DESIGN CONSIDERATIONS AND ECONOMIC IMPACTS OF NEAR FREEZING SOIL TEMPERATURES ON SOIL COMPACTION

by

Michael L. Whelan and Sandy Snider Stahl
Department of Civil and Architectural Engineering
University of Wyoming
P. O. Box 3295
Laramie, Wyoming 82071-3295

March 1997

Acknowledgment

This report was prepared with funds provided by the United States Department of Transportation to the Mountain-Plains Consortium (MPC). The MPC member universities include North Dakota State University, Colorado State University, University of Wyoming, and Utah State University.

The authors would like to express their appreciation to Dr. Thomas Edgar, College of Engineering, University of Wyoming, for his invaluable technical and practical assistance in conducting the laboratory test series.

ABSTRACT

Soils are an important component of any transportation structure. To improve the engineering properties of these soils, compaction requirements are included in virtually all transportation construction specifications. Field observations indicate however, that soils at near-freezing temperatures may require more compactive effort than soils at higher temperatures. This research project was proposed and conducted to verify the phenomenon's existence, to quantify the resulting economic impact on the cost of soil compaction, and to determine the need for more in-depth research as related to highway design procedures. A series of compaction tests were performed on a temperature-controlled, A-2-4 (0) (AASHTO Designation M-145) soil sample. Research results indicated that, while additional compactive effort is in fact required, it is not significant when compared to the 95 percent or less of maximum dry unit weight commonly specified for construction. Further compaction tests with a finer grained soil (preferably an AASHTO A-6 or A-7 classification) were indicated.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

PROBLEM STATEMENT

Soil is a naturally occurring, nonuniform particulate material derived from weathered rock and organic refuse. Most of the principal engineering properties that soil exhibits are a function of this origination. Further, utilizing soil as a construction material, particularly for transportation structures, normally requires some modification of these properties to arrive at an optimal design. When constructing an embankment, for example, simply compacting the soil significantly improves the shear strength of the material, thus making the embankment more stable. For this reason, compaction requirements are included in virtually all transportation construction specifications.

The degree of compaction, as measured by the soil's dry unit weight, that can be attained for a given soil with a given compactive effort has long been recognized as a function of the soil's water content. The relationship between a soil's water content and dry unit weight can be established using a standard Proctor test such as the AASHTO T 99-74 (Standard Methods of Test for the Moisture-Density Relations of Soils Using a 5.5-lb. (2.5 kg) Rammer and a 12-in. (305 mm) Drop) or the ASTM 698-78 (Standard Test methods for Moisture-Density Relations of Soils and Soil-Aggregated Mixtures Using 5.5-lb. (2.49-kg) Rammer and 12-in. (305-mm) Drop). A typical curve resulting from a standard Proctor test, shown in Figure 1.1, illustrates that dry unit weight increases with increasing water content until a maximum value is reached at the corresponding optimum water content. Further increases in water content cause a reduction in the dry unit weight.

It should be noted that the typical curve is created using a standard, specified compactive effort. In the case of a standard Proctor test, the compactive effort -- defined as the amount of energy input per unit volume of soil is equal to 12,375 lb-ft/CF. If the compactive effort is increased, then the curve moves upward and to the left. Conversely, decreasing the compactive effort causes the curve to shift downward and to the right. In either case, the characteristic shape does not change.

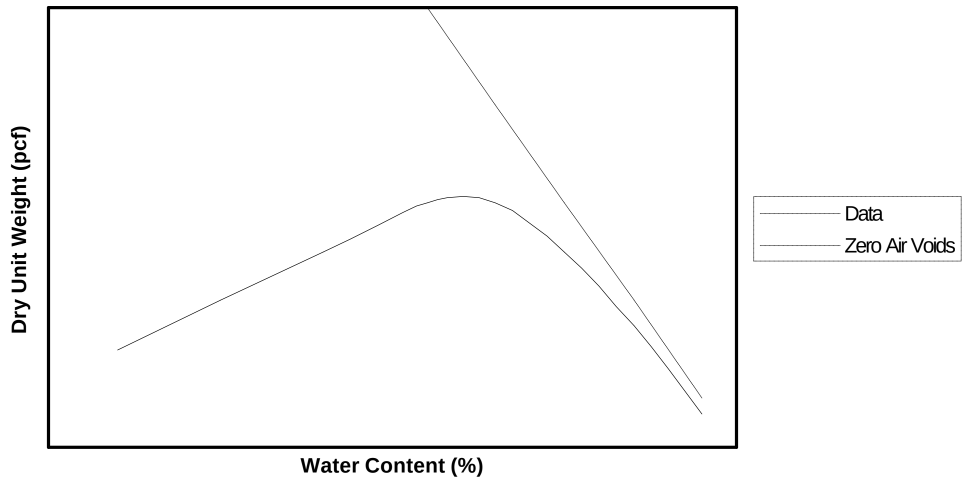


Figure 1.1 - Typical Curve Shape for Water Content vs. Dry Unit Weight

However, discussions with several Wyoming engineers, indicate that more effort may be required to compact cold soils than current laboratory tests show. If such a phenomena does exist, it would then appear that temperature, as well as water content and compactive effort, may have an effect on both the maximum dry unit weight attained and the corresponding optimum water content. Both the possible need for an increased compactive effort and the potential change in the optimum water content should then be addressed in project specifications. Such an increased effort results in commensurately greater costs that should be included in any budgetary plan or construction quotation for compaction. Design engineers and construction contractors alike should be aware of the potential impact that compacting near-freezing soils may have on the construction process.

PROPOSED RESEARCH PROJECT

Responding to the field observations previously noted, a research project to measure and compare the results of compacting a soil near 68° F (20° C) with results from compacting the same soil at various temperatures between 30° and 40° F (-1.1° to 4.4° C) was proposed.

OBJECTIVES

The objectives of this study were:

1) to verify that soil temperatures in the near-freezing range do affect the maximum dry unit weight and/or optimum water content obtained using a standard Proctor test,

2) to calculate the increased compactive effort, and the associated additional cost, to achieve the desired maximum dry unit weight, and

3) to determine the need for more extensive research to quantify the design considerations of this phenomena.

CHAPTER 2

LITERATURE SURVEY

Prior to proposing this project, a preliminary literature survey was conducted. No publications were found addressing the topic of compacting near-freezing soils. During the execution of the project, the literature survey was continued and a few publications presenting some results in this area were identified. It appears that while there has been, and continues to be, substantial work done with compaction of frozen soils, there has been little work carried out regarding compaction of near-freezing soils.

AASHTO T 99-74, and the virtually identical ASTM 698-78, are geotechnical tests used to determine a soil's maximum dry unit weight and corresponding optimum water content for a given compactive effort. More commonly known as a Proctor test, this procedure is normally conducted at room temperature and therefore does not represent temperatures often encountered in field situations. A 1970 study conducted at Purdue University on a sandy clay soil included soil temperatures of 35°, 55°, and 85° F. The researchers determined that low temperature compaction reduced the maximum dry unit weight, but suggested that an increased compactive effort might compensate for the reduction (Highter, Altshchaeffl, and Lovell, 50). The additional compactive effort required was not quantified. The Purdue study also concluded that the optimum water content for effective cold weather compaction of the soil increased by as much as 4-5 percent.

In a 1973 report by the U.S. Army Corps of Engineers, Bieganousky and Lovell stated that the degree of difficulty in obtaining the desired dry unit weight was a function of the temperature, texture, and moisture content of the soil. The dependency of compaction on temperature was believed to be due to the viscosity of the water, which determined the ease or difficulty with which soil particles could reorient themselves during the compactive process. A decrease in soil temperature resulted in a decrease in maximum dry unit weight and a corresponding increase in the optimum water content (Bieganousky and Lovell, 136). The reported increase in optimum water content was 2-3 percent for cold weather compaction.

In a 1990 Transportation Research Board publication "Guide to Earthwork Construction," Waidelich referred to a 1957 New York State Department of Public Works, Bureau of Soil Mechanics study on the effect of cold temperatures on soil compaction. A graph from the 1957 study, adapted as Figure 2.1, shows the relationship between temperature and compaction. The maximum dry unit weight decreased as the temperature dropped from 74° F to 30° F. This study also concluded, as opposed to the two previously cited studies, that the optimum water content was 30° F was *lower* than the value found at

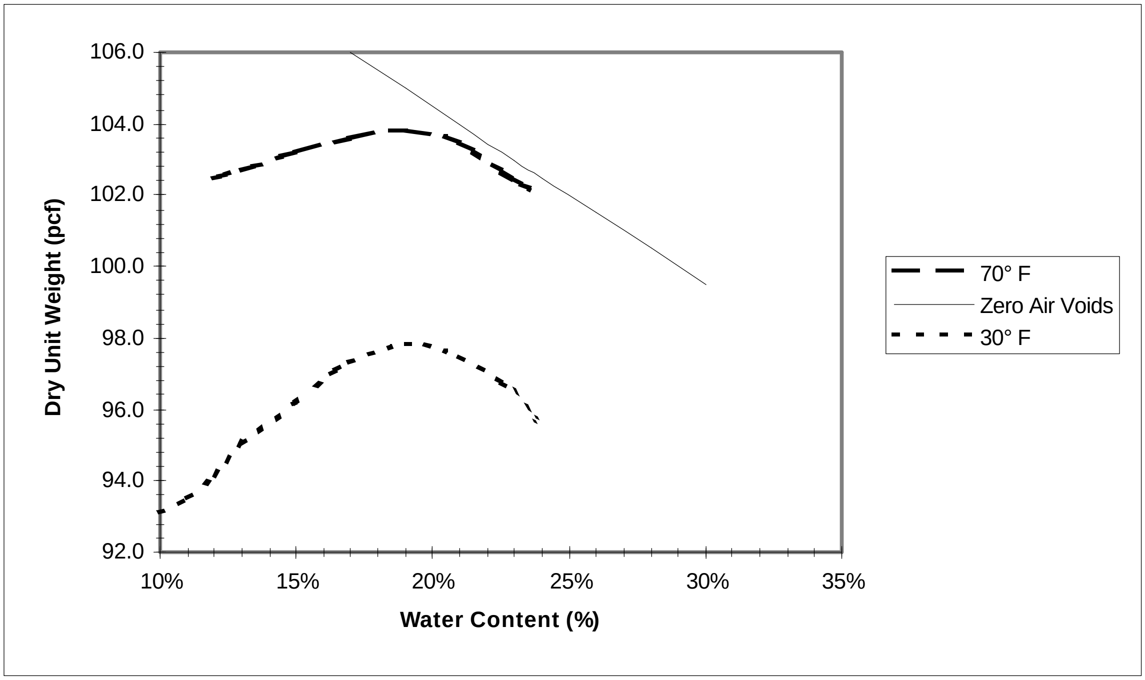


Figure 2.1 - (Adapted from Waidelich) Compaction and Temperature Relationship from 1957 Bureau of Soil Mechanics Study

74° F. The results of these three studies, therefore, pose a question as to whether to add more or less water to achieve maximum dry unit weights at near-freezing soil temperatures.

CHAPTER 3

METHODOLOGY

The first task for this research project was collection of a soil sample reasonably reflective of soils encountered in transportation projects in Wyoming. The second task was to complete a series of tests quantifying critical engineering properties of the soil sample. Next, an initial series of Proctor tests was performed on soil samples at room temperature. Following this initial series of tests, a more extensive set of Proctor tests was conducted using soil samples that were at or near specified temperatures between 30° and 40° F (-1.1° to 4.4° C). Finally, soil tests used to determine engineering properties were redone to detect and quantify any changes caused by the extensive amount of compaction and recompaction required in the testing process.

SOIL SAMPLE COLLECTION AND PREPARATION

A representative, naturally-occurring soil was selected from a construction site on the University of Wyoming campus in Laramie, Wyoming. A sufficiently large soil volume was collected, then prepared for subsequent testing by passing it through a #4 sieve (4.76 mm opening) to remove any excessively large pieces of material from the sample. To improve the accuracy and consistency of the data collected, the total soil volume was randomly divided into thirds with each sample, denoted as A, B, and C, slated for independent testing.

ENGINEERING PROPERTIES DETERMINATION

Soil classification, as well as proper interpretation of data collected from a Proctor test series, requires that the particle size distribution, Atterberg limits, and specific gravity be known for the soil being tested. Therefore, tests were conducted on each soil sample to determine these engineering properties.

Particle size distribution was determined by first conducting a sieve analysis of each soil sample. A sieve analysis consists of shaking a dry soil sample through a stack of progressively finer mesh screens, then weighing the amounts retained on each sieve. Proper plotting of the resulting weight-based percentages allows determination of several parameters and coefficients needed for classification. Completion of the classification, however, usually requires determination of the Atterberg limits for the soil.

Atterberg, a Swedish soil scientist during the early part of the 20th century, defined five states of soil consistency. Two of these, the liquid limit and plastic limit, are necessary to complete classification of any soil containing significant portions of fine-grained materials; i.e., silts and clays. Based on the results of the sieve analysis, enough fine grained materials were present to require the Atterberg limits to complete classification of the soil samples for this project.

The third test conducted was determination of a specific gravity for the soil samples. The specific gravity value is used to compute and plot the zero air voids (ZAV) curve. Representing the maximum unit weight the soil could develop if it was fully saturated, the ZAV curve provides an upper limit for the water content-dry unit weight curve to be produced from the subsequent Proctor tests. It also provides a quick indicator of a potential error should data points on the water content-dry unit weight curve plot above the ZAV curve.

As a final step prior to the start of the series of Proctor tests, each of the soil samples was divided into five subsamples. Water contents for each of the five subsamples were then adjusted so at least two data points would be on each side of the optimum water content for each series of Proctor tests. Throughout the testing process, water contents were adjusted as necessary to maintain a spread that bracketed the optimum water contents being determined.

PROCTOR TESTS USING ROOM TEMPERATURE SOILS

The standard geotechnical test used to determine the relationship between dry unit weight and water content is the Proctor test, as specified either by ASTM or AASHTO. The first series of Proctor tests was conducted at approximately 68° F (20° C) for the purpose of "conditioning" the soil samples. It was believed that since the same soil samples were to be used and reused throughout the test series, any reduction in overall particle size should occur as soon as possible. If such a reduction would occur during the first series of tests, then the impact on the remaining series would be greatly minimized. Following the initial series of tests, a second series was conducted to establish a baseline water content-dry unit weight relationship for the soil samples.

PROCTOR TESTS USING NEAR-FREEZING SOILS

After completing all of the engineering property tests, and conducting a series of Proctor tests at room temperature to condition the soil and establish the baseline relationship, several series of Proctor tests were conducted to determine the effect of near-freezing temperatures of the soil on compaction results. Prior to each series of tests, a set of five subsamples and the compaction mold were placed in an environmental chamber at the designated temperature for at least 24 hours to attain thermal equilibrium. A complete series of Proctor tests was performed on each set of five subsamples for 2° F (1.1° C) temperature increments from 32° to 40° F (0.0° to 4.4° C). To determine how close each subsample remained to the designated temperature during testing, thermocouple readings of the soil temperature were recorded for each layer following its compaction into the mold. Though consideration was given to conducting the test series in a walk-in cooler, early tests indicated that there was no significant heat gain from the surrounding environment during the tests. All tests were therefore conducted with chilled subsamples in a room temperature environment.

VALIDATION TESTS

Following completion of the Proctor tests on near-freezing soils, two sets of tests were performed to determine if there had been any significant change in the soil samples themselves. First, a complete series of Proctor tests was conducted and the results from the repeatedly compacted, repeatedly chilled soil samples were compared to results obtained during the initial, baseline Proctor test series. Second, the sieve analysis and Atterberg limits were repeated to determine if the soil classification had changed significantly during the testing process. Changes in any of the soil characteristics would necessarily have to be considered during analysis of the test results.

CHAPTER 4

PRESENTATION AND DISCUSSION OF RESULTS

RESULTS FROM PRELIMINARY TESTS

Soil Classification Results

Two soil classification systems are in common usage: the Unified Soil Classification System and the AASHTO Soil Classification System. Both systems depend heavily on the determination of particle size distribution and Atterberg limits for complete classification of the soil. Table 4.1 summarizes the findings of the sieve analysis and Atterberg limits test, and the resulting soil classifications for Samples A, B, and C.

Table 4.1 - Pretest Sieve Analysis and Atterberg Limits Results

Sample	SIEVE ANALYSIS % Passing			ATTERBERG LIMITS			USCS Designation	AASHTO Designation
	# 10	# 40	# 200	Liquid Limit	Plastic Limit	Plasticity Index		
A	90.9	50.9	5.9	27.1	18.0	9.1	SP-SC	A-2-4 (0)
B	87.8	47.6	4.8	27.1	18.0	9.1	SP	A-2-4 (0)
C	88.1	47.0	4.6	27.1	18.0	9.1	SP	A-2-4 (0)

Table 4.2 on page 12 presents the results from the final or validation series of tests that were run after the Proctor test series was completed. The repeated compaction of the soil samples for the large number of tests conducted resulted in a larger percentage of fine particles in each sample, thus shifting the classification slightly. While the designations did change due to minor changes in percent passing values, the impact of the change on the test results was not significant.

Table 4.2 - Post-test Sieve Analysis and Atterberg Limits Results

Sample	SIEVE ANALYSIS % Passing			ATTERBERG LIMITS			USCS Designation	AASHTO Designation
	# 10	# 40	# 200	Liquid Limit	Plastic Limit	Plasticity Index		
A	71.5	27.9	9.2	28.1	16.6	11.5	SP-SC	A-2-6 (0)
B	69.7	25.6	6.9	28.5	17.1	11.5	SP-SC	A-2-6 (0)
C	64.1	25.2	7.6	28.5	16.3	12.3	SP-SC	A-2-6 (0)

Zero Air Voids Curve

When tested for specific gravity, the soil had a value of 2.70. The specific gravity value was then used with each Proctor test series to compute and plot a zero air voids (ZAV) curve as a part of the data analysis. The plotted ZAV curves are shown in each of the water content-dry unit weight curves presented in Appendix A.

PROCTOR TEST RESULTS

When each test was completed, the resulting data was transferred to an Excel spreadsheet. The spreadsheet was used to calculate the average temperature, the wet, dry, and ZAV unit weights, and the corresponding water contents. From these data points, water content-dry unit weight and ZAV curves were plotted for each Proctor test. These curves are shown in Appendix A.

Soil temperatures varied more than expected, so ranges of three rather than two degrees Fahrenheit were used in the data analysis. This was an advantage in the analysis since it resulted in more data points in each temperature range. It also was a disadvantage due to a lack of detail resulting from the larger temperature ranges. The original temperature ranges were 1° F (0.6° C) above and below 32° F (0.0° C), 34° F (1.1° C), 36° F (2.2° C), 38° F (3.3° C), 40° F (4.4° C), and 68° F (20° C). The revised temperature ranges used were 1.5° F (0.8° C) above and below 32° F (0.0° C), 35° F (1.7° C), 38° F (3.3°

C), 41° F (5° C), and 71° F (21.7 ° C). Composite water content-dry unit weight curves combining results from Samples A, B, and C for each temperature range are presented in Appendix B.

TESTING DISCREPANCIES

Two sources of discrepancy and possible error were identified during the testing process. They were: 1) use of a hammer that did not meet ASTM or AASHTO specifications and 2) use of a microwave oven to dry samples rather than a convection oven. Upon identification, all possible steps were taken to quantify and remove their impact from the test results and conclusions drawn.

The compaction hammer used for all the tests previously had been repaired, thus altering its weight so it was no longer a standard Proctor hammer. To determine whether its use had affected the results of the tests or not, a Proctor test was conducted at room temperature using a standard weight hammer. Multiple regression analysis of the resulting test data, followed by a comparison of curves using an analysis of variance procedure, concluded that use of the non-standard hammer had not impacted the test results significantly.

The laboratory used for the Proctor tests contained a microwave oven that was commonly used for drying soil samples. The use of a microwave oven did not comply to the ASTM or AASHTO standards, but was thought to be inconsequential in determining water contents. When plotting the test results however, a few data points were observed to be above the ZAV curve: a situation that, at least in theory, cannot occur. This situation occurred infrequently and only at the highest water contents. After some exploration and consultation, it is believed that use of the microwave may have removed some of the moisture that is part of the clay cellular structure in addition to the moisture in the voids surrounding the clay particles. As a result, the soil appeared to have a saturation greater than 100 percent. Therefore, use of the microwave oven had an unknown impact on the absolute value of water contents as measured. Since the same drying technique was used for all test specimens, the impact on the final conclusions is believed to be insignificant.

INTERPRETATION OF RESULTS

Interpretation of the test results depended on two concepts. First, a regression analysis of the test data was necessary to obtain a smooth, best fit curve reflecting the test results. After some trial and error, it was determined that a power curve-based regression analysis using temperature, water content, and the square of the water content resulted in the least error. The second concept was that engineering design and construction specifications commonly are based on an acceptable compaction level of 95 percent of the maximum dry unit weight determined by the Proctor test. The reduced compaction requirement reflects the wider range of variation and narrower range of control normally associated with field compaction operations. This concept was important because, while the reduction of the dry unit weight for a given compactive effort at lower temperatures may be interesting and significant from a scholarly standpoint, it had no significance from a practical standpoint unless the reduction was in excess of 5 percent of the maximum value. With these two concepts presented, a more meaningful interpretation of the test results could be made.

Figure 4.1 shows the regression analysis curves for the 41° F (5.0° C) and 71° F (21.7° C) temperature ranges. Figures 4.2 and 4.3 present similar information for the 38° F (3.3° C) and 71° F (21.7° C) temperature ranges, and the 35° F (1.7° C) and 71° F (21.7° C) temperature ranges respectively. Figure 4.4 shows the data points for the 32° F (0.0° C) tests rather than a regression analysis curve due to the significant scatter in results from this temperature range.

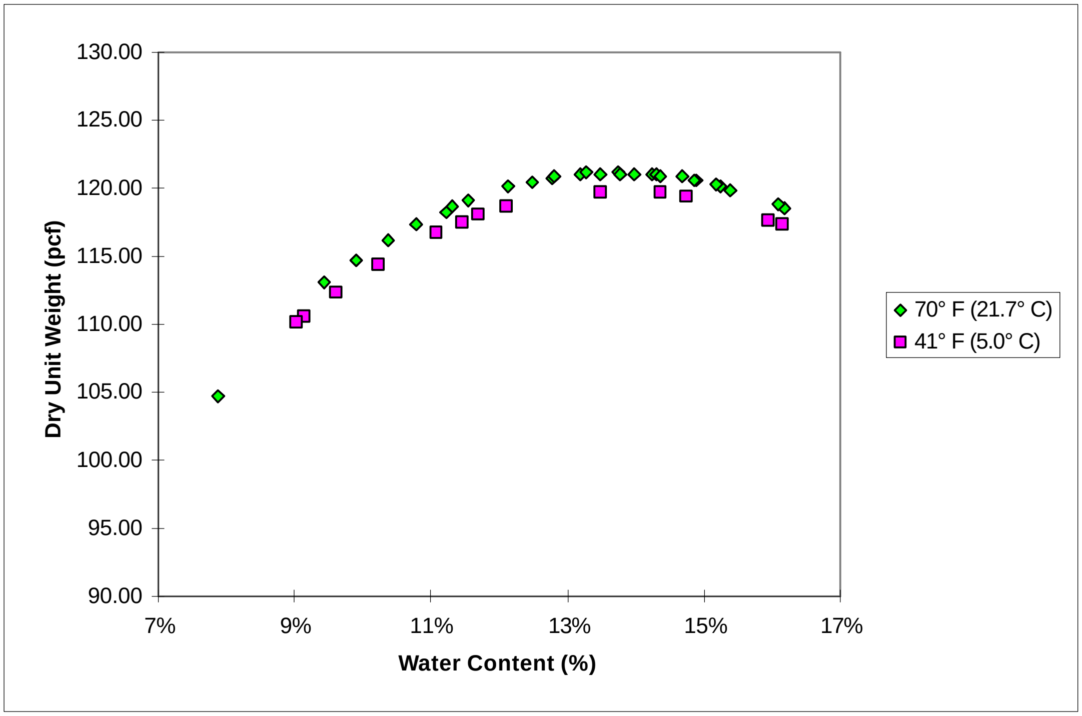


Figure 4.1 - Regression Analysis Results for 41° F (5.0° C) and 71° F (21.7° C)

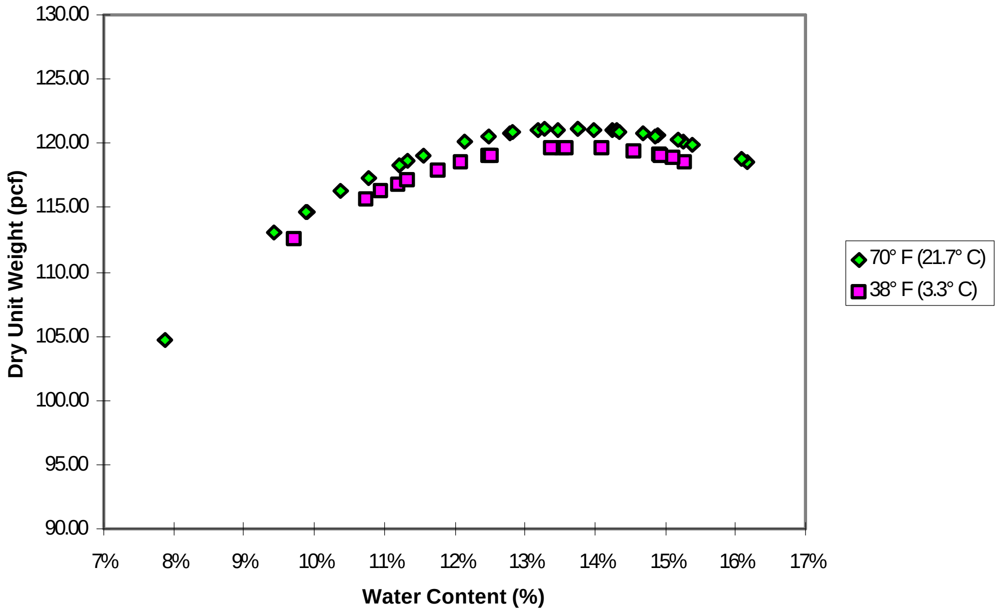


Figure 4.2 - Regression Analysis Results for 38° F (3.3° C) and 71° F (21.7° C)

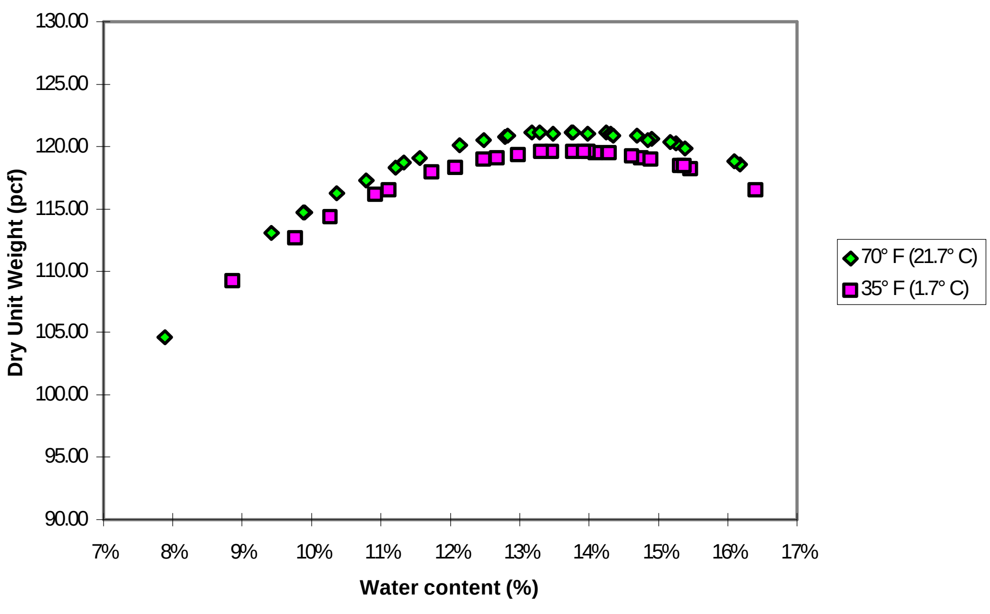


Figure 4.3 - Regression Analysis Results for 35° F (1.7° C) and 71° F (21.7° C)

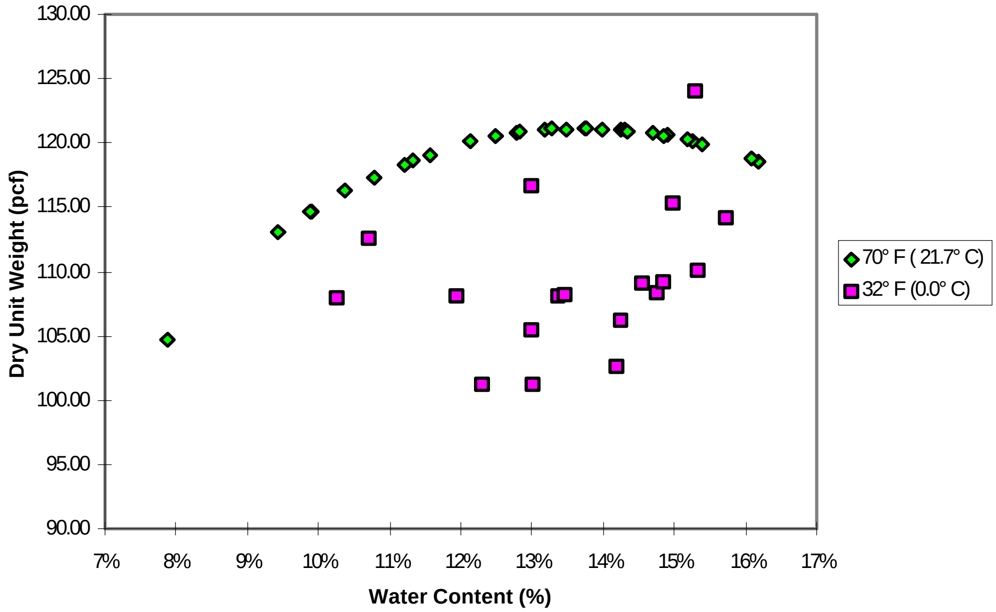


Figure 4.4 - Data and Regression Analysis Results for 32° F (0.0° C) and 71° F (21.7° C)

Results from 35° to 71° F (1.7° to 21.7 ° C) Tests

All water content-dry unit weight curves for the 35° F (1.7° C), 38° F (3.3° C), 41° F (5.0° C), and 71° F (21.7° C) temperature ranges followed a standard Proctor test curve shape. When comparing curves at different temperatures ranges with each other however, significant differences were evident. In particular, the following were noted:

1) The maximum dry unit weight *decreased* with decreasing temperatures.

2) The optimum water content generally *increased* with decreasing temperatures.

3) At 35° F (1.7° C), the optimum water content, reversing its previous trend, *decreased* from the value at the next higher temperature range.

Maximum Dry Unit Weight

Decreasing maximum dry unit weight with decreasing soil temperature was the hypothesis forming the basis for this research. The results confirmed the hypothesis as shown in Figure 4.5. However, even the lowest maximum dry unit weight for these temperature ranges was greater than 95 percent of the maximum dry unit weight at 71° F (21.7 ° C). Therefore, for soil temperatures as low as 35° F (1.7° C) soil temperature had no practical impact on the degree of compaction obtained. Accordingly, there appears to be no significant economic impact when compacting cold soils.

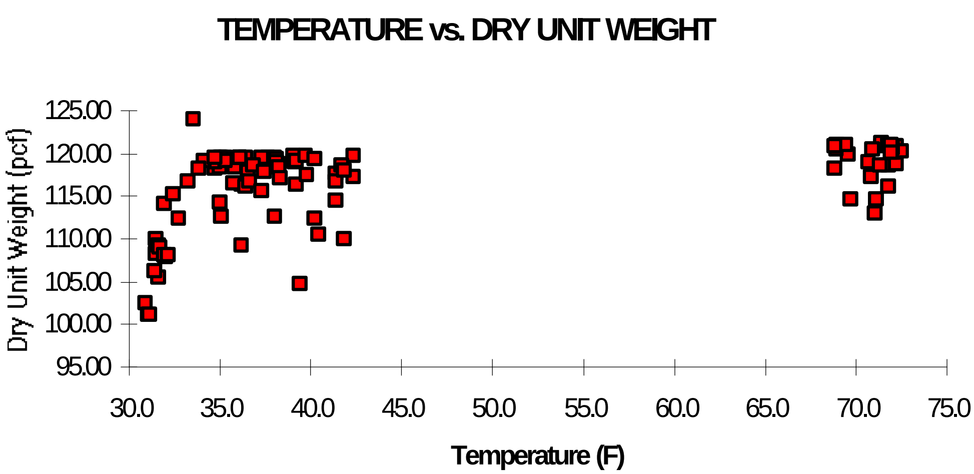


Figure 4.5 - Maximum Dry Unit Weight vs. Temperature

Increasing Water Content

The shift of the water content-dry unit weight curve to the right corresponded to results from previous studies where the maximum dry unit weight was obtained at higher water contents as soil temperature decreased. As the soil cooled, more water was required to reorient soil particles into a more compact arrangement. Based on test results, optimum water content increased by as much as 1.5 percent at 38° F (3.3° C). Below 38° F (3.3° C) the water content should be decreased as noted in the following section.

Decreasing Water Content

The decreased optimum water content at 35° F (1.7° C) seemed contradictory and might be attributable to random error. However, it also agreed with previous research. The Bureau of Soil Mechanics study previously cited (Figure 2.1) indicated a decrease in optimum water content at the maximum dry unit weight for the Proctor test done on 30° F (-1.1° C) soil. A possible explanation for this change might be found in the fact that water reaches its maximum unit weight at 4° C (39.2° F). Because of the strong bonding of water to the clay particles in the soil, the behavior of water largely controls the behavior of the soil. It is likely that the changing unit weight of water is the causative factor behind the test results for the soil at 35° F (1.7° C).

Results from 32° F (0.0° C) Tests

In the lowest range of temperatures, the standard water content-dry unit weight curve was no longer evident due to the considerable scatter exhibited by the data. It appeared that, at the point of freezing, different levels of saturation were occurring at a single water content. To test this hypothesis, an additional Proctor test was conducted on a soil sample that had been frozen, then allowed to warm to 32° F (0.0° C). The result was the standard water content-dry unit weight curve shown in Figure 4.6. It should be noted that the maximum dry unit weight determined with the warming soil was still greater than 95 percent of the maximum obtained from the 71° F (21.7° C) test series.

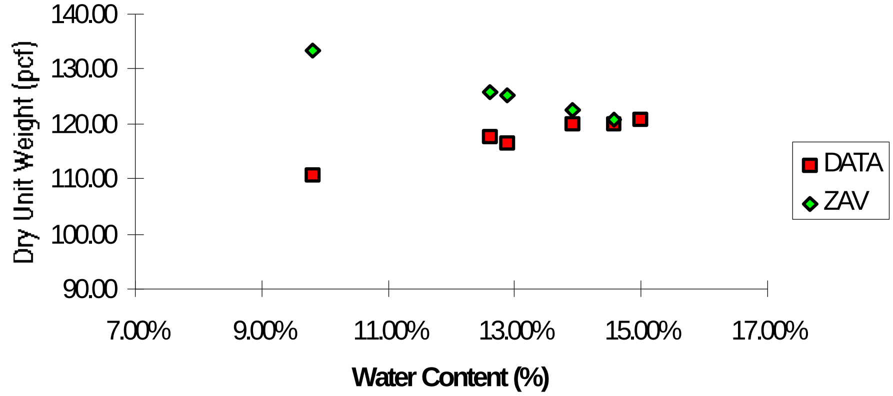


Figure 4.6 - Proctor Test Results for Frozen Soil Warmed to 32° F (0.0° C)

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

For a given compactive effort applied, there is a measurable reduction in maximum dry unit weight attainable for cold soils. However, this reduction is economically insignificant as long as construction specifications require that compaction exceed only 95 percent of the maximum dry unit weight established by a Proctor test. As soil temperatures decrease, the ease with which the required dry unit weight may be achieved is enhanced by *increasing* the water content. This situation exists until the soil temperature reaches approximately 38° F (3.3° C). Below 38° F (3.3° C), the water content should be *decreased* to improve the process of obtaining the maximum dry unit weight. At soil temperatures at or near freezing, compaction should be avoided since the results are erratic and may be tied to the direction of the temperature change occurring in the soil.

Because little research has been done in this area, it is recommended that further work be carried out. Because of the likelihood that temperature has little to no impact on the compaction of granular soils, any further research should be conducted on extremely cohesive soils. In addition, it is recommended that more extensive testing of cold soils at 32° F (0.0° C) be carried out to determine what mechanisms are controlling the compactive efforts required and the dry unit weights obtained.

SELECTED REFERENCES

American Association of State Highway and Transportation Officials (AASHTO). (1995). Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 17th Edition. Washington, D.C.: Author.

American Society of Testing and Materials (ASTM). (1980). 1980 Annual Book of ASTM Standards. Philadelphia, PA.: Author.

Highter, W. M., Altschaeffl, A. G. and Lovell, C. W. (1970). "Low-Temperature Effects on the Compaction and Strength of a Sandy Clay." Highway Research Record.

Bieganousky, W. and Lovell, C.W. (1973). "Do Earthwork in the Cold Weather?" Earthwork Construction. U.S. Army Corps of Engineers.

Waidelich, W. C. (1990). "Earthwork Construction." Guide to Earthwork Construction. Transportation Research Board.

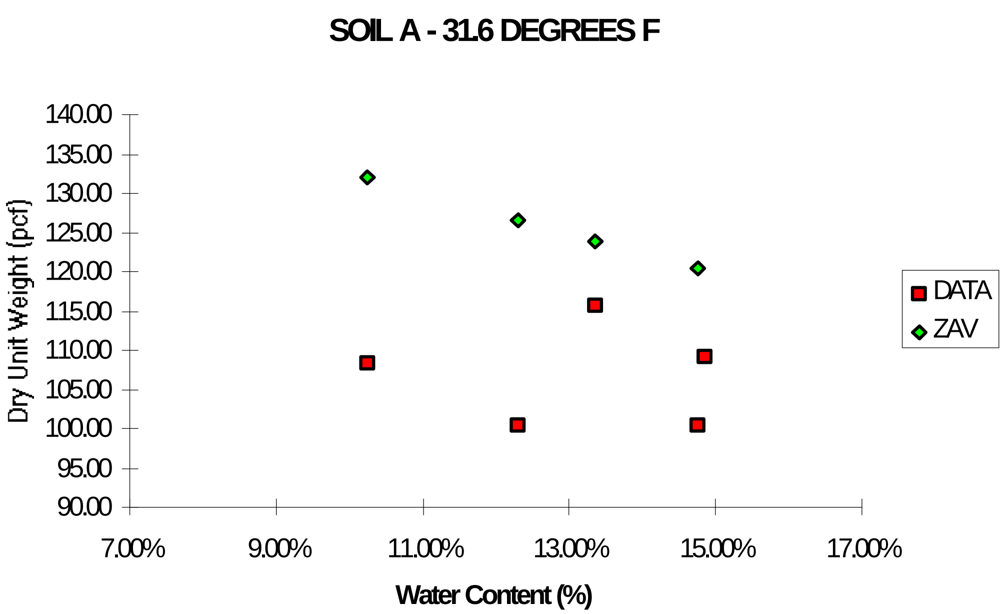
Kotz, J. & Purcell, K. (1991). Chemistry and Chemical Reactivity. Pennsylvania: Saunders College Publishing.

McCarthy, D. F. (1993). Essentials of Soil Mechanics and Foundations. New Jersey: Prentice Hall Career & Technology.

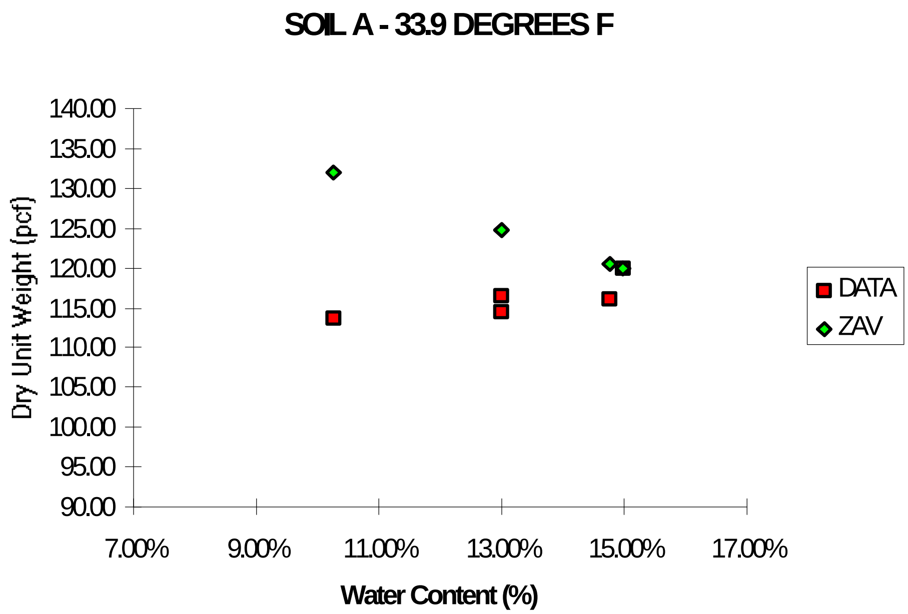
APPENDIX A

Water Content-Dry Unit Weight Curves for Each Test Series

DATE:	10/3/95 to 10/10/1995					
Gs	2.70					
Lower Layer		31.3	31.1	31.8	31.6	31.7
Middle Layer		32.0	31.1	31.8	31.4	31.2
Upper Layer		32.6	31.2	32.0	31.4	32.0
Average Temp		32.0	31.1	31.9	31.5	31.6
Cumulative Average Temperature				31.6		
		A12	**A14**	**A6**	**A8**	**A10**
Wt Mold & Soil		7.93	8.24	8.32	8.32	8.66
Wt Mold		3.95	4.48	3.95	4.48	4.48
Wt Soil		3.98	3.76	4.37	3.84	4.18
Wet Density		119.40	112.80	131.10	115.20	125.40
Dry Density		108.30	100.44	115.65	100.38	109.19
Moisture Tin #		30	16	6A	34	6F
Wt tin & Wet Soil		319.38	322.17	296.69	323.73	246.74
Wt tin & Dry Soil		309.26	309.73	283.83	308.31	232.52
Wt Water		10.12	12.44	12.86	15.42	14.22
Wt Moisture Tin		210.50	208.62	187.59	203.87	136.72
Wt Dry Soil		98.76	101.11	96.24	104.44	95.80
Water Content		10.25%	12.30%	13.36%	14.76%	14.84%
Water Content		10.25%	12.30%	13.36%	14.76%	14.84%
Dry Density (pcf)		108.30	100.44	115.65	100.38	109.19
ZAV		132.01	126.51	123.85	120.50	120.32
Saturation		49.75%	49.00%	78.89%	58.71%	73.74%

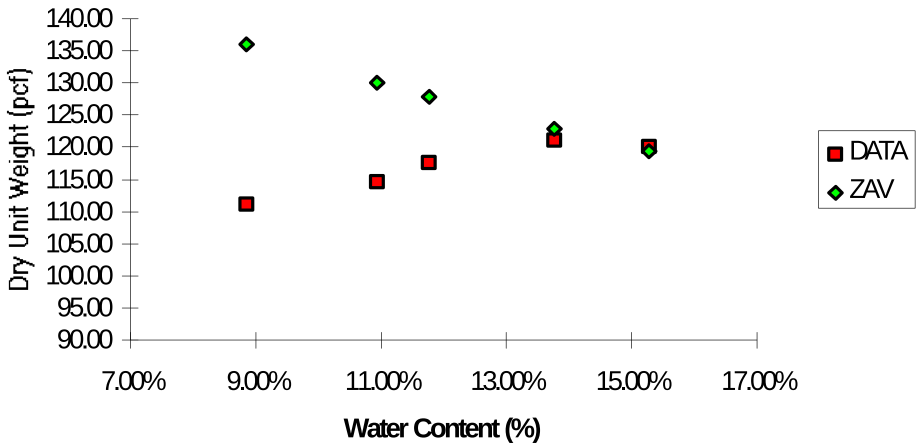


DATE:	10/24/95 to 10/27/1995				
Gs	2.70				
Lower Layer	34.3	33.7	32.9	33.7	31.4
Middle Layer	35.2	33.6	33.9	34.2	33.0
Upper Layer	35.6	35.0	32.7	36.3	32.9
Average Temp	35.0	34.1	33.2	34.7	32.4
Cumulative Average Temperature				33.9	
	A12	**A14**	**A6**	**A8**	**A10**
Mold #	1	2	2	2	1
Wt Mold & Soil	8.13	8.87	8.79	8.92	8.55
Wt Mold	3.95	4.48	4.48	4.48	3.95
Wt Soil	4.18	4.39	4.31	4.44	4.60
Wet Density	125.40	131.70	129.30	133.20	138.00
Dry Density	113.72	116.55	114.43	116.08	120.02
Moisture Tin #	1	-	10A	9A	15A
Wt tin & Wet Soil	319.06	335.66	330.97	322.65	346.48
Wt tin & Dry Soil	307.88	320.00	315.37	305.46	328.52
Wt Water	11.18	15.66	15.60	17.19	17.96
Wt Moisture Tin	199.00	199.49	195.29	188.92	208.64
Wt Dry Soil	108.88	120.51	120.08	116.54	119.88
Water Content	10.27%	12.99%	12.99%	14.75%	14.98%
Water Content	10.27%	12.99%	12.99%	14.75%	14.98%
Dry Density (pcf)	113.72	116.55	114.43	116.08	120.02
ZAV	131.95	124.76	124.77	120.53	120.00
Saturation	57.52%	78.67%	74.19%	88.13%	100.07%



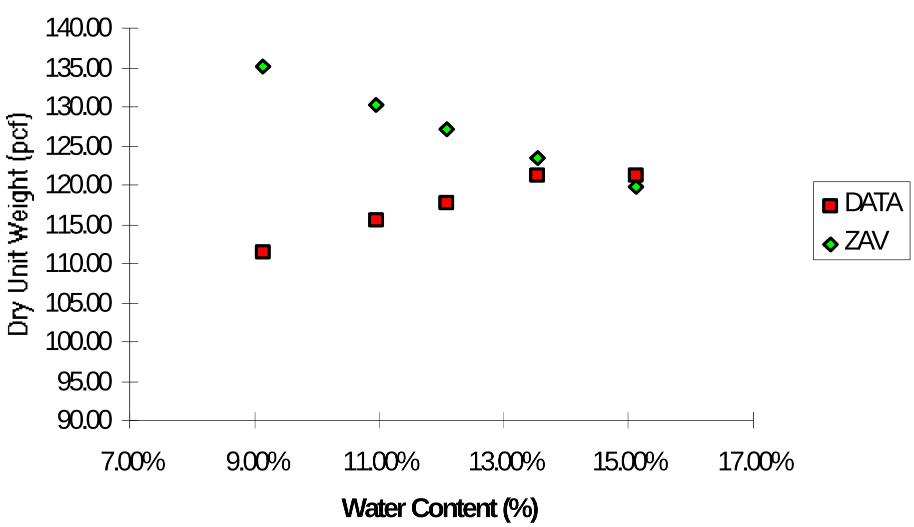
DATE:	6/27/95					
Gs	2.70					
Lower Layer		34.7	35.2	37.3	34.7	36.5
Middle Layer		36.8	36.6	36.6	34.3	36.1
Upper Layer		37.2	37.3	38.3	36.8	37.7
Average Temp		36.2	36.4	37.4	35.3	36.8
Cumulative Average Temperature					36.4	
		A10	**A12**	**A14**	**A6**	**A8**
Wt Mold & Soil		7.98	8.19	8.33	8.54	8.56
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		4.03	4.24	4.38	4.59	4.61
Wet Density		120.90	127.20	131.40	137.70	138.30
Dry Density		111.06	114.66	117.57	121.03	119.98
Moisture Tin #		12E	F	5F	12E	30
Wt tin & Wet Soil		258.70	307.70	260.36	253.64	329.41
Wt tin & Dry Soil		248.93	292.00	247.55	239.72	311.25
Wt Water		9.77	15.70	12.81	13.92	18.16
Wt Moisture Tin		138.66	148.42	138.64	138.66	192.33
Wt Dry Soil		110.27	143.58	108.91	101.06	118.92
Water Content		8.86%	10.93%	11.76%	13.77%	15.27%
Water Content		8.86%	10.93%	11.76%	13.77%	15.27%
Dry Density (pcf)		111.06	114.66	117.57	121.03	119.98
ZAV		136.00	130.12	127.91	122.85	119.33
Saturation		46.23%	62.84%	73.26%	94.75%	101.88%

SOIL A - 36.4 DEGREES F



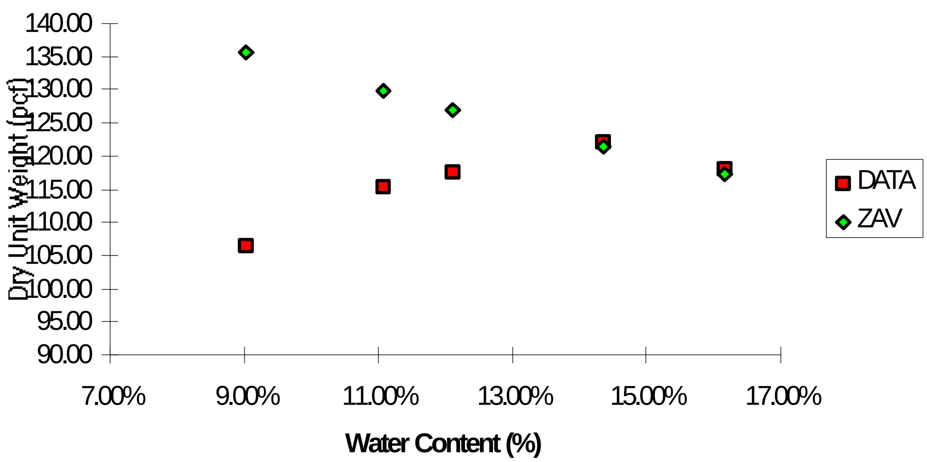
DATE:	8/19/95					
Gs	2.70					
Lower Layer		41.0	38.5	36.7	37.0	38.0
Middle Layer		40.0	38.3	38.7	37.4	37.5
Upper Layer		40.1	40.7	39.2	38.4	39.2
Average Temp		40.4	39.2	38.2	37.6	38.2
Cumulative Average Temperature					38.7	
		A10	**A12**	**A14**	**A6**	**A8**
Wt Mold & Soil		8.00	8.22	8.35	8.54	8.60
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		4.05	4.27	4.40	4.59	4.65
Wet Density		121.50	128.10	132.00	137.70	139.50
Dry Density		111.33	115.46	117.76	121.29	121.19
Moisture Tin #		36	3	37	16	38
Wt tin & Wet Soil		312.80	316.75	340.76	336.50	356.45
Wt tin & Dry Soil		303.25	304.94	326.66	321.26	336.10
Wt Water		9.55	11.81	14.10	15.24	20.35
Wt Moisture Tin		198.74	197.04	210.05	208.62	201.45
Wt Dry Soil		104.51	107.90	116.61	112.64	134.65
Water Content		9.14%	10.95%	12.09%	13.53%	15.11%
Water Content		9.14%	10.95%	12.09%	13.53%	15.11%
Dry Density (pcf)		111.33	115.46	117.76	121.29	121.19
ZAV		135.20	130.11	127.07	123.46	119.71
Saturation		47.99%	64.26%	75.68%	93.73%	104.38%

SOIL A - 38.7 DEGREES F



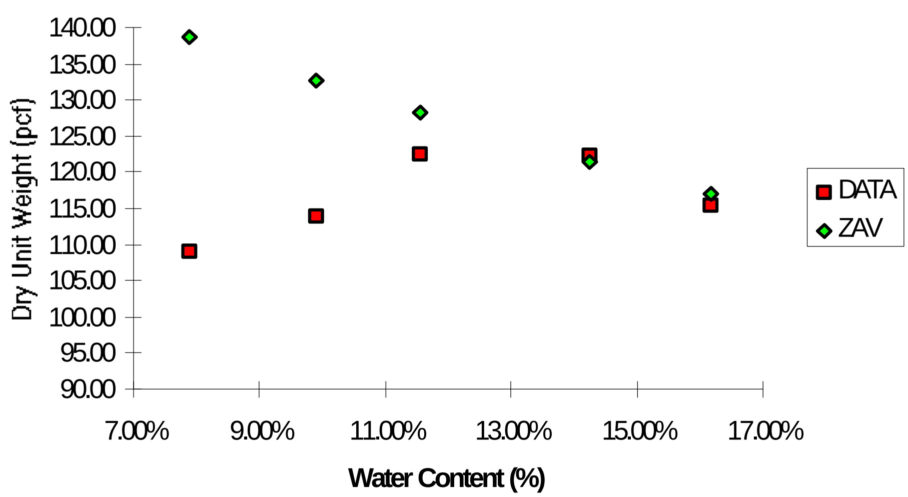
DATE:	6/10/95					
Gs	2.70					
Lower Layer		41.7	40.3	41.0	42.8	42.2
Middle Layer		41.0	41.0	41.3	41.3	41.5
Upper Layer		42.8	42.9	42.8	42.8	43.3
Average Temp		41.8	41.4	41.7	42.3	42.3
Cumulative Average Temperature			41.9			
		A10	**A12**	**A14**	**A6**	**A8**
Wt Mold & Soil		7.82	8.22	8.34	8.61	8.52
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		3.87	4.27	4.39	4.66	4.57
Wet Density		116.10	128.10	131.70	139.80	137.10
Dry Density		106.49	115.33	117.48	122.25	118.02
Moisture Tin #		110F 15A		10F	32	12A
Wt tin & Wet Soil		245.36	323.33	264.45	326.44	308.66
Wt tin & Dry Soil		235.61	311.90	252.11	310.18	291.98
Wt Water		9.75	11.43	12.34	16.26	16.68
Wt Moisture Tin		127.53	208.68	150.13	196.95	188.79
Wt Dry Soil		108.08	103.22	101.98	113.23	103.19
Water Content		9.02%	11.07%	12.10%	14.36%	16.16%
Water Content		9.02%	11.07%	12.10%	14.36%	16.16%
Dry Density (pcf)		106.49	115.33	117.48	122.25	118.02
ZAV (pcf)		135.55	129.76	127.05	121.47	117.35
Saturation		41.79%	64.78%	75.15%	102.34%	101.92%

SOIL A - 41.9 DEGREES F

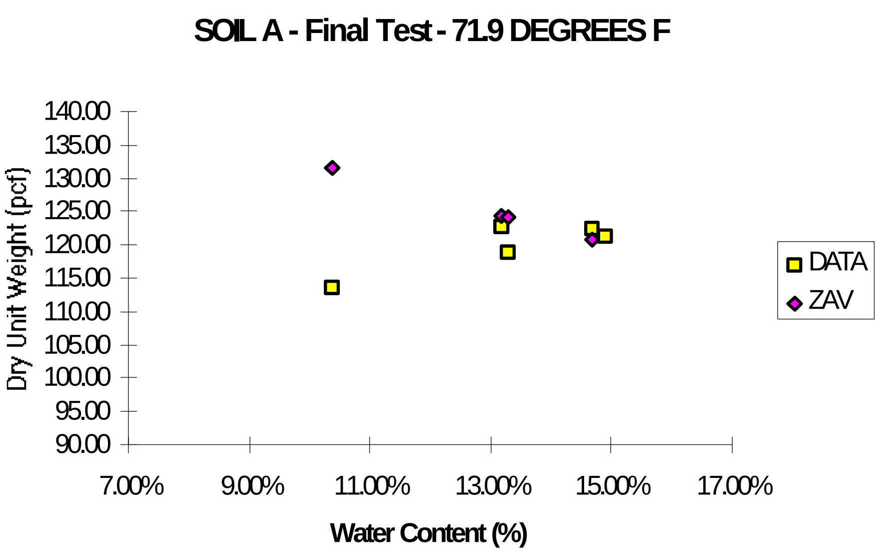


DATE:	5/26/95					
Gs	2.70					
Lower Layer		68.8	69.4	70.4	72.1	72.0
Middle Layer		69.6	69.6	70.8	71.5	71.8
Upper Layer		69.8	70.1	70.8	71.9	71.7
Average Temp		69.4	69.7	70.7	71.8	71.8
Cumulative Average Temperature			70.7			
		A10	**A12**	**A14**	**A6**	**A8**
Wt Mold & Soil		7.87	8.12	8.51	8.61	8.42
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		3.92	4.17	4.56	4.66	4.47
Wet Density		117.60	125.10	136.80	139.80	134.10
Dry Density		109.01	113.83	122.62	122.37	115.44
Moisture Tin #		481	481	157	6	506
Wt tin & Wet Soil		142.60	136.72	136.80	141.30	143.10
Wt tin & Dry Soil		134.33	127.05	125.50	127.10	127.00
Wt Water		8.27	9.67	11.30	14.20	16.10
Wt Moisture Tin		29.39	29.39	27.75	27.42	27.42
Wt Dry Soil		104.94	97.66	97.75	99.68	99.58
Water Content		7.88%	9.90%	11.56%	14.25%	16.17%
Water Content		7.88%	9.90%	11.56%	14.25%	16.17%
Dry Density (pcf)		109.01	113.83	122.62	122.37	115.44
ZAV (pcf)		138.70	132.73	128.20	121.48	117.09
Saturation		39.18%	55.96%	83.96%	102.67%	95.49%

SOIL A - 70.7 DEGREES F



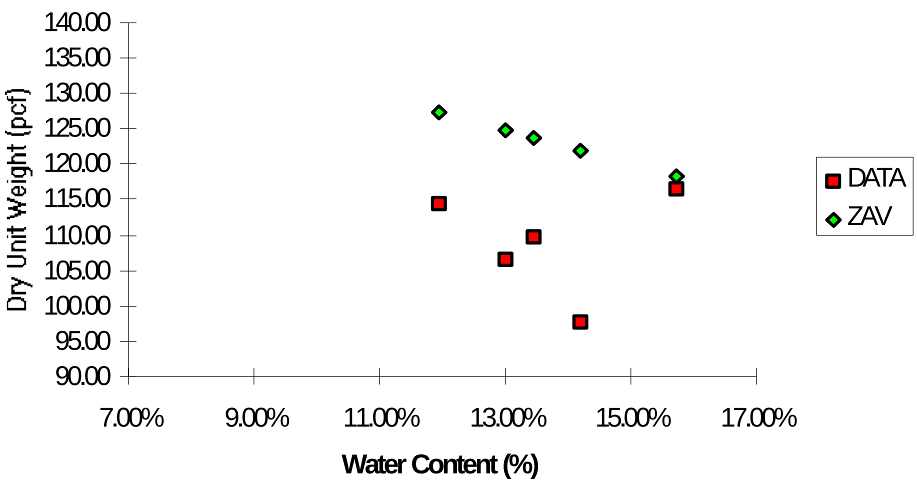
DATE:	12/12 &12/13/95					
Gs	2.70					
Lower Layer		71.7	72.1	71.9	72.1	71.9
Middle Layer		71.7	71.9	71.9	71.9	72.1
Upper Layer		71.9	71.4	71.9	72.5	72.1
Average Temp		71.8	71.8	71.9	72.2	72.0
Cumulative Average Temperature			71.9			
		A12	**A6**	**A14**	**A8**	**A10**
Wt Mold & Soil		8.66	8.58	8.97	8.63	8.59
Wt Mold		4.48	3.95	4.48	3.95	3.95
Wt Soil		4.18	4.63	4.49	4.68	4.64
Wet Density		125.40	138.90	134.70	140.40	139.20
Dry Density		113.62	122.73	118.91	122.41	121.15
Moisture Tin #		37	17	2	17	3
Wt tin & Wet Soil		337.90	318.57	334.27	333.41	328.79
Wt tin & Dry Soil		325.89	302.59	318.18	313.93	310.06
Wt Water		12.01	15.98	16.09	19.48	18.73
Wt Moisture Tin		210.07	181.34	197.05	181.34	184.37
Wt Dry Soil		115.82	121.25	121.13	132.59	125.69
Water Content		10.37%	13.18%	13.28%	14.69%	14.90%
Water Content		10.37%	13.18%	13.28%	14.69%	14.90%
Dry Density (pcf)		113.62	122.73	118.91	122.41	121.15
ZAV		131.67	124.30	124.05	120.67	120.18
Saturation		57.93%	95.33%	85.93%	105.29%	102.86%



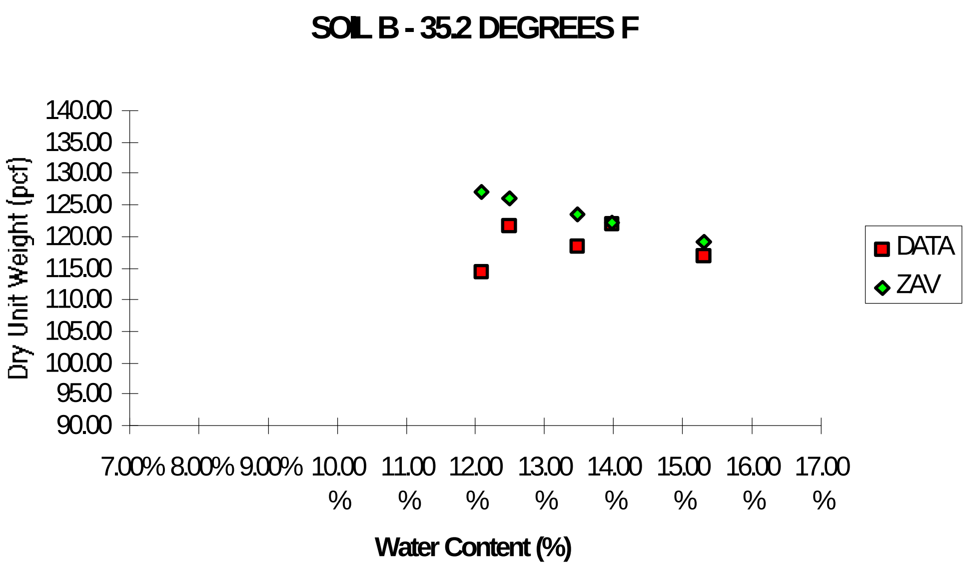
DATE: 10/10/95 to 10/13/1995

Gs	2.70				
Lower Layer	31.5	31.2	31.8	30.9	32.0
Middle Layer	32.0	31.6	32.0	30.6	31.8
Upper Layer	32.9	32.0	32.0	31.1	31.8
Average Temp	32.1	31.6	31.9	30.9	31.9
Cumulative Average Temperature				31.7	
	B14	**B10**	**B12**	**B6**	**B8**
Mold #	1	1	2	2	1
Wt Mold & Soil	8.22	7.96	8.63	8.20	8.44
Wt Mold	3.95	3.95	4.48	4.48	3.95
Wt Soil	4.27	4.01	4.15	3.72	4.49
Wet Density	128.10	120.30	124.50	111.60	134.70
Dry Density	114.43	106.46	109.73	97.73	116.39
Moisture Tin #	+	2	11	9	34
Wt tin & Wet Soil	305.91	334.56	266.83	319.36	334.07
Wt tin & Dry Soil	292.95	318.74	251.96	304.21	316.37
Wt Water	12.96	15.82	14.87	15.15	17.70
Wt Moisture Tin	184.44	197.03	141.46	197.48	203.87
Wt Dry Soil	108.51	121.71	110.50	106.73	112.50
Water Content	11.94%	13.00%	13.46%	14.19%	15.73%
Water Content	11.94%	13.00%	13.46%	14.19%	15.73%
Dry Density (pcf)	114.43	106.46	109.73	97.73	116.39
ZAV	127.44	124.75	123.62	121.84	118.29
Saturation	68.21%	60.19%	67.81%	52.90%	94.81%

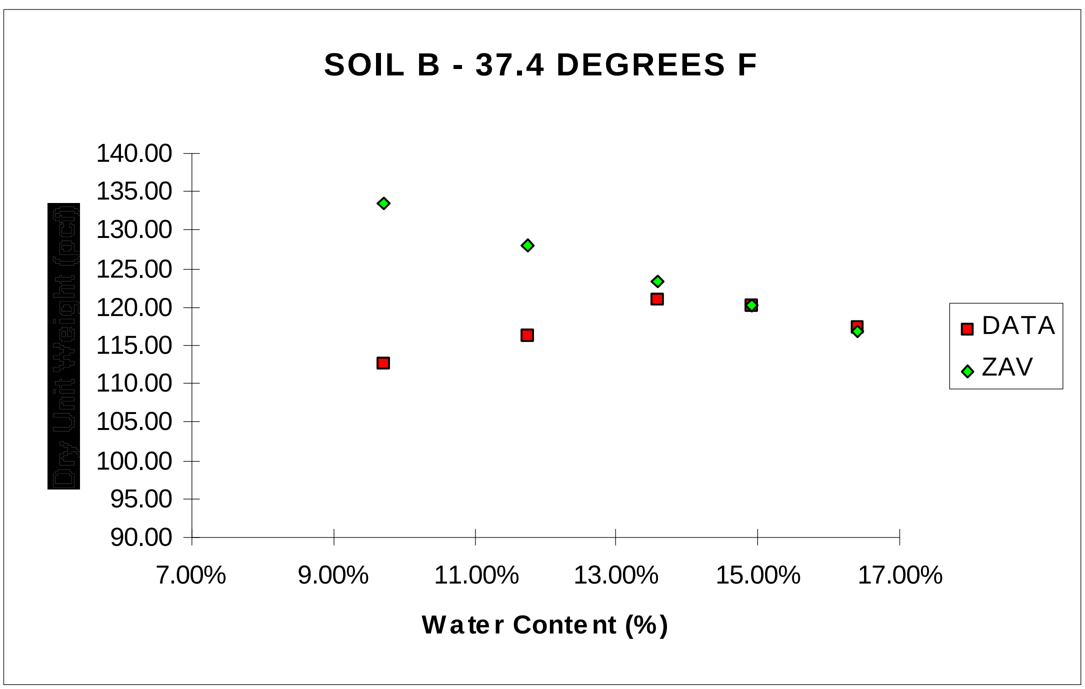
SOIL B - 31.7 DEGREES F



DATE:	10/30/95 to 11/02/1995					
Gs	2.70					
Lower Layer		33.9	35.7	35.7	33.2	35.6
Middle Layer		33.8	34.5	35.9	35.7	34.7
Upper Layer		33.8	37.5	36.8	36.5	34.7
Average Temp		33.8	35.9	36.1	35.1	35.0
Cumulative Average Temperature			35.2			
		B14	**B6**	**B12**	**B10**	**B8**
Mold #		1	1	2	1	2
Wt Mold & Soil		8.22	8.51	8.96	8.58	8.97
Wt Mold		3.95	3.95	4.48	3.95	4.48
Wt Soil		4.27	4.56	4.48	4.63	4.49
Wet Density		128.10	136.80	134.40	138.90	134.70
Dry Density		114.29	121.61	118.44	121.87	116.83
Moisture Tin #		6	6A	7A	37	1A
Wt tin & Wet Soil		373.08	305.96	313.27	350.42	353.58
Wt tin & Dry Soil		356.55	292.81	298.27	333.21	333.15
Wt Water		16.53	13.15	15.00	17.21	20.43
Wt Moisture Tin		219.74	187.55	186.93	210.09	199.59
Wt Dry Soil		136.81	105.26	111.34	123.12	133.56
Water Content		12.08%	12.49%	13.47%	13.98%	15.30%
Water Content		12.08%	12.49%	13.47%	13.98%	15.30%
Dry Density (pcf)		114.29	121.61	118.44	121.87	116.83
ZAV		127.08	126.02	123.58	122.36	119.27
Saturation		68.74%	87.41%	86.01%	98.55%	93.32%



DATE:	6/18/95					
Gs	2.70					
Lower Layer		37.6	36.1	37.0	38.6	35.6
Middle Layer		37.5	36.8	37.4	39.0	36.7
Upper Layer		39.0	36.6	37.4	39.3	36.3
Average Temp		38.0	36.5	37.3	39.0	36.2
Cumulative Average Temperature					37.4	
		B12	**B14**	**B6**	**B10**	**B8**
Wt Mold & Soil		8.07	8.28	8.53	8.55	8.50
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		4.12	4.33	4.58	4.60	4.55
Wet Density		123.60	129.90	137.40	138.00	136.50
Dry Density		112.65	116.26	120.97	120.10	117.26
Moisture Tin #		F	38	9A	-	44
Wt tin & Wet Soil		262.90	323.69	318.39	344.08	346.58
Wt tin & Dry Soil		252.76	311.39	302.92	325.24	326.13
Wt Water		10.14	12.30	15.47	18.84	20.45
Wt Moisture Tin		148.43	206.57	188.98	198.87	201.53
Wt Dry Soil		104.33	104.82	113.94	126.37	124.60
Water Content		9.72%	11.73%	13.58%	14.91%	16.41%
Water Content		9.72%	11.73%	13.58%	14.91%	16.41%
Dry Density (pcf)		112.65	116.26	120.97	120.10	117.26
ZAV		133.52	128.01	123.34	120.18	116.80
Saturation		52.87%	70.42%	93.19%	99.75%	101.28%

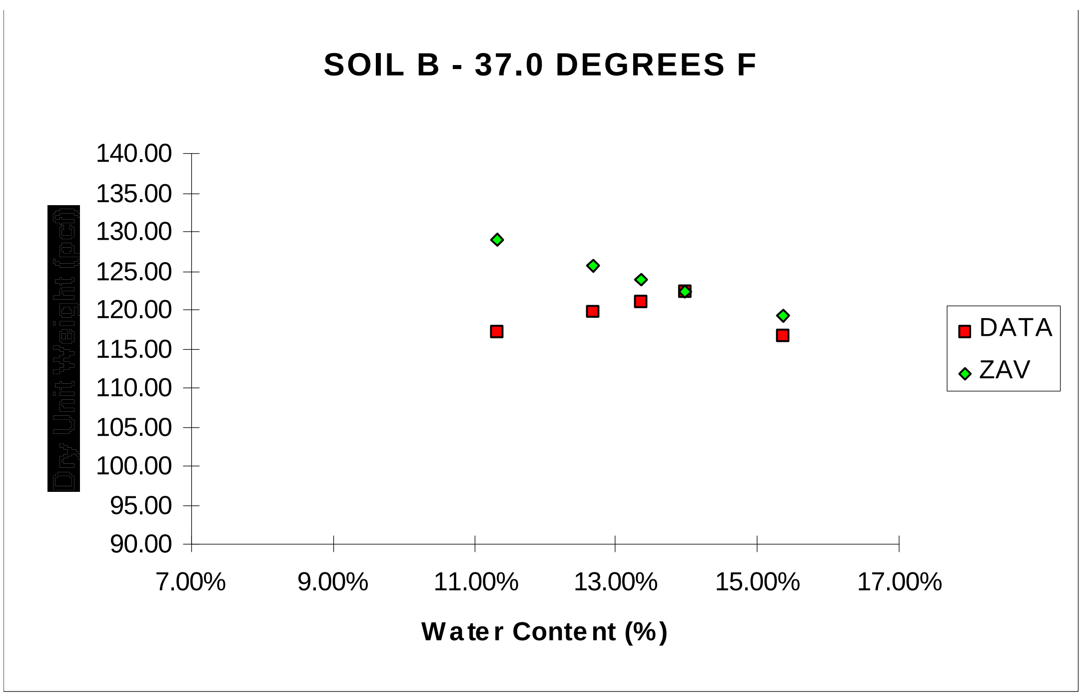


DATE: 11/25/95

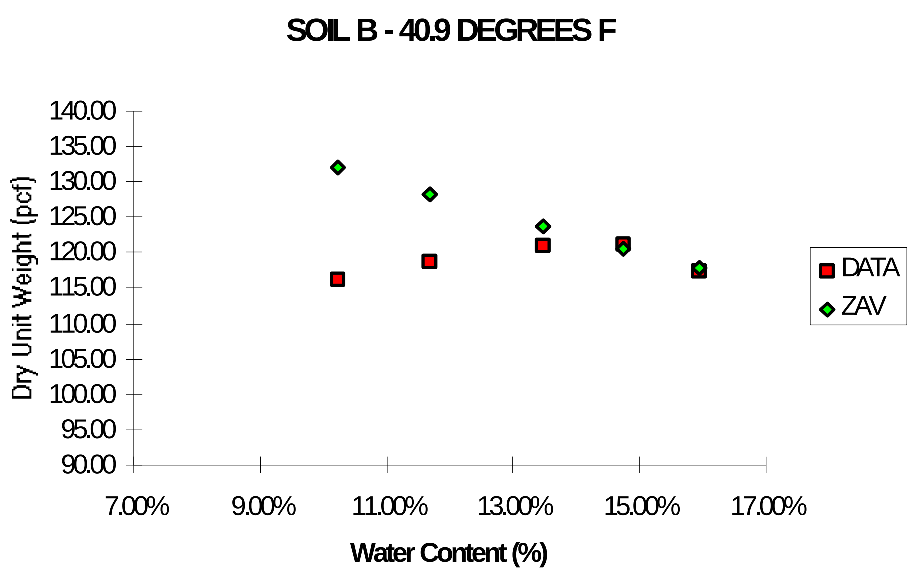
Gs 2.70

Lower Layer	37.5	34.7	37.6	35.7	35.0
Middle Layer	37.7	35.6	38.5	36.1	35.9
Upper Layer	39.8	36.5	41.0	37.4	36.6
Average Temp	38.3	35.6	39.0	36.4	35.8
Cumulative Average Temperature		37.0			

	B14	**B6**	**B12**	**B10**	**B8**
Mold #	1	1	1	1	2
Wt Mold & Soil	8.30	8.45	8.52	8.60	8.97
Wt Mold	3.95	3.95	3.95	3.95	4.48
Wt Soil	4.35	4.50	4.57	4.65	4.49
Wet Density	130.50	135.00	137.10	139.50	134.70
Dry Density	117.23	119.80	120.93	122.39	116.77
Moisture Tin #	16	9	3	+	-
Wt tin & Wet Soil	318.63	322.29	340.76	310.79	348.44
Wt tin & Dry Soil	307.44	308.48	323.81	295.28	328.60
Wt Water	11.19	13.81	16.95	15.51	19.84
Wt Moisture Tin	208.60	199.60	197.03	184.36	199.41
Wt Dry Soil	98.84	108.88	126.78	110.92	129.19
Water Content	11.32%	12.68%	13.37%	13.98%	15.36%
Water Content	11.32%	12.68%	13.37%	13.98%	15.36%
Dry Density (pcf)	117.23	119.80	120.93	122.39	116.77
ZAV	129.08	125.54	123.83	122.34	119.14
Saturation	69.84%	84.20%	91.71%	100.13%	93.53%

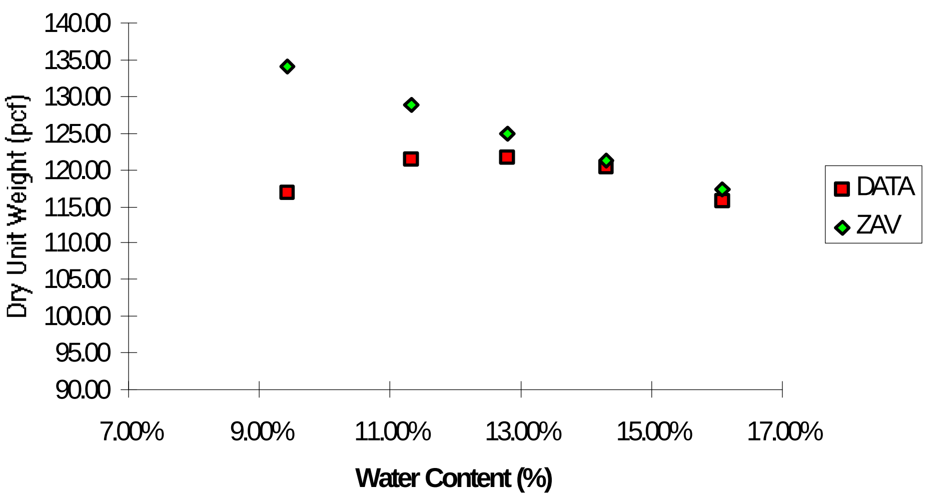


DATE:	5/27/95					
Gs	2.70					
Lower Layer		40.1	41.2	37.5	39.0	41.1
Middle Layer		42.0	41.0	40.5	40.4	41.1
Upper Layer		42.2	43.1	41.0	41.1	42.0
Average Temp		41.4	41.8	39.7	40.2	41.4
Cumulative Average Temperature			40.9			
		B12	**B14**	**B6**	**B10**	**B8**
Wt Mold & Soil		8.22	8.37	8.53	8.59	8.49
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		4.27	4.42	4.58	4.64	4.54
Wet Density		128.10	132.60	137.40	139.20	136.20
Dry Density		116.21	118.72	121.09	121.31	117.47
Moisture Tin #		9	38	11	38	9
Wt tin & Wet Soil		313.59	331.28	320.71	331.57	320.95
Wt tin & Dry Soil		302.84	317.69	305.21	314.85	304.01
Wt Water		10.75	13.59	15.50	16.72	16.94
Wt Moisture Tin		197.77	201.43	190.13	201.44	197.77
Wt Dry Soil		105.07	116.26	115.08	113.41	106.24
Water Content		10.23%	11.69%	13.47%	14.74%	15.95%
Water Content		10.23%	11.69%	13.47%	14.74%	15.95%
Dry Density (pcf)		116.21	118.72	121.09	121.31	117.47
ZAV (pcf)		132.08	128.12	123.61	120.57	117.83
Saturation		61.32%	75.18%	92.76%	102.21%	98.98%

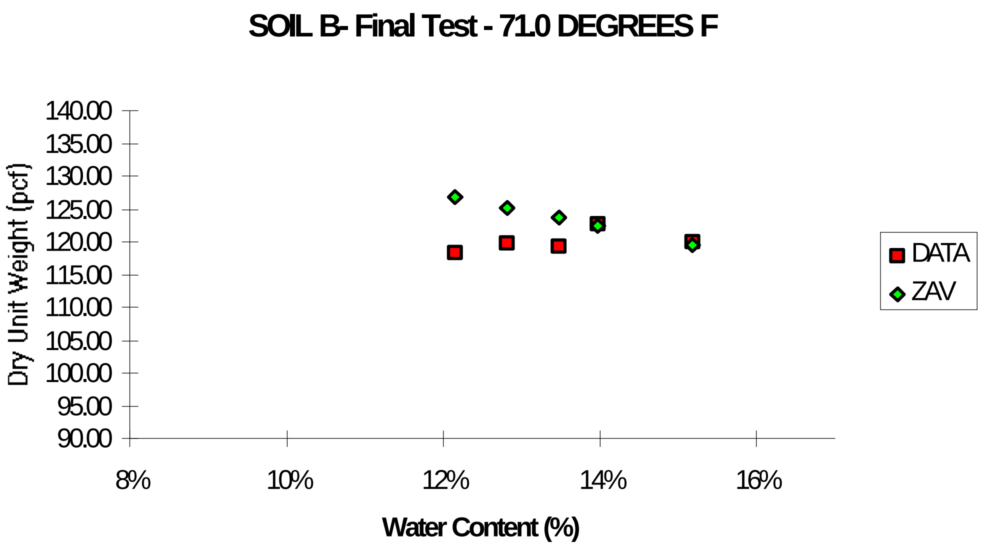


DATE:	5/27/95					
Gs	2.70					
Lower Layer		70.8	71.4	70.8	71.8	71.9
Middle Layer		71.0	71.2	71.8	71.4	72.5
Upper Layer		71.2	71.2	71.6	72.3	72.1
Average Temp		71.0	71.3	71.4	71.8	72.2
Cumulative Average Temperature			71.5			
		B12	**B14**	**B6**	**B10**	**B8**
Wt Mold & Soil		8.21	8.46	8.52	8.54	8.43
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		4.26	4.51	4.57	4.59	4.48
Wet Density		127.80	135.30	137.10	137.70	134.40
Dry Density		116.79	121.54	121.55	120.46	115.77
Moisture Tin #		506	506	481	6	6
Wt tin & Wet Soil		146.82	133.93	147.10	131.88	147.69
Wt tin & Dry Soil		136.53	123.10	133.75	118.80	131.02
Wt Water		10.29	10.83	13.35	13.08	16.67
Wt Moisture Tin		27.42	27.42	29.39	27.42	27.42
Wt Dry Soil		109.11	95.68	104.36	91.38	103.60
Water Content		9.43%	11.32%	12.79%	14.31%	16.09%
Water Content		9.43%	11.32%	12.79%	14.31%	16.09%
Dry Density (pcf)		116.79	121.54	121.55	120.46	115.77
ZAV (pcf)		134.07	128.84	125.03	121.32	117.26
Saturation		57.83%	79.60%	89.98%	97.49%	95.92%

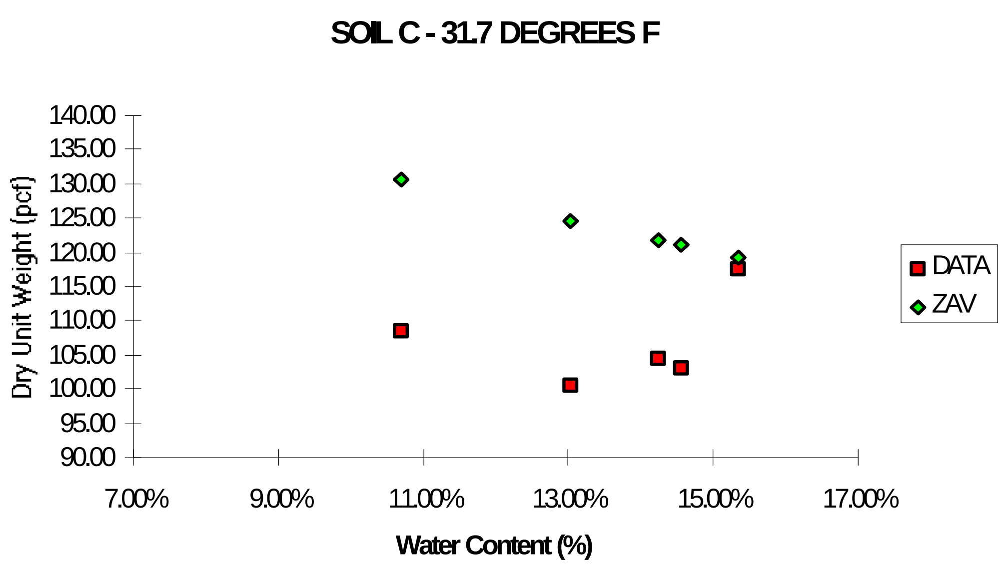
SOIL B - 71.5 DEGREES F



DATE: 12/13 &12/14/95					
Gs 2.70					
Lower Layer	72.1	72.5	69.4	69.0	72.6
Middle Layer	71.9	72.1	69.2	69.2	72.5
Upper Layer	71.7	72.1	68.9	68.9	72.5
Average Temp	71.9	72.2	69.2	69.0	72.5
Cumulative Average Temperature		71.0			
	B14	**B6**	**B12**	**B10**	**B8**
Mold #	2	2	2	1	1
Wt Mold & Soil	8.90	8.98	8.99	8.61	8.56
Wt Mold	4.48	4.48	4.48	3.95	3.95
Wt Soil	4.42	4.50	4.51	4.66	4.61
Wet Density	132.60	135.00	135.30	139.80	138.30
Dry Density	118.24	119.66	119.23	122.65	120.08
Moisture Tin #	3	12	7A	9	x
Wt tin & Wet Soil	320.23	322.85	336.08	335.26	366.60
Wt tin & Dry Soil	306.89	306.64	318.36	318.62	342.59
Wt Water	13.34	16.21	17.72	16.64	24.01
Wt Moisture Tin	197.05	180.21	186.93	199.58	184.39
Wt Dry Soil	109.84	126.43	131.43	119.04	158.20
Water Content	12.14%	12.82%	13.48%	13.98%	15.18%
Water Content	12.14%	12.82%	13.48%	13.98%	15.18%
Dry Density (pcf)	118.24	119.66	119.23	122.65	120.08
ZAV	126.92	125.19	123.56	122.35	119.55
Saturation	77.09%	84.75%	88.02%	100.90%	101.54%



DATE:	10/16/95 to 10/20/95					
GS:	2.70					
Lower Layer		32.3	30.0	31.1	31.5	31.5
Middle Layer		32.0	31.4	31.4	31.8	31.5
Upper Layer		33.7	31.6	31.6	31.8	31.6
Average Temp		32.7	31.0	31.4	31.7	31.5
Cumulative Average Temperature			31.7			
		C8	**C12**	**C14**	**C10**	**C6**
Mold #		1	2	2	1	1
Wt Mold & Soil		7.95	8.27	8.46	7.89	8.47
Wt Mold		3.95	4.48	4.48	3.95	3.95
Wt Soil		4.00	3.79	3.98	3.94	4.52
Wet Density		120.00	113.70	119.40	118.20	135.60
Dry Density		108.40	100.60	104.51	103.18	117.56
Moisture Tin #		1	34	1	4	6A
Wt tin & Wet Soil		337.47	365.21	344.55	352.06	351.45
Wt tin & Dry Soil		324.32	346.62	326.70	331.71	329.65
Wt Water		13.15	18.59	17.85	20.35	21.80
Wt Moisture Tin		201.46	203.86	201.44	191.87	187.57
Wt Dry Soil		122.86	142.76	125.26	139.84	142.08
Water Content		10.70%	13.02%	14.25%	14.55%	15.34%
Water Content		10.70%	13.02%	14.25%	14.55%	15.34%
Dry Density (pcf)		108.40	100.60	104.51	103.18	117.56
ZAV		130.75	124.69	121.71	120.99	119.17
Saturation		52.09%	52.07%	62.80%	62.04%	95.55%

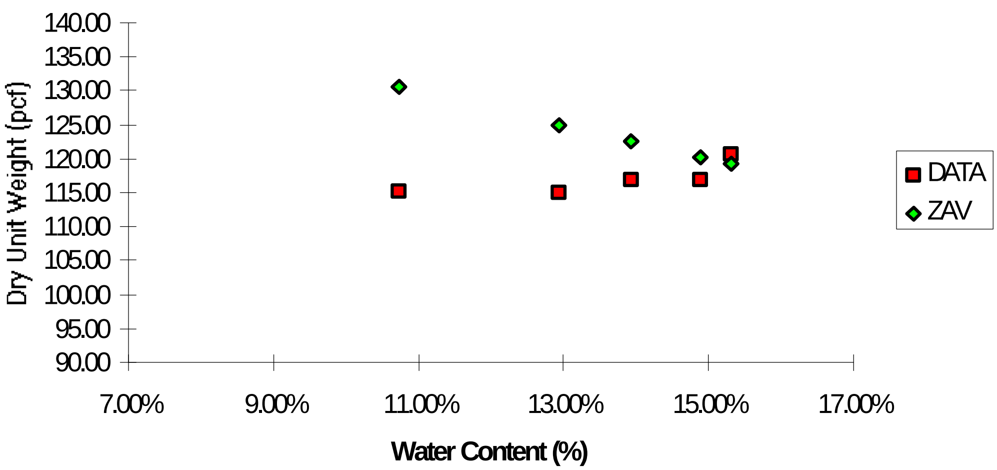


DATE: 11/2-11/17/95

GS: 2.70

	C8	C12	C14	C10	C6
Lower Layer	36.6	32.0	33.9	33.8	32.9
Middle Layer	36.5	34.1	34.8	34.5	33.6
Upper Layer	38.8	34.3	35.4	35.7	33.9
Average Temp	37.3	33.5	34.7	34.7	33.5
Cumulative Average Temperature		34.7			
Mold #	1	2	2	2	1
Wt Mold & Soil	8.2	8.81	8.92	8.96	8.59
Wt Mold	3.95	4.48	4.48	4.48	3.95
Wt Soil	4.25	4.33	4.44	4.48	4.64
Wet Density	127.50	129.90	133.20	134.40	139.20
Dry Density	115.14	115.03	116.91	116.99	120.72
Moisture Tin #	7A	16		10A	+
Wt tin & Wet Soil	303.85	332.98	331.36	342.63	351.63
Wt tin & Dry Soil	292.52	318.74	315.23	323.54	329.43
Wt Water	11.33	14.24	16.13	19.09	22.20
Wt Moisture Tin	186.93	208.61	199.44	195.28	184.37
Wt Dry Soil	105.59	110.13	115.79	128.26	145.06
Water Content	10.73%	12.93%	13.93%	14.88%	15.30%
Water Content	10.73%	12.93%	13.93%	14.88%	15.30%
Dry Density (pcf)	115.14	115.03	116.91	116.99	120.72
ZAV	130.68	124.92	122.47	120.22	119.26
Saturation	62.55%	75.13%	85.28%	91.30%	104.46%

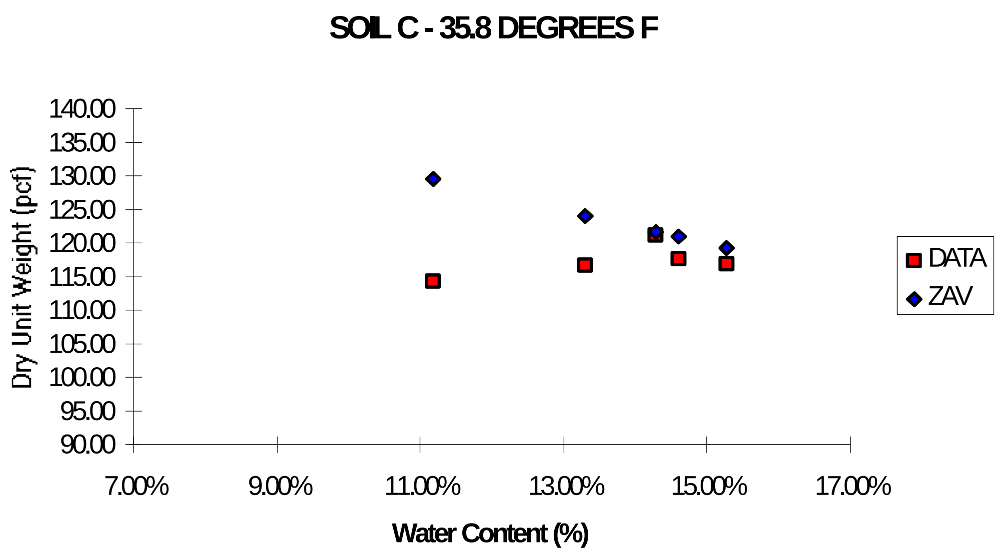
SOIL C - 34.7 DEGREES F



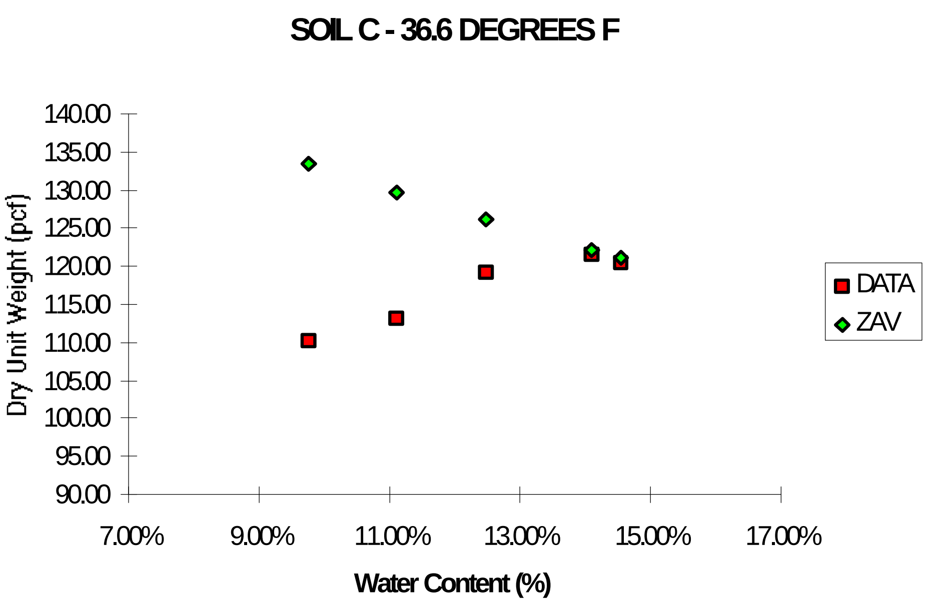
DATE: 11/21-12/1/95

GS: 2.70

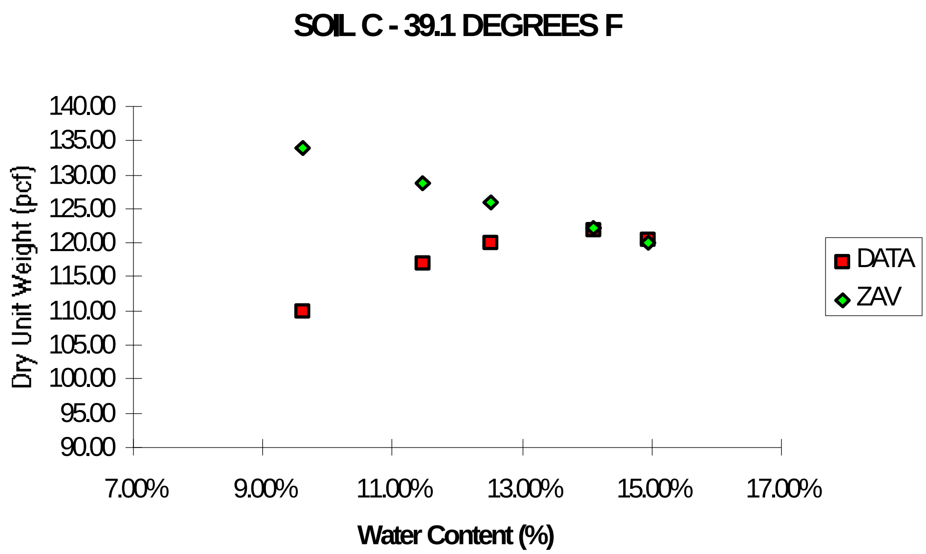
Lower Layer	36.1	35.6	35.6	34.7	34.4
Middle Layer	36.6	35.6	35.8	35.6	34.2
Upper Layer	37.2	37.1	36.8	35.6	35.4
Average Temp	36.6	36.1	36.1	35.3	34.7
Cumulative Average Temperature		35.8			
	C8	**C12**	**C14**	**C10**	**C6**
Mold #	1	2	1	2	2
Wt Mold & Soil	8.19	8.89	8.57	8.97	8.97
Wt Mold	3.95	4.48	3.95	4.48	4.48
Wt Soil	4.24	4.41	4.62	4.49	4.49
Wet Density	127.20	132.30	138.60	134.70	134.70
Dry Density	114.40	116.77	121.28	117.53	116.86
Moisture Tin #	7A	5	III	V	7A
Wt tin & Wet Soil	316.79	337.04	319.45	358.61	329.11
Wt tin & Dry Soil	303.72	319.80	303.56	337.41	310.29
Wt Water	13.07	17.24	15.89	21.20	18.82
Wt Moisture Tin	186.93	190.15	192.32	192.28	187.00
Wt Dry Soil	116.79	129.65	111.24	145.13	123.29
Water Content	11.19%	13.30%	14.28%	14.61%	15.26%
Water Content	11.19%	13.30%	14.28%	14.61%	15.26%
Dry Density (pcf)	114.40	116.77	121.28	117.53	116.86
ZAV	129.43	124.01	121.63	120.86	119.35
Saturation	63.91%	81.08%	99.09%	90.98%	93.31%



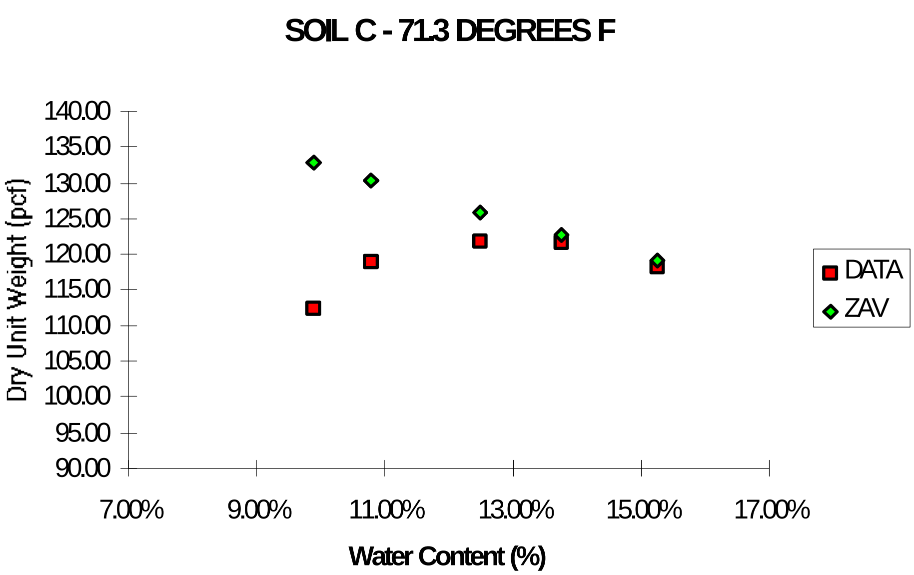
DATE:	7/7/95					
GS:	2.70					
Lower Layer		35.2	34.0	39.2	33.8	37.4
Middle Layer		35.0	36.5	39.0	35.6	37.9
Upper Layer		35.2	36.6	39.0	35.6	39.1
Average Temp		35.1	35.7	39.1	35.0	38.1
Cumulative Average Temperature			36.6			
		C12	**C8**	**C14**	**C6**	**C10**
Wt Mold & Soil		7.98	8.14	8.42	8.57	8.55
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		4.03	4.19	4.47	4.62	4.60
Wet Density		120.90	125.70	134.10	138.60	138.00
Dry Density		110.15	113.13	119.21	121.47	120.47
Moisture Tin #		F	110F	110F	12E	12E
Wt tin & Wet Soil		273.59	242.65	240.38	270.86	242.04
Wt tin & Dry Soil		262.46	231.14	227.85	254.52	228.91
Wt Water		11.13	11.51	12.53	16.34	13.13
Wt Moisture Tin		148.43	127.53	127.53	138.66	138.66
Wt Dry Soil		114.03	103.61	100.32	115.86	90.25
Water Content		9.76%	11.11%	12.49%	14.10%	14.55%
Water Content		9.76%	11.11%	12.49%	14.10%	14.55%
Dry Density (pcf)		110.15	113.13	119.21	121.47	120.47
ZAV		133.40	129.67	126.05	122.08	121.02
Saturation		49.70%	61.22%	81.46%	98.22%	98.41%



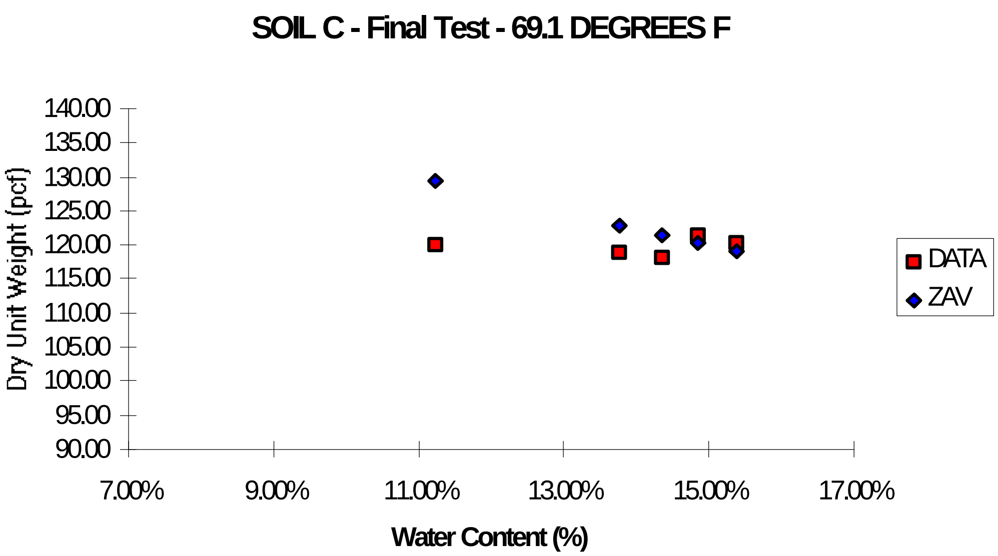
DATE:	8/5&6/95					
GS:	2.70					
Lower Layer		40.2	39.2	39.2	37.8	37.5
Middle Layer		38.6	39.2	39.2	37.0	37.5
Upper Layer		41.9	41.0	39.2	39.2	39.3
Average Temp		40.2	39.8	39.2	38.0	38.1
Cumulative Average Temperature			39.1			
		C12	**C8**	**C14**	**C6**	**C10**
Wt Mold & Soil		7.97	8.30	8.45	8.59	8.57
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		4.02	4.35	4.50	4.64	4.62
Wet Density		120.60	130.50	135.00	139.20	138.60
Dry Density		110.02	117.08	119.97	122.00	120.58
Moisture Tin #		12a	12	V	38	17
Wt tin & Wet Soil		309.84	319.26	313.26	330.05	335.66
Wt tin & Dry Soil		299.21	307.00	300.13	314.16	318.03
Wt Water		10.63	12.26	13.13	15.89	17.63
Wt Moisture Tin		188.71	200.01	195.29	201.44	200.03
Wt Dry Soil		110.50	106.99	104.84	112.72	118.00
Water Content		9.62%	11.46%	12.52%	14.10%	14.94%
Water Content		9.62%	11.46%	12.52%	14.10%	14.94%
Dry Density (pcf)		110.02	117.08	119.97	122.00	120.58
ZAV		133.81	128.73	125.97	122.09	120.11
Saturation		48.81%	70.37%	83.50%	99.73%	101.39%



DATE:	5/29/95					
GS:	2.70					
Lower Layer		71.2	70.3	71.0	71.0	72.2
Middle Layer		70.8	71.2	70.8	71.6	72.1
Upper Layer		71.2	71.0	71.0	71.6	71.9
Average Temp		71.1	70.8	70.9	71.4	72.1
Cumulative Average Temperature			71.3			
		C12	**C8**	**C14**	**C6**	**C10**
Wt Mold & Soil		8.07	8.34	8.52	8.56	8.49
Wt Mold		3.95	3.95	3.95	3.95	3.95
Wt Soil		4.12	4.39	4.57	4.61	4.54
Wet Density		123.60	131.70	137.10	138.30	136.20
Dry Density		112.48	118.88	121.89	121.58	118.18
Moisture Tin #		F5	481	506	6	V
Wt tin & Wet Soil		320.16	148.60	142.85	136.95	350.28
Wt tin & Dry Soil		310.30	137.00	130.04	123.71	330.16
Wt Water		9.86	11.60	12.81	13.24	20.12
Wt Moisture Tin		210.56	29.39	27.42	27.42	198.21
Wt Dry Soil		99.74	107.61	102.62	96.29	131.95
Water Content		9.89%	10.78%	12.48%	13.75%	15.25%
Water Content		9.89%	10.78%	12.48%	13.75%	15.25%
Dry Density (pcf)		112.48	118.88	121.89	121.58	118.18
ZAV (pcf)		132.77	130.29	125.81	122.67	119.15
Saturation		53.87%	70.15%	88.68%	96.80%	97.25%



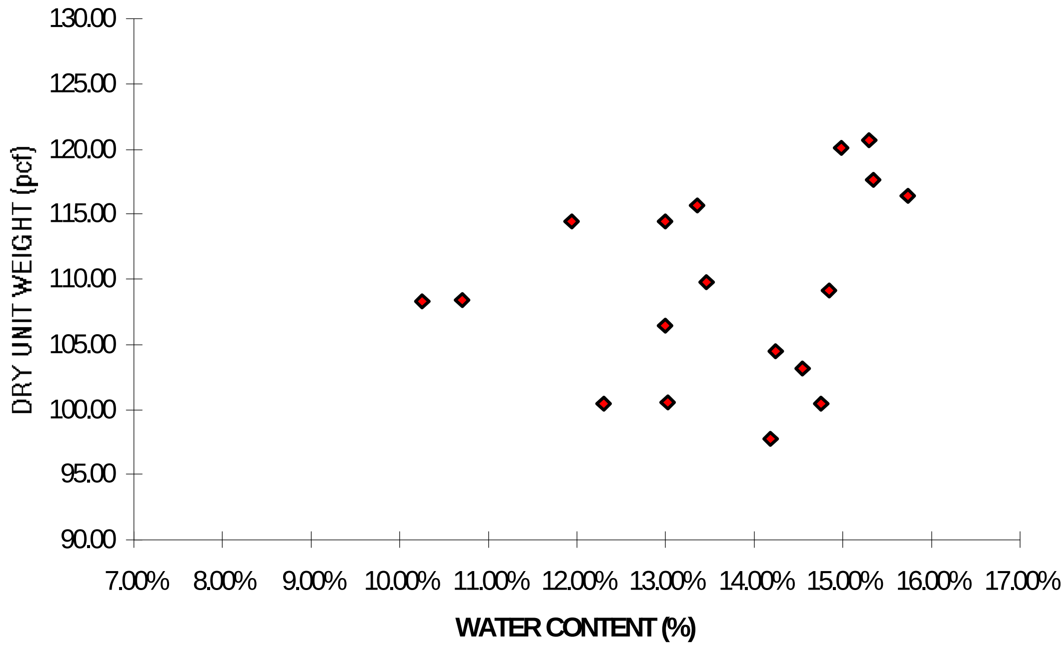
DATE: 12/15 -12/17/95					
GS: 2.70					
Lower Layer	69.0	69.4	68.9	69.2	69.6
Middle Layer	68.7	69.4	68.9	68.9	69.6
Upper Layer	68.7	69.4	68.7	68.5	69.6
Average Temp	68.8	69.4	68.8	68.9	69.6
Cumulative Average Temperature		69.1			
	C8	**C12**	**C14**	**C10**	**C6**
Mold #	1	2	2	1	1
Wt Mold & Soil	8.4	8.99	8.98	8.6	8.58
Wt Mold	3.95	4.48	4.48	3.95	3.95
Wt Soil	4.45	4.51	4.50	4.65	4.63
Wet Density	133.50	135.30	135.00	139.50	138.90
Dry Density	120.03	118.93	118.06	121.46	120.37
Moisture Tin #	7A	7A	9	7A	9
Wt tin & Wet Soil	309.82	308.13	359.56	338.06	324.61
Wt tin & Dry Soil	297.42	293.47	339.49	318.52	307.94
Wt Water	12.40	14.66	20.07	19.54	16.67
Wt Moisture Tin	186.95	186.95	199.62	186.95	199.62
Wt Dry Soil	110.47	106.52	139.87	131.57	108.32
Water Content	11.22%	13.76%	14.35%	14.85%	15.39%
Water Content	11.22%	13.76%	14.35%	14.85%	15.39%
Dry Density (pcf)	120.03	118.93	118.06	121.46	120.37
ZAV	129.34	122.87	121.47	120.30	119.06
Saturation	75.08%	89.19%	90.72%	103.59%	103.98%



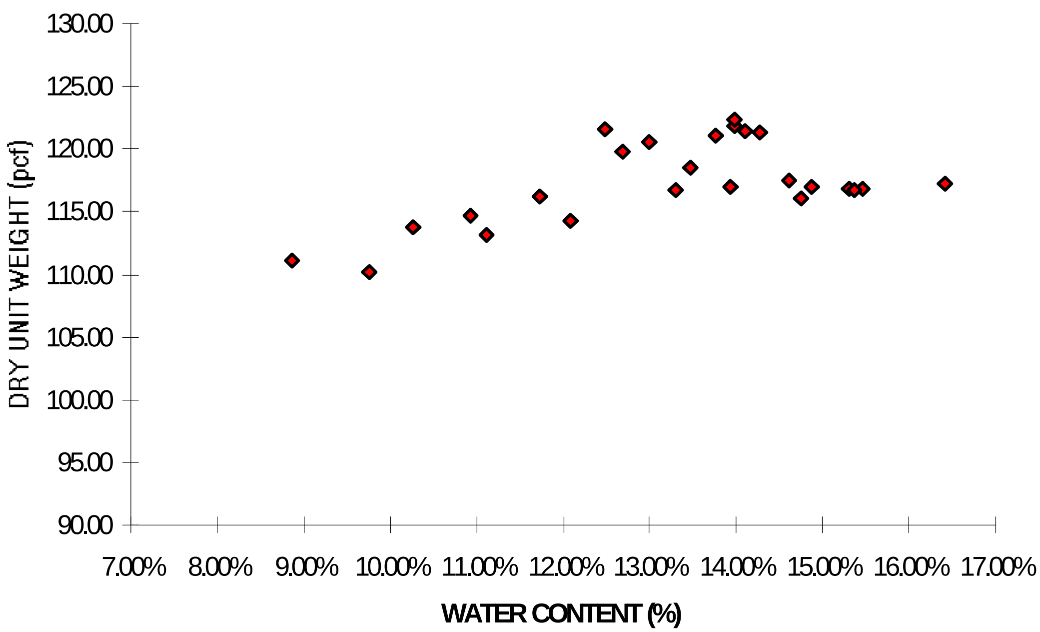
APPENDIX B

Composite Water Content-Dry Unit Weight Curves
for Each Temperature Range

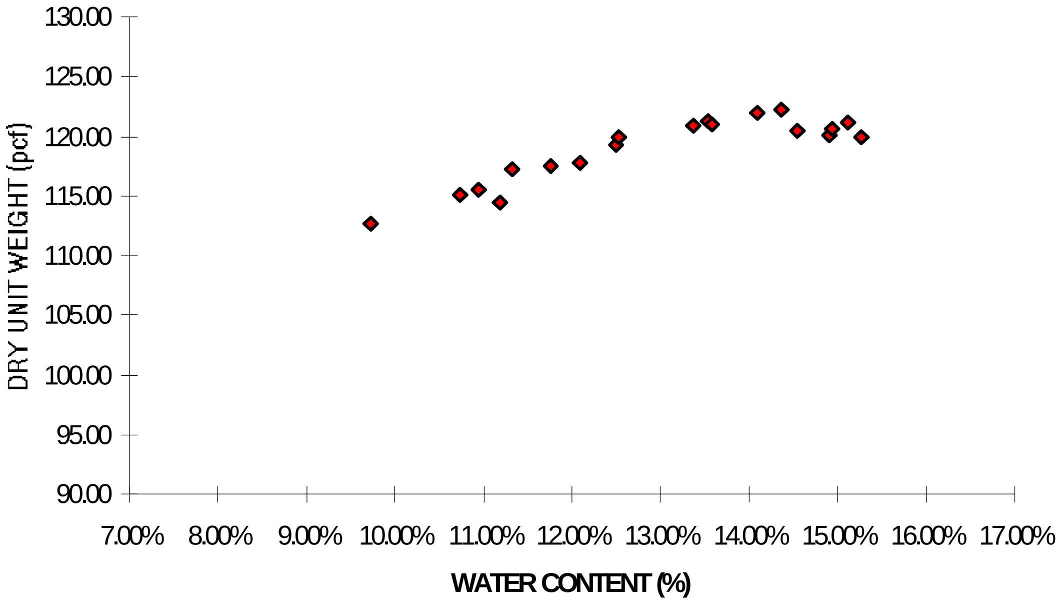
ALL SOILS - 32 DEGREE F RESULTS



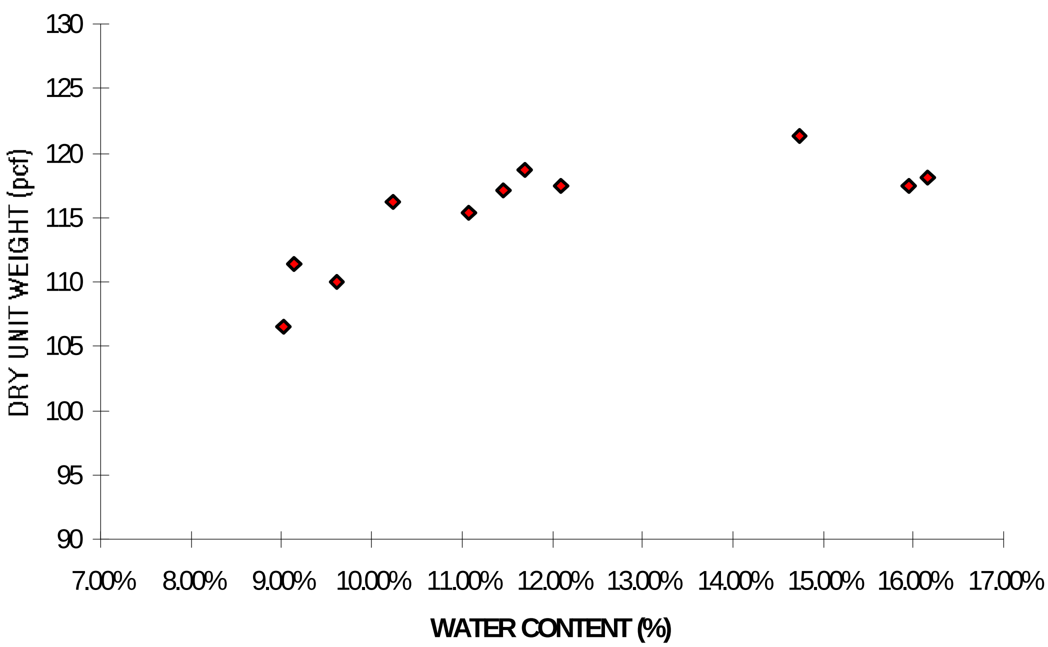
ALL SOILS - 35 DEGREE F RESULTS



ALL SOILS - 38 DEGREE F RESULTS



ALL SOILS -41 DEGREE F RESULTS



ALL SOILS - 71 DEGREES F RESULTS