223.7 | 668 |
| 0.100 | 252.5 | 754 |
| 0.110 | 282.9 | 845 |
| 0.120 | 310.7 | 928 |
| 0.130 | 337.5 | 1008 |
| 0.140 | 365.3 | 1091 |
| 0.150 | 391.8 | 1170 |
| 0.160 | 416.2 | 1243 |
| 0.170 | 437.6 | 1307 |
| 0.180 | 461.1 | 1377 |
| 0.190 | 482.5 | 1441 |
| 0.200 | 501.6 | 1498 |
| 0.225 | 550.8 | 1645 |
| 0.250 | 593.3 | 1772 |
| 0.275 | 629.8 | 1881 |
| 0.300 | 668.3 | 1996 |
| 0.325 | 705.8 | 2108 |
| 0.350 | 744.0 | 2222 |
| 0.375 | 777.8 | 2323 |
| 0.400 | 814.0 | 2431 |
| 0.450 | 881.3 | 2632 |
| 0.500 | 946.9 | 2828 |




**LBR 37.5**

# LBR Data Sheet

**Description of Soil** 100% RAP (3) @ woptimum = 8%

**Date** 6/4/2002 (mixed) 6/5/2002 (compacted) 6/7/2002 (tested)

**Tested By** Francis & Eric

**Compaction** Modified - Method D

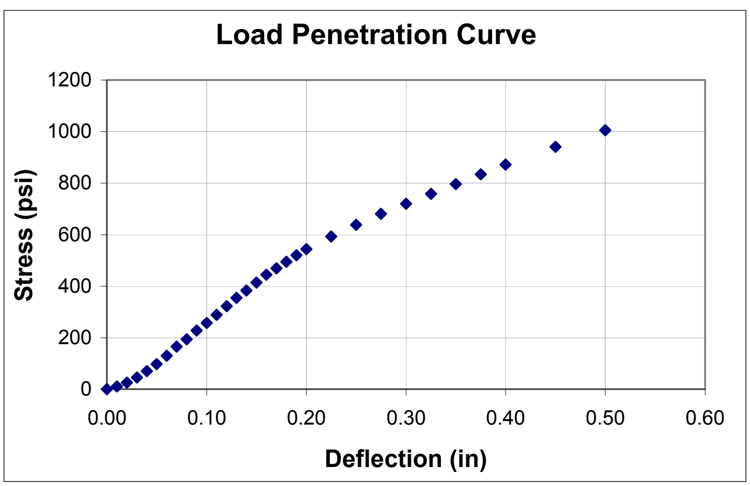
**Comments** Sample was tested as a base material (no surcharge)

| Compaction Moisture Content | | | | |
|---|---|---|---|---|
| *Can Number* | 9 | | 10 | |
| *Mass of Can* | 0.0964 | lb | 0.1470 | lb |
| *Mass of Wet Soil & Can* | 0.9258 | lb | 0.8208 | lb |
| *Mass of Dry Soil & Can* | 0.8654 | lb | 0.7726 | lb |
| *Mass of Dry Soil* | 0.769 | lb | 0.6256 | lb |
| *Mass of Water* | 0.0604 | lb | 0.0482 | lb |
| *w (%)* | 7.85 | | 7.70 | |
| *Average w (%)* | 7.78 | | St Dev = | 0.106 |

| Density Computations | | |
|---|---|---|
| *Mass of Mold* | 9.260 | lb |
| *Mass of Mold and Wet Soil* | 18.795 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.535 | lb |
| *Wet Density* | 127.1 | $lb/ft^3$ |
| *Dry Density* | 117.9 | $lb/ft^3$ |

| Measurements | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 10.0 | 30 |
| 0.020 | 25.4 | 76 |
| 0.030 | 45.2 | 135 |
| 0.040 | 69.6 | 208 |
| 0.050 | 97.4 | 291 |
| 0.060 | 129.9 | 388 |
| 0.070 | 165.1 | 493 |
| 0.080 | 193.5 | 578 |
| 0.090 | 228.0 | 681 |
| 0.100 | 257.5 | 769 |
| 0.110 | 288.6 | 862 |
| 0.120 | 322.1 | 962 |
| 0.130 | 354.3 | 1058 |
| 0.140 | 383.1 | 1144 |
| 0.150 | 414.5 | 1238 |
| 0.160 | 444.0 | 1326 |
| 0.170 | 469.4 | 1402 |
| 0.180 | 494.9 | 1478 |
| 0.190 | 519.7 | 1552 |
| 0.200 | 544.1 | 1625 |
| 0.225 | 593.3 | 1772 |
| 0.250 | 638.2 | 1906 |
| 0.275 | 680.4 | 2032 |
| 0.300 | 719.6 | 2149 |
| 0.325 | 758.4 | 2265 |
| 0.350 | 796.3 | 2378 |
| 0.375 | 833.8 | 2490 |
| 0.400 | 871.9 | 2604 |
| 0.450 | 941.2 | 2811 |
| 0.500 | 1005.5 | 3003 |




**LBR 40**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 100% RAP (4) @ woptimum = 8% | **Date** | 6/10/2002 (mixed)<br>6/11/2002 (compacted)<br>6/13/2002 (tested) |
| **Tested By** | Francis & Eric | | |
| **Compaction** | Modified - Method D | | |
| **Comments** | Sample was tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 5 | | 6 | |
| *Mass of Can* | 0.1248 | lb | 0.1574 | lb |
| *Mass of Wet Soil & Can* | 0.8888 | lb | 0.9128 | lb |
| *Mass of Dry Soil & Can* | 0.8334 | lb | 0.8656 | lb |
| *Mass of Dry Soil* | 0.7086 | lb | 0.7082 | lb |
| *Mass of Water* | 0.0554 | lb | 0.0472 | lb |
| *w (%)* | 7.82 | | 6.66 | |
| *Average w (%)* | 7.24 | | St Dev = | 0.816 |

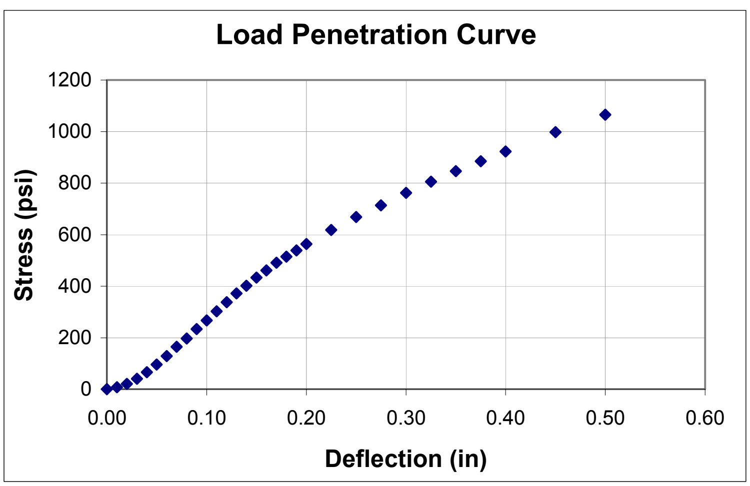
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.259 | lb |
| *Mass of Mold and Wet Soil* | 18.791 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.532 | lb |
| *Wet Density* | 127.1 | $lb/ft^3$ |
| *Dry Density* | 118.5 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 7.4 | 22 |
| 0.020 | 21.1 | 63 |
| 0.030 | 40.5 | 121 |
| 0.040 | 66.3 | 198 |
| 0.050 | 95.1 | 284 |
| 0.060 | 128.9 | 385 |
| 0.070 | 164.1 | 490 |
| 0.080 | 196.9 | 588 |
| 0.090 | 233.7 | 698 |
| 0.100 | 266.5 | 796 |
| 0.110 | 302.7 | 904 |
| 0.120 | 337.5 | 1008 |
| 0.130 | 371.3 | 1109 |
| 0.140 | 401.8 | 1200 |
| 0.150 | 433.3 | 1294 |
| 0.160 | 461.1 | 1377 |
| 0.170 | 490.9 | 1466 |
| 0.180 | 514.3 | 1536 |
| 0.190 | 539.1 | 1610 |
| 0.200 | 563.5 | 1683 |
| 0.225 | 618.5 | 1847 |
| 0.250 | 668.3 | 1996 |
| 0.275 | 714.2 | 2133 |
| 0.300 | 761.8 | 2275 |
| 0.325 | 806.0 | 2407 |
| 0.350 | 846.5 | 2528 |
| 0.375 | 884.7 | 2642 |
| 0.400 | 922.8 | 2756 |
| 0.450 | 997.8 | 2980 |
| 0.500 | 1065.5 | 3182 |




**LBR 44.6**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 80% RAP (1) @ woptimum = 6% | **Date** | 6/18/2002 (mixed) |
| | | | 6/19/2002 (compacted) |
| **Tested By** | Francis | | 6/21/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Sample was tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 3 | | 4 | |
| *Mass of Can* | 0.3092 | lb | 0.1518 | lb |
| *Mass of Wet Soil & Can* | 1.0542 | lb | 0.8292 | lb |
| *Mass of Dry Soil & Can* | 1.0100 | lb | 0.7928 | lb |
| *Mass of Dry Soil* | 0.7008 | lb | 0.641 | lb |
| *Mass of Water* | 0.0442 | lb | 0.0364 | lb |
| *w (%)* | 6.31 | | 5.68 | |
| *Average w (%)* | 5.99 | | St Dev = | 0.444 |

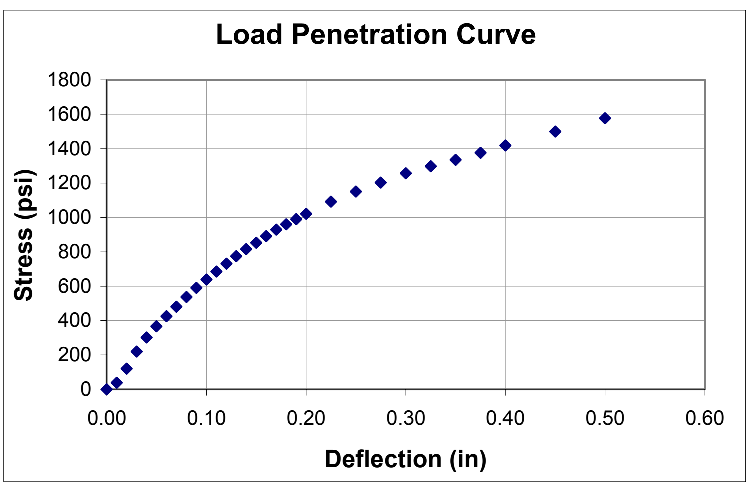
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.295 | lb |
| *Mass of Mold and Wet Soil* | 19.025 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.7305 | lb |
| *Wet Density* | 129.7 | $lb/ft^3$ |
| *Dry Density* | 122.4 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 38.2 | 114 |
| 0.020 | 120.2 | 359 |
| 0.030 | 219.3 | 655 |
| 0.040 | 302.7 | 904 |
| 0.050 | 367.3 | 1097 |
| 0.060 | 424.9 | 1269 |
| 0.070 | 480.2 | 1434 |
| 0.080 | 537.4 | 1605 |
| 0.090 | 590.7 | 1764 |
| 0.100 | 638.2 | 1906 |
| 0.110 | 685.1 | 2046 |
| 0.120 | 730.0 | 2180 |
| 0.130 | 774.8 | 2314 |
| 0.140 | 815.3 | 2435 |
| 0.150 | 853.2 | 2548 |
| 0.160 | 891.4 | 2662 |
| 0.170 | 928.5 | 2773 |
| 0.180 | 960.0 | 2867 |
| 0.190 | 990.5 | 2958 |
| 0.200 | 1020.9 | 3049 |
| 0.225 | 1092.3 | 3262 |
| 0.250 | 1150.9 | 3437 |
| 0.275 | 1203.1 | 3593 |
| 0.300 | 1256.3 | 3752 |
| 0.325 | 1297.9 | 3876 |
| 0.350 | 1335.0 | 3987 |
| 0.375 | 1376.5 | 4111 |
| 0.400 | 1419.1 | 4238 |
| 0.450 | 1499.4 | 4478 |
| 0.500 | 1577.4 | 4711 |




→ **LBR 85**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 80% RAP (2) @ woptimum = 6% | **Date** | 6/18/2002 (mixed)<br>6/19/2002 (compacted)<br>6/21/2002 (tested) |
| **Tested By** | Francis | | |
| **Compaction** | Modified - Method D | | |
| **Comments** | Sample was tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 5 | | 6 | |
| *Mass of Can* | 0.1248 | lb | 0.1575 | lb |
| *Mass of Wet Soil & Can* | 0.9854 | lb | 1.0446 | lb |
| *Mass of Dry Soil & Can* | 0.9350 | lb | 0.9942 | lb |
| *Mass of Dry Soil* | 0.8102 | lb | 0.8367 | lb |
| *Mass of Water* | 0.0504 | lb | 0.0504 | lb |
| *w (%)* | 6.22 | | 6.02 | |
| *Average w (%)* | 6.12 | | St Dev = | 0.139 |

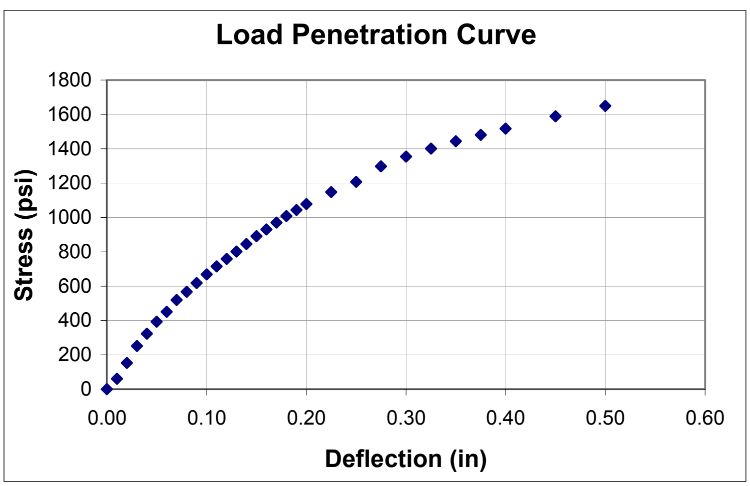
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.322 | lb |
| *Mass of Mold and Wet Soil* | 19.090 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.768 | lb |
| *Wet Density* | 130.2 | $lb/ft^3$ |
| *Dry Density* | 122.7 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 60.6 | 181 |
| 0.020 | 153.7 | 459 |
| 0.030 | 250.8 | 749 |
| 0.040 | 323.1 | 965 |
| 0.050 | 393.4 | 1175 |
| 0.060 | 450.4 | 1345 |
| 0.070 | 519.0 | 1550 |
| 0.080 | 567.9 | 1696 |
| 0.090 | 618.1 | 1846 |
| 0.100 | 668.7 | 1997 |
| 0.110 | 714.6 | 2134 |
| 0.120 | 758.4 | 2265 |
| 0.130 | 801.6 | 2394 |
| 0.140 | 845.1 | 2524 |
| 0.150 | 890.7 | 2660 |
| 0.160 | 931.2 | 2781 |
| 0.170 | 970.4 | 2898 |
| 0.180 | 1008.9 | 3013 |
| 0.190 | 1044.0 | 3118 |
| 0.200 | 1077.9 | 3219 |
| 0.225 | 1148.2 | 3429 |
| 0.250 | 1207.4 | 3606 |
| 0.275 | 1297.2 | 3874 |
| 0.300 | 1354.8 | 4046 |
| 0.325 | 1402.0 | 4187 |
| 0.350 | 1443.5 | 4311 |
| 0.375 | 1480.7 | 4422 |
| 0.400 | 1518.2 | 4534 |
| 0.450 | 1588.8 | 4745 |
| 0.500 | 1650.1 | 4928 |




**LBR 86.9**

# LBR Data Sheet

**Description of Soil** 80% RAP (3) @ woptimum = 6%

**Date** 7/2/2002 (mixed)
7/3/2002 (compacted)
7/5/2002 (tested)

**Tested By** Eric

**Compaction** Modified - Method D

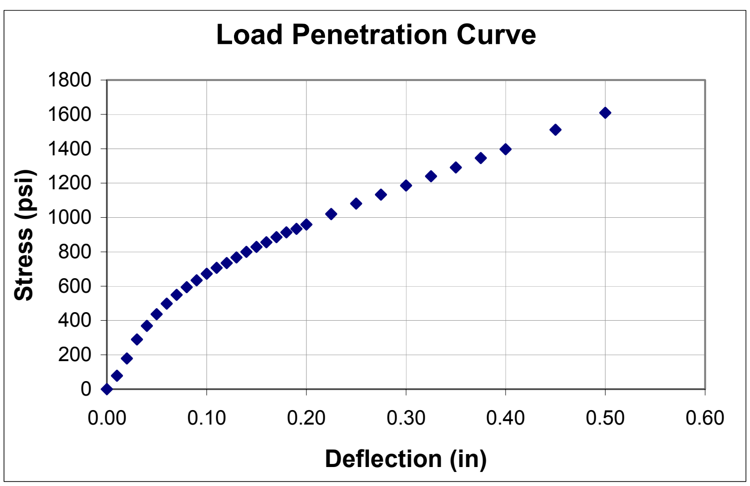
**Comments** Sample was tested as a base material (no surcharge)

| Compaction Moisture Content | | | | |
|---|---|---|---|---|
| *Can Number* | 5 | | 6 | |
| *Mass of Can* | 0.1248 | lb | 0.1574 | lb |
| *Mass of Wet Soil & Can* | 0.9742 | lb | 1.0002 | lb |
| *Mass of Dry Soil & Can* | 0.9234 | lb | 0.9554 | lb |
| *Mass of Dry Soil* | 0.7986 | lb | 0.798 | lb |
| *Mass of Water* | 0.0508 | lb | 0.0448 | lb |
| *w (%)* | 6.36 | | 5.61 | |
| *Average w (%)* | 5.99 | | St Dev = | 0.528 |

| Density Computations | | |
|---|---|---|
| *Mass of Mold* | 9.320 | lb |
| *Mass of Mold and Wet Soil* | 18.988 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.668 | lb |
| *Wet Density* | 128.9 | $lb/ft^3$ |
| *Dry Density* | 121.6 | $lb/ft^3$ |

| Measurements | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 77.3 | 231 |
| 0.020 | 178.5 | 533 |
| 0.030 | 290.0 | 866 |
| 0.040 | 369.0 | 1102 |
| 0.050 | 437.0 | 1305 |
| 0.060 | 498.6 | 1489 |
| 0.070 | 548.5 | 1638 |
| 0.080 | 594.3 | 1775 |
| 0.090 | 634.2 | 1894 |
| 0.100 | 673.0 | 2010 |
| 0.110 | 706.2 | 2109 |
| 0.120 | 734.6 | 2194 |
| 0.130 | 766.8 | 2290 |
| 0.140 | 800.3 | 2390 |
| 0.150 | 828.7 | 2475 |
| 0.160 | 855.9 | 2556 |
| 0.170 | 885.3 | 2644 |
| 0.180 | 914.1 | 2730 |
| 0.190 | 933.9 | 2789 |
| 0.200 | 958.3 | 2862 |
| 0.225 | 1019.3 | 3044 |
| 0.250 | 1080.9 | 3228 |
| 0.275 | 1133.4 | 3385 |
| 0.300 | 1186.0 | 3542 |
| 0.325 | 1239.6 | 3702 |
| 0.350 | 1290.1 | 3853 |
| 0.375 | 1346.7 | 4022 |
| 0.400 | 1396.6 | 4171 |
| 0.450 | 1510.1 | 4510 |
| 0.500 | 1609.6 | 4807 |




→ **LBR 85**

# LBR Data Sheet

**Description of Soil** 80% RAP (4) @ woptimum = 6%

**Date** 7/11/2002 (mixed)
7/12/2002 (compacted)
7/14/2002 (tested)

**Tested By** Eric

**Compaction** Modified - Method D

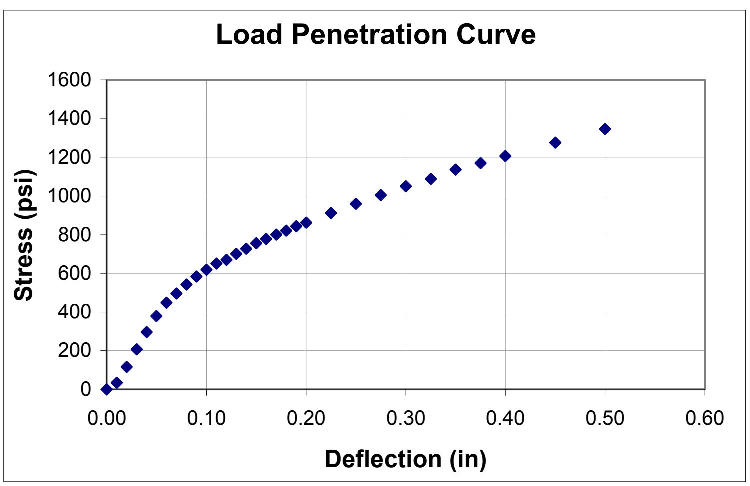
**Comments** Sample was tested as a base material (no surcharge)

| Compaction Moisture Content | | | | |
|---|---|---|---|---|
| *Can Number* | 1 | | 2 | |
| *Mass of Can* | 0.1532 | lb | 0.2832 | lb |
| *Mass of Wet Soil & Can* | 1.0028 | lb | 0.9270 | lb |
| *Mass of Dry Soil & Can* | 0.9578 | lb | 0.8894 | lb |
| *Mass of Dry Soil* | 0.8046 | lb | 0.6062 | lb |
| *Mass of Water* | 0.045 | lb | 0.0376 | lb |
| *w (%)* | 5.59 | | 6.20 | |
| *Average w (%)* | 5.90 | | St Dev = | 0.431 |

| Density Computations | | |
|---|---|---|
| *Mass of Mold* | 9.320 | lb |
| *Mass of Mold and Wet Soil* | 18.929 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.609 | lb |
| *Wet Density* | 128.1 | $lb/ft^3$ |
| *Dry Density* | 121.0 | $lb/ft^3$ |

| Measurements | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 33.8 | 101 |
| 0.020 | 115.5 | 345 |
| 0.030 | 206.3 | 616 |
| 0.040 | 296.3 | 885 |
| 0.050 | 379.0 | 1132 |
| 0.060 | 447.0 | 1335 |
| 0.070 | 495.9 | 1481 |
| 0.080 | 542.4 | 1620 |
| 0.090 | 584.3 | 1745 |
| 0.100 | 617.8 | 1845 |
| 0.110 | 650.9 | 1944 |
| 0.120 | 669.7 | 2000 |
| 0.130 | 701.5 | 2095 |
| 0.140 | 727.9 | 2174 |
| 0.150 | 755.1 | 2255 |
| 0.160 | 778.5 | 2325 |
| 0.170 | 800.6 | 2391 |
| 0.180 | 820.4 | 2450 |
| 0.190 | 843.1 | 2518 |
| 0.200 | 862.2 | 2575 |
| 0.225 | 911.4 | 2722 |
| 0.250 | 959.7 | 2866 |
| 0.275 | 1004.5 | 3000 |
| 0.300 | 1049.7 | 3135 |
| 0.325 | 1088.6 | 3251 |
| 0.350 | 1136.1 | 3393 |
| 0.375 | 1169.9 | 3494 |
| 0.400 | 1206.4 | 3603 |
| 0.450 | 1275.4 | 3809 |
| 0.500 | 1346.7 | 4022 |




**LBR 80**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 60% RAP (1) @ woptimum = 7.8% | **Date** | 6/24/2002 (mixed)<br>6/25/2002 (compacted)<br>6/27/2002 (tested) |
| **Tested By** | Francis & Eric | | |
| **Compaction** | Modified - Method D | | |
| **Comments** | Sample was tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 5 | | 6 | |
| *Mass of Can* | 0.1248 | lb | 0.1576 | lb |
| *Mass of Wet Soil & Can* | 0.9890 | lb | 0.9808 | lb |
| *Mass of Dry Soil & Can* | 0.9242 | lb | 0.9232 | lb |
| *Mass of Dry Soil* | 0.7994 | lb | 0.7656 | lb |
| *Mass of Water* | 0.0648 | lb | 0.0576 | lb |
| *w (%)* | 8.11 | | 7.52 | |
| *Average w (%)* | 7.81 | | St Dev = | 0.412 |

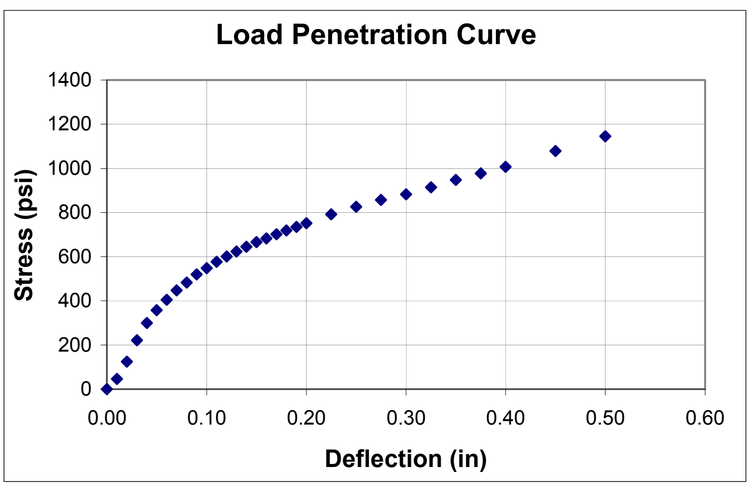
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.322 | lb |
| *Mass of Mold and Wet Soil* | 18.904 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.582 | lb |
| *Wet Density* | 127.7 | $lb/ft^3$ |
| *Dry Density* | 118.5 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 46.9 | 140 |
| 0.020 | 124.9 | 373 |
| 0.030 | 222.0 | 663 |
| 0.040 | 300.4 | 897 |
| 0.050 | 357.3 | 1067 |
| 0.060 | 404.5 | 1208 |
| 0.070 | 447.7 | 1337 |
| 0.080 | 483.5 | 1444 |
| 0.090 | 519.7 | 1552 |
| 0.100 | 548.8 | 1639 |
| 0.110 | 576.6 | 1722 |
| 0.120 | 601.7 | 1797 |
| 0.130 | 623.1 | 1861 |
| 0.140 | 645.2 | 1927 |
| 0.150 | 666.3 | 1990 |
| 0.160 | 683.1 | 2040 |
| 0.170 | 701.8 | 2096 |
| 0.180 | 719.6 | 2149 |
| 0.190 | 735.0 | 2195 |
| 0.200 | 751.7 | 2245 |
| 0.225 | 791.6 | 2364 |
| 0.250 | 826.1 | 2467 |
| 0.275 | 856.9 | 2559 |
| 0.300 | 882.3 | 2635 |
| 0.325 | 914.5 | 2731 |
| 0.350 | 947.3 | 2829 |
| 0.375 | 977.7 | 2920 |
| 0.400 | 1007.2 | 3008 |
| 0.450 | 1079.2 | 3223 |
| 0.500 | 1145.5 | 3421 |




→ **LBR 70**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 60% RAP (2) @ woptimum = 7.8% | **Date** | 7/2/2002 (mixed) |
| | | | 7/3/2002 (compacted) |
| **Tested By** | Eric | | 7/5/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Sample was tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| Can Number | 1 | | 2 | |
|---|---|---|---|---|
| *Mass of Can* | 0.1532 | lb | 0.2832 | lb |
| *Mass of Wet Soil & Can* | 0.9016 | lb | 0.9438 | lb |
| *Mass of Dry Soil & Can* | 0.8458 | lb | 0.8956 | lb |
| *Mass of Dry Soil* | 0.6926 | lb | 0.6124 | lb |
| *Mass of Water* | 0.0558 | lb | 0.0482 | lb |
| *w (%)* | 8.06 | | 7.87 | |
| *Average w (%)* | 7.96 | | St Dev = | 0.131 |

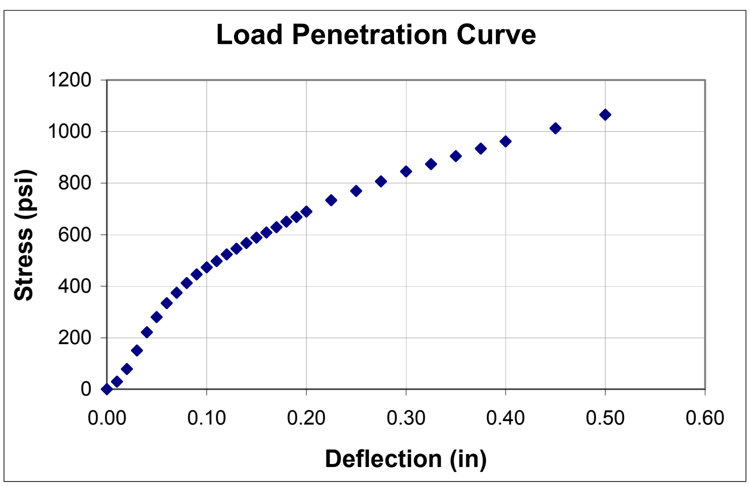
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.256 | lb |
| *Mass of Mold and Wet Soil* | 18.857 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.601 | lb |
| *Wet Density* | 128.0 | $lb/ft^3$ |
| *Dry Density* | 118.5 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 29.5 | 88 |
| 0.020 | 78.7 | 235 |
| 0.030 | 150.3 | 449 |
| 0.040 | 221.3 | 661 |
| 0.050 | 280.3 | 837 |
| 0.060 | 334.2 | 998 |
| 0.070 | 374.7 | 1119 |
| 0.080 | 411.9 | 1230 |
| 0.090 | 445.0 | 1329 |
| 0.100 | 472.8 | 1412 |
| 0.110 | 497.2 | 1485 |
| 0.120 | 522.7 | 1561 |
| 0.130 | 545.5 | 1629 |
| 0.140 | 567.6 | 1695 |
| 0.150 | 588.0 | 1756 |
| 0.160 | 607.7 | 1815 |
| 0.170 | 628.5 | 1877 |
| 0.180 | 650.6 | 1943 |
| 0.190 | 668.3 | 1996 |
| 0.200 | 689.4 | 2059 |
| 0.225 | 733.6 | 2191 |
| 0.250 | 770.1 | 2300 |
| 0.275 | 806.6 | 2409 |
| 0.300 | 845.5 | 2525 |
| 0.325 | 873.9 | 2610 |
| 0.350 | 905.4 | 2704 |
| 0.375 | 934.2 | 2790 |
| 0.400 | 961.3 | 2871 |
| 0.450 | 1012.9 | 3025 |
| 0.500 | 1065.5 | 3182 |




**LBR 61.3**

# LBR Data Sheet

**Description of Soil** 60% RAP (3) @ woptimum = 7.8%

**Date** 7/22/2002 (mixed)
7/23/2002 (compacted)
7/25/2002 (tested)

**Tested By** Eric

**Compaction** Modified - Method D

**Comments** Sample was tested as a base material (no surcharge)

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 3 | | 4 | |
| *Mass of Can* | 0.3092 | lb | 0.1516 | lb |
| *Mass of Wet Soil & Can* | 0.9444 | lb | 0.9990 | lb |
| *Mass of Dry Soil & Can* | 0.8980 | lb | 0.9362 | lb |
| *Mass of Dry Soil* | 0.5888 | lb | 0.7846 | lb |
| *Mass of Water* | 0.0464 | lb | 0.0628 | lb |
| *w (%)* | 7.88 | | 8.00 | |
| *Average w (%)* | 7.94 | | St Dev = | 0.087 |

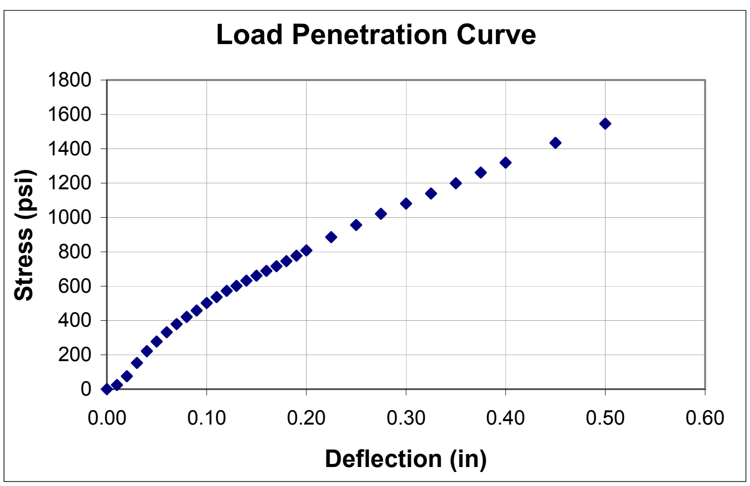
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.289 | lb |
| *Mass of Mold and Wet Soil* | 19.132 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.843 | lb |
| *Wet Density* | 131.2 | $lb/ft^3$ |
| *Dry Density* | 121.6 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 23.8 | 71 |
| 0.020 | 74.7 | 223 |
| 0.030 | 153.7 | 459 |
| 0.040 | 220.7 | 659 |
| 0.050 | 278.6 | 832 |
| 0.060 | 332.2 | 992 |
| 0.070 | 379.0 | 1132 |
| 0.080 | 421.2 | 1258 |
| 0.090 | 458.7 | 1370 |
| 0.100 | 501.6 | 1498 |
| 0.110 | 536.4 | 1602 |
| 0.120 | 572.9 | 1711 |
| 0.130 | 601.4 | 1796 |
| 0.140 | 632.5 | 1889 |
| 0.150 | 661.0 | 1974 |
| 0.160 | 689.4 | 2059 |
| 0.170 | 716.6 | 2140 |
| 0.180 | 746.4 | 2229 |
| 0.190 | 776.8 | 2320 |
| 0.200 | 808.0 | 2413 |
| 0.225 | 885.0 | 2643 |
| 0.250 | 955.6 | 2854 |
| 0.275 | 1020.6 | 3048 |
| 0.300 | 1081.5 | 3230 |
| 0.325 | 1138.5 | 3400 |
| 0.350 | 1199.1 | 3581 |
| 0.375 | 1260.3 | 3764 |
| 0.400 | 1319.3 | 3940 |
| 0.450 | 1433.8 | 4282 |
| 0.500 | 1546.3 | 4618 |




→ **LBR 66.9**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 60% RAP (4) @ woptimum = 7.8% | **Date** | 7/22/2002 (mixed) |
| | | | 7/23/2002 (compacted) |
| **Tested By** | Eric | | 7/25/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Sample was tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| Can Number | 5 | | 6 | |
|---|---|---|---|---|
| *Mass of Can* | 0.1248 | lb | 0.1574 | lb |
| *Mass of Wet Soil & Can* | 0.9378 | lb | 0.9822 | lb |
| *Mass of Dry Soil & Can* | 0.8752 | lb | 0.9214 | lb |
| *Mass of Dry Soil* | 0.7504 | lb | 0.764 | lb |
| *Mass of Water* | 0.0626 | lb | 0.0608 | lb |
| *w (%)* | 8.34 | | 7.96 | |
| *Average w (%)* | 8.15 | | St Dev = | 0.272 |

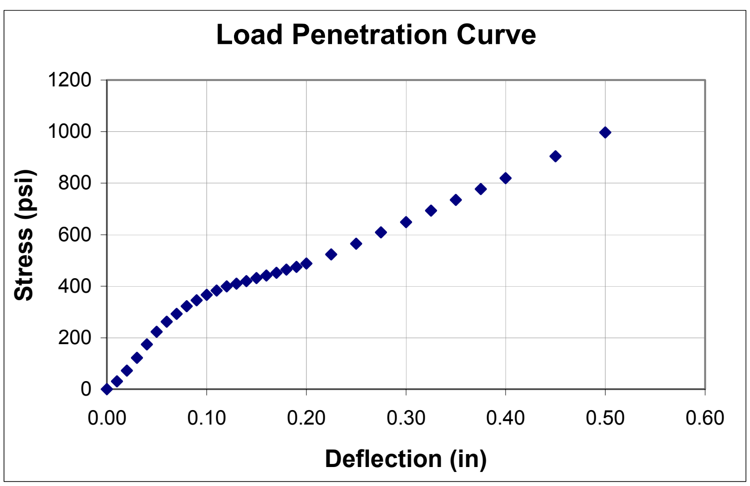
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.318 | lb |
| *Mass of Mold and Wet Soil* | 19.060 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.742 | lb |
| *Wet Density* | 129.9 | $lb/ft^3$ |
| *Dry Density* | 120.1 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 29.8 | 89 |
| 0.020 | 71.7 | 214 |
| 0.030 | 121.9 | 364 |
| 0.040 | 174.1 | 520 |
| 0.050 | 223.0 | 666 |
| 0.060 | 261.8 | 782 |
| 0.070 | 292.3 | 873 |
| 0.080 | 322.1 | 962 |
| 0.090 | 345.2 | 1031 |
| 0.100 | 366.3 | 1094 |
| 0.110 | 383.4 | 1145 |
| 0.120 | 398.8 | 1191 |
| 0.130 | 409.8 | 1224 |
| 0.140 | 419.9 | 1254 |
| 0.150 | 430.9 | 1287 |
| 0.160 | 441.7 | 1319 |
| 0.170 | 452.0 | 1350 |
| 0.180 | 464.1 | 1386 |
| 0.190 | 475.1 | 1419 |
| 0.200 | 487.9 | 1457 |
| 0.225 | 523.0 | 1562 |
| 0.250 | 564.5 | 1686 |
| 0.275 | 609.4 | 1820 |
| 0.300 | 648.6 | 1937 |
| 0.325 | 693.1 | 2070 |
| 0.350 | 734.6 | 2194 |
| 0.375 | 777.2 | 2321 |
| 0.400 | 818.7 | 2445 |
| 0.450 | 904.1 | 2700 |
| 0.500 | 996.5 | 2976 |




→ **LBR 46.9**

# LBR Data Sheet

**Description of Soil** 100% RAP (1) @ woptimum = 8%

**Tested By** Francis & Eric

**Compaction** Modified - Method D

**Comments** Tested as a subgrade material (15 lb surcharge)

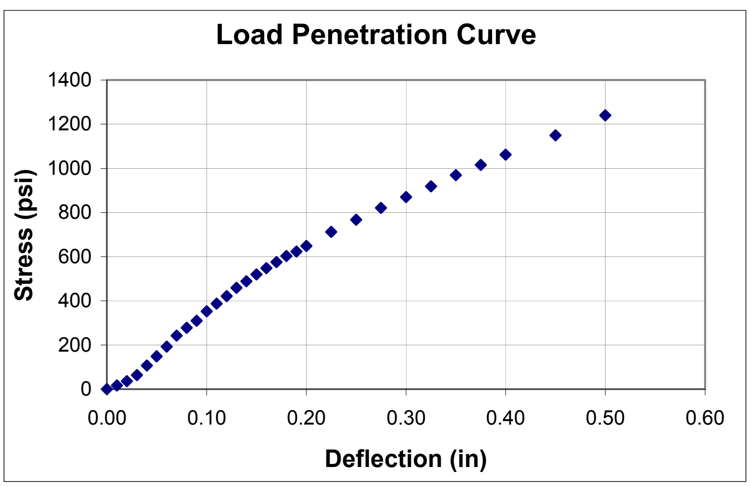
**Date** 6/10/2002 (mixed)
6/11/2002 (compacted)
6/13/2002 (tested)

| Compaction Moisture Content | | | | |
|---|---|---|---|---|
| *Can Number* | 3 | | 4 | |
| *Mass of Can* | 0.3094 | lb | 0.1516 | lb |
| *Mass of Wet Soil & Can* | 0.9562 | lb | 0.9678 | lb |
| *Mass of Dry Soil & Can* | 0.9032 | lb | 0.9086 | lb |
| *Mass of Dry Soil* | 0.5938 | lb | 0.757 | lb |
| *Mass of Water* | 0.053 | lb | 0.0592 | lb |
| *w (%)* | 8.93 | | 7.82 | |
| *Average w (%)* | 8.37 | | St Dev = | 0.782 |

| Density Computations | | |
|---|---|---|
| *Mass of Mold* | 9.324 | lb |
| *Mass of Mold and Wet Soil* | 18.889 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.565 | lb |
| *Wet Density* | 127.5 | $lb/ft^3$ |
| *Dry Density* | 117.7 | $lb/ft^3$ |

| Measurements | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 17.1 | 51 |
| 0.020 | 36.8 | 110 |
| 0.030 | 63.6 | 190 |
| 0.040 | 106.5 | 318 |
| 0.050 | 148.7 | 444 |
| 0.060 | 193.2 | 577 |
| 0.070 | 242.8 | 725 |
| 0.080 | 277.9 | 830 |
| 0.090 | 310.4 | 927 |
| 0.100 | 352.9 | 1054 |
| 0.110 | 387.1 | 1156 |
| 0.120 | 421.2 | 1258 |
| 0.130 | 458.4 | 1369 |
| 0.140 | 488.2 | 1458 |
| 0.150 | 520.0 | 1553 |
| 0.160 | 547.8 | 1636 |
| 0.170 | 576.3 | 1721 |
| 0.180 | 603.7 | 1803 |
| 0.190 | 623.8 | 1863 |
| 0.200 | 648.3 | 1936 |
| 0.225 | 712.5 | 2128 |
| 0.250 | 767.8 | 2293 |
| 0.275 | 820.4 | 2450 |
| 0.300 | 870.3 | 2599 |
| 0.325 | 919.1 | 2745 |
| 0.350 | 969.4 | 2895 |
| 0.375 | 1015.9 | 3034 |
| 0.400 | 1062.5 | 3173 |
| 0.450 | 1149.5 | 3433 |
| 0.500 | 1239.6 | 3702 |




→ **LBR 50.6**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 100% RAP (2) @ woptimum = 8% | **Date** | 6/14/2002 (mixed) |
| | | | 6/15/2002 (compacted) |
| **Tested By** | Francis | | 6/17/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 1 | | 2 | |
| *Mass of Can* | 0.1534 | lb | 0.2834 | lb |
| *Mass of Wet Soil & Can* | 0.8226 | lb | 1.0184 | lb |
| *Mass of Dry Soil & Can* | 0.7718 | lb | 0.9666 | lb |
| *Mass of Dry Soil* | 0.6184 | lb | 0.6832 | lb |
| *Mass of Water* | 0.0508 | lb | 0.0518 | lb |
| *w (%)* | 8.21 | | 7.58 | |
| *Average w (%)* | 7.90 | | St Dev = | 0.447 |

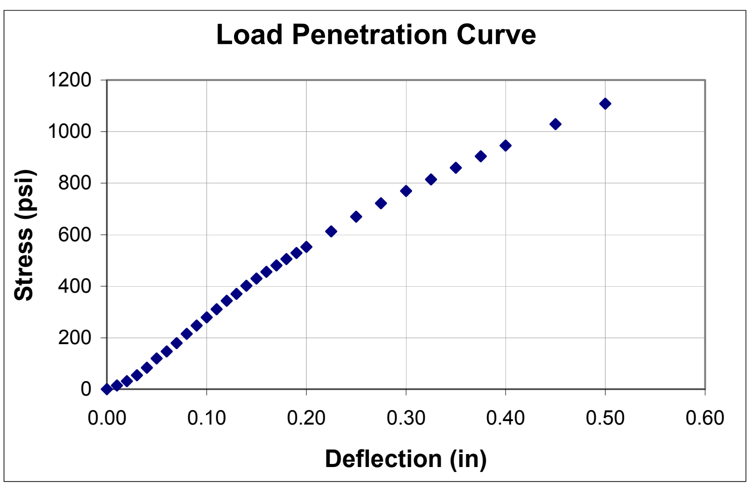
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.2585 | lb |
| *Mass of Mold and Wet Soil* | 18.811 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.5525 | lb |
| *Wet Density* | 127.3 | $lb/ft^3$ |
| *Dry Density* | 118.0 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 14.4 | 43 |
| 0.020 | 31.1 | 93 |
| 0.030 | 54.2 | 162 |
| 0.040 | 83.0 | 248 |
| 0.050 | 119.5 | 357 |
| 0.060 | 146.3 | 437 |
| 0.070 | 179.1 | 535 |
| 0.080 | 214.3 | 640 |
| 0.090 | 246.4 | 736 |
| 0.100 | 278.9 | 833 |
| 0.110 | 310.1 | 926 |
| 0.120 | 342.9 | 1024 |
| 0.130 | 370.0 | 1105 |
| 0.140 | 401.8 | 1200 |
| 0.150 | 429.3 | 1282 |
| 0.160 | 455.4 | 1360 |
| 0.170 | 480.5 | 1435 |
| 0.180 | 505.3 | 1509 |
| 0.190 | 529.1 | 1580 |
| 0.200 | 551.8 | 1648 |
| 0.225 | 612.8 | 1830 |
| 0.250 | 669.7 | 2000 |
| 0.275 | 721.3 | 2154 |
| 0.300 | 770.1 | 2300 |
| 0.325 | 814.3 | 2432 |
| 0.350 | 859.9 | 2568 |
| 0.375 | 903.7 | 2699 |
| 0.400 | 945.6 | 2824 |
| 0.450 | 1028.6 | 3072 |
| 0.500 | 1108.7 | 3311 |




→ **LBR 40**

## LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 100% RAP (3) @ woptimum = 8% | **Date** | 6/14/2002 (mixed)<br>6/15/2002 (compacted)<br>6/17/2002 (tested) |
| **Tested By** | Francis | | |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 3 | | 4 | |
| *Mass of Can* | 0.3092 | lb | 0.1516 | lb |
| *Mass of Wet Soil & Can* | 0.9456 | lb | 1.0282 | lb |
| *Mass of Dry Soil & Can* | 0.8984 | lb | 0.9652 | lb |
| *Mass of Dry Soil* | 0.5892 | lb | 0.8136 | lb |
| *Mass of Water* | 0.0472 | lb | 0.063 | lb |
| *w (%)* | 8.01 | | 7.74 | |
| *Average w (%)* | 7.88 | | St Dev = | 0.189 |

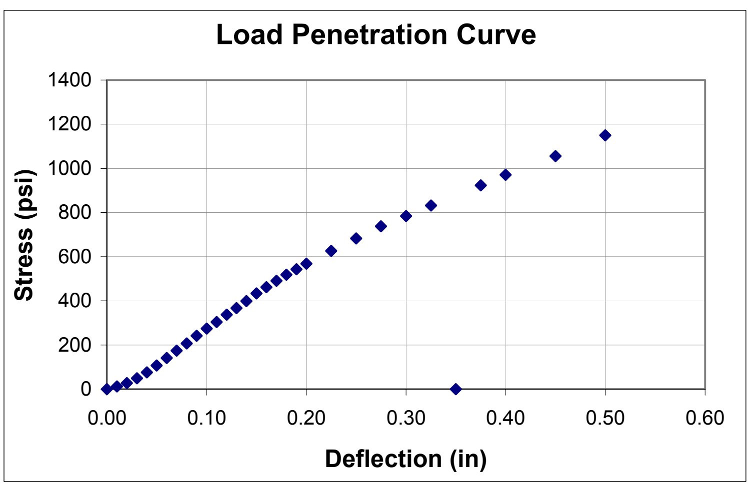
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.295 | lb |
| *Mass of Mold and Wet Soil* | 18.793 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.498 | lb |
| *Wet Density* | 126.6 | $lb/ft^3$ |
| *Dry Density* | 117.4 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 11.7 | 35 |
| 0.020 | 27.1 | 81 |
| 0.030 | 49.9 | 149 |
| 0.040 | 76.0 | 227 |
| 0.050 | 107.5 | 321 |
| 0.060 | 141.0 | 421 |
| 0.070 | 173.8 | 519 |
| 0.080 | 207.9 | 621 |
| 0.090 | 241.1 | 720 |
| 0.100 | 274.6 | 820 |
| 0.110 | 304.0 | 908 |
| 0.120 | 337.2 | 1007 |
| 0.130 | 367.7 | 1098 |
| 0.140 | 399.1 | 1192 |
| 0.150 | 433.3 | 1294 |
| 0.160 | 462.1 | 1380 |
| 0.170 | 490.9 | 1466 |
| 0.180 | 518.0 | 1547 |
| 0.190 | 543.1 | 1622 |
| 0.200 | 568.6 | 1698 |
| 0.225 | 626.8 | 1872 |
| 0.250 | 683.1 | 2040 |
| 0.275 | 738.0 | 2204 |
| 0.300 | 784.5 | 2343 |
| 0.325 | 831.7 | 2484 |
| 0.350 | #VALUE! | - |
| 0.375 | 923.5 | 2758 |
| 0.400 | 970.7 | 2899 |
| 0.450 | 1056.1 | 3154 |
| 0.500 | 1149.5 | 3433 |




→ **LBR 41**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 100% RAP (4) @ woptimum = 8% | **Date** | 6/18/2002 (mixed)<br>6/19/2002 (compacted)<br>6/21/2002 (tested) |
| **Tested By** | Francis | | |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

**Compaction Moisture Content**

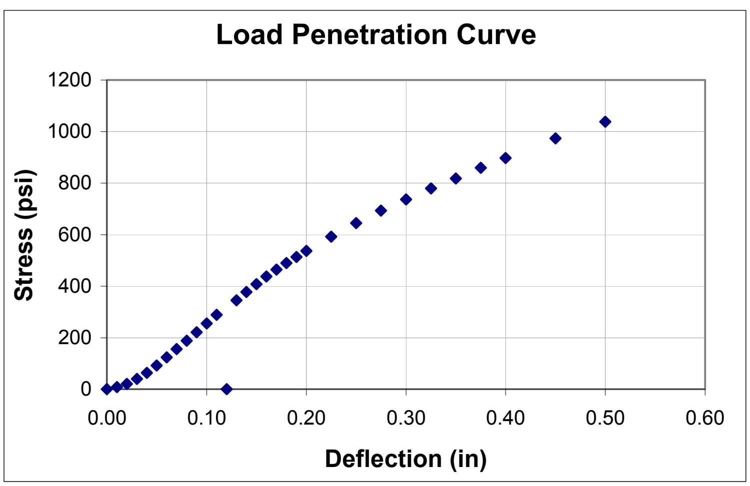
| | | | | |
|---|---|---|---|---|
| *Can Number* | 1 | | 2 | |
| *Mass of Can* | 0.1534 | lb | 0.2834 | lb |
| *Mass of Wet Soil & Can* | 0.9966 | lb | 1.0568 | lb |
| *Mass of Dry Soil & Can* | 0.9356 | lb | 1.0040 | lb |
| *Mass of Dry Soil* | 0.7822 | lb | 0.7206 | lb |
| *Mass of Water* | 0.061 | lb | 0.0528 | lb |
| *w (%)* | 7.80 | | 7.33 | |
| *Average w (%)* | 7.56 | | St Dev = | 0.333 |

**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.257 | lb |
| *Mass of Mold and Wet Soil* | 18.738 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.481 | lb |
| *Wet Density* | 126.4 | $lb/ft^3$ |
| *Dry Density* | 117.5 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |




| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 8.4 | 25 |
| 0.020 | 20.4 | 61 |
| 0.030 | 39.8 | 119 |
| 0.040 | 63.6 | 190 |
| 0.050 | 92.1 | 275 |
| 0.060 | 123.6 | 369 |
| 0.070 | 156.4 | 467 |
| 0.080 | 188.5 | 563 |
| 0.090 | 221.7 | 662 |
| 0.100 | 255.2 | 762 |
| 0.110 | 288.0 | 860 |
| 0.120 | #VALUE! | - |
| 0.130 | 345.2 | 1031 |
| 0.140 | 377.4 | 1127 |
| 0.150 | 407.2 | 1216 |
| 0.160 | 437.6 | 1307 |
| 0.170 | 464.8 | 1388 |
| 0.180 | 490.2 | 1464 |
| 0.190 | 513.6 | 1534 |
| 0.200 | 537.4 | 1605 |
| 0.225 | 591.7 | 1767 |
| 0.250 | 645.2 | 1927 |
| 0.275 | 693.5 | 2071 |
| 0.300 | 736.3 | 2199 |
| 0.325 | 778.8 | 2326 |
| 0.350 | 818.0 | 2443 |
| 0.375 | 859.2 | 2566 |
| 0.400 | 897.4 | 2680 |
| 0.450 | 974.4 | 2910 |
| 0.500 | 1038.0 | 3100 |

→ **LBR 39.9**

# LBR Data Sheet

**Description of Soil** 80% RAP (1) @ woptimum = 6%

**Date** 6/10/2002 (mixed)
6/11/2002 (compacted)
6/13/2002 (tested)

**Tested By** Francis & Eric

**Compaction** Modified - Method D

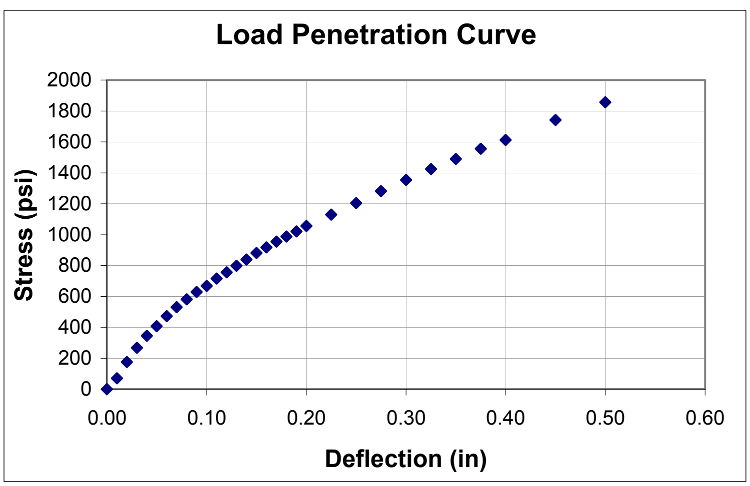
**Comments** Tested as a subgrade material (15 lb surcharge)

| Compaction Moisture Content | | | | |
|---|---|---|---|---|
| *Can Number* | 7 | | 8 | |
| *Mass of Can* | 0.2790 | lb | 0.1326 | lb |
| *Mass of Wet Soil & Can* | 1.0378 | lb | 0.9466 | lb |
| *Mass of Dry Soil & Can* | 0.9984 | lb | 0.9016 | lb |
| *Mass of Dry Soil* | 0.7194 | lb | 0.769 | lb |
| *Mass of Water* | 0.0394 | lb | 0.045 | lb |
| *w (%)* | 5.48 | | 5.85 | |
| *Average w (%)* | 5.66 | | St Dev = | 0.265 |

| Density Computations | | |
|---|---|---|
| *Mass of Mold* | 9.295 | lb |
| *Mass of Mold and Wet Soil* | 19.037 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.742 | lb |
| *Wet Density* | 129.9 | $lb/ft^3$ |
| *Dry Density* | 122.9 | $lb/ft^3$ |

| Measurements | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 70.3 | 210 |
| 0.020 | 176.5 | 527 |
| 0.030 | 267.5 | 799 |
| 0.040 | 345.2 | 1031 |
| 0.050 | 408.5 | 1220 |
| 0.060 | 473.5 | 1414 |
| 0.070 | 530.4 | 1584 |
| 0.080 | 581.6 | 1737 |
| 0.090 | 629.2 | 1879 |
| 0.100 | 669.0 | 1998 |
| 0.110 | 715.2 | 2136 |
| 0.120 | 757.1 | 2261 |
| 0.130 | 798.6 | 2385 |
| 0.140 | 838.8 | 2505 |
| 0.150 | 880.3 | 2629 |
| 0.160 | 916.8 | 2738 |
| 0.170 | 955.0 | 2852 |
| 0.180 | 988.8 | 2953 |
| 0.190 | 1021.9 | 3052 |
| 0.200 | 1055.8 | 3153 |
| 0.225 | 1130.8 | 3377 |
| 0.250 | 1203.4 | 3594 |
| 0.275 | 1280.8 | 3825 |
| 0.300 | 1354.4 | 4045 |
| 0.325 | 1424.4 | 4254 |
| 0.350 | 1490.1 | 4450 |
| 0.375 | 1555.7 | 4646 |
| 0.400 | 1612.6 | 4816 |
| 0.450 | 1742.2 | 5203 |
| 0.500 | 1857.0 | 5546 |




**LBR 86.3**

# LBR Data Sheet

**Description of Soil** 80% RAP (2) @ woptimum = 6%

**Date** 6/14/2002 (mixed)
6/15/2002 (compacted)
6/17/2002 (tested)

**Tested By** Francis

**Compaction** Modified - Method D

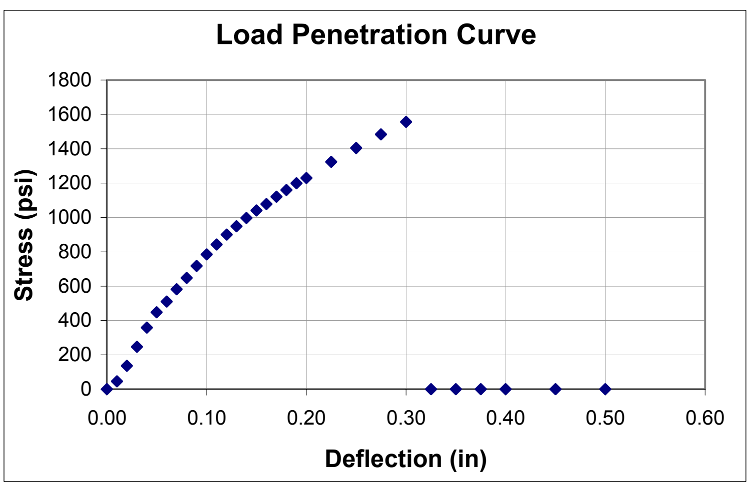
**Comments** Tested as a subgrade material (15 lb surcharge)

| Compaction Moisture Content | | | | |
|---|---|---|---|---|
| *Can Number* | 5 | | 6 | |
| *Mass of Can* | 0.1248 | lb | 0.1574 | lb |
| *Mass of Wet Soil & Can* | 0.9700 | lb | 0.9372 | lb |
| *Mass of Dry Soil & Can* | 0.9196 | lb | 0.8948 | lb |
| *Mass of Dry Soil* | 0.7948 | lb | 0.7374 | lb |
| *Mass of Water* | 0.0504 | lb | 0.0424 | lb |
| *w (%)* | 6.34 | | 5.75 | |
| *Average w (%)* | 6.05 | | St Dev = | 0.418 |

| Density Computations | | |
|---|---|---|
| *Mass of Mold* | 9.323 | lb |
| *Mass of Mold and Wet Soil* | 19.153 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.83 | lb |
| *Wet Density* | 131.0 | $lb/ft^3$ |
| *Dry Density* | 123.6 | $lb/ft^3$ |

| Measurements | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 45.9 | 137 |
| 0.020 | 135.9 | 406 |
| 0.030 | 246.4 | 736 |
| 0.040 | 358.3 | 1070 |
| 0.050 | 448.7 | 1340 |
| 0.060 | 510.3 | 1524 |
| 0.070 | 581.6 | 1737 |
| 0.080 | 648.9 | 1938 |
| 0.090 | 717.9 | 2144 |
| 0.100 | 784.5 | 2343 |
| 0.110 | 842.8 | 2517 |
| 0.120 | 901.4 | 2692 |
| 0.130 | 949.6 | 2836 |
| 0.140 | 996.5 | 2976 |
| 0.150 | 1041.0 | 3109 |
| 0.160 | 1078.5 | 3221 |
| 0.170 | 1120.7 | 3347 |
| 0.180 | 1159.9 | 3464 |
| 0.190 | 1198.4 | 3579 |
| 0.200 | 1229.9 | 3673 |
| 0.225 | 1323.6 | 3953 |
| 0.250 | 1404.3 | 4194 |
| 0.275 | 1483.7 | 4431 |
| 0.300 | 1556.7 | 4649 |
| 0.325 | #VALUE! | - |
| 0.350 | #VALUE! | - |
| 0.375 | #VALUE! | - |
| 0.400 | #VALUE! | - |
| 0.450 | #VALUE! | - |
| 0.500 | #VALUE! | - |




**LBR 102.5**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 80% RAP (3) @ woptimum = 6% | **Date** | 7/11/2002 (mixed) |
| | | | 7/12/2002 (compacted) |
| **Tested By** | Eric | | 7/14/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 5 | | 6 | |
| *Mass of Can* | 0.1248 | lb | 0.1574 | lb |
| *Mass of Wet Soil & Can* | 0.9364 | lb | 0.9350 | lb |
| *Mass of Dry Soil & Can* | 0.8816 | lb | 0.8822 | lb |
| *Mass of Dry Soil* | 0.7568 | lb | 0.7248 | lb |
| *Mass of Water* | 0.0548 | lb | 0.0528 | lb |
| *w (%)* | 7.24 | | 7.28 | |
| *Average w (%)* | 7.26 | | St Dev = | 0.031 |

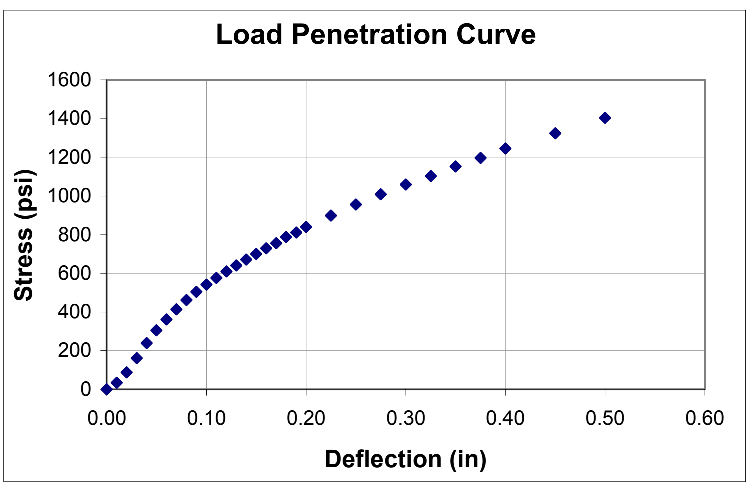
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.291 | lb |
| *Mass of Mold and Wet Soil* | 18.924 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.633 | lb |
| *Wet Density* | 128.4 | $lb/ft^3$ |
| *Dry Density* | 119.7 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 34.5 | 103 |
| 0.020 | 88.1 | 263 |
| 0.030 | 161.4 | 482 |
| 0.040 | 240.1 | 717 |
| 0.050 | 304.7 | 910 |
| 0.060 | 362.0 | 1081 |
| 0.070 | 413.9 | 1236 |
| 0.080 | 461.1 | 1377 |
| 0.090 | 504.3 | 1506 |
| 0.100 | 540.8 | 1615 |
| 0.110 | 576.3 | 1721 |
| 0.120 | 610.1 | 1822 |
| 0.130 | 639.9 | 1911 |
| 0.140 | 670.4 | 2002 |
| 0.150 | 699.8 | 2090 |
| 0.160 | 728.3 | 2175 |
| 0.170 | 755.7 | 2257 |
| 0.180 | 787.9 | 2353 |
| 0.190 | 811.3 | 2423 |
| 0.200 | 839.5 | 2507 |
| 0.225 | 899.4 | 2686 |
| 0.250 | 956.3 | 2856 |
| 0.275 | 1008.5 | 3012 |
| 0.300 | 1059.4 | 3164 |
| 0.325 | 1102.6 | 3293 |
| 0.350 | 1152.9 | 3443 |
| 0.375 | 1197.1 | 3575 |
| 0.400 | 1245.9 | 3721 |
| 0.450 | 1324.0 | 3954 |
| 0.500 | 1404.0 | 4193 |




**LBR 80.3**

# LBR Data Sheet

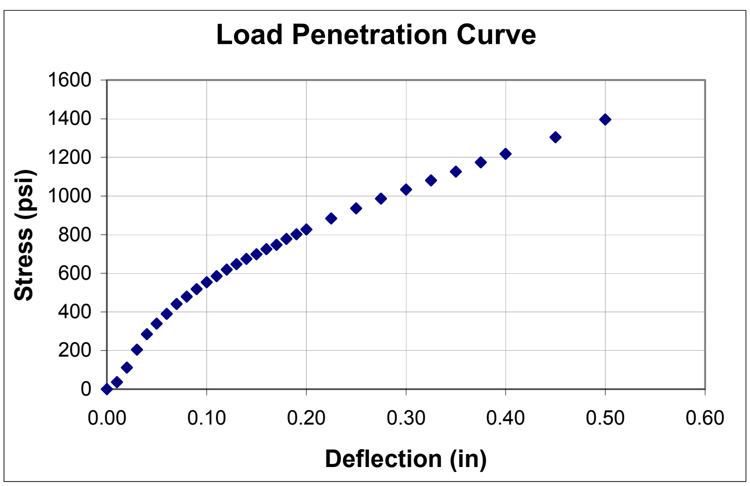
| | | | |
|---|---|---|---|
| **Description of Soil** | 80% RAP (4) @ woptimum = 6% | **Date** | 7/11/2002 (mixed) |
| | | | 7/12/2002 (compacted) |
| **Tested By** | Eric | | 7/14/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

| Compaction Moisture Content | | | | |
|---|---|---|---|---|
| *Can Number* | 3 | | 4 | |
| *Mass of Can* | 0.3092 | lb | 0.1514 | lb |
| *Mass of Wet Soil & Can* | 0.9322 | lb | 0.9322 | lb |
| *Mass of Dry Soil & Can* | 0.8936 | lb | 0.8858 | lb |
| *Mass of Dry Soil* | 0.5844 | lb | 0.7344 | lb |
| *Mass of Water* | 0.0386 | lb | 0.0464 | lb |
| *w (%)* | 6.61 | | 6.32 | |
| *Average w (%)* | 6.46 | | St Dev = | 0.203 |

| Density Computations | | |
|---|---|---|
| *Mass of Mold* | 9.255 | lb |
| *Mass of Mold and Wet Soil* | 18.878 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.623 | lb |
| *Wet Density* | 128.3 | $lb/ft^3$ |
| *Dry Density* | 120.5 | $lb/ft^3$ |

| Measurements | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 36.2 | 108 |
| 0.020 | 112.2 | 335 |
| 0.030 | 204.6 | 611 |
| 0.040 | 284.6 | 850 |
| 0.050 | 339.2 | 1013 |
| 0.060 | 389.8 | 1164 |
| 0.070 | 441.7 | 1319 |
| 0.080 | 479.5 | 1432 |
| 0.090 | 518.0 | 1547 |
| 0.100 | 553.2 | 1652 |
| 0.110 | 585.6 | 1749 |
| 0.120 | 619.1 | 1849 |
| 0.130 | 646.2 | 1930 |
| 0.140 | 674.4 | 2014 |
| 0.150 | 698.8 | 2087 |
| 0.160 | 724.9 | 2165 |
| 0.170 | 748.0 | 2234 |
| 0.180 | 778.5 | 2325 |
| 0.190 | 801.6 | 2394 |
| 0.200 | 827.4 | 2471 |
| 0.225 | 883.3 | 2638 |
| 0.250 | 935.2 | 2793 |
| 0.275 | 986.1 | 2945 |
| 0.300 | 1034.3 | 3089 |
| 0.325 | 1080.9 | 3228 |
| 0.350 | 1126.4 | 3364 |
| 0.375 | 1174.0 | 3506 |
| 0.400 | 1217.8 | 3637 |
| 0.450 | 1303.5 | 3893 |
| 0.500 | 1396.3 | 4170 |




**LBR 72.5**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 60% RAP (1) @ woptimum = 7.8% | **Date** | 6/24/2002 (mixed)<br>6/25/2002 (compacted)<br>6/27/2002 (tested) |
| **Tested By** | Francis & Eric | | |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

**Compaction Moisture Content**

| *Can Number* | 1 | | 2 | |
|---|---|---|---|---|
| *Mass of Can* | 0.1534 | lb | 0.2836 | lb |
| *Mass of Wet Soil & Can* | 0.9378 | lb | 0.9214 | lb |
| *Mass of Dry Soil & Can* | 0.8812 | lb | 0.8788 | lb |
| *Mass of Dry Soil* | 0.7278 | lb | 0.5952 | lb |
| *Mass of Water* | 0.0566 | lb | 0.0426 | lb |
| *w (%)* | 7.78 | | 7.16 | |
| *Average w (%)* | 7.47 | | St Dev = | 0.438 |

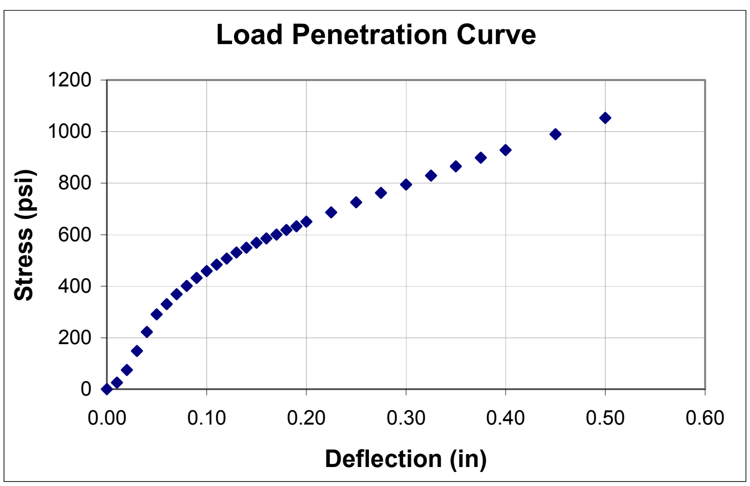
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.256 | lb |
| *Mass of Mold and Wet Soil* | 18.800 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.544 | lb |
| *Wet Density* | 127.2 | $lb/ft^3$ |
| *Dry Density* | 118.4 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 25.4 | 76 |
| 0.020 | 75.0 | 224 |
| 0.030 | 148.7 | 444 |
| 0.040 | 222.0 | 663 |
| 0.050 | 290.0 | 866 |
| 0.060 | 330.5 | 987 |
| 0.070 | 369.0 | 1102 |
| 0.080 | 401.1 | 1198 |
| 0.090 | 432.6 | 1292 |
| 0.100 | 459.1 | 1371 |
| 0.110 | 483.5 | 1444 |
| 0.120 | 507.0 | 1514 |
| 0.130 | 530.1 | 1583 |
| 0.140 | 549.5 | 1641 |
| 0.150 | 567.9 | 1696 |
| 0.160 | 585.0 | 1747 |
| 0.170 | 600.0 | 1792 |
| 0.180 | 618.1 | 1846 |
| 0.190 | 632.2 | 1888 |
| 0.200 | 650.3 | 1942 |
| 0.225 | 686.4 | 2050 |
| 0.250 | 725.6 | 2167 |
| 0.275 | 762.1 | 2276 |
| 0.300 | 794.2 | 2372 |
| 0.325 | 829.4 | 2477 |
| 0.350 | 865.2 | 2584 |
| 0.375 | 898.4 | 2683 |
| 0.400 | 928.9 | 2774 |
| 0.450 | 989.8 | 2956 |
| 0.500 | 1053.1 | 3145 |




→ **LBR 60**

## LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 60% RAP (2) @ woptimum = 7.8% | **Date** | 6/24/2002 (mixed) |
| | | | 6/25/2002 (compacted) |
| **Tested By** | Francis & Eric | | 6/27/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 3 | | 4 | |
| *Mass of Can* | 0.3094 | lb | 0.1516 | lb |
| *Mass of Wet Soil & Can* | 0.9792 | lb | 0.9372 | lb |
| *Mass of Dry Soil & Can* | 0.9286 | lb | 0.8780 | lb |
| *Mass of Dry Soil* | 0.6192 | lb | 0.7264 | lb |
| *Mass of Water* | 0.0506 | lb | 0.0592 | lb |
| *w (%)* | 8.17 | | 8.15 | |
| *Average w (%)* | 8.16 | | St Dev = | 0.016 |

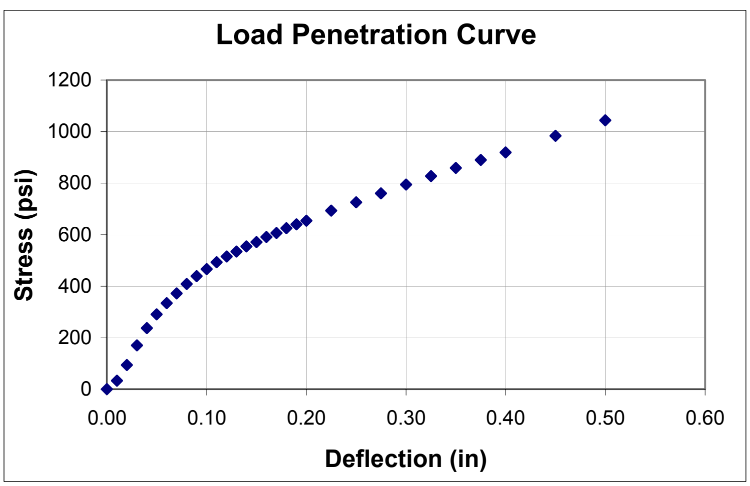
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.293 | lb |
| *Mass of Mold and Wet Soil* | 18.838 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.545 | lb |
| *Wet Density* | 127.2 | $lb/ft^3$ |
| *Dry Density* | 117.6 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 33.5 | 100 |
| 0.020 | 93.8 | 280 |
| 0.030 | 170.1 | 508 |
| 0.040 | 237.1 | 708 |
| 0.050 | 290.0 | 866 |
| 0.060 | 333.5 | 996 |
| 0.070 | 371.7 | 1110 |
| 0.080 | 408.8 | 1221 |
| 0.090 | 438.6 | 1310 |
| 0.100 | 465.8 | 1391 |
| 0.110 | 492.9 | 1472 |
| 0.120 | 515.3 | 1539 |
| 0.130 | 534.4 | 1596 |
| 0.140 | 553.8 | 1654 |
| 0.150 | 571.6 | 1707 |
| 0.160 | 591.0 | 1765 |
| 0.170 | 606.4 | 1811 |
| 0.180 | 624.8 | 1866 |
| 0.190 | 639.9 | 1911 |
| 0.200 | 654.3 | 1954 |
| 0.225 | 693.5 | 2071 |
| 0.250 | 725.6 | 2167 |
| 0.275 | 760.1 | 2270 |
| 0.300 | 793.9 | 2371 |
| 0.325 | 827.7 | 2472 |
| 0.350 | 858.5 | 2564 |
| 0.375 | 889.7 | 2657 |
| 0.400 | 919.5 | 2746 |
| 0.450 | 983.8 | 2938 |
| 0.500 | 1044.0 | 3118 |




**LBR 61.3**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 60% RAP (3) @ woptimum = 7.8% | **Date** | 7/2/2002 (mixed) |
| | | | 7/3/2003 (compacted) |
| **Tested By** | Eric | | 7/5/2002 (tested) |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

**Compaction Moisture Content**

| Can Number | 3 | | 4 | |
|---|---|---|---|---|
| *Mass of Can* | 0.3092 | lb | 0.1516 | lb |
| *Mass of Wet Soil & Can* | 0.9786 | lb | 0.9882 | lb |
| *Mass of Dry Soil & Can* | 0.9300 | lb | 0.9248 | lb |
| *Mass of Dry Soil* | 0.6208 | lb | 0.7732 | lb |
| *Mass of Water* | 0.0486 | lb | 0.0634 | lb |
| *w (%)* | 7.83 | | 8.20 | |
| *Average w (%)* | 8.01 | | St Dev = | 0.262 |

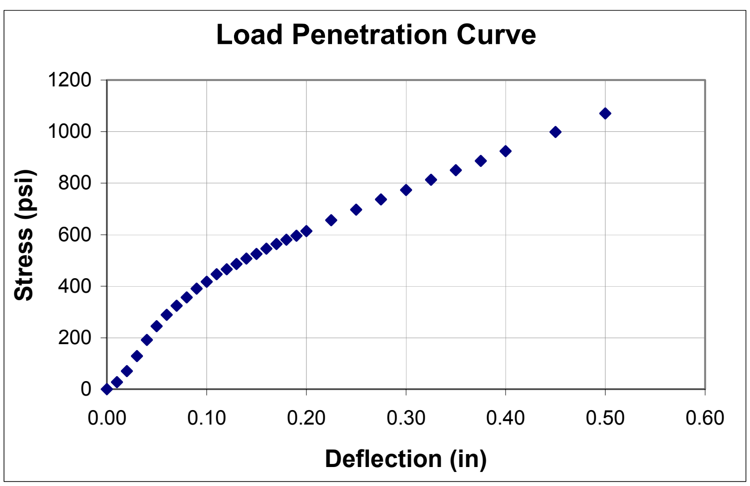
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.291 | lb |
| *Mass of Mold and Wet Soil* | 18.886 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.595 | lb |
| *Wet Density* | 127.9 | $lb/ft^3$ |
| *Dry Density* | 118.4 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 27.1 | 81 |
| 0.020 | 70.0 | 209 |
| 0.030 | 128.2 | 383 |
| 0.040 | 191.2 | 571 |
| 0.050 | 245.1 | 732 |
| 0.060 | 288.0 | 860 |
| 0.070 | 324.8 | 970 |
| 0.080 | 356.6 | 1065 |
| 0.090 | 390.1 | 1165 |
| 0.100 | 417.2 | 1246 |
| 0.110 | 446.0 | 1332 |
| 0.120 | 465.4 | 1390 |
| 0.130 | 485.9 | 1451 |
| 0.140 | 507.0 | 1514 |
| 0.150 | 525.0 | 1568 |
| 0.160 | 545.8 | 1630 |
| 0.170 | 563.2 | 1682 |
| 0.180 | 580.6 | 1734 |
| 0.190 | 596.0 | 1780 |
| 0.200 | 613.8 | 1833 |
| 0.225 | 656.0 | 1959 |
| 0.250 | 696.8 | 2081 |
| 0.275 | 736.3 | 2199 |
| 0.300 | 773.8 | 2311 |
| 0.325 | 813.7 | 2430 |
| 0.350 | 849.8 | 2538 |
| 0.375 | 886.3 | 2647 |
| 0.400 | 924.2 | 2760 |
| 0.450 | 998.8 | 2983 |
| 0.500 | 1070.2 | 3196 |




→ **LBR 55.0**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 60% RAP (4) @ woptimum = 7.8% | **Date** | 7/22/2002 (mixed)<br>7/23/2002 (compacted)<br>7/25/2002 (tested) |
| **Tested By** | Eric | | |
| **Compaction** | Modified - Method D | | |
| **Comments** | Tested as a subgrade material (15 lb surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 1 | | 2 | |
| *Mass of Can* | 0.1532 | lb | 0.2832 | lb |
| *Mass of Wet Soil & Can* | 0.9646 | lb | 0.9880 | lb |
| *Mass of Dry Soil & Can* | 0.9020 | lb | 0.9364 | lb |
| *Mass of Dry Soil* | 0.7488 | lb | 0.6532 | lb |
| *Mass of Water* | 0.0626 | lb | 0.0516 | lb |
| *w (%)* | 8.36 | | 7.90 | |
| *Average w (%)* | 8.13 | | St Dev = | 0.326 |

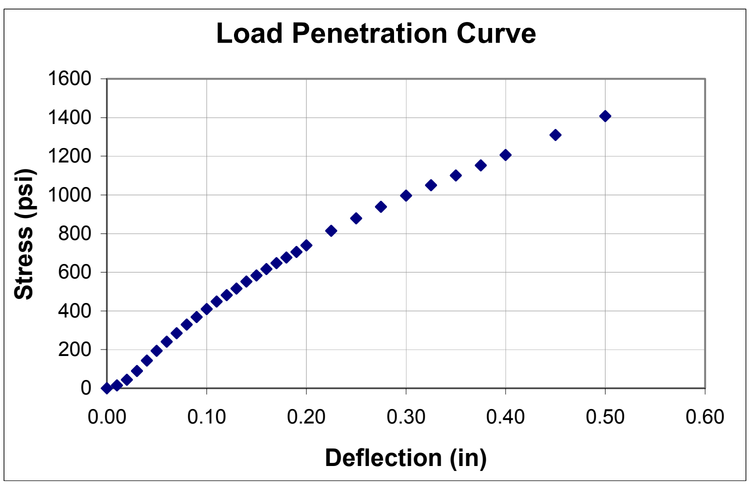
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.254 | lb |
| *Mass of Mold and Wet Soil* | 19.160 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.906 | lb |
| *Wet Density* | 132.0 | $lb/ft^3$ |
| *Dry Density* | 122.1 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 15.4 | 46 |
| 0.020 | 44.2 | 132 |
| 0.030 | 89.1 | 266 |
| 0.040 | 143.6 | 429 |
| 0.050 | 193.5 | 578 |
| 0.060 | 241.1 | 720 |
| 0.070 | 285.3 | 852 |
| 0.080 | 329.5 | 984 |
| 0.090 | 368.3 | 1100 |
| 0.100 | 409.5 | 1223 |
| 0.110 | 448.4 | 1339 |
| 0.120 | 482.2 | 1440 |
| 0.130 | 515.3 | 1539 |
| 0.140 | 552.8 | 1651 |
| 0.150 | 584.0 | 1744 |
| 0.160 | 617.1 | 1843 |
| 0.170 | 647.3 | 1933 |
| 0.180 | 676.0 | 2019 |
| 0.190 | 705.2 | 2106 |
| 0.200 | 739.0 | 2207 |
| 0.225 | 814.0 | 2431 |
| 0.250 | 878.6 | 2624 |
| 0.275 | 938.6 | 2803 |
| 0.300 | 996.2 | 2975 |
| 0.325 | 1049.7 | 3135 |
| 0.350 | 1101.3 | 3289 |
| 0.375 | 1152.9 | 3443 |
| 0.400 | 1206.4 | 3603 |
| 0.450 | 1310.2 | 3913 |
| 0.500 | 1407.7 | 4204 |




**LBR 57.5**

# LBR Data Sheet

| | | | | |
|---|---|---|---|---|
| **Description of Soil** | 100% RAP (1) @ woptimum = 8% | **Date** | 2/3/2003 | (mixed) |
| | | | 2/4/2003 | (compacted) |
| **Tested By** | Eric | | 2/6/2003 | (tested) |
| **Compaction** | Double Modified | | | |
| **Comments** | Tested as a base material (no surcharge) | | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 9 | | 10 | |
| *Mass of Can* | 0.0970 | lb | 0.1490 | lb |
| *Mass of Wet Soil & Can* | 0.5800 | lb | 0.6140 | lb |
| *Mass of Dry Soil & Can* | 0.5430 | lb | 0.5810 | lb |
| *Mass of Dry Soil* | 0.446 | lb | 0.432 | lb |
| *Mass of Water* | 0.037 | lb | 0.033 | lb |
| *w (%)* | 8.30 | | 7.64 | |
| *Average w (%)* | 7.97 | | St Dev = | 0.465 |

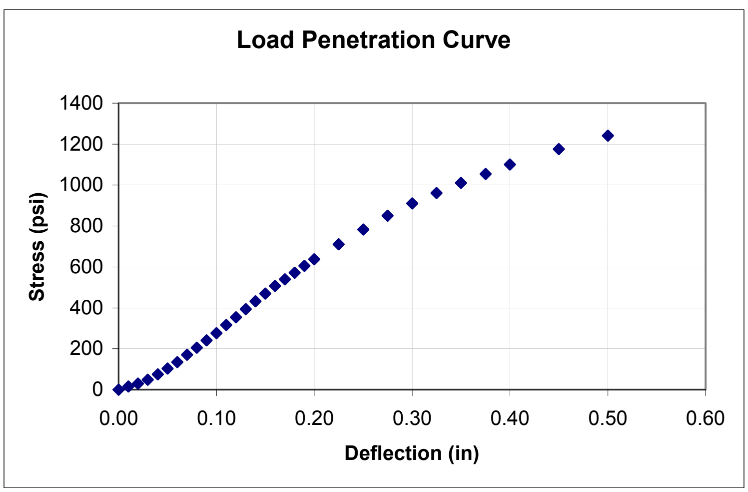
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.284 | lb |
| *Mass of Mold and Wet Soil* | 18.985 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.701 | lb |
| *Wet Density* | 129.3 | $lb/ft^3$ |
| *Dry Density* | 119.8 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 15.1 | 45 |
| 0.020 | 29.5 | 88 |
| 0.030 | 49.2 | 147 |
| 0.040 | 75.3 | 225 |
| 0.050 | 103.5 | 309 |
| 0.060 | 134.3 | 401 |
| 0.070 | 170.1 | 508 |
| 0.080 | 204.6 | 611 |
| 0.090 | 241.4 | 721 |
| 0.100 | 276.2 | 825 |
| 0.110 | 316.1 | 944 |
| 0.120 | 353.9 | 1057 |
| 0.130 | 394.1 | 1177 |
| 0.140 | 432.3 | 1291 |
| 0.150 | 469.4 | 1402 |
| 0.160 | 506.3 | 1512 |
| 0.170 | 538.4 | 1608 |
| 0.180 | 571.2 | 1706 |
| 0.190 | 604.4 | 1805 |
| 0.200 | 636.2 | 1900 |
| 0.225 | 710.9 | 2123 |
| 0.250 | 782.9 | 2338 |
| 0.275 | 850.5 | 2540 |
| 0.300 | 910.1 | 2718 |
| 0.325 | 961.7 | 2872 |
| 0.350 | 1010.6 | 3018 |
| 0.375 | 1054.8 | 3150 |
| 0.400 | 1100.3 | 3286 |
| 0.450 | 1175.6 | 3511 |
| 0.500 | 1241.6 | 3708 |




**LBR 46.3**

# LBR Data Sheet

| | | | |
|---|---|---|---|
| **Description of Soil** | 100% RAP (2) @ woptimum = 8% | **Date** | 3/3/2003 (mixed) |
| | | | 3/4/2003 (compacted) |
| **Tested By** | Eric | | 3/6/2003 (tested) |
| **Compaction** | Double Modified | | |
| **Comments** | Tested as a base material (no surcharge) | | |

**Compaction Moisture Content**

| | | | | |
|---|---|---|---|---|
| *Can Number* | 8 | | 5 | |
| *Mass of Can* | 0.1330 | lb | 0.1240 | lb |
| *Mass of Wet Soil & Can* | 1.1900 | lb | 1.0020 | lb |
| *Mass of Dry Soil & Can* | 1.1130 | lb | 0.9380 | lb |
| *Mass of Dry Soil* | 0.98 | lb | 0.814 | lb |
| *Mass of Water* | 0.077 | lb | 0.064 | lb |
| *w (%)* | 7.86 | | 7.86 | |
| *Average w (%)* | 7.86 | | St Dev = | 0.004 |

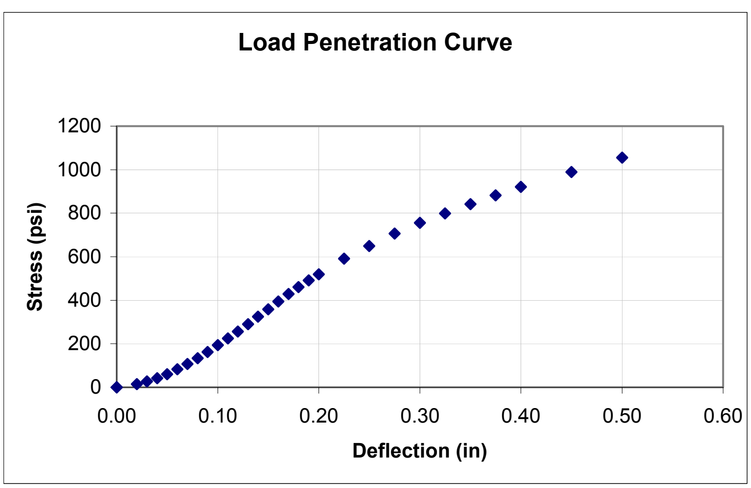
**Density Computations**

| | | |
|---|---|---|
| *Mass of Mold* | 9.252 | lb |
| *Mass of Mold and Wet Soil* | 18.954 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.702 | lb |
| *Wet Density* | 129.3 | $lb/ft^3$ |
| *Dry Density* | 119.9 | $lb/ft^3$ |

**Measurements**

| | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.000 | 0.0 | |
| 0.020 | 14.4 | 43 |
| 0.030 | 26.5 | 79 |
| 0.040 | 41.5 | 124 |
| 0.050 | 60.3 | 180 |
| 0.060 | 82.4 | 246 |
| 0.070 | 107.1 | 320 |
| 0.080 | 133.3 | 398 |
| 0.090 | 162.1 | 484 |
| 0.100 | 193.9 | 579 |
| 0.110 | 225.0 | 672 |
| 0.120 | 256.5 | 766 |
| 0.130 | 290.3 | 867 |
| 0.140 | 324.8 | 970 |
| 0.150 | 357.9 | 1069 |
| 0.160 | 394.4 | 1178 |
| 0.170 | 428.3 | 1279 |
| 0.180 | 460.4 | 1375 |
| 0.190 | 491.5 | 1468 |
| 0.200 | 519.7 | 1552 |
| 0.225 | 591.3 | 1766 |
| 0.250 | 648.9 | 1938 |
| 0.275 | 706.5 | 2110 |
| 0.300 | 755.1 | 2255 |
| 0.325 | 798.9 | 2386 |
| 0.350 | 842.1 | 2515 |
| 0.375 | 882.6 | 2636 |
| 0.400 | 920.8 | 2750 |
| 0.450 | 989.5 | 2955 |
| 0.500 | 1056.1 | 3154 |




**LBR 40.9**

# LBR Data Sheet

**Description of Soil** 100% RAP (3) @ woptimum = 8%

**Tested By** Eric

**Compaction** Double Modified

**Comments** Tested as a base material (no surcharge)

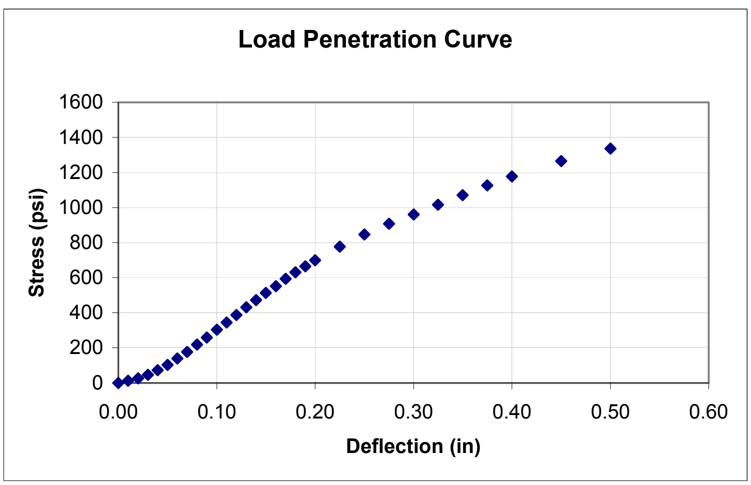
**Date** 3/3/2003 (mixed)
3/4/2003 (compacted)
3/6/2003 (tested)

| Compaction Moisture Content | | | | |
|---|---|---|---|---|
| *Can Number* | 9 | | 10 | |
| *Mass of Can* | 0.0980 | lb | 0.1470 | lb |
| *Mass of Wet Soil & Can* | 1.1570 | lb | 0.8630 | lb |
| *Mass of Dry Soil & Can* | 1.0760 | lb | 0.8090 | lb |
| *Mass of Dry Soil* | 0.978 | lb | 0.662 | lb |
| *Mass of Water* | 0.081 | lb | 0.054 | lb |
| *w (%)* | 8.28 | | 8.16 | |
| *Average w (%)* | 8.22 | | St Dev = | 0.088 |

| Density Computations | | |
|---|---|---|
| *Mass of Mold* | 9.316 | lb |
| *Mass of Mold and Wet Soil* | 19.093 | lb |
| *Vol of Mold* | 0.07502 | $ft^3$ |
| *Mass of Wet Soil* | 9.777 | lb |
| *Wet Density* | 130.3 | $lb/ft^3$ |
| *Dry Density* | 120.4 | $lb/ft^3$ |

| Measurements | | |
|---|---|---|
| *Diameter of Piston* | 1.95 | in |
| *Area of Piston* | 2.98648 | $in^2$ |

| Deflection (in) | Stress (psi) | Load (lb) |
|---|---|---|
| 0.000 | 0.0 | 0 |
| 0.010 | 12.7 | 38 |
| 0.020 | 26.8 | 80 |
| 0.030 | 46.5 | 139 |
| 0.040 | 72.7 | 217 |
| 0.050 | 103.5 | 309 |
| 0.060 | 139.0 | 415 |
| 0.070 | 177.1 | 529 |
| 0.080 | 218.3 | 652 |
| 0.090 | 259.2 | 774 |
| 0.100 | 302.4 | 903 |
| 0.110 | 345.2 | 1031 |
| 0.120 | 387.4 | 1157 |
| 0.130 | 430.6 | 1286 |
| 0.140 | 472.8 | 1412 |
| 0.150 | 513.3 | 1533 |
| 0.160 | 551.5 | 1647 |
| 0.170 | 593.3 | 1772 |
| 0.180 | 631.2 | 1885 |
| 0.190 | 665.0 | 1986 |
| 0.200 | 699.2 | 2088 |
| 0.225 | 776.8 | 2320 |
| 0.250 | 846.1 | 2527 |
| 0.275 | 907.4 | 2710 |
| 0.300 | 960.7 | 2869 |
| 0.325 | 1015.6 | 3033 |
| 0.350 | 1070.2 | 3196 |
| 0.375 | 1125.4 | 3361 |
| 0.400 | 1178.0 | 3518 |
| 0.450 | 1264.7 | 3777 |
| 0.500 | 1335.4 | 3988 |




**LBR 53.0**

# Appendix I

## RAP-Soil Mixtures Mohr-Coulomb Failure Envelopes

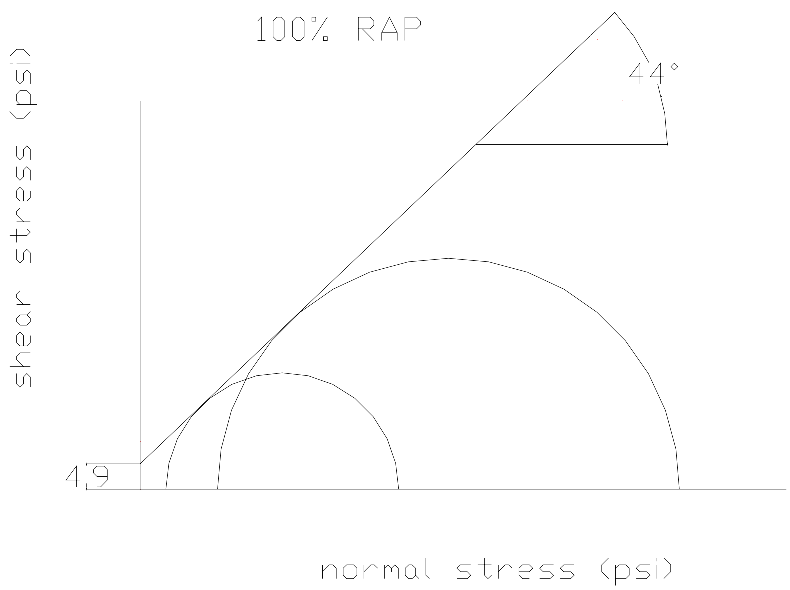



**Figure I-1. Mohr-Coulomb failure envelope of 100% RAP**

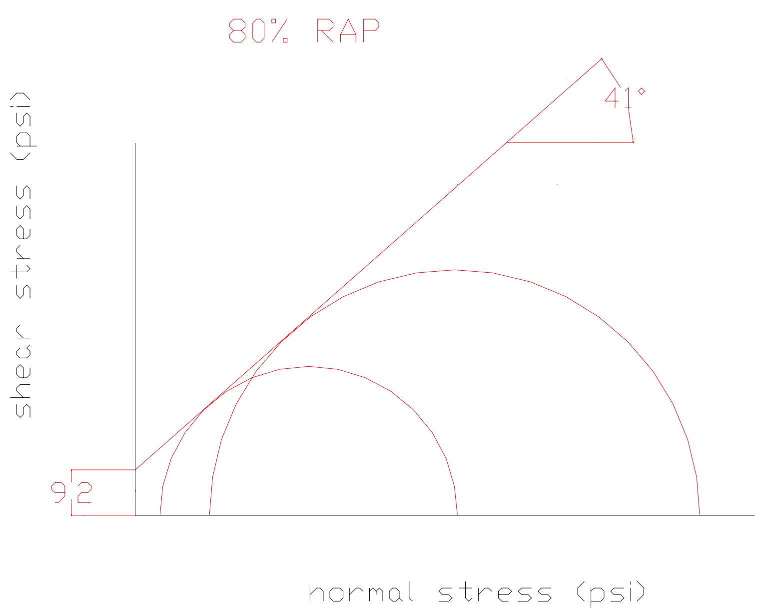



**Figure I-2. Mohr-Coulomb failure envelope of 80% RAP**

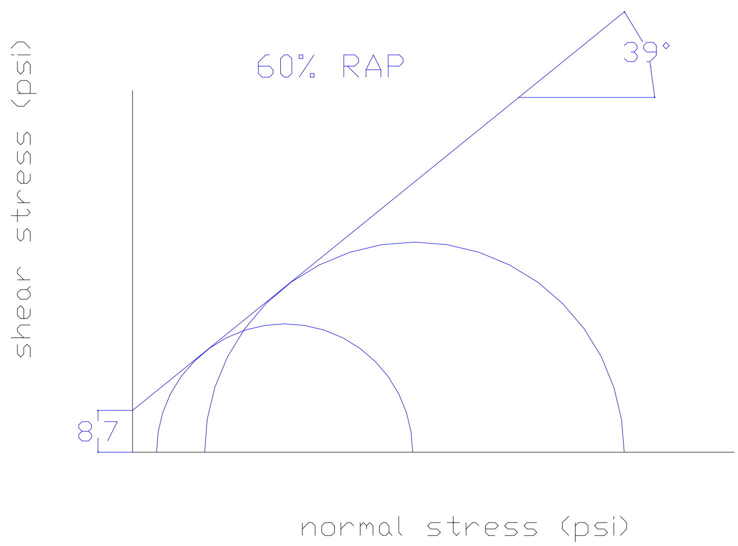



**Figure I-3. Mohr-Coulomb failure envelope of 60% RAP**

# Appendix J

## Surface and Leachate Water Data

Table J.1 Silver (Ag) concentration versus time in surface runoff and leachate samples collected from the RAP and Limerock collection systems.

| Time of Exposure (days) | Concentrations (μg/l) [b] | | | | | |
|---|---|---|---|---|---|---|
| | RAP Surface Runoff 1 [a] | RAP Surface Runoff 2 [a] | RAP Leachate | Limerock Surface Runoff 1 [a] | Limerock Surface Runoff 2 [a] | Limerock Leachate |
| 38 | BDL | - | - | - | - | - |
| 44 | 1.25 | - | BDL | BDL | - | 1.01 |
| 58 | 2.31 | - | 2.09 | - | - | 1.98 |
| 61 | 1.95 | - | 2.02 | - | - | 2.38 |
| 80 | 1.59 | - | 1.45 | 1.63 | - | 1.56 |
| 90 | 1.94 | - | 1.71 | 1.87 | - | 1.43 |
| 99 | 1.72 | - | 1.49 | - | 1.68 | 1.32 |
| 110 | - | - | - | 1.08 | - | - |
| 122 | BDL | - | BDL | - | - | BDL |
| 134 | BDL | BDL | 1.15 | 1.27 | 1.28 | 1.09 |
| 141 | - | - | - | BDL | - | - |
| 147 | BDL | BDL | BDL | BDL | - | BDL |
| 155 | BDL | BDL | BDL | BDL | 1.04 | BDL |
| 165 | BDL | BDL | BDL | - | BDL | BDL |

"-" = Insufficient quantity for collection
BDL = below detection limit, Ag < 1 μg/l
[a] Samples were collected from separate collection tanks
[b] EPA Standard = 1000 μg/l

Table J.2 Cadmium (Cd) concentration versus Time in surface runoff and leachate samples collected from the RAP and Limerock collection systems.

| Time of Exposure (days) | Concentrations (µg/l) [b] | | | | | |
|---|---|---|---|---|---|---|
| | RAP Surface Runoff 1 [a] | RAP Surface Runoff 2 [a] | RAP Leachate | Limerock Surface Runoff 1 [a] | Limerock Surface Runoff 2 [a] | Limerock Leachate |
| 38 | 2.78 | - | - | - | - | - |
| 44 | BDL | - | BDL | 2.21 | - | BDL |
| 58 | BDL | - | BDL | - | - | BDL |
| 61 | BDL | - | BDL | - | - | BDL |
| 80 | BDL | - | BDL | BDL | - | BDL |
| 90 | BDL | - | BDL | BDL | - | BDL |
| 99 | BDL | - | BDL | - | BDL | BDL |
| 110 | - | - | - | BDL | - | - |
| 122 | BDL | - | BDL | - | - | BDL |
| 134 | BDL | BDL | BDL | BDL | BDL | BDL |
| 141 | - | - | - | 3.28 | - | - |
| 147 | BDL | BDL | BDL | BDL | - | BDL |
| 155 | BDL | BDL | BDL | BDL | BDL | BDL |
| 165 | BDL | BDL | BDL | - | BDL | BDL |

"-" = Insufficient quantity for analysis
BDL = Below detection limit, Cd < 1 µg/l
[a] Samples were colleted from separate collection tanks
[b] EPA Standard = 1000 µg/l

Table J.3 Chromium (Cr) concentration versus Time in surface runoff and leachate collected from the RAP and Limerock collection systems.

| Time of Exposure (days) | Concentrations (μg/l) [b] | | | | | |
|---|---|---|---|---|---|---|
| | RAP Surface Runoff 1 [a] | RAP Surface Runoff 2 [a] | RAP Leachate | Limerock Surface Runoff 1 [a] | Limerock Surface Runoff 2 [a] | Limerock Leachate |
| 38 | BDL | - | - | - | - | - |
| 44 | BDL | - | BDL | 9.14 | - | BDL |
| 58 | BDL | - | BDL | - | - | BDL |
| 61 | BDL | - | BDL | - | - | BDL |
| 80 | BDL | - | BDL | BDL | - | BDL |
| 90 | BDL | - | BDL | BDL | - | BDL |
| 99 | BDL | - | BDL | - | BDL | BDL |
| 110 | - | - | - | BDL | - | - |
| 122 | BDL | - | BDL | - | - | BDL |
| 134 | BDL | BDL | BDL | BDL | BDL | BDL |
| 141 | - | - | - | BDL | - | - |
| 147 | BDL | BDL | BDL | BDL | - | BDL |
| 155 | BDL | BDL | BDL | BDL | BDL | BDL |
| 165 | BDL | BDL | BDL | - | BDL | BDL |

"-" = Insufficient quantity for analysis
BDL = Below detection limit, Cr < 5 μg/l
[a] Samples were colleted from separate collection tanks
[b] EPA Standard = 5000 μg/l

Table J.4 Lead (Pb) concentration versus Time in surface runoff and leachate samples collected from the RAP and Limerock collection systems.

| Time of Exposure (days) | Concentrations (μg/l) [b] | | | | | |
|---|---|---|---|---|---|---|
| | RAP Surface Runoff 1 [a] | RAP Surface Runoff 2 [a] | RAP Leachate | Limerock Surface Runoff 1 [a] | Limerock Surface Runoff 2 [a] | Limerock Leachate |
| 38 | 38.39 | - | - | - | - | - |
| 44 | BDL | - | BDL | 8.5 | - | BDL |
| 58 | BDL | - | 7.76 | - | - | BDL |
| 61 | 334.76 | - | BDL | - | - | 6.35 |
| 80 | BDL | - | BDL | BDL | - | BDL |
| 90 | BDL | - | BDL | BDL | - | BDL |
| 99 | BDL | - | BDL | - | BDL | BDL |
| 110 | - | - | - | BDL | - | - |
| 122 | BDL | - | BDL | - | - | BDL |
| 134 | BDL | BDL | BDL | BDL | BDL | BDL |
| 141 | - | - | - | BDL | - | - |
| 147 | BDL | BDL | BDL | 6.41 | - | 5.71 |
| 155 | BDL | BDL | BDL | 6.52 | BDL | BDL |
| 165 | 20.77 | BDL | BDL | - | BDL | BDL |
| 179 | BDL | BDL | BDL | 8.80 | - | BDL |
| 197 | BDL | BDL | BDL | 8.77 | - | BDL |
| 290 | BDL | BDL | BDL | BDL | - | BDL |

"-" = Insufficient quantity for analysis
BDL = Below detection limit, Pb < 5 μg/l
[a] Samples were colleted from separate collection tanks
[b] EPA Standard = 5000 μg/l

Table J.5 Selenium (Se) concentration versus Time in surface runoff and leachate samples collected from the RAP and Limerock collection systems.

| Time of Exposure (day) | Concentrations (μg/l)[b] | | | | | |
|---|---|---|---|---|---|---|
| | RAP Surface Runoff 1 [a] | RAP Surface Runoff 2 [a] | RAP Leachate | Limerock Surface Runoff 1 [a] | Limerock Surface Runoff 2 [a] | Limerock Leachate |
| 38 | 1.79 | - | - | - | - | - |
| 44 | 2.55 | - | 85.00 | 50.22 | - | 11.44 |
| 58 | BDL | - | 2.77 | - | - | 57.46 |
| 61 | BDL | - | 9.36 | - | - | 24.72 |
| 80 | BDL | - | 3.92 | 38.04 | - | 65.96 |
| 90 | 1.13 | - | 2.42 | 30.54 | - | 1,026.80 |
| 99 | 1.55 | - | 1.28 | - | 15.22 | 1,061.60 |
| 110 | - | - | - | 18.66 | - | - |
| 122 | 1.23 | - | BDL | - | - | 967.60 |
| 134 | BDL | 4.32 | 2.53 | 14.49 | 12.95 | 412.00 |
| 141 | - | - | - | 16.79 | - | - |
| 147 | BDL | 3.26 | 1.73 | 14.79 | - | 434.15 |
| 155 | BDL | BDL | 1.06 | 7.79 | 6.36 | 526.60 |
| 165 | BDL | 2.52 | 4.54 | - | 6.64 | 103.55 |

"-" = represents not Insufficient quantity for analysis
BDL = Below detection limit, Se < 1 μg/l
[a] Samples were colleted from separate collection tanks
[b] EPA Standard = = 1000 μg/l

Table J.6 Concentration of cadmium (Cd) versus time from column leaching tests on RAP and limerock

| Time (min) | Concentrations (µg/l) [a] | | |
|---|---|---|---|
| | RAP DDW | RAP Acid Rain | Limerock DDW |
| 0 | BDL | 12.89 | BDL |
| 120 | BDL | 7.63 | BDL |
| 180 | BDL | 3.29 | BDL |
| 240 | BDL | 1.52 | BDL |
| 300 | BDL | BDL | BDL |
| 360 | BDL | BDL | BDL |

BDL = Below detection limit, Cd < 1 µg/l

[a] EPA Standard-1000 µg/l

Table J.7 Concentration of lead (Pb) versus time from column leaching test on RAP and Limerock

| Time (min) | Concentrations (μg/l)[a] | | |
|---|---|---|---|
| | RAP DDW | RAP Acid Rain | Limerock DDW |
| 0 | BDL | BDL | BDL |
| 120 | BDL | BDL | 112.96 |
| 180 | BDL | BDL | 6.92 |
| 240 | BDL | BDL | BDL |
| 300 | BDL | BDL | BDL |
| 360 | BDL | BDL | BDL |

BDL = Below detection limit, Pb < 5 μg/l l

[a] EPA Standard-5000 μg/l

Table J.8 Selenium (Se) concentration versus time from column leaching tests on RAP and Limerock

| Time (min) | Concentrations (μg/l)[a] | | | | |
|---|---|---|---|---|---|
| | RAP DDW1 | RAP DDW2 | RAP Acid Rain | Limerock DDW1 | Limerock DDW2 |
| 0 | BDL | BDL | BDL | BDL | BDL |
| 120 | 1.31 | BDL | BDL | 1,949.00 | 1,843.50 |
| 180 | BDL | BDL | BDL | 1,867.00 | 1,890.00 |
| 240 | BDL | 1.29 | BDL | 1,668.50 | 1,833.00 |
| 300 | BDL | BDL | BDL | 1,462.50 | 1,735.00 |
| 360 | 1.26 | 1.03 | BDL | 1,191.00 | 1,499.00 |

BDL = Below detection limit, Se < 1 μg/l
[a] EPA Standard = 1000 μg/l

# Appendix K

# RAP-Soil Mixtures Resilient Modulus Data

**Resilient Modulus Test Results**

Foundations Laboratory - State Materials Office

**Procedure: SHRP (P46) - Type 1**

Lab # : 20889
Date: 25-Jun-02 | Sample # : 1B
Proj. NO.: FIT RAP Study | LBR :

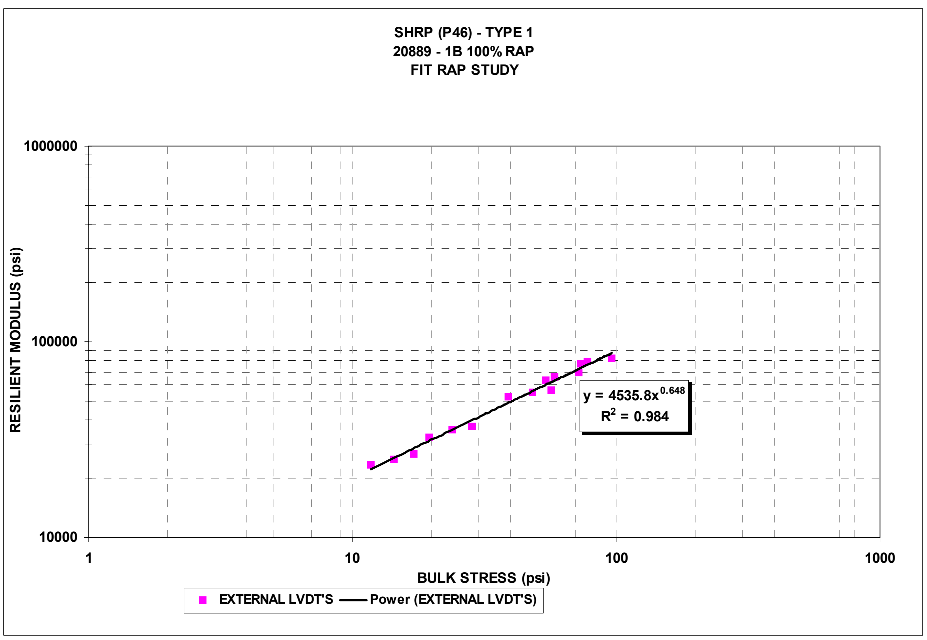
Material Discription: 100% RAP at 8% moisture
Comments: $w_f$ = 6.9% | Soil Class :

| Conditioning Information: |
|---|
| Repetitions = 500 |
| σ Deviator = 15 psi |
| σ Confining = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 118 @ 8% |
| ACTUAL MOISTURE / DENSITY: |
| 118.3 @ 7.8% |

**2 EXTERNAL LVDT'S**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 2.72 | 0.29 | 3.01 | 11.72 | 0.00092688 | 0.00011586 | 23440 |
| 2 | 3 | 5.46 | 0.56 | 6.01 | 14.46 | 0.00174603 | 0.00021825 | 24996 |
| 3 | 3 | 8.12 | 0.90 | 9.02 | 17.12 | 0.00243118 | 0.0003039 | 26709 |
| 4 | 5 | 4.50 | 0.51 | 5.01 | 19.50 | 0.00111691 | 0.00013961 | 32245 |
| 5 | 5 | 8.97 | 1.04 | 10.01 | 23.97 | 0.00201276 | 0.0002516 | 35649 |
| 6 | 5 | 13.49 | 1.52 | 15.01 | 28.49 | 0.00291465 | 0.00036433 | 37015 |
| 7 | 10 | 8.96 | 1.04 | 10.01 | 38.96 | 0.00136209 | 0.00017026 | 52640 |
| 8 | 10 | 18.03 | 1.98 | 20.01 | 48.03 | 0.00260828 | 0.00032603 | 55297 |
| 9 | 10 | 27.00 | 3.02 | 30.02 | 57.00 | 0.00379715 | 0.00047464 | 56887 |
| 10 | 15 | 9.02 | 0.99 | 10.01 | 54.02 | 0.0011307 | 0.00014134 | 63785 |
| 11 | 15 | 13.51 | 1.51 | 15.02 | 58.51 | 0.00162754 | 0.00020344 | 66414 |
| 12 | 15 | 27.02 | 2.98 | 30.01 | 72.02 | 0.00310684 | 0.00038835 | 69587 |
| 13 | 20 | 13.46 | 1.55 | 15.01 | 73.46 | 0.00139135 | 0.00017392 | 77382 |
| 14 | 20 | 18.04 | 1.96 | 20.00 | 78.04 | 0.00181369 | 0.00022671 | 79567 |
| 15 | 20 | 36.00 | 4.02 | 40.02 | 96.00 | 0.00351189 | 0.00043899 | 82000 |



**Resilient Modulus Test Results**

Foundations Laboratory - State Materials Office

**Procedure: SHRP (P46) - Type 1**

Lab # : 20889
Sample # : 1C
LBR :

Date: 25-Jun-02
Proj. NO.: FIT RAP Study

Material Discription: 100% RAP at 8% moisture
Comments: $w_f$ =7.0%

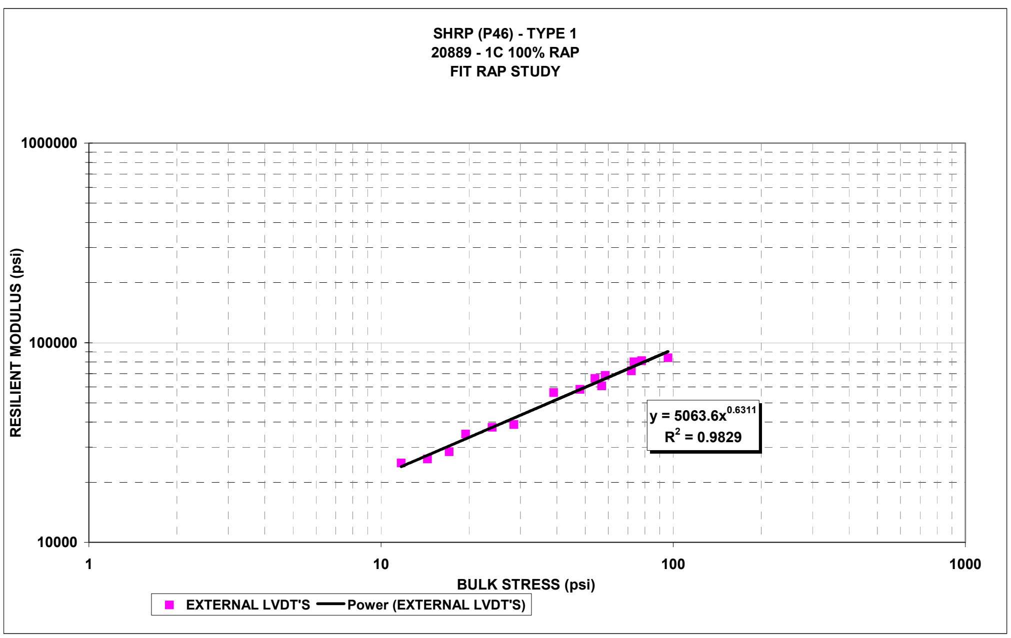
Soil Class :

| Conditioning Information: |
|---|
| Repetitions = 500 |
| σ Deviator = 15 psi |
| σ Confining = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 118 @ 8% |
| ACTUAL MOISTURE / DENSITY: |
| 117.9 @ 8.3% |

**2 EXTERNAL LVDT'S**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 2.72 | 0.30 | 3.01 | 11.72 | 0.00087086 | 0.00010886 | 24971 |
| 2 | 3 | 5.42 | 0.60 | 6.01 | 14.42 | 0.00165770 | 0.00020721 | 26145 |
| 3 | 3 | 8.11 | 0.90 | 9.01 | 17.11 | 0.00228424 | 0.00028553 | 28419 |
| 4 | 5 | 4.49 | 0.53 | 5.01 | 19.49 | 0.00103073 | 0.00012884 | 34833 |
| 5 | 5 | 9.01 | 0.99 | 10.00 | 24.01 | 0.00191322 | 0.00023915 | 37690 |
| 6 | 5 | 13.52 | 1.49 | 15.01 | 28.52 | 0.00278322 | 0.00034790 | 38867 |
| 7 | 10 | 8.99 | 1.02 | 10.01 | 38.99 | 0.00127850 | 0.00015981 | 56252 |
| 8 | 10 | 18.02 | 1.99 | 20.00 | 48.02 | 0.00246780 | 0.00030848 | 58408 |
| 9 | 10 | 26.96 | 3.06 | 30.01 | 56.96 | 0.00354593 | 0.00044324 | 60814 |
| 10 | 15 | 9.02 | 0.99 | 10.01 | 54.02 | 0.00108890 | 0.00013611 | 66270 |
| 11 | 15 | 13.56 | 1.45 | 15.01 | 58.56 | 0.00158143 | 0.00019768 | 68583 |
| 12 | 15 | 26.99 | 3.02 | 30.01 | 71.99 | 0.00298489 | 0.00037311 | 72335 |
| 13 | 20 | 13.53 | 1.48 | 15.01 | 73.53 | 0.00135089 | 0.00016886 | 80127 |
| 14 | 20 | 18.03 | 1.98 | 20.01 | 78.03 | 0.00177577 | 0.00022197 | 81225 |
| 15 | 20 | 36.04 | 3.98 | 40.02 | 96.04 | 0.00343476 | 0.00042934 | 83939 |



**Resilient Modulus Test Results**

Foundations Laboratory - State Materials Office

**Procedure: SHRP (P46) - Type 1**

Lab # : 20889
Sample # : 2C
LBR :

Date: 27-Jun-02
Proj. NO.: FIT RAP Study

Material Discription: 80% RAP at 6% moisture
Comments: $w_f$ = 6.8%

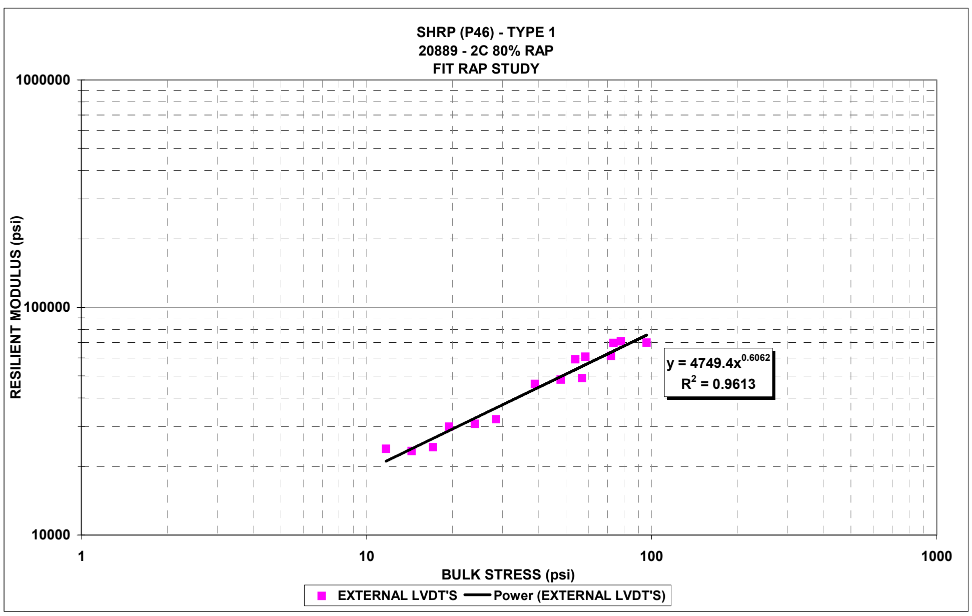
Soil Class :

| Conditioning Information: |
|---|
| Repetitions = 500 |
| σ Deviator = 15 psi |
| σ Confining = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 122 @ 6% |
| ACTUAL MOISTURE / DENSITY: |
| 118.4 @ 6.3% |

**2 EXTERNAL LVDT'S**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 2.70 | 0.31 | 3.01 | 11.70 | 0.00090447 | 0.00011306 | 23919 |
| 2 | 3 | 5.39 | 0.62 | 6.01 | 14.39 | 0.00184127 | 0.00023016 | 23410 |
| 3 | 3 | 8.11 | 0.91 | 9.02 | 17.11 | 0.00267210 | 0.00033401 | 24295 |
| 4 | 5 | 4.48 | 0.53 | 5.01 | 19.48 | 0.00119921 | 0.00014990 | 29900 |
| 5 | 5 | 9.01 | 1.00 | 10.00 | 24.01 | 0.00234111 | 0.00029264 | 30776 |
| 6 | 5 | 13.49 | 1.51 | 15.00 | 28.49 | 0.00334858 | 0.00041857 | 32236 |
| 7 | 10 | 8.99 | 1.02 | 10.01 | 38.99 | 0.00155945 | 0.00019493 | 46139 |
| 8 | 10 | 18.04 | 1.97 | 20.01 | 48.04 | 0.00299566 | 0.00037446 | 48175 |
| 9 | 10 | 27.05 | 2.97 | 30.02 | 57.05 | 0.00442584 | 0.00055323 | 48893 |
| 10 | 15 | 9.01 | 0.99 | 10.00 | 54.01 | 0.00121860 | 0.00015233 | 59162 |
| 11 | 15 | 13.56 | 1.47 | 15.00 | 58.56 | 0.00178481 | 0.00022310 | 60650 |
| 12 | 15 | 27.02 | 3.00 | 30.02 | 72.02 | 0.00353128 | 0.00044141 | 61202 |
| 13 | 20 | 13.50 | 1.51 | 15.01 | 73.50 | 0.00154609 | 0.00019326 | 69840 |
| 14 | 20 | 18.02 | 2.01 | 20.03 | 78.02 | 0.00203244 | 0.00025406 | 70937 |
| 15 | 20 | 36.00 | 4.01 | 40.01 | 96.00 | 0.00411128 | 0.00051391 | 70053 |



**Resilient Modulus Test Results**

Foundations Laboratory - State Materials Office

**Procedure: SHRP (P46) - Type 1**

Lab # : 20889
Sample # : 2B
LBR :

Date: 25-Jun-02
Proj. NO.: FIT RAP Study

Material Discription: 80% RAP at 6% moisture
Comments: $w_f$ = 6.8%

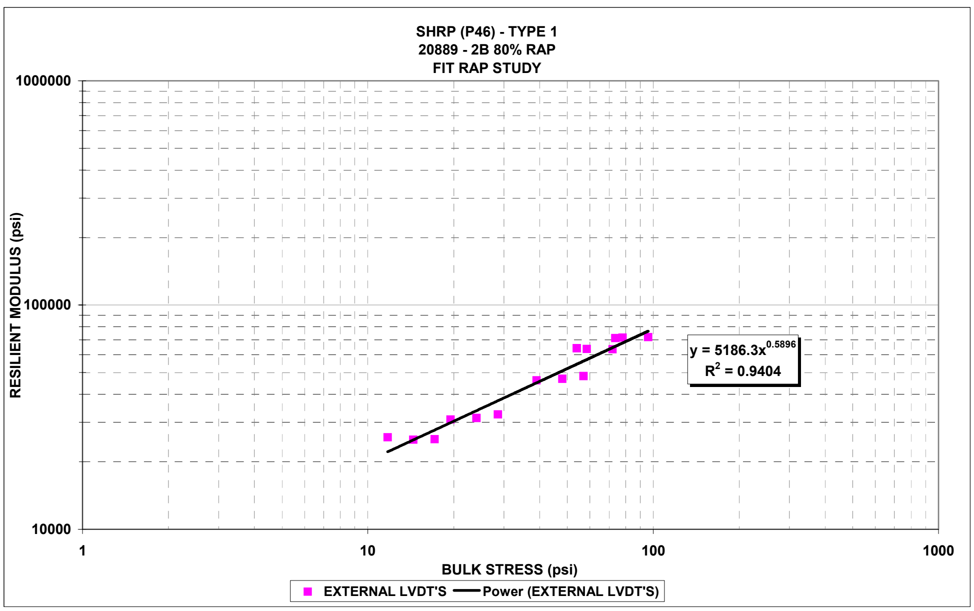
Soil Class :

| Conditioning Information: |
|---|
| Repetitions = 500 |
| σ Deviator = 15 psi |
| σ Confining = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 122 @ 6% |
| ACTUAL MOISTURE / DENSITY: |
| 120.6 @ 6.3% |

**2 EXTERNAL LVDT'S**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 2.73 | 0.28 | 3.01 | 11.73 | 0.00085018 | 0.00010627 | 25725 |
| 2 | 3 | 5.42 | 0.59 | 6.01 | 14.42 | 0.00172923 | 0.00021615 | 25090 |
| 3 | 3 | 8.13 | 0.90 | 9.03 | 17.13 | 0.00257639 | 0.00032205 | 25237 |
| 4 | 5 | 4.50 | 0.51 | 5.02 | 19.50 | 0.00116690 | 0.00014586 | 30864 |
| 5 | 5 | 9.05 | 0.96 | 10.01 | 24.05 | 0.00230923 | 0.00028865 | 31343 |
| 6 | 5 | 13.56 | 1.44 | 15.01 | 28.56 | 0.00333564 | 0.00041696 | 32527 |
| 7 | 10 | 9.02 | 0.99 | 10.01 | 39.02 | 0.00156333 | 0.00019542 | 46171 |
| 8 | 10 | 18.07 | 1.95 | 20.02 | 48.07 | 0.00308314 | 0.00038539 | 46883 |
| 9 | 10 | 27.04 | 2.99 | 30.02 | 57.04 | 0.00448444 | 0.00056056 | 48229 |
| 10 | 15 | 8.95 | 1.06 | 10.01 | 53.95 | 0.00111562 | 0.00013945 | 64181 |
| 11 | 15 | 13.51 | 1.50 | 15.01 | 58.51 | 0.00169863 | 0.00021233 | 63649 |
| 12 | 15 | 27.05 | 2.97 | 30.02 | 72.05 | 0.00340674 | 0.00042584 | 63519 |
| 13 | 20 | 13.58 | 1.45 | 15.03 | 73.58 | 0.00152541 | 0.00019068 | 71233 |
| 14 | 20 | 18.09 | 1.93 | 20.02 | 78.09 | 0.00202052 | 0.00025256 | 71614 |
| 15 | 20 | 36.04 | 3.99 | 40.04 | 96.04 | 0.00400915 | 0.00050114 | 71921 |



**Resilient Modulus Test Results**

Foundations Laboratory - State Materials Office

**Procedure: SHRP (P46) - Type 1**

Lab # : 20889
Sample # : 3A
LBR :

Date: 28-Jun-02
Proj. NO.: FIT RAP Study

Material Discription: 60% RAP at 8% moisture
Comments: $w_f$ = 8.8%

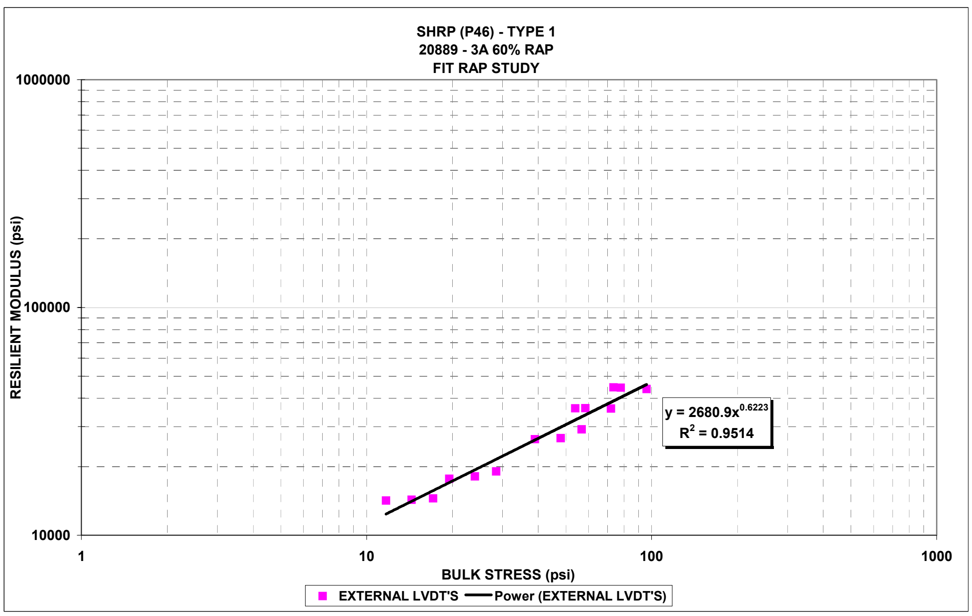
Soil Class :

| Conditioning Information: |
|---|
| Repetitions = 500 |
| σ Deviator = 15 psi |
| σ Confining = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 121 @ 8% |
| ACTUAL MOISTURE / DENSITY: |
| 116.1 @ 8.6% |

**2 EXTERNAL LVDT'S**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 2.71 | 0.30 | 3.01 | 11.71 | 0.00152670 | 0.00019084 | 14192 |
| 2 | 3 | 5.40 | 0.61 | 6.01 | 14.40 | 0.00301979 | 0.00037747 | 14304 |
| 3 | 3 | 8.13 | 0.89 | 9.02 | 17.13 | 0.00448228 | 0.00056029 | 14506 |
| 4 | 5 | 4.51 | 0.50 | 5.01 | 19.51 | 0.00203862 | 0.00025483 | 17705 |
| 5 | 5 | 9.00 | 1.01 | 10.01 | 24.00 | 0.00397382 | 0.00049673 | 18121 |
| 6 | 5 | 13.51 | 1.50 | 15.01 | 28.51 | 0.00567288 | 0.00070911 | 19054 |
| 7 | 10 | 8.98 | 1.03 | 10.01 | 38.98 | 0.00272376 | 0.00034047 | 26389 |
| 8 | 10 | 18.01 | 1.99 | 20.00 | 48.01 | 0.00540357 | 0.00067545 | 26669 |
| 9 | 10 | 26.85 | 3.20 | 30.05 | 56.85 | 0.00735700 | 0.00091963 | 29193 |
| 10 | 15 | 8.96 | 1.05 | 10.01 | 53.96 | 0.00198648 | 0.00024831 | 36091 |
| 11 | 15 | 13.53 | 1.48 | 15.01 | 58.53 | 0.00299479 | 0.00037435 | 36137 |
| 12 | 15 | 26.98 | 3.02 | 30.00 | 71.98 | 0.00599133 | 0.00074892 | 36030 |
| 13 | 20 | 13.48 | 1.52 | 15.00 | 73.48 | 0.00241954 | 0.00030244 | 44573 |
| 14 | 20 | 18.04 | 1.97 | 20.01 | 78.04 | 0.00324774 | 0.00040597 | 44440 |
| 15 | 20 | 36.05 | 3.98 | 40.03 | 96.05 | 0.00658597 | 0.00082325 | 43790 |



**Resilient Modulus Test Results**

Foundations Laboratory - State Materials Office

**Procedure: SHRP (P46) - Type 1**

Lab # : 20889
Sample # : 3B
LBR :

Date: 25-Jun-02
Proj. NO.: FIT RAP Study

Material Discription: 60% RAP at 8% moisture
Comments: $w_f$ = 8.4%

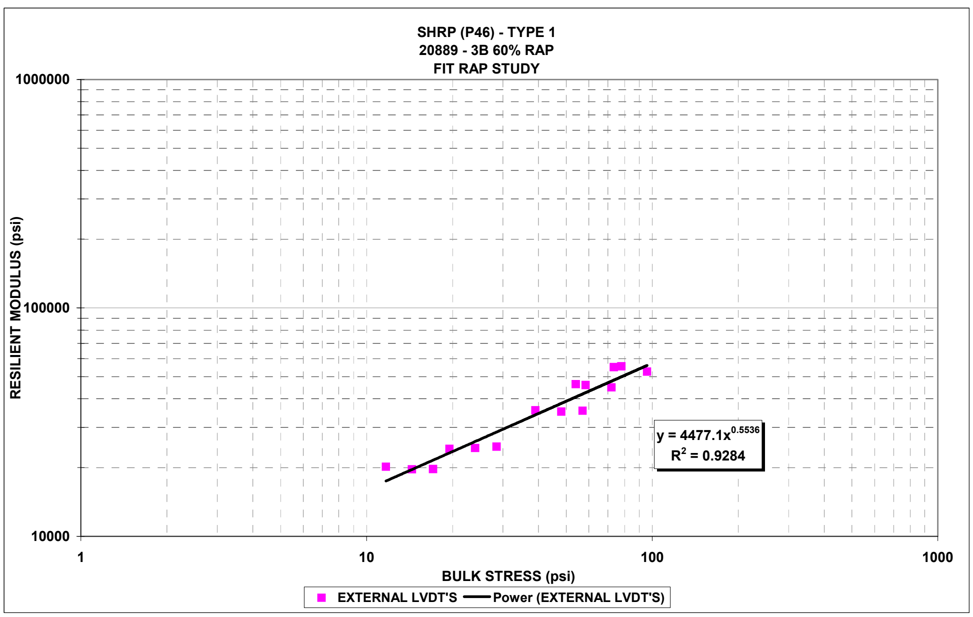
Soil Class :

| Conditioning Information: |
|---|
| Repetitions = 500 |
| σ Deviator = 15 psi |
| σ Confining = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 121 @ 8% |
| ACTUAL MOISTURE / DENSITY: |
| 117.0 @ 8.4% |

**2 EXTERNAL LVDT'S**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 2.69 | 0.32 | 3.01 | 11.69 | 0.00106693 | 0.00013337 | 20190 |
| 2 | 3 | 5.42 | 0.59 | 6.01 | 14.42 | 0.00220452 | 0.00027556 | 19669 |
| 3 | 3 | 8.10 | 0.92 | 9.02 | 17.10 | 0.00328652 | 0.00041082 | 19710 |
| 4 | 5 | 4.51 | 0.51 | 5.02 | 19.51 | 0.00149352 | 0.00018669 | 24136 |
| 5 | 5 | 8.99 | 1.02 | 10.01 | 23.99 | 0.00294912 | 0.00036864 | 24375 |
| 6 | 5 | 13.52 | 1.48 | 15.00 | 28.52 | 0.00437844 | 0.00054730 | 24708 |
| 7 | 10 | 9.02 | 0.99 | 10.01 | 39.02 | 0.00202655 | 0.00025332 | 35588 |
| 8 | 10 | 18.05 | 1.96 | 20.01 | 48.05 | 0.00410180 | 0.00051272 | 35195 |
| 9 | 10 | 27.05 | 2.96 | 30.01 | 57.05 | 0.00610034 | 0.00076254 | 35472 |
| 10 | 15 | 9.03 | 0.98 | 10.01 | 54.03 | 0.00155600 | 0.00019450 | 46402 |
| 11 | 15 | 13.50 | 1.51 | 15.01 | 58.50 | 0.00234887 | 0.00029361 | 45973 |
| 12 | 15 | 27.03 | 2.98 | 30.01 | 72.03 | 0.00481581 | 0.00060198 | 44908 |
| 13 | 20 | 13.48 | 1.53 | 15.01 | 73.48 | 0.00195760 | 0.00024470 | 55085 |
| 14 | 20 | 18.01 | 2.00 | 20.01 | 78.01 | 0.00259276 | 0.00032410 | 55562 |
| 15 | 20 | 35.98 | 4.03 | 40.01 | 95.98 | 0.00547294 | 0.00068412 | 52595 |



## RESILIENT MODULUS TEST RESULTS

FOUNDATIONS LABORATORY - STATE MATERIALS OFFICE

**PROCEDURE: SHRP (P46) - TYPE II**

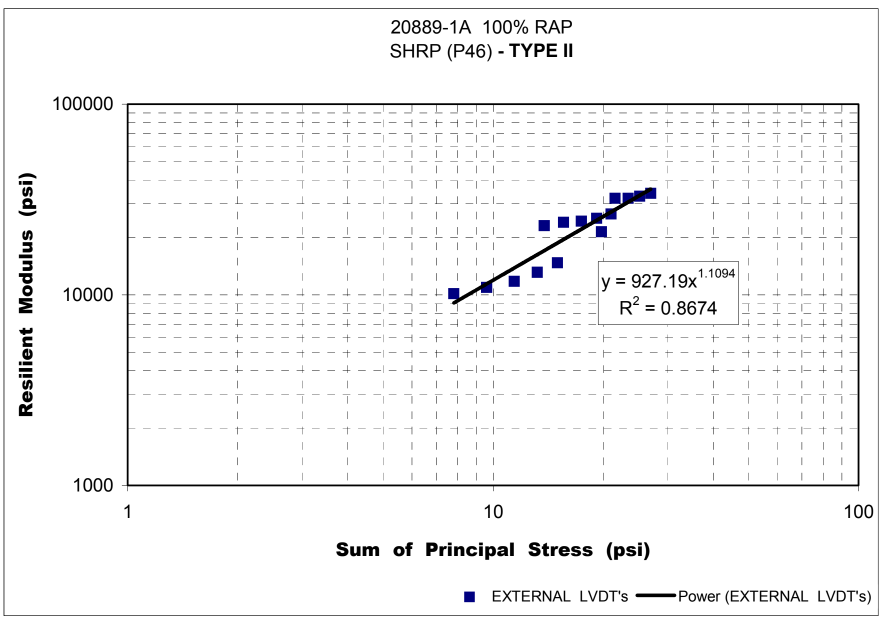
LAB #: 20889
DATE: July 11, 2002
SAMPLE #: 1A
PROJ. NO.:
LBR:
MATERIAL DESCRIPTION: 100% RAP
COMMENTS:
SOIL CLASS:

| CONDITIONING INFORMATION: |
|---|
| REPETITIONS = 500 |
| σ DEVIATOR = 15 psi |
| σ CONFINING = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 118 @ 8% |
| ACTUAL MOISTURE / DENSITY: |
| 117.7 @ 7.7% |

**2 EXTERNAL LVDT's**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 1.80 | 0.21 | 2.00 | 19.80 | 0.00067113 | 0.00008389 | 21436 |
| 2 | 6 | 3.59 | 0.42 | 4.00 | 21.59 | 0.00089370 | 0.00011171 | 32111 |
| 3 | 6 | 5.44 | 0.57 | 6.01 | 23.44 | 0.00135649 | 0.00016956 | 32073 |
| 4 | 6 | 7.19 | 0.80 | 7.99 | 25.19 | 0.00175139 | 0.00021892 | 32864 |
| 5 | 6 | 8.97 | 1.03 | 10.00 | 26.97 | 0.00210541 | 0.00026318 | 34098 |
| 6 | 4 | 1.81 | 0.19 | 2.00 | 13.81 | 0.00062858 | 0.00007857 | 23043 |
| 7 | 4 | 3.60 | 0.41 | 4.01 | 15.60 | 0.00119792 | 0.00014974 | 24018 |
| 8 | 4 | 5.44 | 0.57 | 6.01 | 17.44 | 0.00178525 | 0.00022316 | 24357 |
| 9 | 4 | 7.20 | 0.81 | 8.01 | 19.20 | 0.00228682 | 0.00028585 | 25201 |
| 10 | 4 | 9.02 | 0.99 | 10.00 | 21.02 | 0.00272204 | 0.00034025 | 26504 |
| 11 | 2 | 1.81 | 0.20 | 2.00 | 7.81 | 0.00142931 | 0.00017866 | 10125 |
| 12 | 2 | 3.61 | 0.40 | 4.01 | 9.61 | 0.00264275 | 0.00033034 | 10927 |
| 13 | 2 | 5.43 | 0.58 | 6.01 | 11.43 | 0.00369287 | 0.00046161 | 11761 |
| 14 | 2 | 7.21 | 0.80 | 8.01 | 13.21 | 0.00439826 | 0.00054978 | 13111 |
| 15 | 2 | 9.01 | 0.99 | 10.00 | 15.01 | 0.00490544 | 0.00061318 | 14694 |



## RESILIENT MODULUS TEST RESULTS

FOUNDATIONS LABORATORY - STATE MATERIALS OFFICE

**PROCEDURE : SHRP (P46) - TYPE II**

DATE: July 19, 2002
PROJ. NO.: FIT RAP STUDY
MATERIAL DESCRIPTION : 100% RAP
COMMENTS :

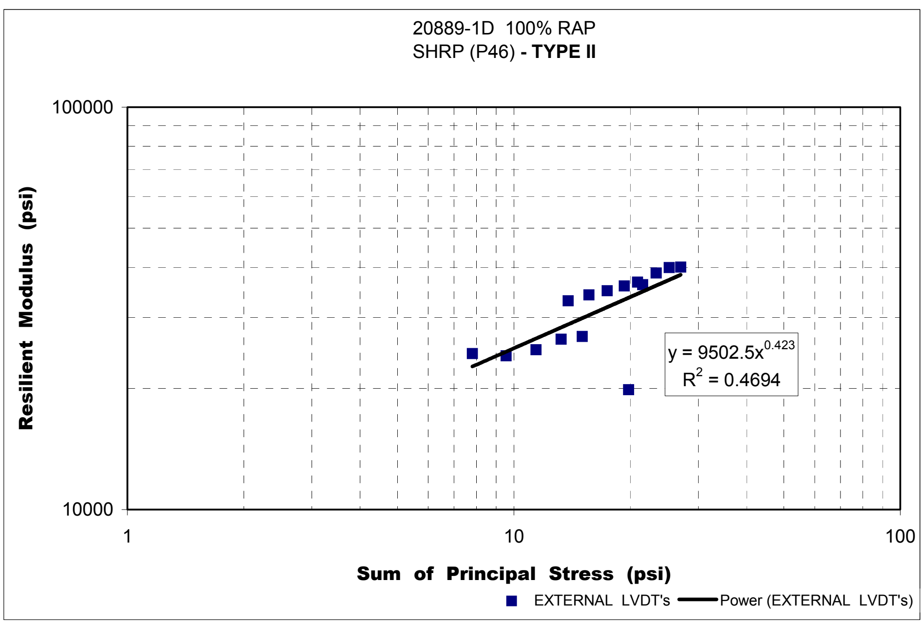
LAB # : 20889
SAMPLE # : 1D
LBR :
SOIL CLASS :

| CONDITIONING INFORMATION: |
|---|
| REPETITIONS = 500 |
| σ DEVIATOR = 15 psi |
| σ CONFINING = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 118 @ 8% |
| ACTUAL MOISTURE / DENSITY: |
| 116.6 @ 8.4% |

**2 EXTERNAL LVDT's**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 1.82 | 0.21 | 2.03 | 19.82 | 0.00073384 | 0.00009173 | 19846 |
| 2 | 6 | 3.57 | 0.44 | 4.00 | 21.57 | 0.00078813 | 0.00009852 | 36197 |
| 3 | 6 | 5.37 | 0.62 | 5.99 | 23.37 | 0.00111002 | 0.00013875 | 38717 |
| 4 | 6 | 7.24 | 0.74 | 7.98 | 25.24 | 0.00145000 | 0.00018125 | 39943 |
| 5 | 6 | 9.04 | 1.01 | 10.05 | 27.04 | 0.00180550 | 0.00022569 | 40061 |
| 6 | 4 | 1.81 | 0.20 | 2.01 | 13.81 | 0.00043866 | 0.00005483 | 33034 |
| 7 | 4 | 3.64 | 0.37 | 4.01 | 15.64 | 0.00085362 | 0.00010670 | 34124 |
| 8 | 4 | 5.44 | 0.57 | 6.01 | 17.44 | 0.00124489 | 0.00015561 | 34977 |
| 9 | 4 | 7.33 | 0.68 | 8.01 | 19.33 | 0.00163012 | 0.00020376 | 35950 |
| 10 | 4 | 8.90 | 1.11 | 10.01 | 20.90 | 0.00193785 | 0.00024223 | 36753 |
| 11 | 2 | 1.81 | 0.19 | 2.00 | 7.81 | 0.00059411 | 0.00007426 | 24409 |
| 12 | 2 | 3.55 | 0.46 | 4.01 | 9.55 | 0.00117982 | 0.00014748 | 24086 |
| 13 | 2 | 5.42 | 0.57 | 5.99 | 11.42 | 0.00173655 | 0.00021707 | 24955 |
| 14 | 2 | 7.26 | 0.75 | 8.01 | 13.26 | 0.00219288 | 0.00027411 | 26490 |
| 15 | 2 | 9.04 | 0.97 | 10.01 | 15.04 | 0.00268541 | 0.00033568 | 26927 |



## RESILIENT MODULUS TEST RESULTS

FOUNDATIONS LABORATORY - STATE MATERIALS OFFICE

**PROCEDURE : SHRP (P46) - TYPE II**

LAB # : 20889

DATE: July 9, 2002

SAMPLE # : 2A

PROJ. NO.:

LBR :

MATERIAL DESCRIPTION : 80% RAP

COMMENTS :

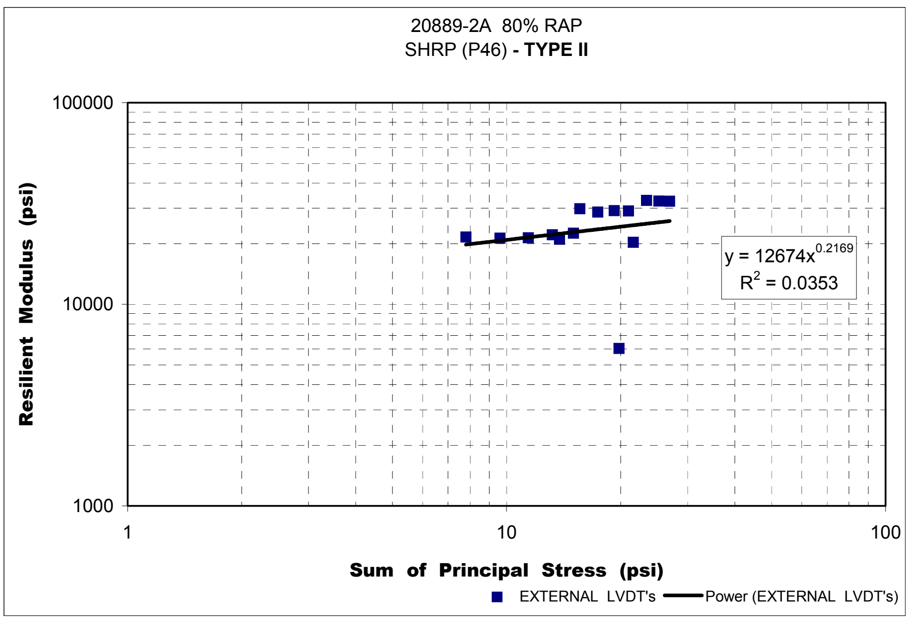
SOIL CLASS :

| CONDITIONING INFORMATION: |
|---|
| REPETITIONS = 500 |
| σ DEVIATOR = 15 psi |
| σ CONFINING = 15 psi |

| INSITU or TARGET MOIST. / DENSITY: |
|---|
| 122 @ 6% |
| ACTUAL MOISTURE / DENSITY: |
| 119.2 @ 6.0% |

**2 EXTERNAL LVDT's**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 1.80 | 0.20 | 2.00 | 19.80 | 0.00238981 | 0.00029873 | 6038 |
| 2 | 6 | 3.60 | 0.42 | 4.01 | 21.60 | 0.00141682 | 0.00017710 | 20300 |
| 3 | 6 | 5.41 | 0.60 | 6.01 | 23.41 | 0.00132073 | 0.00016509 | 32750 |
| 4 | 6 | 7.22 | 0.80 | 8.01 | 25.22 | 0.00177404 | 0.00022176 | 32536 |
| 5 | 6 | 8.94 | 1.06 | 10.01 | 26.94 | 0.00220711 | 0.00027589 | 32412 |
| 6 | 4 | 1.81 | 0.20 | 2.01 | 13.81 | 0.00068802 | 0.00008600 | 21020 |
| 7 | 4 | 3.60 | 0.41 | 4.01 | 15.60 | 0.00096653 | 0.00012082 | 29801 |
| 8 | 4 | 5.41 | 0.60 | 6.01 | 17.41 | 0.00150688 | 0.00018836 | 28713 |
| 9 | 4 | 7.22 | 0.79 | 8.01 | 19.22 | 0.00198121 | 0.00024765 | 29159 |
| 10 | 4 | 8.98 | 1.02 | 10.00 | 20.98 | 0.00247082 | 0.00030885 | 29073 |
| 11 | 2 | 1.81 | 0.20 | 2.01 | 7.81 | 0.00066920 | 0.00008365 | 21605 |
| 12 | 2 | 3.61 | 0.40 | 4.01 | 9.61 | 0.00135822 | 0.00016978 | 21284 |
| 13 | 2 | 5.41 | 0.60 | 6.01 | 11.41 | 0.00202311 | 0.00025289 | 21384 |
| 14 | 2 | 7.21 | 0.80 | 8.01 | 13.21 | 0.00260310 | 0.00032539 | 22159 |
| 15 | 2 | 9.03 | 0.97 | 10.00 | 15.03 | 0.00320293 | 0.00040037 | 22548 |



## RESILIENT MODULUS TEST RESULTS

FOUNDATIONS LABORATORY - STATE MATERIALS OFFICE

**PROCEDURE : SHRP (P46) - TYPE II**

LAB # : 20889
SAMPLE # : 2D
LBR :
SOIL CLASS :

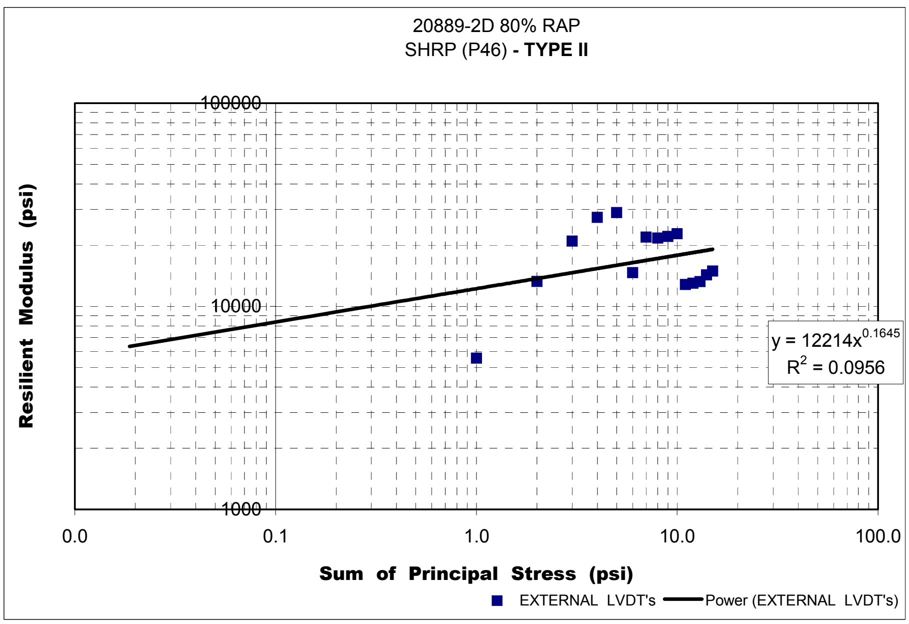
DATE: July 18, 2002
PROJ. NO.: FIT RAP STUDY
MATERIAL DESCRIPTION : 80% RAP
COMMENTS :

| CONDITIONING INFORMATION: |
|---|
| REPETITIONS = 500 |
| σ DEVIATOR = 15 psi |
| σ CONFINING = 15 psi |

| INSITU or TARGET MOIST. / DENSI |
|---|
| 122 @ 6% |
| ACTUAL MOISTURE / DENSITY: |
| 119.9 @ 6.8% |

**2 EXTERNAL LVDT's**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 1.81 | 0.19 | 2.00 | 19.81 | 0.00260513 | 0.00032564 | 5555 |
| 2 | 6 | 3.58 | 0.43 | 4.01 | 21.58 | 0.00216267 | 0.00027033 | 13240 |
| 3 | 6 | 5.46 | 0.57 | 6.02 | 23.46 | 0.00208750 | 0.00026094 | 20917 |
| 4 | 6 | 7.31 | 0.71 | 8.01 | 25.31 | 0.00213514 | 0.00026689 | 27384 |
| 5 | 6 | 8.91 | 1.10 | 10.01 | 26.91 | 0.00246392 | 0.00030799 | 28917 |
| 6 | 4 | 1.80 | 0.20 | 2.00 | 13.80 | 0.00098438 | 0.00012305 | 14635 |
| 7 | 4 | 3.64 | 0.37 | 4.01 | 15.64 | 0.00132978 | 0.00016622 | 21912 |
| 8 | 4 | 5.33 | 0.69 | 6.01 | 17.33 | 0.00196580 | 0.00024572 | 21675 |
| 9 | 4 | 7.08 | 0.93 | 8.01 | 19.08 | 0.00256864 | 0.00032108 | 22057 |
| 10 | 4 | 9.02 | 0.99 | 10.00 | 21.02 | 0.00317319 | 0.00039665 | 22729 |
| 11 | 2 | 1.79 | 0.21 | 2.01 | 7.79 | 0.00112381 | 0.00014048 | 12776 |
| 12 | 2 | 3.58 | 0.43 | 4.01 | 9.58 | 0.00220796 | 0.00027600 | 12969 |
| 13 | 2 | 5.45 | 0.57 | 6.01 | 11.45 | 0.00329471 | 0.00041184 | 13225 |
| 14 | 2 | 7.25 | 0.77 | 8.01 | 13.25 | 0.00406431 | 0.00050804 | 14266 |
| 15 | 2 | 9.02 | 0.98 | 10.00 | 15.02 | 0.00484942 | 0.00060618 | 14887 |



## RESILIENT MODULUS TEST RESULTS

FOUNDATIONS LABORATORY - STATE MATERIALS OFFICE

**PROCEDURE : SHRP (P46) - TYPE II**

DATE: July 18, 2002

PROJ. NO.: FIT RAP STUDY

MATERIAL DESCRIPTION : 60% RAP

COMMENTS :

LAB # : 20889

SAMPLE # : 3C

LBR :

SOIL CLASS :

CONDITIONING INFORMATION:

REPETITIONS = 500

σ DEVIATOR = 15 psi

σ CONFINING = 15 psi

INSITU or TARGET MOIST. / DENSITY

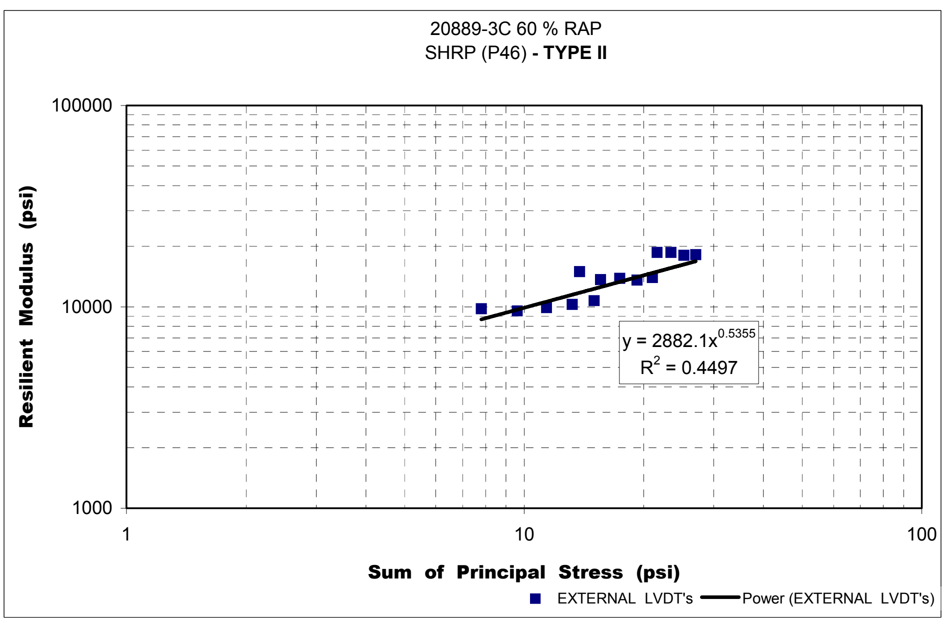
121 @ 8%

ACTUAL MOISTURE / DENSITY:

116.4 @ 9.1%

**2 EXTERNAL LVDT's**

| TEST SEQ. # | CONFINING STRESS (psi) | CYCLIC STRESS (psi) | CONTACT STRESS (psi) | MAX. AXIAL STRESS (psi) | BULK STRESS (psi) | RESILIENT DEFORMATION (in) | RESILIENT STRAIN (in/in) | RESILIENT MODULUS (psi) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 1.82 | 0.19 | 2.00 | 19.82 | 0.00194865 | 0.00024358 | 7452 |
| 2 | 6 | 3.61 | 0.40 | 4.00 | 21.61 | 0.00154954 | 0.00019369 | 18630 |
| 3 | 6 | 5.42 | 0.60 | 6.01 | 23.42 | 0.00232690 | 0.00029086 | 18619 |
| 4 | 6 | 7.23 | 0.78 | 8.01 | 25.23 | 0.00320724 | 0.00040091 | 18034 |
| 5 | 6 | 9.03 | 0.97 | 10.00 | 27.03 | 0.00397985 | 0.00049748 | 18141 |
| 6 | 4 | 1.79 | 0.21 | 2.00 | 13.79 | 0.00095963 | 0.00011995 | 14943 |
| 7 | 4 | 3.58 | 0.43 | 4.01 | 15.58 | 0.00209722 | 0.00026215 | 13646 |
| 8 | 4 | 5.40 | 0.61 | 6.01 | 17.40 | 0.00311976 | 0.00038997 | 13849 |
| 9 | 4 | 7.23 | 0.78 | 8.01 | 19.23 | 0.00425649 | 0.00053206 | 13586 |
| 10 | 4 | 9.02 | 1.02 | 10.03 | 21.02 | 0.00516321 | 0.00064540 | 13969 |
| 11 | 2 | 1.81 | 0.19 | 2.00 | 7.81 | 0.00147974 | 0.00018497 | 9788 |
| 12 | 2 | 3.61 | 0.40 | 4.01 | 9.61 | 0.00302927 | 0.00037866 | 9540 |
| 13 | 2 | 5.38 | 0.63 | 6.01 | 11.38 | 0.00434871 | 0.00054359 | 9903 |
| 14 | 2 | 7.22 | 0.79 | 8.01 | 13.22 | 0.00562204 | 0.00070275 | 10274 |
| 15 | 2 | 9.00 | 1.00 | 10.00 | 15.00 | 0.00670103 | 0.00083763 | 10740 |



## Appendix L

## Compaction Summary of RAP-Soil Mixtures

# Compaction Characteristics of RAP-Soil Mixtures

| Test | | 100% RAP | | 80% RAP | | 60% RAP | | Mold size | |
|---|---|---|---|---|---|---|---|---|---|
| | | $\omega$ (%) | $\gamma$ (lb/ft$^3$) | $\omega$ (%) | $\gamma$ (lb/ft$^3$) | $\omega$ (%) | $\gamma$ (lb/ft$^3$) | diameter (in) | volume (ft$^3$) |
| Moisture - Density | | 8.0 | 117.8 | 6.0 | 121.7 | 7.8 | 121.2 | 6 | 0.0750 |
| | C.E. (ft-lb/ft$^3$) | 56,000 | | 56,000 | | 56,000 | | | |
| LBR - BASE | ave. | 7.8 | 117.6 | 6.0 | 121.9 | 8.0 | 119.7 | 6 | 0.0750 |
| | stdv. | 0.43 | 0.75 | 0.08 | 0.77 | 0.17 | 1.49 | | |
| | C.E. (ft-lb/ft$^3$) | 56,000 | | 56,000 | | 56,000 | | | |
| | R.C | 99.8% | | 100.2% | | 98.8% | | | |
| LBR - SUBGRADE | ave. | 8.0 | 117.7 | 6.4 | 121.7 | 8.0 | 119.1 | 6 | 0.0750 |
| | stdv. | 0.33 | 0.26 | 0.70 | 1.87 | 0.31 | 2.02 | | |
| | C.E. (ft-lb/ft$^3$) | 56,000 | | 56,000 | | 56,000 | | | |
| | R.C | 99.9% | | 100.0% | | 98.3% | | | |
| Static Triaxial Compression | ave. | 7.8 | 119.8 | 6.0 | 123.7 | 8.6 | 118.0 | 4 | 0.0609 |
| | stdv. | 0.11 | 0.15 | 0.60 | 0.30 | 0.10 | 0.27 | | |
| | C.E. (ft-lb/ft$^3$) | 56,153 | | 56,153 | | 56,153 | | | |
| | R.C | 101.7% | | 101.6% | | 97.4% | | | |
| Resilient Modulus BASE | ave. | 8.1 | 118.1 | 6.3 | 119.5 | 8.5 | 116.6 | 4 | 0.0582 |
| | stdv. | 0.35 | 0.28 | 0.00 | 1.56 | 0.14 | 0.64 | | |
| | C.E. (ft-lb/ft$^3$) | 58,785 | | 58,785 | | 58,785 | | | |
| | R.C | 100.3% | | 98.2% | | 96.2% | | | |
| Resilient Modulus SUBGRADE | ave. | 8.1 | 117.2 | 6.4 | 119.6 | 9.1 | 116.4 | 4 | 0.0582 |
| | stdv. | 0.49 | 0.78 | 0.57 | 0.49 | - | - | | |
| | C.E. (ft-lb/ft$^3$) | 58,785 | | 58,785 | | 58,785 | | | |
| | R.C | 99.5% | | 98.3% | | 96.0% | | | |
| Permeability | ave. | 7.4 | 120.5 | 6.1 | 122.3 | 7.9 | 114.9 | 4 | 0.0317[a] |
| | stdv. | 0.97 | 0.46 | 0.16 | 1.10 | 0.14 | 0.60 | | 0.0333[b] |
| | C.E. (ft-lb/ft$^3$) | 56,702 | | 56,246 | | 56,246 | | | |
| | R.C (%) | 102.3% | | 100.5% | | 94.8% | | | |

$\omega$ : moisture content
$\gamma$ : unit weight
C.E. : compactive effort
R.C. : relative compaction
[a] : volume of mold for 100% RAP samples
[b] : volume of mold for 80 and 60% RAP samples