RECLAIMED FLY ASH AS SELECT FILL UNDER PCC PAVEMENT

Sponsored by the Project Development Division
of the Iowa Department of Transportation
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CTRE Management Project 98-38

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ABSTRACT

With the support of the Iowa Fly Ash Affiliates, research on reclaimed fly ash for use as a construction material has been ongoing since 1991. The material exhibits engineering properties similar to those of soft limestone or sandstone and a lightweight aggregate. It is unique in that it is rich in calcium, silica, and aluminum and exhibits pozzolanic properties (i.e. gains strength over time) when used untreated or when a calcium activator is added. Reclaimed Class C fly ashes have been successfully used as a base material on a variety of construction projects in southern and western Iowa. A pavement design guide has been developed with the support of the Iowa Fly Ash Affiliates.

Soils in Iowa generally rate fair to poor as subgrade soils for paving projects. This is especially true in the southern quarter of the state and for many areas of eastern and western Iowa. Many of the soil types encountered for highway projects are unsuitable soils under the current Iowa DOT specifications. The bulk of the remaining soils are Class 10 soils. Select soils for use directly under the pavement are often difficult to find on a project, and in many instances are economically unavailable. This was the case for a 4.43-mile grading (STP-S-90(22)-SE-90) and paving project in Wapello County. The project begins at the Alliant Utilities generating station in Chillicothe, Iowa, and runs west to the Monroe-Wapello county line. This road carries a significant amount of truck traffic hauling coal from the generating station to the Cargill corn processing plant in Eddyville, Iowa. The proposed 10-inch Portland Cement Concrete (PCC) pavement was for construction directly on a Class 10 soil subgrade, which is not a desirable condition if other alternatives are available.

Wapello County Engineer Wendell Folkerts supported the use of reclaimed fly ash for a portion of the project. Construction of about three miles of the project was accomplished using 10 inches of reclaimed fly ash as a select fill beneath the PCC slab. The remaining mile was constructed according to the original design to be used as a control section for performance monitoring. The project was graded during the summers of 1998 and 1999. Paving was completed in the fall of 1999. This report presents the results of design considerations and laboratory and field testing results during construction. Recommendations for use of reclaimed fly ash as a select fill are also presented.

INTRODUCTION

Research on reclaimed hydrated class C fly ash as a construction material has been ongoing since 1991 with the support of the Iowa Fly Ash Affiliate Program. Reclaimed hydrated fly ash exhibits engineering properties similar to those of soft limestone or sandstone and a lightweight aggregate. The material has pozzolanic properties, gaining strength over time as long as free calcium is available.

Reclaimed hydrated fly ashes are produced at sluice pond disposal sites at generating stations burning sub-bituminous coals. Raw Class C fly ash is collected from the electrostatic precipitators at the power plant. If the supply of the raw fly ash exceeds demand, the excess raw fly ash is transported to the sluice pond or other disposal site. At a sluice pond site, the raw fly ash is dozed into the sluice pond where it hydrates to form a cementitious, solid mass in the sluice pond. To create a working platform where additional raw fly ash is spread, water is added, and the product is compacted. The raw fly ash hydrates and forms a solid mass. Once the ash has hydrated, it is reclaimed using conventional recycling-reclaiming equipment to pulverize the material. The reclaimed fly ash is then stockpiled on site, ready for use as a construction material. Table 1 presents fly ash sources in Iowa, and the estimated ash production for each facility.

TABLE 1 Iowa Fly Ash Sources and Ash Production

Fly Ash Source	Ash Type	Raw Ash Production (tons/year)	Reclaimed Ash Status
Ames	C	10,000	Potential
Clinton	F	15,000	NA
Council Bluffs	C	100,000	Active
Cedar Rapids	C	30,000	Active
Bettendorf	C	25,000	Active
Burlington	C	25,000	Active
Ottumwa	C	100,000	Active
Lansing	C	40,000	Potential
Louisa	C	120,000	Active
Marshalltown	C	10,000	Active
Sioux City (units 2, 3 & 4)	C	150,000	Active

Reclaimed fly ash has successfully been used as pavement base materials or as a select fill on a variety of construction projects in southern and western Iowa. A pavement thickness design guide has been developed through research at Iowa State University (ISU) supported by the Iowa Fly Ash Affiliate Program (1). In 1994, a test road was constructed in Marshalltown, Iowa, at the Sutherland Power Plant (2). The road is an access road to the power plant, and consists of an 11-inch cement kiln dust (CKD) and atmospheric fluidized bed combustion (AFBC) activated reclaimed fly ash base with a double sealcoat surface. The road is performing well, and is being monitored yearly. In 1995, a half-mile test road was constructed near Ottumwa, Iowa, using a CKD and AFBC activated reclaimed fly ash, topped by a 1 1/2 inch asphalt surface (3). This road primarily carries semi-truck traffic in and out of the Ottumwa-Midland Landfill. Yearly performance evaluations are conducted on the road, and thus far, the road has been performing very well.

When combined with a calcium activator, the reclaimed fly ash performs similalyr to a low strength concrete as a rigid base material. Although there are applications for this type of material, this project focuses on using reclaimed fly ash by itself, without a calcium activator, to perform as a select fill material.

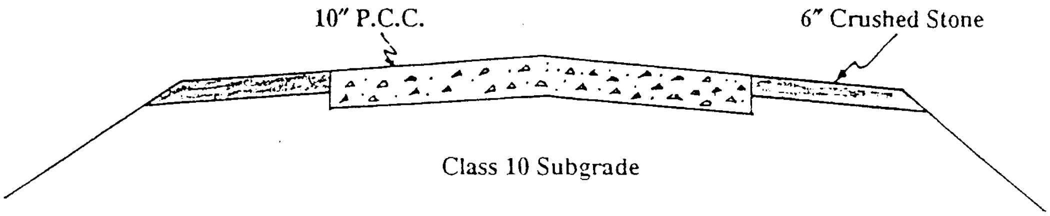
In general, soils in Iowa rate in the fair to poor range as subgrade soils for paving projects. Many soils encountered for highway construction in Iowa are considered as unsuitable under Iowa Department of Transportation (Iowa DOT) specifications, with the majority of the remaining soils being Class 10 soils. In many instances, select soils, and even suitable soils, are difficult to find on a project, and may not be economically feasible. This is the case on a 4.43 mile grading and paving project in Wapello County.

This project begins at the Alliant Utilities generating station in Chillicothe, Iowa, and runs west to the Monroe-Wapello county line. The road will carry a significant amount of semi-tractor trailer traffic hauling coal from the generating station to a Cargill corn processing plant in Eddyville, Iowa. Select subgrade soils are not available on site; thus the pavement was to be constructed directly on a Class 10 subgrade. This situation is not desirable if other alternatives are available. The Wapello County engineer supported the use of reclaimed fly ash as a select fill material for a portion of the project. Approximately 3.1 miles out of the 4.43-mile project were constructed with 10 inches of reclaimed fly ash select fill beneath 9 1/2 inches of PCC pavement. The remainder of the project was constructed using typical construction practices, utilizing the Class 10 soils on site, and serves as a control section for performance evaluation.

The reclaimed fly ash was constructed 12 inches thick and full width (49 feet) during the grading process. After compaction of the reclaimed fly ash fill, a two- to three-inch thick temporary surfacing of crushed limestone was placed. Prior to paving, approximately two inches of the reclaimed fly ash fill were trimmed to be used for shouldering material, leaving approximately ten inches of select fill to support the pavement. Pavement thickness designs conducted by the Iowa Concrete Paving Association resulted in an allowable thickness reduction from 10 to nine inches using reclaimed fly ash select fill. The Wapello County engineer elected to use a 9 1/2-inch slab as a conservative approach. A graphical representation of the original design, and the design utilizing reclaimed fly ash is shown in Figure 1.

The reclaimed fly ash fill was constructed in one 12-inch thick lift, using a sheepsfoot roller for initial compaction. A steel or pneumatic wheel roller was used for final compaction to create a smooth surface. The reclaimed fly ash fill was specified to be compacted at ± 2 percent of the Standard Proctor optimum moisture content to 90 percent of Standard Proctor density for the bottom six inches, and 95 percent of Standard Proctor density for the top six inches.

As Designed



As Proposed

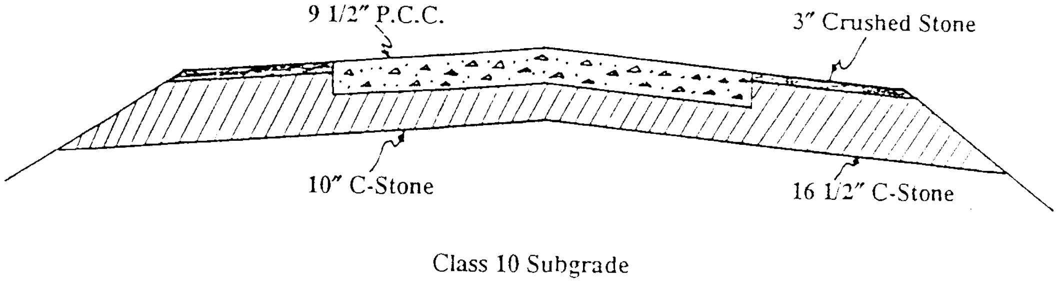


FIGURE 1 Original and Proposed Design

TESTING PROGRAM

Pre-Construction Testing

In September 1998, ISU personnel collected samples of reclaimed hydrated fly ash from the Ottumwa Generating station sluice pond site. A backhoe was used to dig to a depth of 10 feet into the reclaimed ash, with samples being taken at three different depths. The samples that were collected were returned to the laboratory for moisture content determination and Standard Proctor testing. The data collected from these initial tests were used to determine general variability of the material, and give initial estimates of required density and moisture content based on the construction specifications. Table 2 summarizes the pre-construction test data.

TABLE 2 Pre-construction Test Data

Depth (feet)	In-Place Moisture Range (%)	Optimum Moisture Range (%)	Maximum Dry Density Range (lb/ft^3)
1-4	19-26	25-28	90-95
4-7	26-35	28-32	82-90
7-10	28-37	29-32	85-89

Construction Testing

Standard Proctor Testing

One-point Standard Proctor testing was conducted daily to monitor variations in the reclaimed fly ash as the reclaiming depth increased. The testing was run in accordance with ASTM D698 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort, except the compaction samples were run at the moisture content at which they were collected, and only one compactive trial was made. Because a full suite of Standard Proctor testing was completed prior to the actual construction, ranges of optimum moisture content and maximum dry unit weight were already known. Knowing the general compaction characteristics, the one-point Proctor tests were used to monitor daily variation of moisture content and dry unit weight. A summary of the results is presented in Table 3. A summary of all of the individual test data is given in the appendix.

TABLE 3 Standard Proctor Testing

Construction Period	Total Number of Tests	Average Standard Proctor Dry Unit Weight (lb/ft^3)	Moisture Content (%)
Fall 1998	19	94.7	23.8
Standard Deviation		1.8	1.8
Summer 1999	22	93.7	24.0
Standard Deviation		2.5	2.9
Overall Average	41	94.2	23.9
Overall Standard Deviation		2.2	2.5

Moisture Content Testing

Moisture content determinations were made at least once daily during construction of the test road to ensure that the moisture content was within the specified range. During construction in the fall of 1998, moisture control was not a large problem. The fly ash that was reclaimed was near the optimum moisture content and no water had to be added. During construction in the summer of 1999; however, the in-situ moisture content of the hydrated fly ash was well below the optimum moisture content, and water had to be added to the material to increase the moisture content to near optimum. The in-situ moisture content of the hydrated fly ash during the summer of 1999 remained around 18–19 percent. With an optimum moisture content near 24 percent, a large volume of water needed to be added to the reclaimed fly ash to increase the moisture content into the specified range. The average moisture contents of the reclaimed fly ash as placed are presented in Table 4. The moisture contents were determined using an electric burner. Several tests were run using a microwave to dry the reclaimed fly ash, but the microwave method produced moisture contents that were consistently lower than those obtained from both laboratory ovens and the electric burner. A complete tabulation of each moisture content determination during the construction periods is given in the appendix.

TABLE 4 Moisture Content of Reclaimed Fly Ash as Placed

Construction Period	Total Number of Tests	Moisture Content (%)
Fall 1998	26	23.0
Standard Deviation		1.6
Summer 1999	48	23.0
Standard Deviation		2.8
Overall Average	74	23.0
Overall Standard Deviation		2.4

Particle Size Analyses

Wet sieve analysis tests were conducted daily during the construction periods to monitor changes in the gradation of the reclaimed fly ash. A summary of the results of particle size analyses completed during construction is given in Table 5. The strength of cementation of the reclaimed ash to form clods is highly variable, and the gradation becomes finer when compacted. The particle size analyses testing was not completed to represent the gradation of the material as placed, but rather as a means to asses the variability of the material as it is produced. Although there were significant daily variations in gradation (full daily results are tabulated in the appendix), the average gradations for each of the two construction periods are very consistent.

TABLE 5 Particle Size Distribution of Reclaimed Fly Ash

Construction Period	Total Number of Tests	Percent Passing Sieve						
		1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8
Fall 1998	11	89.5	83.1	75.5	67.5	58.5	41.7	27.6
Standard Deviation		5.3	7.0	8.3	8.9	8.9	8.5	6.7
Summer 1999	21	90.7	82.0	72.2	62.7	53.3	36.9	25.0
Standard Deviation		4.3	6.0	6.8	6.3	6.9	7.2	7.1
Overall Average	32	90.3	82.3	73.3	64.4	55.1	38.5	25.9
Overall Standard Deviation		4.6	6.3	7.3	7.2	7.6	7.7	6.9

Rubber Balloon Compaction Testing

Density tests were completed on the reclaimed ash test sections shortly after completion of sheepsfoot rolling in accordance with ASTM D2167. All results are presented based on a Standard Proctor maximum dry unit weight of 98 pounds per cubic foot, which is the highest dry unit weight obtained from all compaction tests. The selection of 98 pounds per cubic foot as the maximum dry unit weight is a conservative approach. The maximum dry unit weight of the reclaimed ash was seen to vary, but there is no trend in the variation; therefore a single value of maximum dry unit weight was selected to compute compaction at each test location. A summary of the compaction test results is presented in Table 6. Overall, good compaction was achieved, with an average of 95.9 percent of Standard Proctor compaction achieved for the top six inches and 90.4 percent of Standard Proctor achieved for the bottom six inches. The average moisture content was lower in the summer 1999 construction period due to seasonal variation and the need to add water to the reclaimed ash to facilitate compaction. The reclaimed fly ash dried very quickly under the summer heat if not immediately compacted, thus keeping the material in the optimum moisture range was very difficult during warm, dry periods of the construction season. A tabulation of individual test results is given in the appendix.

TABLE 6 Summary of Rubber Balloon Compaction Tests

Construction Period	Depth of Test	Total Number of Tests	g_d (pcf)	w (%)	Compaction (%)
Fall 1998	0"-6"	30	94.4	22.1	96.3
Standard Deviation			4.8	2.2	4.9
Summer 1999	0"-6"	80	93.8	20.8	95.7
Standard Deviation			3.6	2.9	3.7
Fall 1998	6"-12"	5	92.4	22.6	94.3
Standard Deviation			2.4	1.1	2.5
Summer 1999	6"-12"	18	87.5	21.7	89.3
Standard Deviation			3.0	1.9	3.0
Overall Average	0"-6"	110	94.0	21.2	95.9
Overall Standard Deviation			3.9	2.7	4.0
Overall Average	6"-12"	23	88.6	21.9	90.4
Overall Standard Deviation			2.9	0.2	2.9

Nuclear Densometer Compaction Testing

A nuclear densometer was also used to monitor compaction during construction of the test road. Density testing was conducted in accordance with ASTM D2922, and moisture testing was done in accordance with ASTM D 3017. The wet density results were generally slightly higher than the dry density determined using the rubber balloon method. The moisture content determined by the nuclear gauge was always much lower than the values obtained from moisture content determinations for the rubber balloon testing. The wet density value obtained from the nuclear densometer is believed to be slightly high because of high amounts of calcium in the material. Calcium absorbs more radiation than typical soil elements, which results in a wet density reading that is higher than the actual wet density. The density readings are only slightly higher than the actual density, and can be corrected without a large loss of precision. The variation in moisture content readings was random, with no clear trends. The mechanisms controlling this phenomena are uncertain. General experience has shown that small concentrations of certain elements such as boron and cadmium can greatly affect the moisture reading, but attempts to quantify the relationships have been unsuccessful (Donald Shanklin, Telephone Conversation, 1999). A summary of the data obtained from nuclear densometer testing is given in Table 7. Rubber balloon density tests were run at the same locations as the nuclear densometer tests, and a complete summary of results are given in the appendix. Because the rubber balloon density test directly measures the density of the material, the data obtained from those tests was used as a basis for compaction evaluation.

TABLE 7 Nuclear Densometer Test Results

Construction Period	Total Number of Tests	g (pcf)	g_d (pcf)	w (%)
Fall 1998	33	119.7	110.5	8.3
Standard Deviation		3.20	2.70	1.00
Summer 1999	75	114.9	105.5	8.9
Standard Deviation		4.0	3.3	1.2
Overall Average	108	116.4	107.0	8.7
Overall Standard Deviation		3.8	3.1	1.1

Dynamic Cone Penetrometer (DCP) Testing

Dynamic cone penetration (DCP) tests were conducted on freshly placed reclaimed fly ash to evaluate the short-term strength of the material. The dynamic cone penetrometer consists of a 20 mm diameter, 60^o cone mounted on a steel rod. A sliding mass of 17.6 pounds is dropped 22.6 inches to drive the cone into the test material. The number of hammer drops is recorded with respect to the depth of penetration of the cone. The numerical result of the DCP test is the DCP index, which is measured in millimeters of penetration per hammer drop. The DCP index has been correlated with California Bearing Ratio (CBR), and the DCP results presented herein are given in terms of the correlated CBR.

DCP testing was completed on the reclaimed ash fill at selected time periods after initial compaction to monitor strength gain of the reclaimed ash as a function of time. The reclaimed fly ash that was placed in the fall of 1998 was retested in the spring of 1999, approximately seven months after placement, and was tested again in the late summer of 1999, or approximately nine months after placement. The reclaimed ash that was placed during the summer of 1999 was tested prior to paving operations in the fall of 1999, about three to four months after placement. A summary of the DCP results on the reclaimed ash fill is presented in Table 8. Although the average CBR values for the reclaimed fly ash fill are very high at nine months and 3.5 months, these results can be misleading. There is very high variability in the DCP results as a function of time. For instance, the CBR values obtained from 0–6 inches in the reclaimed fly ash fill that was tested nine months after placement range from 14–182 percent. This variability will be discussed later, and can be seen by referring to the individual test results located in the appendix.

TABLE 8 DCP Test Results on Reclaimed Fly Ash Fill

Construction Period	Age when Tested (months)	Number of Tests	Avereage CBR from DCP Testing Reclaimed Ash Fill 0"-6"	 Reclaimed Ash Fill 6"-12"	 Subgrade Soils 0"-6"	 Subgrade Soils 6"-12"
Fall 1998	0	23	23.8	18.8	9.7	7.6
Standard Deviation			8.70	8.00	3.30	3.40
Fall 1998	7	28	57.1	34.3	20.5	8.8
Standard Deviation			16.2	18.2	17.5	3.4
Fall 1998	9	12	92.3	68.9	16.5	9.0
Standard Deviation			50.3	43.0	12.2	4.5
Summer 1999	0	79	34.0	30.5	21.9	12.6
Standard Deviation			19.9	17.3	12.8	8.2
Summer 1999	3.5	26	101.3	73.8	34.5	13.1
Standard Deviation			71.8	53.8	48.4	9.4

Strength gain of the reclaimed fly ash fill over time is shown in Figures 2 and 3. Figure 2 presents the strength gain data for material placed in October 1998, and Figure 3 presents data for material placed in July 1999. Both Figures 2 and 3 present the increase in the average CBR over time. Error bars are given for each data point and represent plus and minus one standard deviation from the mean and the high and low values obtained from each test set. An average strength gain of approximately 70 percent per month is seen in Figure 2, and an average gain of 60 percent per month is seen in Figure 3. Original laboratory testing on reclaimed fly ash at Iowa State University shows an approximate 70 percent per month strength gain under laboratory-cured conditions (1). The strength gain of the reclaimed fly ash in the field is seen to be nearly the same as that of the laboratory tests. A dormant period is depicted in Figure 2 that extends from the time of placement until approximately April 1999. This dormant period occurs because the ambient temperatures are too low for strength gain to take place in the fly ash. Fly ash needs available water and heat to gain strength. When temperatures are below freezing, pozzolanic reactions and strength gain stops, thus only minimal strength gain is expected between approximately October and late March in the Midwest because temperatures are frequently below freezing in this time period.

Dynamic cone penetration testing was also completed on the control section of the test project at different times of the year to determine the seasonal variation of CBR. The average DCP results for each test period are presented in Table 9. It is seen that the overall average CBR of the subgrade soils is 8.0 percent, with seasonal variation taking the CBR at the top six inches down to 4.2 percent. Many of the CBR values obtained are less than six percent, which is generally regarded as the minimum CBR to support construction equipment without rutting and shear failure of the subgrade soils (4).

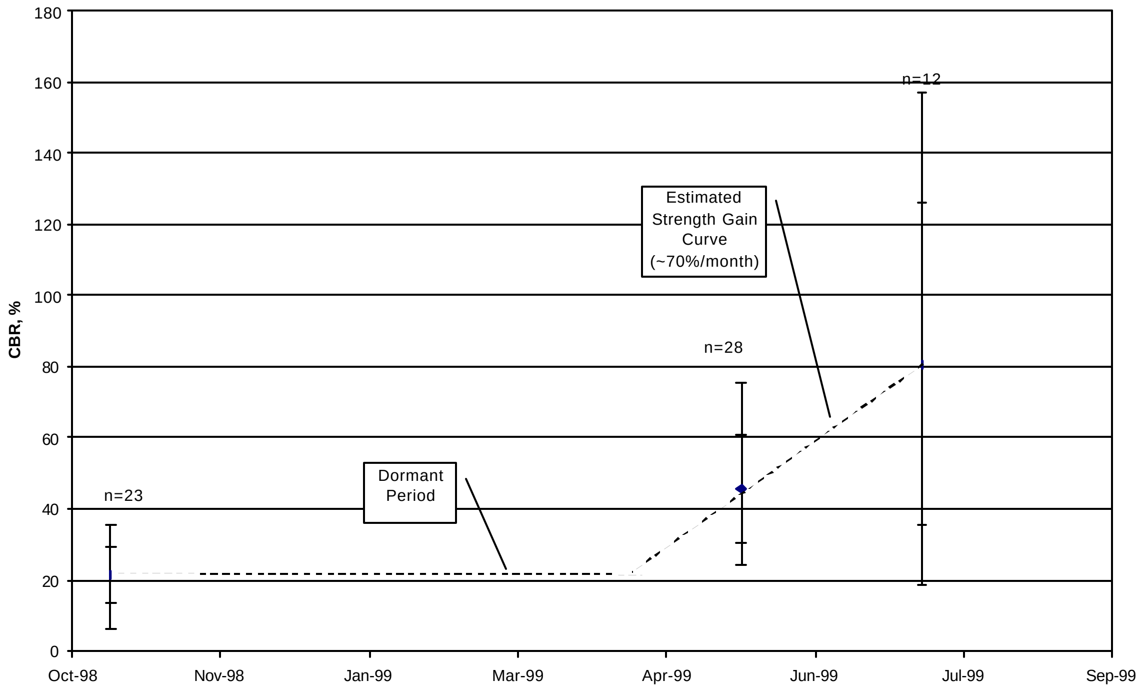


FIGURE 2 Strength Gain of Reclaimed Fly Ash Fill Placed in October 1998

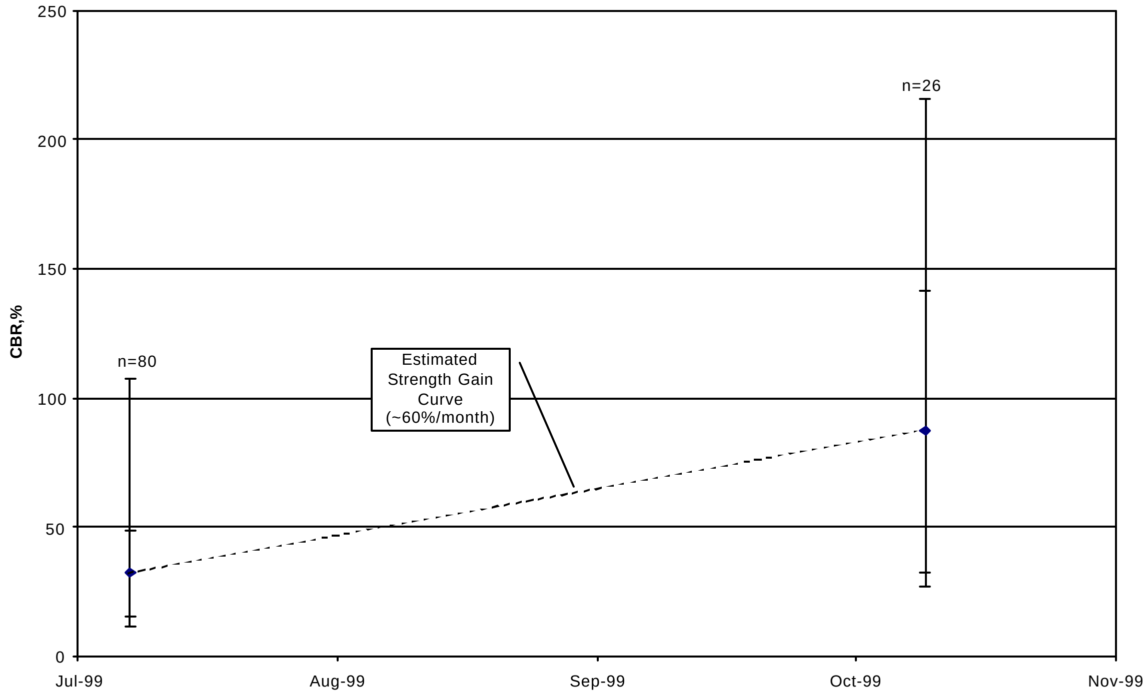


FIGURE 3 Strength Gain of Reclaimed Fly Ash Fill Placed in July of 1999

TABLE 9 DCP Test Results on Control Section

Time	Number of Tests	Average CBR from DCP Testing				
		0"-6"	6"-12"	12"-18"	18"-24"	Average
Late Fall 1998	22	5.0	7.2	9.5	9.7	8.0
Standard Deviation		2.0	2.9	4.0	3.7	2.7
Late Spring 1999	22	4.2	4.5	6.2	8.0	5.7
Standard Deviation		1.7	3.0	3.3	4.4	2.3
Late Summer 1999	8	19.8	16.1	13.0	9.3	14.5
Standard Deviation		5.5	5.6	5.9	4.7	4.1
Overall Average	52	6.9	7.4	8.6	8.9	8.0
Overall Standard Deviation		2.4	3.3	4.0	4.2	2.7

Field CBR Testing

Field CBR testing was completed on compacted reclaimed fly ash fill in the summer of 1999. All testing was done in accordance with ASTM D 4429, Standard Test Method for Bearing Ratio of Soils in Place, except a 76 pound per square foot surcharge was used over a six-inch diameter area surrounding the penetration piston. A summary of the individual CBR tests is given in Table 10. The average CBR obtained for the testing was 40.2 percent at 0.1 inches or 41.8 percent at 0.2 inches. Experience has shown that the CBR for reclaimed fly ash materials is often higher at 0.2 inches than at 0.1 inches. According to the ASTM standard the test should be rerun if this situation occurs, however, because of the frequency of occurrence, the tests were not rerun, and the CBR is reported at both 0.1 inches and 0.2 inches. The range in CBR at 0.2 inches for the reclaimed fly ash fill ranges from 19.7–86.3 percent, which is extremely high variation for any material. There are many possible explanations for this variation which will be discussed in a later section.

Preparation of the test area is a factor that is difficult to account for when running a field CBR on reclaimed fly ash fill. Per the ASTM standard, the loose, dry material was cleared away from the site before testing, but in many locations there appeared to be an intermediate layer between the loose, dry material and the moist, well compacted material. This intermediate layer was not easily broken up to remove the material prior to testing, yet it had a fairly low CBR. Because of these difficulties, a seating pressure of 25 pounds per square inch was used when seating the penetration piston in an effort to eliminate low CBR readings caused by the intermediate layer.

TABLE 10 Field CBR Test Results on Reclaimed Fly Ash Fill

Date	Station	Location	CBR at 0.100" (%)	CBR at 0.200" (%)
7/22/99	222+75	10' LT	26.7	23.4
7/22/99	224+50	10' LT	25.3	31.9
7/22/99	225+80	10' RT	53.4	86.3
8/2/99	168+20	15' RT	68.9	63.8
8/2/99	166+35	12' LT	50.6	52.5
8/2/99	164+50	8' RT	74.5	83.4
8/2/99	162+50	8' LT	54.8	53.4
8/3/99	160+50	15' RT	60.5	63.8
8/3/99	158+50	15' RT	39.4	48.8
8/3/99	156+50	12' LT	36.6	36.6
8/3/99	154+50	10' RT	50.6	52.4
8/3/99	152+50	10' LT	40.8	41.3
8/4/99	150+50	8' LT	22.5	20.6
8/4/99	148+50	12' LT	36.6	30.9
8/4/99	146+50	15' RT	29.5	27.2
8/4/99	144+50	7' LT	50.6	53.4
8/4/99	142+50	Centerline	36.6	32.8
8/4/99	140+50	Centerline	30.9	30.0
8/5/99	138+50	12' LT	30.9	32.8
8/5/99	136+50	10' RT	30.9	30.0
8/5/99	130+50	15' LT	29.5	25.3
8/5/99	128+50	8' RT	36.6	33.8
8/5/99	126+50	10' RT	26.7	27.2
8/5/99	124+50	Centerline	38.0	42.2
8/5/99	122+50	5' RT	26.7	25.3
8/9/99	134+50	15' RT	49.2	56.3
8/9/99	132+50	15' RT	43.6	54.4
8/9/99	120+50	15' RT	35.2	35.6
8/9/99	118+50	Centerline	28.1	24.4
8/10/99	116+50	10' LT	39.4	47.8
8/10/99	114+50	15' LT	53.4	68.4
8/10/99	112+50	15' RT	38.0	41.3
8/16/99	98+00	15' LT	48.1	25.3
8/16/99	102+30	15' RT	38.0	40.3
8/16/99	106+50	15' RT	43.6	42.2
8/16/99	110+50	12' LT	54.8	60.0
8/19/99	236+00	10' RT	25.3	22.5
8/19/99	234+00	5' LT	21.1	19.7
Averages			40.2	41.8
Standard Deviations			12.8	17.0

Clegg Hammer Testing

Laboratory Correlations A Clegg Impact hammer was used as another test to evaluate in-situ strength of the reclaimed fly ash fill. Clegg impact tests were run in accordance with ASTM D 5874, “Standard Test Method for Determination of the Impact Value of a Soil.” This test method utilizes a 4.5 kilogram hammer with a 50 millimeter diameter circular face that is dropped 450 millimeters. The hammer contains an accelerometer that measures the deceleration of the hammer when it impacts the material that is being tested. Four hammer blows are made, and the highest impact value, measured in tens of gravities, is called the impact value of that material.

Correlations exist between the impact value and CBR of a material, but the ASTM standard recommends running a calibration for each material to be tested with the Clegg hammer. A correlation was run for the Ottumwa reclaimed fly ash by compacting samples in six-inch diameter CBR molds, and performing an impact test on the sample in the mold. When the impact test was complete, an identical sample was prepared (same moisture content and compactive energy) and a laboratory CBR was run on the sample. A range of both moisture content and compaction was tested to determine a correlation between the impact value and CBR of the material. The correlation chart is shown in Figure 4. A 95 percent confidence level is shown in the chart, and is based on a standard deviation of 4.75.

Because the Clegg Impact test is a simple test to run, many trials were made on the test road, and estimations of the standard deviation were noted. For an impact value of 20, the standard deviation is around 2.0 for a four-test set, and for an impact value of 30, the standard deviation is around 4.0 for a four-test set. Using these values for standard deviation, a 95 percent confidence interval was established for the correlation between Clegg Impact value and CBR, which is illustrated in Figure 4. The variation of the impact values increases markedly as the impact value increases. At an impact value of 30, there is only 95 percent confidence that the actual CBR is in a range from 55–85 percent. This range is very high and indicates that a large number of tests should be run with the Clegg hammer to determine a representative impact value for the material.

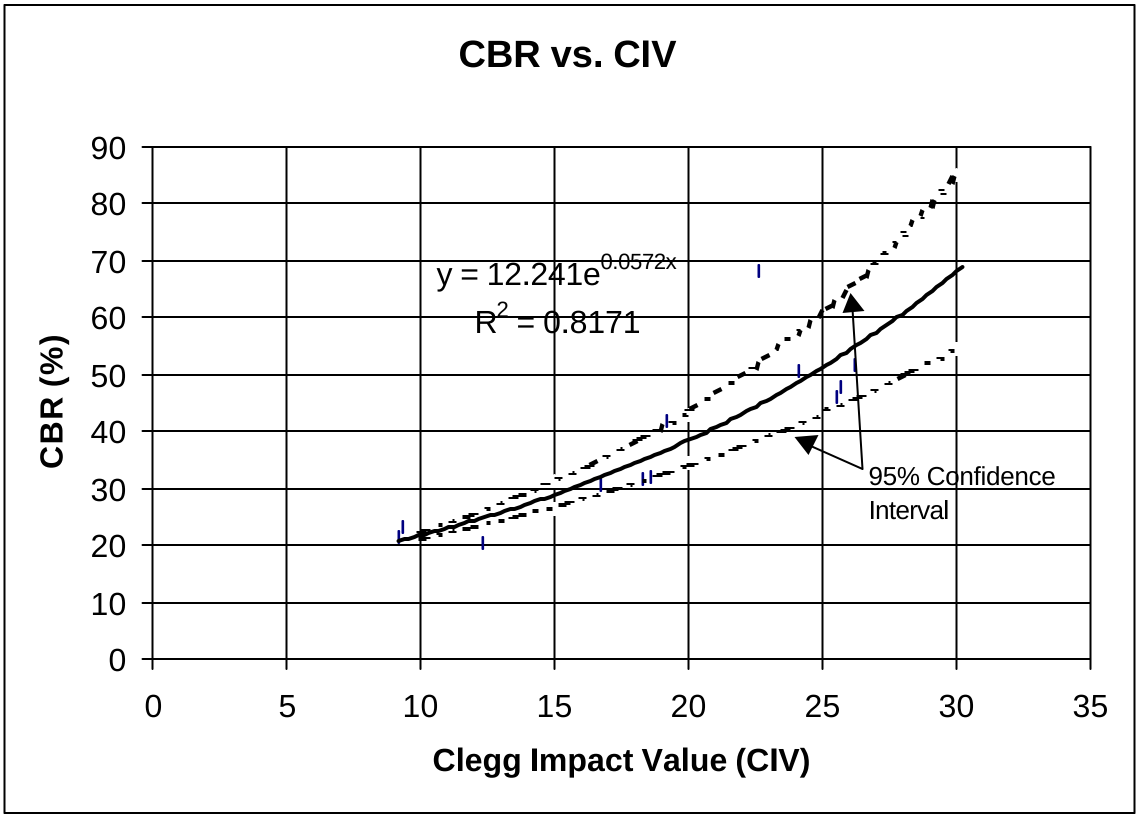


FIGURE 4 Clegg Impact Value Correlation Chart

Field Testing The Clegg hammer was used for testing during the fall of 1998 as an alternative means of evaluating the strength of the reclaimed fly ash fill. The Clegg hammer tests were run at random locations on the test road, and only one determination of impact value was made at each location. After analyzing the results, it was decided to run a series of four impact tests at each test location to gain a better understanding of the variability of the impact value in a very small area that should have similar properties.

Beginning in the summer of 1999 construction period, the Clegg hammer tests were run in series of four tests per location. The tests were run at the same locations that DCP tests, field CBR tests, and density tests were conducted in an effort to further define the interrelationships between the material properties obtained from each test. After analyzing the test data for the series of Clegg hammer tests, it was decided that the median value of the four tests would be used for correlation purposes. It was noticed that out of the four determinations of impact value, there were typically at least two values that were very similar, and at least one value that did not appear correct. By taking the median value of the four tests, the extremities obtained in some of the test sets are disregarded, and essentially an average of the two intermediate values is taken. The raw data for both the fall of 1998 and summer of 1999 construction periods is given in the Appendix. Table 11 presents the average impact values obtained from testing during the construction periods. It is seen that for a large number of tests, the median is approximately equal to the mean. For a small number of tests, however, the median is not always near the mean. From a practicality standpoint, it is believed that the median of a four-test set in one location is a good estimator of the impact value of the material.

TABLE 11 Average Impact Values from Clegg Impact Test

Construction Period	Number of Tests	Average Impact Value	Median Impact Value
Fall 1998	37	30.2	29.0
Standard Deviation		9.8	9.8
Summer 1999	312	30.7	30.9
Standard Deviation		9.7	9.9
Overall Average	349	30.6	30.7
Overall Standard Deviation		9.7	9.9

ANALYSIS OF TEST DATA

Testing of reclaimed fly ash fill and studying the applicability of different test methods utilized is a major component of this research. The field testing program for the reclaimed fly ash fill centers around four main objectives:

- determining applicability of nuclear densometer testing for compaction control of reclaimed fly ash fill
- determining the influence of moisture content and compaction on the strength of the fill material
- evaluating the validity and applicability of different test methods for determining in-situ strength parameters
- evaluating of short-term strength gain of the reclaimed fly ash fill.

Applicability of Nuclear Densometer Testing of Reclaimed Fly Ash Fill

As previously indicated, there is some type of anomaly that causes the nuclear densometer to incorrectly determine moisture content, but determine wet unit weight reasonably accurately. Figure 5 presents a graphical correlation between wet unit weight determined by a nuclear densometer and wet unit weight determined using the rubber balloon method. Although it seems there is a fairly good correlation in Figure 5, the sensitivity of the data must be taken into account. For the best-fit curve, there is approximately an eight pound per cubic foot spread (four pcf on either side of the curve), which is about seven percent variation. When selecting a test method for compaction control, this is too much variation. The nuclear densometer will give a reasonably close reading for total unit weight, but it is not accurate enough to warrant its use.

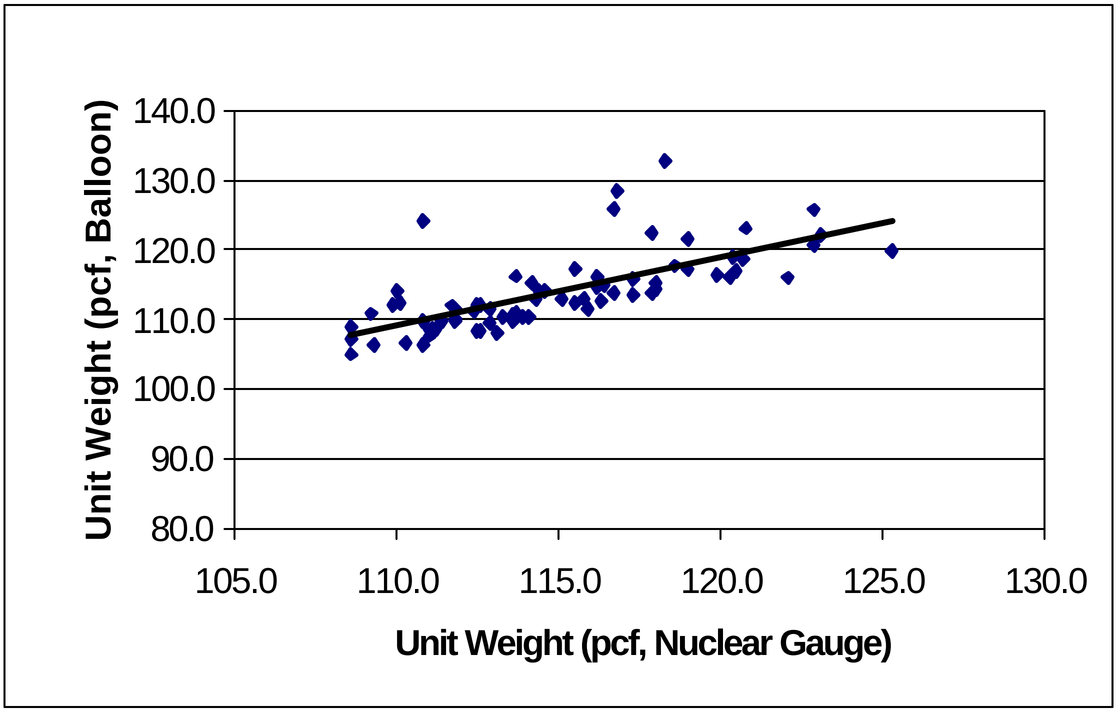


FIGURE 5 Nuclear Densometer Calibration Chart for Unit Weight

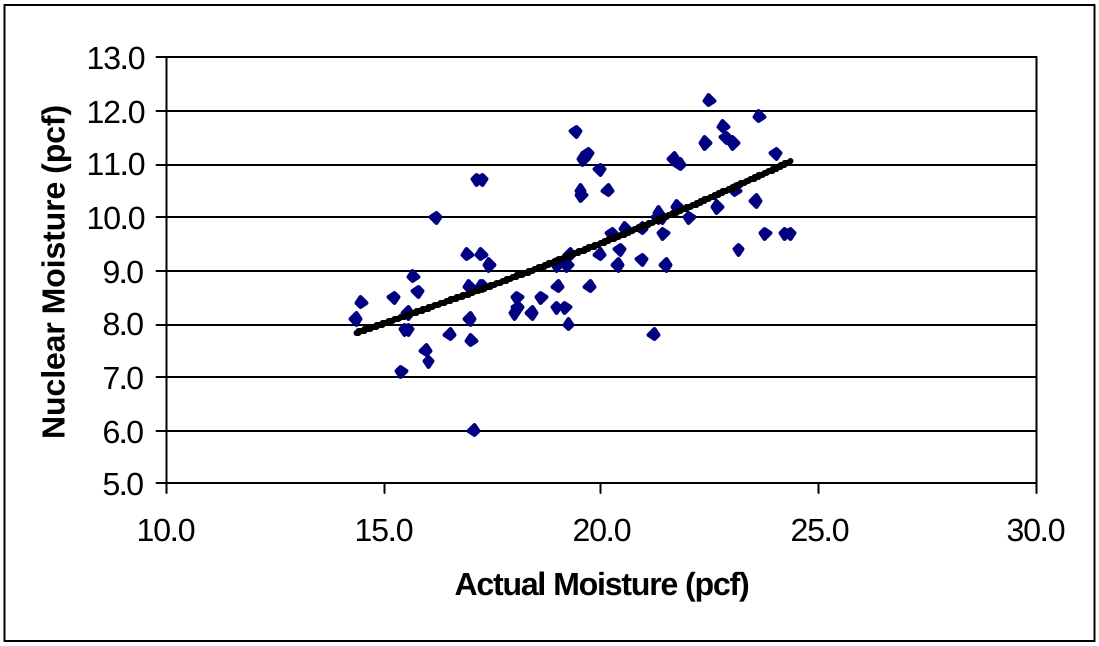


FIGURE 6 Moisture Content as Measured by Nuclear Gauge versus Actual Moisture Content

Figure 6 presents the data comparing moisture content in pounds per cubic foot of soil as measured by the nuclear densometer with the actual moisture content of the reclaimed fly ash fill. It is apparent that there is little relationship between the moisture measured by the nuclear densometer and the actual moisture content of the material. The nuclear densometer measures moisture content through the use of a fast neutron source and a slow neutron detector to determine the amount of hydrogen present in the material. Because the nuclear densometer is computing moisture contents that are lower than the actual moisture content, it appears that the hydrogen, and therefore the water, is being held by the material in a different form. It was hypothesized that the water held by the reclaimed fly ash, or the structural water, was not being measured by the nuclear gauge. Extensive moisture content testing of the reclaimed fly ash material was completed in an attempt to determine how the moisture held by the material behaves. For natural soils, the structural water is burned off at temperatures higher than 60^o Celsius. Under the assumption that the structural water of the reclaimed fly ash behaves the same as that of natural soils, moisture content determinations were made at both 60^o and 110^o Celsius to determine the amount of structural water and the amount of total water contained in the material. From this testing, the structural water was found to only be around one to two percent of the dry weight of the material, while the total moisture content was in the range of 20–30 percent of the dry weight. Hygroscopic moisture content determinations on the same material revealed that there is only about four percent hygroscopic moisture held by the reclaimed fly ash.

These moisture content determinations disprove the hypothesis that the nuclear gauge is only measuring the free water of the reclaimed fly ash. The anomaly therefore seems to stem from the elemental and compound structure of the reclaimed fly ash material, and the interaction of the fast neutrons with the structure of the reclaimed fly ash. At this point, it is still uncertain how the fast neutrons are being affected by the chemical composition of the reclaimed fly ash, and therefore it is uncertain exactly why the moisture readings are so greatly affected.

Strength Testing of Reclaimed Fly Ash Fill

Dependence of Strength on Compaction and Moisture Content

The strength testing results of the reclaimed fly ash fill conducted on the test road were reported previously. The three methods that were used to evaluate the strength of the fill material were the Dynamic Cone Penetrometer (DCP), the field CBR, and the Clegg hammer. These tests were all conducted at locations where density and moisture content data were available to determine relationships between dry unit weight, moisture content, and in-situ strength of the material. The data presented in this section are only the data obtained from the summer of 1999 construction period. The data obtained during the summer of 1999 consisted of a suite of different tests all conducted at the same location, whereas the data obtained in the fall of 1998 consist of different tests at different locations.

For the testing that was completed, there appears to be some relationship between dry unit weight and strength, although it is not a strong relationship. There does not appear to be any kind of relationship between moisture content and strength. The data presented in Figure 7 represent the relationship between dry unit weight and average DCP index for the top six inches of reclaimed fly ash fill. It is obvious that the DCP index is inversely proportional to the dry unit weight, but there is not a strong correlation.

The data in Figure 8 presents the relationship between field CBR and dry unit weight. In general, the field CBR is seen to increase with dry unit weight, but there is not a strong correlation. Figure 9 presents the relationship between the median Clegg hammer impact value and dry unit weight. It is again seen that a strong correlation does not exist, but that the impact value generally increases with dry unit weight.

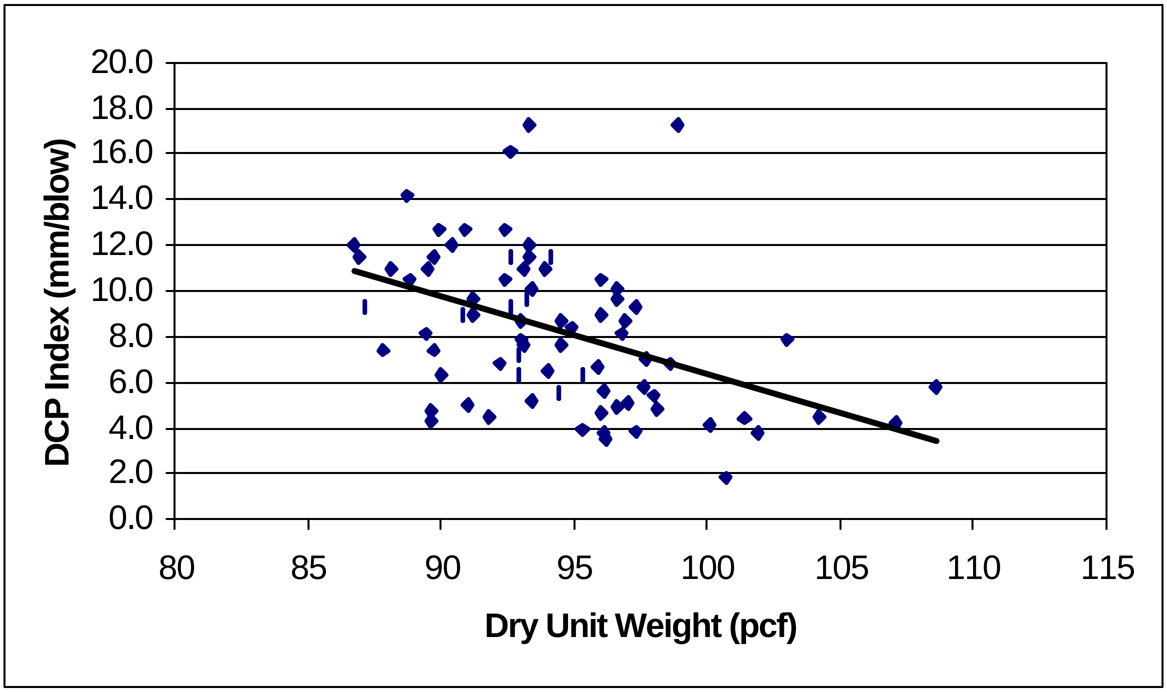


FIGURE 7 DCP Index versus Dry Unit Weight

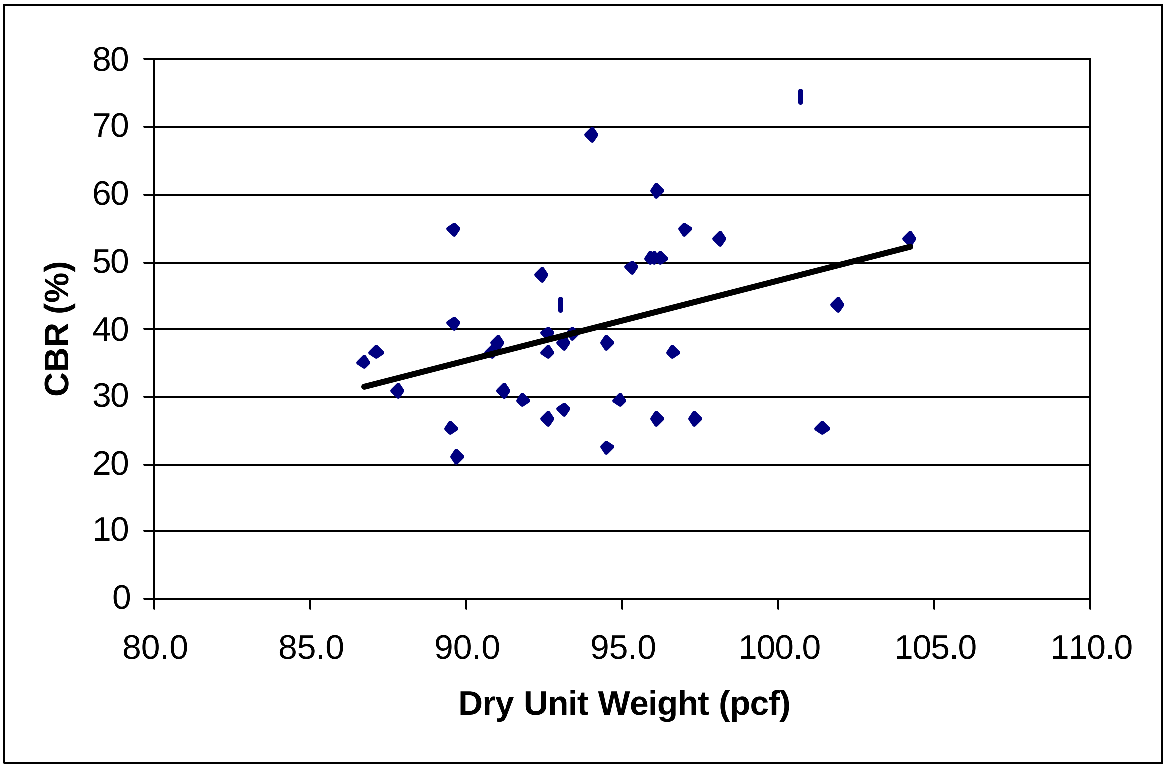


FIGURE 8 Field CBR versus Dry Unit Weight

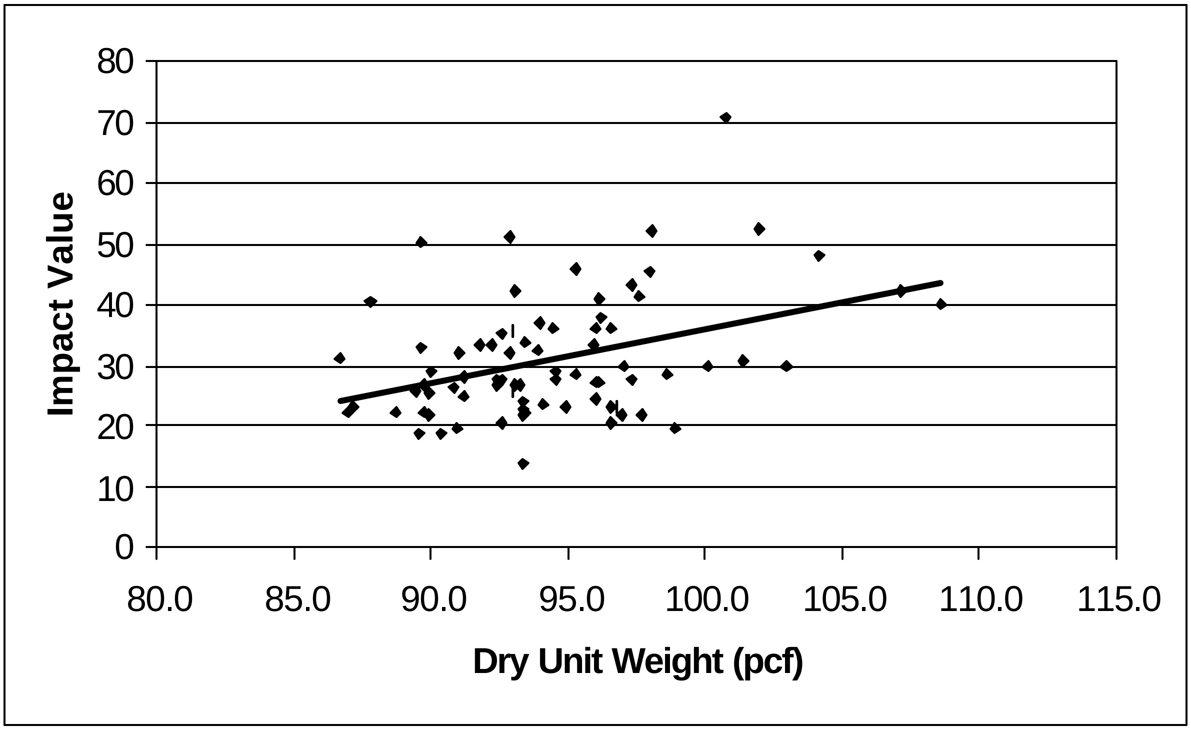


FIGURE 9 Clegg Impact Value versus Dry Unit Weight

Moisture content has very little direct influence on strength parameters of the reclaimed fly ash fill. The moisture content of the material at time of compaction is one of the variables that will control the strength gain of the material, but by itself, moisture content does not control the strength parameters. When the moisture content at time of compaction is near the optimum moisture content, the material will compact easier, and typically is compacted more than material that is not in the optimum moisture content range. It has already been shown that dry unit weight has an effect on strength, and since moisture content is one of the factors that will control the dry unit weight obtained from compaction, moisture content is an indirect component of strength. The data presented in Figure 10 demonstrate that moisture content of the reclaimed fly ash fill has little effect on the DCP index, where the DCP index is an average over the top six inches of reclaimed fly ash fill. Figure 11 demonstrates the effect of moisture content on field CBR, and Figure 12 demonstrates the effect of moisture content on Clegg Impact Value. It can be seen in Figures 10, 11 and 12 that the moisture content does not have a consistent effect on any of the strength tests, but generally shows random scatter.

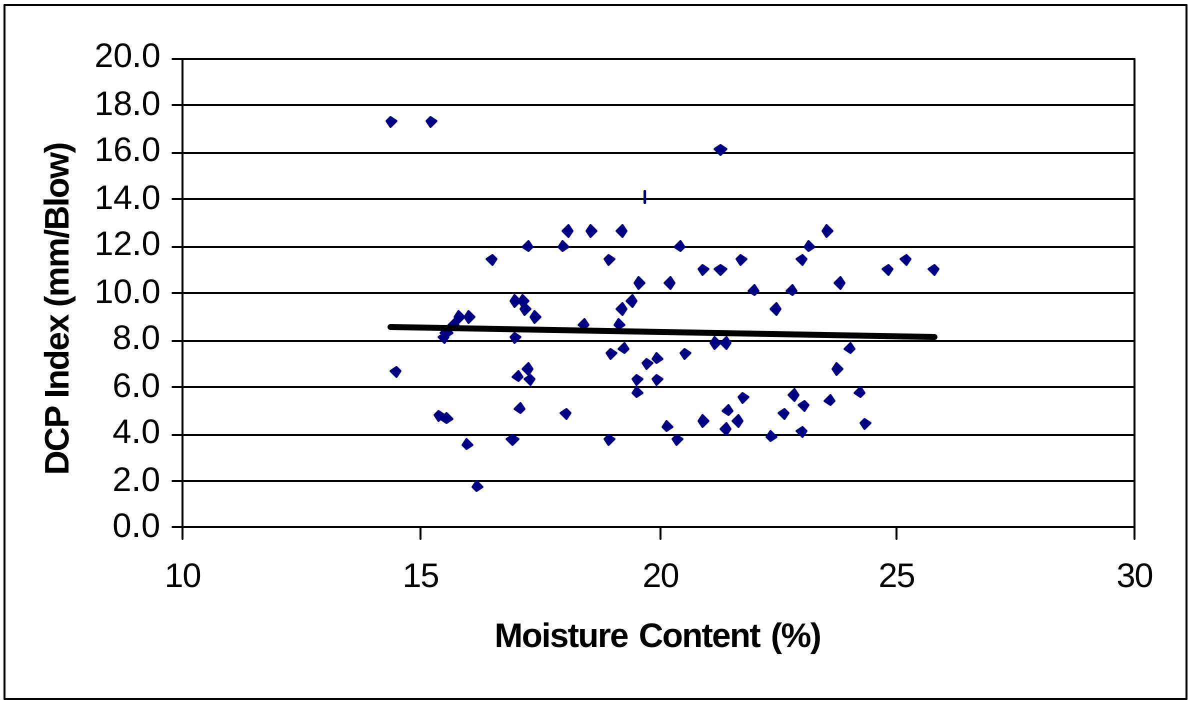


FIGURE 10 DCP Index versus Moisture Content

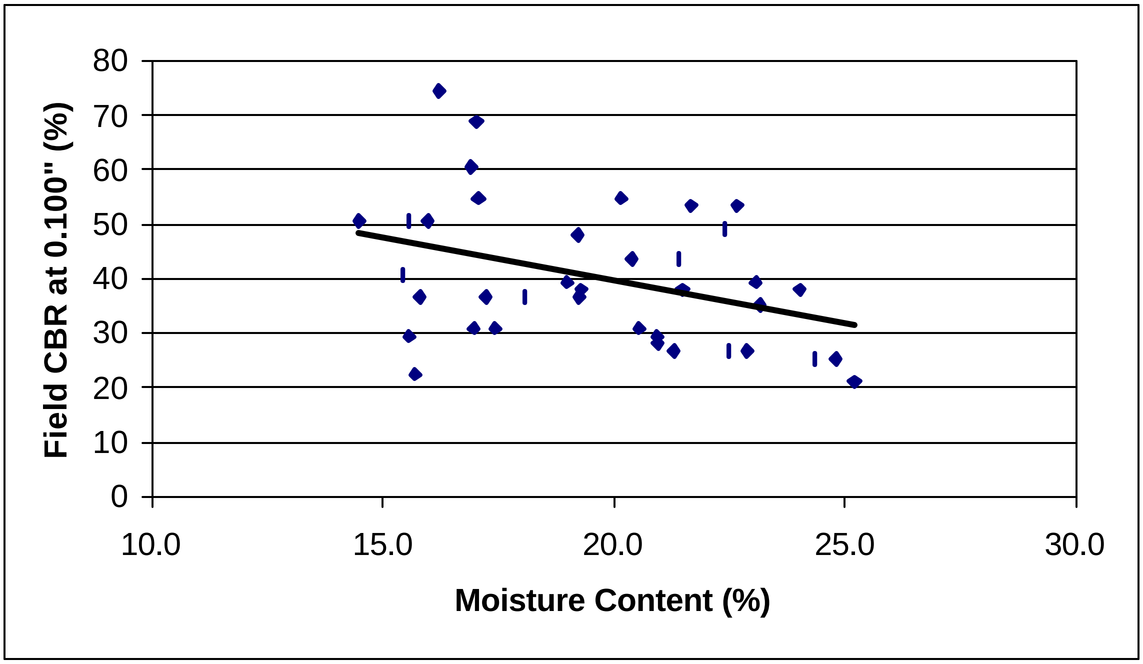


FIGURE 11 Field CBR versus Moisture Content

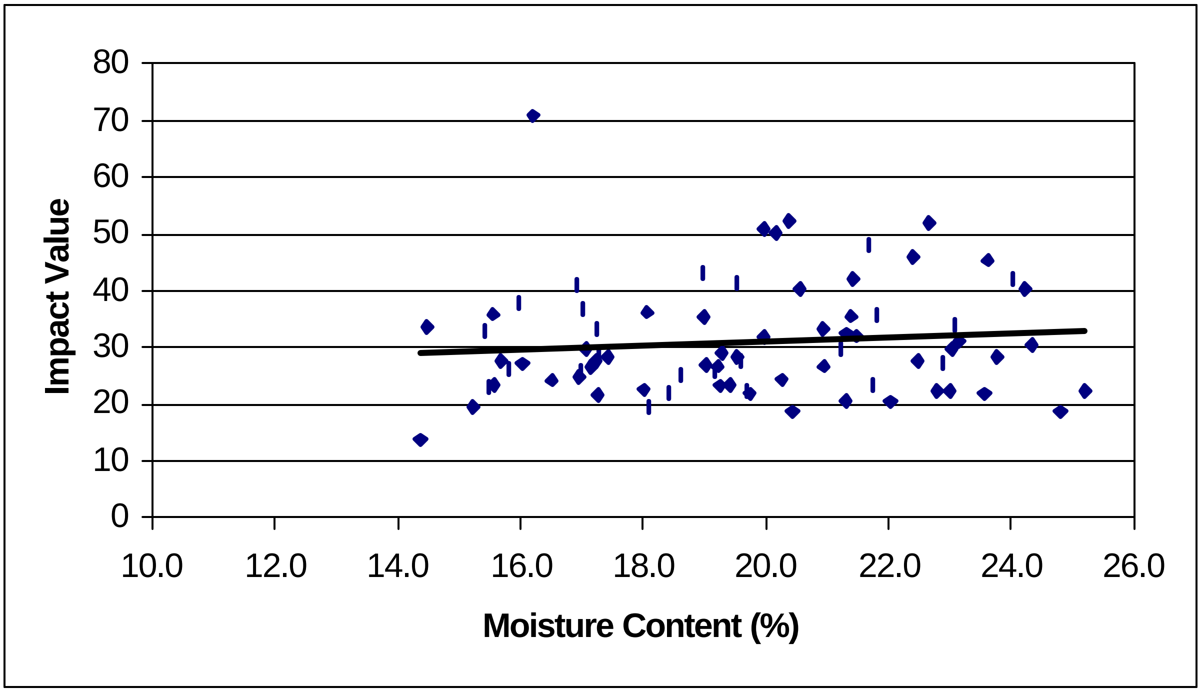


FIGURE 12 Impact Value versus Moisture Content

Evaluation of Strength Tests

The tests that were used to evaluate in-situ strength of the compacted fly ash fill range from the simple Clegg hammer, which can be completed in around one minute, to the field CBR that takes nearly a half-hour to complete. The CBR test is the most widely accepted test as it has a relatively long history, and most pavement design methods utilize the CBR. Because the CBR is so popular but time consuming to run, many simpler tests such as the Clegg hammer and DCP have been correlated to CBR. It is therefore of interest to determine both quantitatively and qualitatively how the Clegg hammer and DCP tests compare to the CBR test. The test results from each set of tests will first be compared to determine if there are any correlations between methods, and then the methods will be qualitatively analyzed in an effort to determine which methods give the most relevant, reliable data.

The first relationship to be analyzed is that between the field CBR and DCP index. For this evaluation, the DCP index is averaged over the top 4.5 inches of reclaimed fly ash fill. A depth of 4.5 inches was chosen because it is the height of sample used for a laboratory CBR test. In reality, the top one-half inch of the material would likely have the greatest influence on CBR, with the influence decreasing with depth. Although the average DCP index taken over 4.5 inches does not likely accurately represent the same zone the CBR test utilizes, it is believed that the material is consistent enough in this shallow range to negate any effects due to depth. The relationship between CBR and DCP is shown in Figure 13. The curve represented by the equation $y=82.817x^{-0.4088}$ represents the best-fit curve for the data set. The curve represented by the equation $y=292x^{-1.12}$ is the standard correlation supplied with the DCP equipment and used by the Corps of Engineers. It is obvious that there is a lot of scatter, and that neither curve depicts a strong correlation between CBR and DCP index.

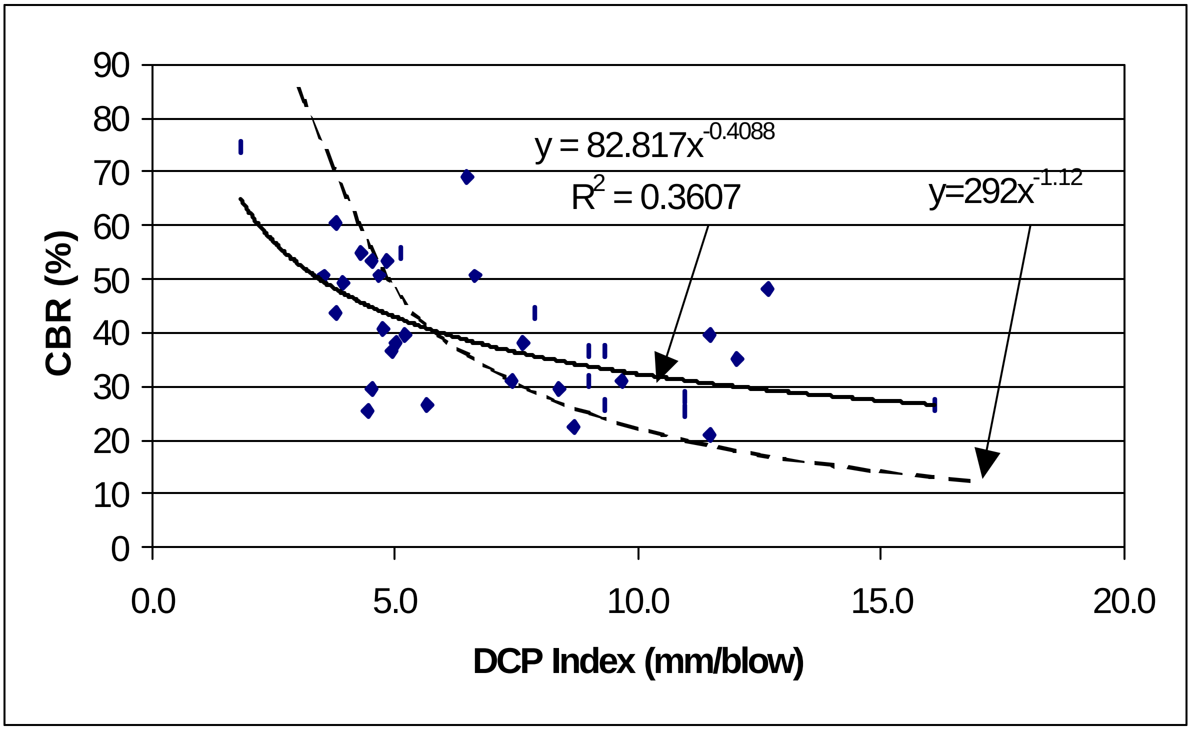


FIGURE 13 Field CBR versus DCP Index

The next relationship is that between field CBR and the impact value of the reclaimed fly ash fill as determined by a Clegg Impact hammer. The data presented in Figure 14 represent the field CBR as a function of the median Clegg impact value of the reclaimed fly ash fill. The curve representing the equation y=0.8783x+10.186 is the best-fit line for the data set. The curve of $y=0.07x^2$ represents the standard correlation given on the literature accompanying the Clegg Hammer equipment. The best-fit line equation for this data set gives a reasonably good correlation, but there is too much scatter in the data to determine a CBR value from Clegg hammer results with the precision that is required for pavement design. The curve on the plot of $y=12.241e^{0.0572x}$ represents the equation obtained from the laboratory calibration. It is seen from the curves on the plot that the equations obtained from the laboratory calibration and the Clegg hammer literature are not valid for field conditions.

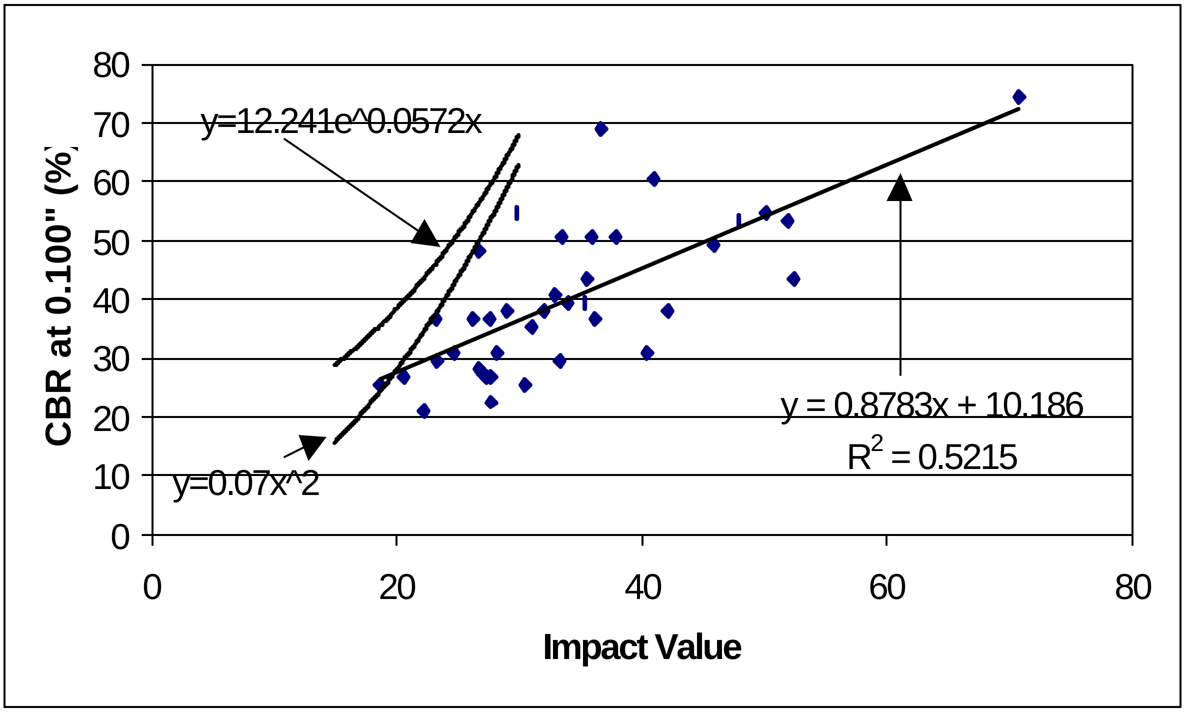


FIGURE 14 Field CBR as a Function of Impact Value

The reasons for the large difference between the laboratory calibration and actual field testing are at this point unknown. The major difference, and probably the controlling factor, is the type of compaction. In the field, a padfoot roller was used for initial compaction, followed by a rubber-tire roller to smooth the surface. In the laboratory, a Proctor hammer was used for compaction. The padfoot roller provides some kneading action on the fill material whereas the Proctor hammer imparts essentially only dynamic compaction on a specimen. The other difference between laboratory and field conditions is the use of a mold while testing. When the laboratory calibration was completed, the samples were tested in a CBR mold. Because the samples were compacted in mold, the compaction characteristics may be different than those obtained in the field, causing the tests to have different effects under the different situations.

The relationship between DCP index and impact value is presented in Figure 15. The DCP index is averaged over a 4.5-inch depth as in previous examples. There is a reasonably good correlation between DCP index and impact value, which is logical because both test methods utilize dynamic masses to determine strength parameters. The difference in the test methods is the depth of testing. The DCP test results in a continuous profile with depth, while the Clegg hammer only tests at the surface.

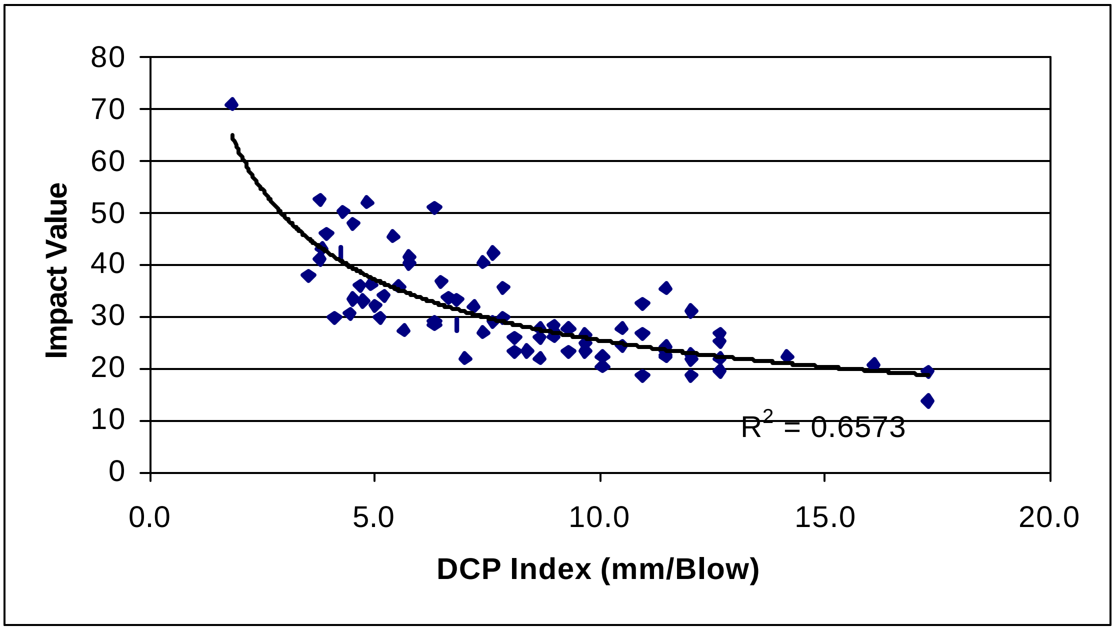


FIGURE 15 Clegg Impact Value as a Function of DCP Index

Each type of strength test that was utilized on the test road for this project has advantages and disadvantages. Out of the three types of tests that were completed, the field CBR test is generally the most accepted method. The main drawbacks for the field CBR are equipment cost and test time. A reaction frame, generally a heavy truck, and instrumentation such as dial gauges, jacks, and penetration pistons are necessary to run a field CBR test. A field CBR test takes a minimum of a half-hour to complete, so extensive testing is typically not economically feasible. From the field CBR data obtained on the test road, it is also seen that there can be rather high variability with the method, and that a number of tests are required to determine a representative CBR value for the material. The CBR test is only influenced by material in the top few inches of the strata. To collect deeper than approximately four or five inches, an area on the site must be cleared off to the depth in question, and another CBR test run.

The DCP test ranks between the field CBR and the Clegg Hammer test for test time and cost. The DCP equipment is relatively inexpensive, and a complete test can be finished in less than 10 minutes, allowing for many tests to be run over the period of a day. The principal advantage of the DCP test is that it results in a continuous strength profile with depth, at depths up to three feet. Being able to obtain strength data up to three feet in depth is very valuable when assessing subgrade conditions, and the effect of subgrade structural support for the base course. There is some variability with the DCP test, but the variability is offset by the simplicity of the test.

The simplest and least time consuming test is the Clegg hammer test. A single determination of impact value using the Clegg hammer takes around one minute, so an extremely large number of tests can be run in a short period of time. As previously discussed, the Clegg hammer results can be extremely variable over a short area, thus multiple determinations of impact value should be used when evaluating a material.

Each of the testing methods has ideal usage conditions. The field CBR is best utilized when definitive data str needed, and time and cost is not an object. A number of CBR tests can be run on the material to establish a working range, and designs can be completed from this data. The DCP test is an extremely good tool for quality control and forensic investigations. Because the DCP test gives a profile of strength with depth, problem areas such as soft spots in the profile can be easily identified. The DCP test can be used to easily determine if the actual strength of the material is near the expected strength. Reasonable results can be expected from Clegg hammer testing if a large enough set of tests is run. Because the Clegg hammer is a simple test to run, it is a good tool to use when quick, approximate determinations of field CBR are needed.

CONSTRUCTION

Fall 1998 Construction

Construction of the test road using reclaimed fly ash fill began on October 16, 1998. A total of 11 working days were used to construct a one-mile portion of the test road from station 0+00 to station 56+00. The production for the fall 1998 construction is summarized in Table 12. A total of 16,510 tons of reclaimed fly ash were placed, slightly higher than the 16,000 ton estimate. The peak production for this period was 7.6 stations, or 2,240 tons, which was placed on October 29. An average of 5.1 stations, or 1,500 tons, was constructed per day for this construction period.

TABLE 12 Fall 1998 Reclaimed Fly Ash Construction

Date	Day	Daily Tons	Approximate Location	Approximate Stations Constructed
10/16/98	Friday	320	53+00 - 54+00	1.1
10/19/98	Monday	0	-	-
10/20/98	Tuesday	825	54+00 - 56+00 52+00 -53+00	2.8
10/21/98	Wednesday	2160	45+00 - 52+00	7.3
10/22/98	Thursday	1990	38+00 - 45+00	6.8
10/23/98	Friday	2071	31+00 - 38+00	7.0
10/24/98	Saturday	1731	25+00 - 31+00	5.9
10/26/98	Monday	1266	21+00 - 25+00	4.3
10/27/98	Tuesday	1435	16+00 - 21+00	4.9
10/28/98	Wednesday	1343	11+00 - 16+00	4.6
10/29/98	Thursday	2240	3+00 - 11+00	7.6
10/30/98	Friday	1129	0+00 - 3+00	3.7
	Total	16,510 Tons		56.0 Stations

Construction began at station 56+00 and proceeded west to station 0+00, located at the intersection of Power Plant Road and County Line Road. It was decided prior to construction to construct the road in this direction, allowing the loaded haul trucks to operate over completed sections of the reclaimed fly ash fill, possibly providing extra compaction. The haul units used to transport the reclaimed fly ash fill to the site were semi-tractors with belly dump trailers, weighing approximately 19–20 tons as loaded. Certain areas of the completed select fill developed ruts and soft spots under the traffic of the haul units and are discussed in more detail in the following section.

On October 29, 1998, the temperature dropped into the 30–40^{o} F range. On October 30, 1998, the final 400 feet of reclaimed fly ash fill were placed for the year, from stations 0+00 to 4+00. A drizzling rain began the day after the final select fill was placed, and continued for two days, with a total accumulation of around 2.5 inches. At this time, the contractor had not placed any temporary stone surfacing on any of the compacted select fill. The rain saturated the soft spots that had developed from the loaded haul units, creating large soft areas up to a foot deep. The final 1,500 feet of select fill that were placed (stations 0+00 to 15+00) became saturated as well, with the select fill behaving nearly like a viscous fluid. These areas became impassable for local and construction traffic. After the rain subsided, the area of select fill from station 0+00 to 15+00 and the smaller soft areas previously mentioned were stabilized with a raw class C fly ash. Stone surfacing was placed on the entire section of completed fill areas immediately following the fly ash stabilization. No further problems were encountered with this section of the road.

Summer 1999 Construction

ISU researchers met with representatives from the Wapello County engineer's office, ISG Resources (the select fill and raw fly ash supplier), and the earthwork contractor on June 24, 1999, to devise a plan for the final stages of select fill placement. The main goal of the meeting was to determine a course of action to follow if problems with extremely soft subgrade and soft sections of select fill were encountered. ISU researchers ran DCP tests on the several areas of the subgrade, and suggested that five areas in particular, as shown in Table 13, be stabilized with raw class C fly ash before placing any select fill. The Wapello County Engineer's office elected to stabilize three of these areas, as shown in Table 13. It was further decided that construction would begin at the east end of the project, proceeding westward, running the loaded haul units over the select fill to achieve further compaction.

TABLE 13 Summer 1999 Subgrade Instability Areas

Subgrade Instability Areas	Fly Ash Stabilization
Station to Station	**Station to Station**
138+00 to 141+00	139+00 to 140+00
141+00 to 144+00	141+00 to 144+00
174+00 to 178+00	Not Stabilized
184+00 to 188+00	Not Stabilized
205+00 to 208+00	205+00 to 208+00

Construction of the final two miles of select fill began on July 13, 1999, at station 231+00. The work progressed westward to station 96+00 and finally commenced by completing stations 231+00 to 236+00. A summary of the production is given in Table 14. A total of 140 stations was constructed in 22 working days, for an average of 6.4 stations constructed per day. A total of 42,894 tons of reclaimed fly ash fill was placed during this time period, for an average of 306 tons per station. The select fill placement was completed on August 19, 1999.

During the summer 1999 construction season, several soft areas again developed in the select fill due to the weight of the loaded haul units. These areas are discussed in more detail in the following section.

TABLE 14 Summer 1999 Construction Summary

Date	Day	Tons Placed	Approximate Location	Approximate Number of Stations
7/13/99	Tuesday	589	227+50 - 231+00	1.8
7/14/99	Wednesday	1763	226+00 - 231+00 208+00 - 210+00	6
7/15/99	Thursday	1537	215+00 - 219+00	5.5
7/16/99	Friday	1471	210+00 - 215+00	5.1
7/19/99	Monday	1942	201+00 - 208+00	7
7/21/99	Wednesday	2402	197+00 - 201+00 221+00 - 226+00	8.1
7/22/99	Thursday	2331	219+00 - 221+00 191+00 - 197+00	7.6
7/23/99	Friday	1896	184+00 - 191+00	6.5
7/26/99	Monday	2110	184+00 - 176+00	7.9
7/27/99	Tuesday	2490	168+00 - 176+00	8.4
7/28/99	Wednesday	2449	159+00 - 168+00	8.5
7/29/99	Thursday	2442	150+00 - 159+00	8.6
7/30/99	Friday	609	148+00 - 150+00	2.1
8/3/99	Tuesday	2347	141+00 - 148+00	7.4
8/4/99	Wednesday	2284	129+00 - 132+00 136+00 - 140+00	7.1
8/5/99	Thursday	2156	122+00 - 129+00	7.1
8/6/99	Friday	2812	132+00 - 136+00 118+00 - 122+00	8.6
8/9/99	Monday	2650	110+00 - 118+00	7.9
8/10/99	Tuesday	1497	106+00 - 110+00	3.6
8/11/99	Wednesday	2725	97+00 - 106+00	9.2
8/17/99	Tuesday	1413	231+00 - 237+00	3.6
8/19/99	Thursday	979	231+00 - 237+00	2.4
	Total	42894 tons		140.0 Stations

One of the most notable differences between the fall 1998 and summer 1999 construction periods was moisture control of the reclaimed fly ash fill. During the fall 1998 construction period, the moisture content of the select fill as it was reclaimed was near optimum moisture content for the material. In the summer of 1999, however, the moisture contents were very low, due to seasonal variation in moisture content. When the material was reclaimed in the summer of 1999, the moisture content was around 18 percent. Because the optimum moisture content for the reclaimed fly ash fill is approximately 24.5 percent, large amounts of water had to be added to the material to facilitate compaction and elevate the moisture content into the specified zone. The moisture was added to the reclaimed fly ash fill before it was hauled to the construction site.

Fall 1999 Paving

Paving operations began for the road in late September 1999 and were completed in October 1999. No problems were encountered that were directly related to the select fill material. Some areas of instability did develop in the select fill under traffic from loaded concrete trucks, and these areas were moistened and recompacted with a vibratory steel-wheel roller prior to paving. Most of the unstable areas that were present at this time occurred at earlier stages of construction likely due to soft subgrade conditions, but had since "healed," only to reappear under the heavy concrete trucks.

Problems Encountered

Unstable Areas in Compacted Reclaimed Fly Ash

As previously mentioned, numerous areas on the test road developed unstable areas in the reclaimed fly ash fill when subjected to heavy traffic. These areas would start out as small depressions in the material, and with more traffic would turn into large "bathtub" shaped areas. The reclaimed ash in these areas would break down into a fine powder and quickly dry out. The exact cause of these unstable areas is unknown, but they can be related to a number of factors, depending on the location and time that they occurred.

During the fall 1998 construction period, a few of these areas developed, and were disregarded, with no immediate remedial action being taken. After the placement of the reclaimed fly ash fill was completed and the rain set in, all of these unstable areas grew larger and became problematic for traffic. The rain also caused an approximate 1,500-foot section of material to become unstable and impassable. The problems were most likely caused by undercompaction and cold temperatures. The reclaimed fly ash fill is a pozzolanic material, gaining strength with time. Pozzolanic activity slows down at low temperatures, and stops at temperatures near freezing. At the time of the year that construction was taking place, temperatures were right around freezing, thus minimal strength gain was occurring. The minimal strength gain coupled with undercompaction of the material and long drizzling rain was a combination that caused the reclaimed fly ash fill to perform poorly.

In general, the areas that occurred were limited to relatively small sections less than 30 feet long, and less than 12 feet wide. Nearly all of these occurred in the lane being used by loaded haul trucks. The cause of these unstable areas cannot be narrowed down to a single item, but it appears combinations of factors were working together to cause the reclaimed fly ash fill to fail. The recurring factor that is suspected to be the principle cause of the unstable areas is soft subgrade conditions. Nearly all of the soils on the site were classified as "unsuitable" soils for road construction. Many areas of the site had poor drainage conditions that would leave the subgrade saturated for many days after only a light rain. Although the reclaimed fly ash fill can bridge soft subgrades in certain conditions, it was not able to bridge all of the soft subgrade areas on the site. When the reclaimed fly ash fill was subjected to heavy haul units, the load of the haul units caused the soft subgrade soils to deflect. Because the reclaimed fly ash fill cannot withstand tensile stresses, it began to break up when the subgrade beneath it was flexing. Once a small area of the reclaimed fly ash fill had broken up, a depression was made on the surface of the road. The wheels from the haul trucks struck the sides of the depression, causing the depression to grow larger and larger. It was noted that a subgrade CBR of at least six percent is necessary for the reclaimed fly ash fill to form a bridge.

Another factor that was noticed to contribute to the occurrence of unstable areas in the reclaimed fly ash fill was low compaction and/or low moisture content of the fill. On a few occasions, the moisture content of the reclaimed fly ash fill was not controlled and some loads of material were sent to the job site that were drier than the specified range of moisture contents. Because the moisture content was so low for these loads, the desired compaction level was not obtained. Unstable areas occurred in the fill at some of the locations where the moisture content and compaction of the reclaimed fly ash fill were low. It is believed that the low compaction in conjunction with relatively poor subgrade soils is a combination that leads to failure of the select fill.

The surface of the select fill must be sealed, and must remain sealed to protect the integrity of the structure. During construction, a pneumatic roller was on site and was used as final compaction for the reclaimed fly ash fill in an effort to smooth out surface dimples left by the sheepsfoot roller. In some instances, track-mounted construction equipment was driven along or across compacted sections of reclaimed fly ash fill. The tracks on the equipment loosened up the material at the surface, which quickly dried out in the summer heat. With traffic, more and more of the reclaimed fly ash fill was loosened, creating deep ruts in the mat where the track-mounted vehicles originally drove. Although these unstable areas created by construction equipment are easily repaired by adding water and recompacting, construction would proceed much faster if recompaction weren't necessary. Reclaimed fly ash fill is very sensitive to surface effects, and for ease of construction, a smooth, sealed surface should be maintained.

Different methods were used to repair sections of the roadway where unstable areas developed. The problematic select fill areas encountered in the fall of 1998 were fly-ash stabilized. Although this method is very effective, it requires a significant amount of time and money. By stabilizing the soft subgrade areas, the possibility of recurrence of the unstable select fill area is minimized. During the summer of 1999, a different method was utilized to repair sections of the roadway that became unstable under construction traffic. When unstable areas occurred in the summer of 1999, ISU researchers ran DCP tests in the area to determine subgrade conditions. If it appeared the subgrade was relatively strong (CBR>6 percent), it was assumed that the subgrade was not at fault and it was a failure of the select fill. Under this situation, the select fill was watered down and recompacted. This method worked very well as long as the subgrade was able to support the repaired fill. In certain areas it was determined that soft subgrade soils were a contributing factor to the failure of the select fill; however, it was noticed that the select fill would only fail under loaded haul units, and not light, local traffic, and typical construction traffic. On these areas, the select fill was moistened and recompacted, and heavy traffic was kept off of them for a few days to allow the select fill to gain strength. Under heavy traffic of loaded haul units, most, but not all of the unstable areas recurred.

When construction of the select fill was completed, any unstable areas that were present on the road were moistened and recompacted. Paving operations began approximately one month after the construction of the select fill was completed. Although some unstable areas occurred under loaded concrete trucks, many of the areas that were repaired a month previous maintained their integrity. This evidence suggests that the reclaimed fly ash fill can bridge soft subgrade areas if enough strength gain is achieved. However, for the most durable pavement structure, soft subgrade areas (CBR<6 percent) should be stabilized or replaced with appropriate fill material prior to placement of select fill.

CONCLUSION

From the testing results and research done on this project, it appears that reclaimed fly ash is a suitable material to be used as a select fill on certain projects. The reclaimed fly ash fill is inexpensive compared to typical pavement base materials and is seen to gain strength over time.

From a construction standpoint, there are a few precautions that must be taken, and a few general guidelines to follow that are somewhat different than those typically encountered. Moisture control of the reclaimed fly ash is one of the most important facets of construction with this material. It was seen that in the fall of the year, with relatively cool temperatures, the natural moisture content of the reclaimed ash was near the optimum moisture content. However, during the warm summer months, the moisture content of the material severely dropped, and large quantities of water had to be added. As with any soil, when the moisture content is not in the optimum range specified, compaction is typically not achieved and strength is decreased. When working with reclaimed fly ash in the fall of the year, it is also important to realize that the material will not likely gain strength until the next year. This is an important fact to consider when a design value of CBR or modulus of subgrade reaction is used that is dependent on some strength gain of the material. It was seen in the fall of 1998 that cold weather combined with severe rain is a combination that can be very destructive to freshly placed reclaimed fly ash. For compaction, a heavy sheepsfoot roller, preferably vibratory should be used for initial compaction. Final compaction should be achieved using a smooth-wheel roller such as a steel-drum roller or a pneumatic roller. The smooth wheels on these rollers smooth the surface of the reclaimed fly ash so that water will run off and not penetrate the material. Shortly after finish rolling the reclaimed fly ash pad, temporary surfacing material should be placed. It should also be noted that although the reclaimed fly ash gains strength over time, it is not able to bridge extremely soft soils. If soft soils are encountered on a site, they should first be stabilized or replaced before placing reclaimed ash on top of them.

Performance monitoring of the test road will be done yearly to evaluate time effects on the reclaimed fly ash. It is anticipated that strength gain will continue, although the rate of gain will likely begin to slow down after the first year.

RECOMMENDATIONS

Design

It is recommended that the procedure outlined in “Iowa Thickness Design Guide for Low Volume Roads using Reclaimed Hydrated Class C Fly Ash Bases” (1) be followed when using reclaimed fly ash select fill as support for a flexible pavement. The Design Guide contains laboratory CBR data that can be used to establish a design CBR which can then can be correlated to the modulus of subgrade reaction (k) for use in the design of a rigid pavement. The methodology presented in the Design Guide is believed to result in very conservative designs because the CBR values are based on a seven-day value, and thus do not take strength gain beyond seven days into account.

Construction Testing

Although different quality control practices are used throughout the country and even throughout the state of Iowa, the most popular method is using moisture and density control, typically utilizing a nuclear densometer. The density of construction materials is typically easier to monitor than the stability, and certain soils should be compacted to a minimum density to avoid problems such as differential settlement. For these reasons, and the ease and quickness of a nuclear densometer, the majority of quality control testing is completed using a moisture range and minimum density requirements. It was seen in this project that nuclear densometers do not give accurate or reliable results when used on reclaimed fly ash select fill. Because of this difficulty, compaction testing should be done using equipment such as a rubber balloon (ASTM D2167) or sand cone (ASTM D1556) to determine wet density, and a direct method to determine moisture content, using either a laboratory oven or a stove.

The stability of the reclaimed fly ash fill can be determined using the DCP, and if a limiting value of DPI is established, the DCP could be used in place of density testing as long as a moisture control is used in conjunction with DCP testing. There is too much variability with the Clegg hammer test results to warrant its use as a quality control method. However, because of the speed and ease of testing, the Clegg hammer can be used for approximate determinations of CBR.

Construction

The select fill that was placed for the test road was placed in one 12-inch thick lift and was compacted using a standard pull-behind sheepsfoot roller. Using the single twelve-inch thick lift, compaction was approximately 96 percent of Standard Proctor for the top six inches and approximately 90 percent of Standard Proctor for the bottom six inches. It is believed that these compaction levels will be adequate to support the pavement. If more than 12 inches of select fill is to be placed, it is recommended that the material be placed in eight-inch thick lifts to eliminate an “Oreo cookie” effect of a lower density section sandwiched between two higher density sections.

Compaction of reclaimed fly ash fill should be initiated with a heavy sheepsfoot or padfoot roller, preferably vibratory. If the reclaimed fly ash fill is within the optimum moisture content range, initial compaction can be considered complete when walkout of the roller occurs. Final compaction should then be completed using a smooth-wheel roller such as a steel drum or pneumatic roller. The final compaction with the smooth-wheel roller serves to smooth and seal the surface of the select fill to minimize abrasion and allow water to run off.

A temporary granular surfacing at least two inches thick should be placed on the select fill shortly after compaction is completed if the road is being subjected to traffic. In warm weather, the surface of the select fill dries out very quickly, and becomes very dusty. In wet weather, the loose material at the surface of the select fill becomes very slick, and can become a traffic hazard. The placement of a temporary surfacing serves to both reduce dust and provide traction under wet conditions.

Although no weather-related problems occurred while placing the select fill, cold weather will halt the strength gain of the material. If the full design strength of the select fill is not necessary for an extended amount of time, late fall construction is a possibility. If, however, the full design strength of the material is needed shortly after construction, construction should not be commenced in the late fall. If the select fill is placed in cold weather, compaction, surface sealing, and temporary surfacing are all crucial to avoid problems if there is significant precipitation.

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APPENDIX

Fall 1999 Proctors

						Standard Proctor	
Date	Time	Tech	Sample Type	Location	Test Type	g_d (pcf)	Moisture Content
9/24/1998	-	MW	Test Pits	OGS, 1'-4', East	Standard	95	25
9/24/1998	-	MW	Test Pits	OGS, 1'-4', West	Standard	95	25
9/24/1998	-	MW	Test Pits	OGS, 1'-4' Center	Standard	90	28
10/16/1998	A.M.	KB	Stockpile	OGS	Standard	94	24
10/20/1998	A.M.	KB	Field	54+00 to 55+00	One-Point	96	22
10/20/1998	P.M.	KB	Field	55+00 to 56+00	One-Point	98	22
10/21/1998	A.M.	KB	Field	51+00 to 53+00	One-Point	98	23
10/21/1998	P.M.	KB	Field	46+00 to 47+00	One-Point	95	24
10/22/1998	A.M.	KB	Field	41+00 to 43+00	One-Point	95	23
10/22/1998	P.M.	KB	Field	40+00 to 42+00	One-Point	96	26
10/23/1998	A.M.	KB	Field	37+00 to 39+00	One-Point	96	24
10/23/1998	P.M.	KB	Field	33+00 to 35+00	One-Point	94	21
10/26/1998	P.M.	DM	Stockpile	OGS	One-Point	96	20
10/27/1998	A.M.	DM	Field	17+00 to 19+00	One-Point	95	24
10/28/1998	A.M.	KB	Field	13+00 to 15+00	One-Point	93	21
10/28/1998	P.M.	KB	Field	11+00 to 13+00	One-Point	93	24
10/28/1998	P.M.	KB	Field	10+00 to 13+00	One-Point	94	23
10/29/1998	A.M.	KB	Field	9+00 to 10+00	One-Point	93	23
10/30/1998	P.M.	DM	Field	0+00 to 2+00	One-Point	94	25
					Averages	94.7	23.8
					Standard Deviation	1.8	1.8

Summary 1999 Proctors

						Standard Proctor	
Date	**Time**	**Tech**	**Sample Type**	**Location**	**Test Type**	**g_d (pcf)**	**Moisture Content**
7/13/1999	A.M.	DM	Stockpile	OGS	1-Pt	92.9	19.3
7/13/1999	A.M.	DM	Stockpile	OGS	1-Pt	91.5	19.9
7/14/1999	A.M.	DM	Field	230+00	1-Pt	90.6	19.3
7/15/1999	A.M.	DM	Field	218+00 to 219+00	1-Pt	88.6	31.1
7/16/1999	A.M.	DM	Field	210+00 to 215+00	1-Pt	96.2	24.1
7/19/1999	P.M.	DM	Field	200+00 to 201+00	1-Pt	94.9	23.9
7/21/1999	A.M.	DM	Field	200+00 to 201+00	1-Pt	96.0	23.8
7/22/1999	A.M.	DM	Field	220+00 to 221+00	1-Pt	92.5	24.2
7/23/1999	A.M.	DM	Field	190+00 to 191+00	1-Pt	96.1	23.8
7/26/1999	P.M.	DM	Field	177+00 to 178+00	1-Pt	96.0	23.4
7/27/1999	A.M.	DM	Field	175+00 to 176+00	1-Pt	96.1	25.4
7/28/1999	A.M.	DM	Field	167+00 to 168+00	1-Pt	92.7	27.5
7/29/1999	A.M.	DM	Field	157+00 to 158+00	1-Pt	89.8	28.8
7/30/1999	A.M.	DM	Field	148+00 to 149+00	1-Pt	90.9	21.3
8/3/1999	A.M.	DM	Field	147+00 to 148+00	1-Pt	92.8	25.2
8/4/1999	A.M.	DM	Field	139+00 to 140+00	1-Pt	91.6	22.9
8/5/1999	P.M.	DM	Field	126+00 to 127+00	1-Pt	93.5	21.9
8/6/1999	A.M.	DM	Field	135+00 to 136+00	1-Pt	97.5	25.3
8/9/1999	P.M.	DM	Field	111+00 to 112+00	1-Pt	94.8	22.9
8/10/1999	P.M.	DM	Field	108+00 to 109+00	1-Pt	95.3	22.8
8/11/1999	A.M.	DM	Field	106+00 to 107+00	1-Pt	95.0	27.2
8/19/1999	A.M.	DM	Field	232+00 to 233+00	1-Pt	95.9	24.1
					Averages	93.7	24.0
					Standard Deviations	2.5	2.9

Moisture Contents - Fall 1998

Date	Time	Tech	Sample Type	Location	Test Type	Moisture Content (%)	Water Added?
10/16/1998	A.M.	KB	Field	53+50 to 54+00	Speedy	23	No
10/16/1998	A.M.	KB	Field	53+50 to 54+00	Speedy	20	No
10/16/1998	A.M.	KB	Stockpile	53+50 to 54+00	Speedy	24	No
10/20/1998	A.M.	KB	Field	54+00 to 55+00	Oven	23	No
10/20/1998	A.M.	KB	Field	54+00 to 55+00	Oven	21	No
10/20/1998	A.M.	KB	Field	54+00 to 55+00	Oven	22	No
10/20/1998	P.M.	KB	Field	54+00 to 55+00	Oven	21	No
10/20/1998	P.M.	KB	Field	55+00 to 56+00	Oven	22	No
10/20/1998	P.M.	KB	Field	55+00 to 56+00	Oven	22	No
10/21/1998	A.M.	KB	Field	51+00 to 53+00	Oven	24	No
10/21/1998	A.M.	KB	Field	51+00 to 53+00	Oven	22	No
10/21/1998	P.M.	KB	Field	46+00 to 47+00	Oven	24	No
10/21/1998	P.M.	KB	Field	46+00 to 47+00	Oven	25	No
10/22/1998	A.M.	KB	Field	41+00 to 43+00	Oven	24	No
10/22/1998	A.M.	KB	Field	41+00 to 43+00	Oven	23	No
10/22/1998	P.M.	KB	Field	40+00 to 42+00	Oven	25	No
10/22/1998	P.M.	KB	Field	40+00 to 42+00	Oven	26	No
10/23/1998	A.M.	KB	Field	37+00 to 39+00	Oven	24	No
10/26/1998	P.M.	DM	Stockpile	OGS	Oven	20	No
10/27/1998	A.M.	DM	Field	17+00 to 19+00	Oven	24	No
10/27/1998	P.M.	KB	Field	15+00 to 17+00	Oven	22	No
10/28/1998	A.M.	KB	Field	13+00 to 15+00	Oven	21	No
10/28/1998	P.M.	KB	Field	11+00 to 13+00	Oven	24	No
10/28/1998	P.M.	KB	Field	10+00 to 13+00	Oven	23	No
10/29/1998	A.M.	KB	Field	9+00 to 10+00	Oven	23	No
10/30/1998	P.M.	DM	Field	0+00 to 2+00	Oven	25	No
					Average	23.0	
					Standard Deviation	1.6	

Moisture Contents - Summer 1999

Date	Time	Tech	Sample Type	Location	Test Type	Moisture Content (%)	Water Added?
7/13/1999	A.M.	DM	Stockpile	OGS	Oven	19.3	No
7/13/1999	A.M.	DM	Stockpile	OGS	Oven	19.9	No
7/13/1999	A.M.	DM	Field	231+00	Oven	27.8	Yes
7/13/1999	P.M.	DM	Field	230+00	Oven	24.7	Yes
7/13/1999	P.M.	DM	Field	229+00	Oven	19.1	Yes
7/13/1999	P.M.	DM	Field	228+00	Oven	26.3	Yes
7/14/1999	A.M.	DM	Field	230+00	Oven	19.3	Yes
7/14/1999	P.M.	DM	Field	226+50	Oven	18.5	Yes
7/14/1999	P.M.	DM	Field	227+30	Oven	21.1	Yes
7/14/1999	P.M.	DM	Field	228+00	Oven	22.6	Yes
7/15/1999	A.M.	DM	Field	218+00 to 219+00	Oven	31.1	Yes
7/15/1999	A.M.	DM	Field	209+50	Oven	22.8	Yes
7/15/1999	A.M.	DM	Field	208+50	Oven	23.1	Yes
7/15/1999	P.M.	DM	Field	219+50	Oven	20.2	Yes
7/15/1999	P.M.	DM	Field	218+50	Oven	19.0	Yes
7/15/1999	P.M.	DM	Field	218+50	Oven	19.2	Yes
7/16/1999	A.M.	DM	Field	214+00 to 215+00	Oven	23.2	Yes
7/19/1999	P.M.	DM	Field	200+00 to 201+00	Oven	23.9	Yes
7/19/1999	P.M.	DM	Field	197+25	Oven	21.2	Yes
7/19/1999	P.M.	DM	Field	198+75	Oven	18.4	Yes
7/19/1999	P.M.	DM	Field	200+75	Oven	24.1	Yes
7/21/1999	A.M.	DM	Field	200+00 to 201+00	Oven	23.8	No
7/22/1999	A.M.	DM	Field	220+00 to 221+00	Oven	24.2	Yes
7/23/1999	A.M.	DM	Field	190+00 to 191+00	Oven	22.5	Yes
7/26/1999	P.M.	DM	Field	177+00 to 178+00	Oven	23.9	Yes
7/27/1999	A.M.	DM	Field	175+00 to 176+00	Oven	25.4	Yes
7/27/1999	P.M.	DM	Field	170+00	Oven	20.5	Yes
7/27/1999	P.M.	DM	Field	171+50	Oven	20.1	Yes
7/27/1999	P.M.	DM	Field	173+50	Oven	23.1	Yes
7/28/1999	A.M.	DM	Field	167+00 to 168+00	Oven	27.5	Yes
7/29/1999	A.M.	DM	Field	157+00 to 158+00	Oven	28.8	Yes
7/30/1999	A.M.	DM	Field	148+00 to 149+00	Oven	21.3	Yes
8/3/1999	A.M.	DM	Field	147+00 to 148+00	Oven	25.2	Yes
8/4/1999	A.M.	DM	Field	139+00 to 140+00	Oven	22.9	No
8/5/1999	P.M.	DM	Field	126+00 to 127+00	Oven	21.9	Yes
8/5/1999	P.M.	DM	Field	125+00 to 126+00	Oven	25.0	Yes
8/5/1999	P.M.	DM	Field	124+50	Oven	20.4	Yes
8/5/1999	P.M.	DM	Field	122+50	Oven	23.0	Yes
8/5/1999	P.M.	DM	Field	126+50	Oven	23.1	Yes
8/5/1999	P.M.	DM	Field	126+50	Oven	22.6	Yes
8/6/1999	A.M.	DM	Field	135+00 to 136+00	Oven	25.3	Yes

Moisture Contents - Summer 1999 Continued

Date	Time	Tech	Sample Type	Location	Test Type	Moisture Content (%)	Water Added?
8/9/1999	P.M.	DM	Field	111+00 to 112+00	Oven	22.9	Yes
8/10/1999	P.M.	DM	Field	108+00 to 109+00	Oven	22.8	Yes
8/11/1999	A.M.	DM	Field	106+00 to 107+00	Oven	27.2	Yes
8/19/1999	P.M.	DM	Field	235+00 to 236+00	Oven	24.1	Yes
8/19/1999	P.M.	DM	Field	236+00	Oven	24.8	Yes
8/19/1999	P.M.	DM	Field	234+00	Oven	25.2	Yes
8/19/1999	P.M.	DM	Field	232+00	Oven	23.0	Yes
					Average	23.0	
					Standard Deviation	2.8	

Particle Size Distributions - Fall 1998

Date	Tech	Sample Type	Location	Percent Passing Sieve						
				1 1/2"	1"	3/4"	1/2"	3/8"	#4	#8
10/20/98	KB	Field	54+00 to 55+00	87	70	62	54	45	31	20
10/20/98	KB	Field	54+00 to 55+00	82	75	64	56	47	29	18
10/20/98	KB	Field	55+00 to 56+00	89	82	70	60	51	34	21
10/21/98	KB	Field	51+00 to 53+00	97	93	86	78	67	48	32
10/22/98	KB	Field	41+00 to 43+00	85	80	71	62	54	38	26
10/23/98	KB	Field	37+00 to 39+00	94	88	81	72	62	45	29
10/26/98	DM	Stockpile	OGS	84	81	77	71	63	47	32
10/27/98	DM	Field	17+00 to 19+00	100	94	89	82	74	55	38
10/28/98	KB	Field	13+00 to 15+00	88	82	76	69	59	42	26
10/29/98	KB	Field	9+00 to 10+00	87	80	71	62	53	36	23
10/30/98	DM	Field	0+00 to 2+00	92	89	83	77	69	54	39
			Averages	89.5	83.1	75.5	67.5	58.5	41.7	27.6
			Standard Deviations	5.3	7.0	8.3	8.9	8.9	8.5	6.7

Particle Size Distributions - Summer 1999

		Sample		**Percent Passing Sieve**						
Date	**Tech**	**Type**	**Location**	**1 1/2"**	**1"**	**3/4"**	**1/2"**	**3/8"**	**#4**	**#8**
7/13/1999	DM	Field	228+00 to 229+00	99	89	77	66	57	39	29
7/14/1999	DM	Field	229+00 to 230+00	91	90	83	75	67	48	34
7/15/1999	DM	Field	218+00 to 219+00	92	86	78	69	60	43	28
7/16/1999	DM	Field	212+00 to 213+00	93	88	80	72	63	45	31
7/19/1999	DM	Field	201+00 to 202+00	96	87	75	63	51	30	14
7/21/1999	DM	Field	200+00 to 201+00	96	86	74	61	49	28	13
7/22/1999	DM	Field	220+00 to 221+00	90	84	77	66	58	47	28
7/23/1999	DM	Field	189+00 to 190+00	92	85	78	62	52	29	19
7/26/1999	DM	Field	177+00 to 178+00	88	82	73	60	49	44	17
7/27/1999	DM	Field	175+00 to 176+00	93	82	68	57	48	33	23
7/28/1999	DM	Field	167+00 to 168+00	92	83	67	56	51	36	25
7/29/1999	DM	Field	157+00 to 158+00	89	80	66	59	55	38	28
7/30/1999	DM	Field	148+00 to 149+00	80	69	62	54	45	33	24
8/3/1999	DM	Field	147+00 to 148+00	84	66	52	46	33	17	8
8/4/1999	DM	Field	139+00 to 140+00	86	80	72	63	54	38	26
8/5/1999	DM	Field	126+00 to 127+00	95	86	72	63	55	41	29
8/6/1999	DM	Field	135+00 to 136+00	90	81	75	66	53	33	31
8/9/1999	DM	Field	111+00 to 112+00	88	81	73	67	56	39	32
8/10/1999	DM	Field	108+00 to 109+00	89	81	73	67	56	39	32
8/11/1999	DM	Field	106+00 to 107+00	91	77	69	62	54	38	25
8/19/1999	DM	Field	232+00 to 233+00	90	78	72	63	53	36	30
			Averages	90.7	82.0	72.2	62.7	53.3	36.9	25.0
			Standard Deviations	4.3	6.0	6.8	6.3	6.9	7.2	7.1

Rubber Balloon Moisture-Density Tests - ASTM D 2167
Top 6" Densities - Fall 1998

				Standard Proctor			Field Test		Compaction	Depth
Date	**Tech**	**Station**	**Location**	**Date**	**g_d (pcf)**	**% w**	**g_d (pcf)**	**% w**	**%**	**(inches)**
10/16/98	KB	53+50	20' RT	10/20/98	98	24	92	23	94	Top 6
10/20/98	DM/KB	53+20	15' LT	10/20/98	98	24	93	26	95	Top 6
10/20/98	DM/KB	53+48	5' RT	10/20/98	98	24	94	25	96	Top 6
10/20/98	DM/KB	53+74	12' LT	10/20/98	98	24	98	22	100	Top 6
10/21/98	KB	54+50	10' LT	10/20/98	98	24	106	23	108	Top 6
10/21/98	KB	55+00	5' RT	10/20/98	98	24	93	22	95	Top 6
10/21/98	KB	55+75	15' RT	10/20/98	98	24	95	22	97	Top 6
10/22/98	KB	46+40	Centerline	10/20/98	98	24	92	24	94	Top 6
10/23/98	DM/KB	41+42	15' RT	10/20/98	98	24	97	22	99	Top 6
10/23/98	DM/KB	40+41	15' LT	10/20/98	98	24	94	23	96	Top 6
10/23/98	DM/KB	39+40	9' LT	10/20/98	98	24	92	22	94	Top 6
10/23/98	DM/KB	38+39	6' LT	10/20/98	98	24	94	26	96	Top 6
10/26/98	DM	32+70	12' RT	10/20/98	98	24	90	19	92	Top 6
10/26/98	DM	31+50	10' LT	10/20/98	98	24	100	19	102	Top 6
10/26/98	DM	30+00	6' RT	10/20/98	98	24	90	16	92	Top 6
10/26/98	DM	28+48	9' RT	10/20/98	98	24	94	19	96	Top 6
10/26/98	DM	26+66	6' LT	10/20/98	98	24	91	20	93	Top 6
10/27/98	DM	24+30	3' RT	10/20/98	98	24	91	20	93	Top 6
10/27/98	DM	22+70	12' RT	10/20/98	98	24	88	20	90	Top 6
10/28/98	KB	21+00	15' RT	10/20/98	98	24	99	23	101	Top 6
10/28/98	KB	18+60	18' LT	10/20/98	98	24	108	25	110	Top 6
10/28/98	KB	17+00	12' LT	10/20/98	98	24	102	22	104	Top 6
10/28/98	KB	15+00	8' LT	10/20/98	98	24	90	22	92	Top 6
10/28/98	KB	13+00	Centerline	10/20/98	98	24	99	23	101	Top 6
10/29/98	KB	11+00	10' LT	10/20/98	98	24	90	22	92	Top 6
10/29/98	KB	9+00	9' LT	10/20/98	98	24	95	23	97	Top 6
10/29/98	DM	7+00	4' RT	10/20/98	98	24	92	21	94	Top 6
10/30/98	DM	5+00	Centerline	10/20/98	98	24	91	23	93	Top 6

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Continued
Rubber Balloon Moisture-Density Tests - ASTM D 2167
Top 6" Densities - Fall 1998

				Standard Proctor			Field Test		Compaction	Depth
Date	**Tech**	**Station**	**Location**	**Date**	**g_d (pcf)**	**% w**	**g_d (pcf)**	**% w**	**%**	**(inches)**
10/30/98	KB	3+00	Centerline	10/20/98	98	24	91	22	93	Top 6
10/31/98	KB	1+50	Centerline	10/20/98	98	24	91	24	93	Top 6
Averages					98	24	94.4	22.1	96.3	
Standard Deviations					0	0	4.8	2.2	4.9	

Rubber Balloon Moisture-Density Tests - ASTM D 2167
Bottom 6" Densities - Fall 1998

				Standard Proctor			Field Test		Compaction	Depth
Date	**Tech**	**Station**	**Location**	**Date**	**g_d (pcf)**	**% w**	**g_d (pcf)**	**% w**	**%**	**(inches)**
10/16/98	KB	53+50	20' RT	10/20/98	98	24	94	23	96	Bottom 6
10/22/98	KB	51+65	12' LT	10/20/98	98	24	95	22	97	Bottom 6
10/22/98	KB	50+45	12' LT	10/20/98	98	24	91	23	93	Bottom 6
10/22/98	KB	48+30	10' LT	10/20/98	98	24	93	24	95	Bottom 6
10/27/98	DM	24+60	10' LT	10/20/98	98	24	89	21	91	Bottom 6
Averages					98	24	92.4	22.6	94.3	
Standard Deviations					0	0	2.4	1.1	2.5	

Rubber Balloon Moisture-Density Tests - ASTM D 2167
Top 6" Densities - Summer 1999

				Standard Proctor			Field Test		Compaction	Depth
Date	Tech	Station	Location	Date	g_d (pcf)	% w	g_d (pcf)	% w	%	(inches)
7/13/99	DM	228+50	15' RT	8/6/99	97.5	25.3	88.1	25.8	90	0-6
7/13/99	DM	230+15	12' RT	8/6/99	97.5	25.3	88.8	23.8	91	0-6
7/14/99	DM	230+50	12' LT	8/6/99	97.5	25.3	90.9	19.9	93	0-6
7/14/99	DM	228+00	10' LT	8/6/99	97.5	25.3	90.4	22.6	93	0-6
7/14/99	DM	227+30	Centerline	8/6/99	97.5	25.3	96.0	21.1	98	0-6
7/14/99	DM	226+50	10' RT	8/6/99	97.5	25.3	93.3	18.5	96	0-6
7/15/99	DM	209+50	10' RT	8/6/99	97.5	25.3	96.6	22.8	99	0-6
7/15/99	DM	208+50	15' LT	8/6/99	97.5	25.3	94.1	23.1	97	0-6
7/15/99	DM	218+30	5' RT	8/6/99	97.5	25.3	96.9	19.0	99	0-6
7/15/99	DM	219+50	12' RT	8/6/99	97.5	25.3	97.7	20.2	100	0-6
7/19/99	DM	212+50	15' LT	8/6/99	97.5	25.3	96.8	16.0	99	0-6
7/19/99	DM	214+00	15' RT	8/6/99	97.5	25.3	98.9	15.4	101	0-6
7/19/99	DM	215+50	15' LT	8/6/99	97.5	25.3	96.0	16.7	98	0-6
7/19/99	DM	217+00	15' RT	8/6/99	97.5	25.3	93.3	15.4	96	0-6
7/20/99	DM	204+00	10' RT	8/6/99	97.5	25.3	98.6	24.1	101	0-6
7/20/99	DM	205+50	7' LT	8/6/99	97.5	25.3	93.4	24.4	96	0-6
7/20/99	DM	207+00	15' RT	8/6/99	97.5	25.3	97.6	20.0	100	0-6
7/20/99	DM	211+00	15' RT	8/6/99	97.5	25.3	100.1	23.0	103	0-6
7/21/99	DM	197+25	7' RT	8/6/99	97.5	25.3	92.4	21.2	95	0-6
7/21/99	DM	198+75	4' LT	8/6/99	97.5	25.3	93.2	18.4	96	0-6
7/21/99	DM	200+75	Centerline	8/6/99	97.5	25.3	98.0	24.1	101	0-6
7/21/99	DM	202+50	10' RT	8/6/99	97.5	25.3	89.9	26.2	92	0-6
7/22/99	DM	221+00	10' RT	8/6/99	97.5	25.3	88.7	22.2	91	0-6
7/22/99	DM	222+75	10' LT	8/6/99	97.5	25.3	96.1	23.8	99	0-6
7/22/99	DM	224+50	10' LT	8/6/99	97.5	25.3	101.4	24.0	104	0-6
7/22/99	DM	225+80	10' RT	8/6/99	97.5	25.3	104.2	20.8	107	0-6
7/26/99	DM	192+25	15' RT	8/6/99	97.5	25.3	93.4	22.3	96	0-6
7/26/99	DM	190+25	10' LT	8/6/99	97.5	25.3	91.0	20.6	93	0-6

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Rubber Balloon Moisture-Density Tests - ASTM D 2167
Top 6" Densities – Summer 1999

				Standard Proctor			Field Test		Compaction	Depth
Date	Tech	Station	Location	Date	g_d (pcf)	% w	g_d (pcf)	% w	%	(inches)
7/26/99	DM	194+25	18' RT	8/6/99	97.5	25.3	96.1	20.0	99	0-6
7/26/99	DM	196+10	17' RT	8/6/99	97.5	25.3	97.3	19.5	100	0-6
7/27/99	DM	182+50	16'LT	8/6/99	97.5	25.3	89.9	20.7	92	0-6
7/27/99	DM	186+40	17' LT	8/6/99	97.5	25.3	90.0	19.2	92	0-6
7/27/99	DM	180+75	10' RT	8/6/99	97.5	25.3	92.9	21.5	95	0-6
7/27/99	DM	179+00	15' LT	8/6/99	97.5	25.3	93.3	17.7	96	0-6
7/27/99	DM	188+30	15' RT	8/6/99	97.5	25.3	89.4	19.0	92	0-6
7/27/99	DM	184+50	18' RT	8/6/99	97.5	25.3	89.7	21.2	92	0-6
7/27/99	DM	177+00	10' LT	8/6/99	97.5	25.3	93.3	19.3	96	0-6
7/27/99	DM	175+00	10' RT	8/6/99	97.5	25.3	93.9	22.7	96	0-6
7/27/99	DM	173+50	12' LT	8/6/99	97.5	25.3	94.4	23.1	97	0-6
7/27/99	DM	171+50	6' RT	8/6/99	97.5	25.3	96.6	20.1	99	0-6
7/27/99	DM	170+00	5' LT	8/6/99	97.5	25.3	95.3	20.5	98	0-6
8/2/99	DM	168+20	15' RT	8/6/99	97.5	25.3	94.0	18.1	96	0-6
8/2/99	DM	166+35	12' LT	8/6/99	97.5	25.3	96.2	16.6	99	0-6
8/2/99	DM	164+50	8' RT	8/6/99	97.5	25.3	100.7	16.1	103	0-6
8/2/99	DM	162+50	8' LT	8/6/99	97.5	25.3	97.0	17.6	99	0-6
8/3/99	DM	160+50	15' RT	8/6/99	97.5	25.3	96.1	17.6	99	0-6
8/3/99	DM	158+50	15' RT	8/6/99	97.5	25.3	92.6	20.5	95	0-6
8/3/99	DM	156+50	12' LT	8/6/99	97.5	25.3	96.6	18.7	99	0-6
8/3/99	DM	154+50	10' RT	8/6/99	97.5	25.3	96.0	16.2	98	0-6
8/3/99	DM	152+50	10' LT	8/6/99	97.5	25.3	89.6	17.2	92	0-6
8/4/99	DM	150+50	8' LT	8/6/99	97.5	25.3	94.5	16.6	97	0-6
8/4/99	DM	148+50	12' LT	8/6/99	97.5	25.3	90.8	17.4	93	0-6
8/4/99	DM	146+50	15' RT	8/6/99	97.5	25.3	91.8	22.8	94	0-6
8/4/99	DM	144+50	7' LT	8/6/99	97.5	25.3	95.9	15.1	98	0-6
8/4/99	DM	142+50	Centerline	8/6/99	97.5	25.3	92.6	18.6	95	0-6
8/4/99	DM	140+50	Centerline	8/6/99	97.5	25.3	91.2	18.6	94	0-6

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Rubber Balloon Moisture-Density Tests - ASTM D 2167

Top 6" Densities – Summer 1999

Date	Tech	Station	Location	Standard Proctor Date	Standard Proctor g_d (pcf)	Standard Proctor % w	Field Test g_d (pcf)	Field Test % w	Compaction %	Depth (inches)
8/5/99	DM	138+50	12' LT	8/6/99	97.5	25.3	87.8	23.4	90	0-6
8/5/99	DM	136+50	10' RT	8/6/99	97.5	25.3	91.2	19.1	94	0-6
8/5/99	DM	130+50	15' LT	8/6/99	97.5	25.3	94.9	16.4	97	0-6
8/5/99	DM	128+50	8' RT	8/6/99	97.5	25.3	87.1	22.1	89	0-6
8/5/99	DM	126+50	16' RT	8/6/99	97.5	25.3	97.3	23.1	100	0-6
8/5/99	DM	124+50	Centerline	8/6/99	97.5	25.3	94.5	20.4	97	0-6
8/5/99	DM	122+50	5' RT	8/6/99	97.5	25.3	92.6	23.0	95	0-6
8/9/99	DM	134+50	15' RT	8/6/99	97.5	25.3	95.3	23.5	98	0-6
8/9/99	DM	132+50	15' RT	8/6/99	97.5	25.3	101.9	20.0	105	0-6
8/9/99	DM	120+50	15' RT	8/6/99	97.5	25.3	86.7	26.7	89	0-6
8/9/99	DM	118+50	Centerline	8/6/99	97.5	25.3	93.1	22.8	95	0-6
8/10/99	DM	116+50	10' LT	8/6/99	97.5	25.3	93.4	24.7	96	0-6
8/10/99	DM	114+50	15' LT	8/6/99	97.5	25.3	98.1	23.1	101	0-6
8/10/99	DM	112+50	15' RT	8/6/99	97.5	25.3	93.1	23.8	95	0-6
8/16/99	DM	98+00	15' LT	8/6/99	97.5	25.3	92.4	20.8	95	0-6
8/16/99	DM	100+15	12' LT	8/6/99	97.5	25.3	93.0	20.6	95	0-6
8/16/99	DM	102+30	15' RT	8/6/99	97.5	25.3	91.0	23.6	93	0-6
8/16/99	DM	104+50	15' RT	8/6/99	97.5	25.3	92.2	18.7	95	0-6
8/16/99	DM	106+50	15' RT	8/6/99	97.5	25.3	93.0	23.0	95	0-6
8/16/99	DM	108+50	10' RT	8/6/99	97.5	25.3	92.9	21.5	95	0-6
8/16/99	DM	110+50	12' LT	8/6/99	97.5	25.3	89.6	22.5	92	0-6
8/19/99	DM	236+00	10' RT	8/6/99	97.5	25.3	89.5	24.8	92	0-6
8/19/99	DM	234+00	5' LT	8/6/99	97.5	25.3	89.7	25.2	92	0-6
8/19/99	DM	232+00	Centerline	8/6/99	97.5	25.3	86.9	23.0	89	0-6
Averages							**93.8**	**20.8**	**96.2**	
Standard Deviations							**3.6**	**2.9**	**3.7**	

Bottom 6" Densities - Summer 1999

				Standard Proctor			Field Test		Compaction	Depth
Date	Tech	Station	Location	Date	g_d (pcf)	% w	g_d (pcf)	% w	%	(inches)
7/13/99	DM	230+15	12' RT	8/6/99	97.5	25.3	87.3	21.1	90	6-12
7/14/99	DM	228+00	10' LT	8/6/99	97.5	25.3	85.5	20.5	88	6-12
7/15/99	DM	218+30	5' RT	8/6/99	97.5	25.3	87.5	19.2	90	6-12
7/19/99	DM	217+00	15' RT	8/6/99	97.5	25.3	89.9	19.1	92	6-12
7/21/99	DM	198+75	4' LT	8/6/99	97.5	25.3	79.7	23.6	82	6-12
7/21/99	DM	200+75	Centerline	8/6/99	97.5	25.3	91.6	25.1	94	6-12
7/26/99	DM	196+10	17' RT	8/6/99	97.5	25.3	85.4	20.2	88	6-12
7/26/99	DM	192+25	15' RT	8/6/99	97.5	25.3	87.4	22.2	90	6-12
7/27/99	DM	173+50	12' LT	8/6/99	97.5	25.3	83.1	22.4	85	6-12
8/2/99	DM	166+35	12' LT	8/6/99	97.5	25.3	91.1	19.6	93	6-12
8/3/99	DM	156+50	12' LT	8/6/99	97.5	25.3	92.1	19	94	6-12
8/5/99	DM	136+50	10' RT	8/6/99	97.5	25.3	87.4	20.5	90	6-12
8/5/99	DM	126+50	10' RT	8/6/99	97.5	25.3	87.8	22.6	90	6-12
8/9/99	DM	134+50	15' RT	8/6/99	97.5	25.3	87.9	22	90	6-12
8/9/99	DM	118+50	Centerline	8/6/99	97.5	25.3	88.6	24.2	91	6-12
8/10/99	DM	116+50	10' LT	8/6/99	97.5	25.3	87.3	22.1	90	6-12
8/16/99	DM	106+50	15' RT	8/6/99	97.5	25.3	88	21.5	90	6-12
8/19/99	DM	234+00	5' LT	8/6/99	97.5	25.3	86.5	24.8	89	6-12
						Averages	87.5	21.7	90	
						Standard Deviations	3.0	1.9	3.0	

Nuclear Density Tests - ASTM D 2922
Fall 1998

					Standard Proctor			Nuclear Density						
Date	Tech	Station	Location	Depth (inches)	Date	g_d (pcf)	w (%)	WD (pcf)	DD (pcf)	M (pcf)	Moisture (%) (Measured)	Moisture (%, Oven)	Computed g_d (pcf)	Compaction (%)
10/19/1998	KB	53+65	20' LT	8	10/20/1998	98	24	122.0	111.0	11.0	9.9	24.0	98.4	100
10/19/1998	KB	53+40	4' LT	8	10/20/1998	98	24	122.0	112.0	10.0	8.9	24.0	98.4	100
10/19/1998	KB	53+30	20' RT	8	10/20/1998	98	24	122.0	111.0	11.0	9.9	24.0	98.4	100
10/19/1998	KB	53+25	20' LT	8	10/20/1998	98	24	123.0	112.0	11.0	9.8	24.0	99.2	101
10/21/1998	KB	54+50	10' LT	8	10/20/1998	98	24	122.0	112.0	10.0	8.9	22.5	99.6	102
10/21/1998	KB	55+00	5' RT	8	10/20/1998	98	24	123.0	114.0	9.0	7.9	21.9	100.9	103
10/21/1998	KB	55+75	15' RT	8	10/20/1998	98	24	122.0	112.0	10.0	8.9	22.4	99.7	102
10/23/1998	KB	45+55	5' RT	8	10/20/1998	98	24	123.0	113.0	10.0	8.8	23.0	100.0	102
10/23/1998	KB	44+50	10' LT	8	10/20/1998	98	24	121.0	113.0	8.0	7.1	20.6	100.3	102
10/23/1998	KB	43+50	20' RT	8	10/20/1998	98	24	121.0	112.0	9.0	8.0	23.3	98.1	100
10/23/1998	KB	42+40	10' LT	8	10/20/1998	98	24	121.0	112.0	9.0	8.0	22.7	98.6	101
10/23/1998	DM	41+42	15' RT	8	10/20/1998	98	24	123.0	113.0	10.0	8.8	22.3	100.6	103
10/23/1998	DM	40+41	15' LT	8	10/20/1998	98	24	121.0	112.0	9.0	8.0	23.3	98.1	100
10/23/1998	DM	39+40	9' LT	8	10/20/1998	98	24	122.0	113.0	9.0	8.0	21.8	100.2	102
10/23/1998	DM	38+39	6' LT	8	10/20/1998	98	24	123.0	112.0	11.0	9.8	25.6	97.9	100
10/26/1998	DM	32+70	12' RT	8	10/20/1998	98	24	115.2	107.7	7.5	7.0	18.6	97.1	99
10/26/1998	DM	30+00	6' LT	6	10/20/1998	98	24	116.5	109.3	7.2	6.6	16.2	100.3	102
10/26/1998	DM	28+48	9' RT	6	10/20/1998	98	24	117.4	109.4	8.0	7.3	19.3	98.4	100
10/26/1998	DM	26+66	6' LT	6	10/20/1998	98	24	117.7	110.2	7.5	6.8	19.8	98.2	100
10/27/1998	DM	24+30	3' RT	6	10/20/1998	98	24	117.2	109.4	7.8	7.1	19.6	98.0	100
10/27/1998	DM	22+70	12' RT	6	10/20/1998	98	24	117.3	109.5	7.8	7.1	19.7	98.0	100
10/28/1998	KB	21+00	15' RT	8	10/20/1998	98	24	117.6	107.2	10.4	9.7	22.9	95.7	98
10/28/1998	KB	18+60	18' LT	8	10/20/1998	98	24	125.3	114.1	11.2	9.8	24.6	100.6	103
10/28/1998	KB	17+00	12' LT	8	10/20/1998	98	24	117.3	108.5	8.8	8.1	22.4	95.8	98
10/28/1998	KB	15+00	8' LT	8	10/20/1998	98	24	118.0	108.7	9.3	8.6	22.4	96.4	98
10/28/1998	KB	13+00	Centerline	6	10/20/1998	98	24	119.2	109.6	9.6	8.8	22.6	97.2	99
10/28/1998	KB	13+00	Centerline	8	10/20/1998	98	24	119.8	110.3	9.5	8.6	22.6	97.7	100

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Nuclear Density Tests - ASTM D 2922 Fall 1998

					Standard Proctor			Nuclear Density						
Date	Tech	Station	Location	Depth (inches)	Date	g_d (pcf)	w (%)	WD (pcf)	DD (pcf)	M (pcf)	Moisture (%) (Measured)	Moisture (%, Oven)	Computed g_d (pcf)	Compaction (%)
10/29/1998	KB	11+00	10' LT	8	10/20/1998	98	24	118.6	110.0	8.6	7.8	21.5	97.6	100
10/29/1998	KB	9+00	9' LT	8	10/20/1998	98	24	122.3	114.1	8.2	7.2	23.0	99.4	101
10/30/1998	DM	7+00	4' RT	6	10/20/1998	98	24	118.1	110.3	7.8	7.1	20.7	97.8	100
10/30/1998	DM	5+00	Centerline	6	10/20/1998	98	24	117.7	109.3	8.4	7.7	23.4	95.4	97
10/31/1998	KB	3+00	Centerline	6	10/20/1998	98	24	111.3	102.1	9.2	9.0	22.2	91.1	93
10/31/1998	KB	1+50	Centerline	6	10/20/1998	98	24	112.5	103.5	9.0	8.7	23.5	91.1	93
Averages								119.7	110.5	9.2	8.3	22.1	98.0	100.0
Standard Deviations								3.2	2.7	1.2	1.0	1.9	2.3	2.3

Nuclear Density Tests - ASTM D 2922 Spring 1999

					Standard Proctor			Nuclear Density						
Date	Tech	Station	Location	Depth (inches)	Date	g_d (pcf)	w (%)	WD (pcf)	DD (pcf)	M (pcf)	Moisture (%) (Measured)	Moisture (%, Oven)	Computed g_d (pcf)	Compaction (%)
7/14/1999	DM	230+50	12' LT	6	8/6/1999	97.5	25.3	108.6	100.3	8.3	8.3	19.9	90.6	92.9
7/14/1999	DM	228+00	10' LT	6	8/6/1999	97.5	25.3	109.2	99.8	9.4	9.4	22.6	89.1	91.4
7/14/1999	DM	227+30	Centerline	6	8/6/1999	97.5	25.3	116.2	106.5	9.7	9.1	21.1	96.0	98.4
7/14/1999	DM	226+50	10' RT	6	8/6/1999	97.5	25.3	113.6	102.9	10.7	10.4	18.5	95.9	98.3
7/15/1999	DM	209+50	10' RT	6	8/6/1999	97.5	25.3	120.7	110.7	10.0	9.0	22.8	98.3	100.8
7/15/1999	DM	208+50	15' LT	6	8/6/1999	97.5	25.3	117.3	107.1	10.2	9.5	23.1	95.3	97.7
7/15/1999	DM	218+30	5' RT	6	8/6/1999	97.5	25.3	114.2	106.0	8.2	7.7	19.0	96.0	98.4
7/15/1999	DM	219+50	12' RT	6	8/6/1999	97.5	25.3	115.5	106.8	8.7	8.1	20.2	96.1	98.6
7/19/1999	DM	212+50	15' LT	6	8/6/1999	97.5	25.3	110.1	102.2	7.9	7.7	16.0	94.9	97.3
7/19/1999	DM	214+00	15' RT	6	8/6/1999	97.5	25.3	110.0	101.5	8.5	8.4	15.4	95.3	97.8
7/19/1999	DM	215+50	15' RT	6	8/6/1999	97.5	25.3	109.9	102.6	7.3	7.1	16.7	94.2	96.6
7/19/1999	DM	217+00	15' RT	6	8/6/1999	97.5	25.3	111.0	102.9	8.1	7.9	15.4	96.2	98.7
7/20/1999	DM	204+00	10' RT	6	8/6/1999	97.5	25.3	117.9	108.2	9.7	9.0	24.1	95.0	97.4
7/20/1999	DM	205+50	7' LT	6	8/6/1999	97.5	25.3	116.2	104.5	11.7	11.2	24.4	93.4	95.8

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Nuclear Density Tests - ASTM D 2922 Spring 1999

					Standard Proctor			Nuclear Density						
Date	Tech	Station	Location	Depth (inches)	Date	g_d (pcf)	w (%)	WD (pcf)	DD (pcf)	M (pcf)	Moisture (%) (Measured)	Moisture (%, Oven)	Computed g_d (pcf)	Compaction (%)
7/20/1999	DM	207+00	15' RT	6	8/6/1999	97.5	25.3	115.5	105.0	10.5	10.0	20.0	96.3	98.7
7/20/1999	DM	211+00	15' LT	6	8/6/1999	97.5	25.3	120.8	109.4	11.4	10.4	23.0	98.2	100.7
7/21/1999	DM	197+25	7' LT	6	8/6/1999	97.5	25.3	111.7	100.6	11.1	11.0	21.2	92.2	94.5
7/21/1999	DM	198+75	4' LT	6	8/6/1999	97.5	25.3	114.1	103.4	10.7	10.3	18.4	96.4	98.8
7/21/1999	DM	200+75	Centerline	6	8/6/1999	97.5	25.3	119.0	107.1	11.9	11.1	24.1	95.9	98.3
7/21/1999	DM	202+50	10' RT	6	8/6/1999	97.5	25.3	117.3	107.0	10.3	9.6	26.2	92.9	95.3
7/22/1999	DM	221+00	10' RT	6	8/6/1999	97.5	25.3	112.5	101.3	11.2	11.1	22.2	92.1	94.4
7/22/1999	DM	222+75	10' LT	6	8/6/1999	97.5	25.3	120.4	108.9	11.5	10.6	23.8	97.3	99.7
7/22/1999	DM	224+50	10' LT	6	8/6/1999	97.5	25.3	122.9	113.2	9.7	8.6	24.0	99.1	101.7
7/22/1999	DM	225+80	10' RT	6	8/6/1999	97.5	25.3	116.7	105.6	11.1	10.5	20.8	96.6	99.1
7/26/1999	DM	190+25	10' LT	6	8/6/1999	97.5	25.3	110.8	103.0	7.8	7.6	20.6	91.9	94.2
7/26/1999	DM	192+25	15' RT	6	8/6/1999	97.5	25.3	118.3	108.6	9.7	8.9	22.3	96.7	99.2
7/26/1999	DM	194+25	18' RT	6	8/6/1999	97.5	25.3	116.8	107.1	9.7	9.1	20.0	97.3	99.8
7/26/1999	DM	196+10	17' LT	6	8/6/1999	97.5	25.3	113.7	105.4	8.3	7.9	19.5	95.1	97.6
7/27/1999	DM	182+50	16' LT	6	8/6/1999	97.5	25.3	111.0	102.5	8.5	8.3	20.7	92.0	94.3
7/27/1999	DM	186+40	17' LT	6	8/6/1999	97.5	25.3	108.6	99.9	8.7	8.7	19.2	91.1	93.4
7/27/1999	DM	180+75	10' RT	6	8/6/1999	97.5	25.3	115.1	105.8	9.3	8.8	21.5	94.7	97.2
7/27/1999	DM	188+30	15' RT	6	8/6/1999	97.5	25.3	109.3	101.2	8.1	8.0	19.0	91.8	94.2
7/27/1999	DM	179+00	15' LT	6	8/6/1999	97.5	25.3	110.8	103.0	7.8	7.6	17.7	94.1	96.6
7/27/1999	DM	184+50	18' RT	6	8/6/1999	97.5	25.3	111.2	102.5	8.7	8.5	21.2	91.7	94.1
7/27/1999	DM	177+00	10' LT	6	8/6/1999	97.5	25.3	112.4	104.2	8.2	7.9	19.3	94.2	96.6
7/27/1999	DM	175+00	10' RT	6	8/6/1999	97.5	25.3	118.0	107.9	10.1	9.4	22.7	96.2	98.6
7/27/1999	DM	173+50	12' LT	6	8/6/1999	97.5	25.3	120.3	109.3	11.0	10.1	23.1	97.7	100.2
7/27/1999	DM	171+50	6' RT	6	8/6/1999	97.5	25.3	122.1	110.5	11.6	10.5	20.1	101.7	104.3
7/27/1999	DM	170+00	5' LT	6	8/6/1999	97.5	25.3	116.4	106.0	10.4	9.8	20.5	96.6	99.1
8/2/1999	DM	168+20	15' RT	6	8/6/1999	97.5	25.3	113.7	106.0	7.7	7.3	18.1	96.3	98.7
8/2/1999	DM	166+35	12' LT	6	8/6/1999	97.5	25.3	112.5	105.0	7.5	7.1	16.6	96.5	99.0
8/2/1999	DM	164+50	8' RT	6	8/6/1999	97.5	25.3	120.5	110.5	10.0	9.0	16.1	103.8	106.5
8/2/1999	DM	162+50	8' LT	6	8/6/1999	97.5	25.3	114.4	108.4	6.0	5.5	17.6	97.3	99.8

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Nuclear Density Tests - ASTM D 2922 Spring 1999

					Standard Proctor			Nuclear Density						
Date	Tech	Station	Location	Depth (inches)	Date	g_d (pcf)	w (%)	WD (pcf)	DD (pcf)	M (pcf)	Moisture (%) (Measured)	Moisture (%, Oven)	Computed g_d (pcf)	Compaction (%)
8/3/1999	DM	160+50	15' RT	6	8/6/1999	97.5	25.3	115.8	106.5	9.3	8.7	17.6	98.5	101.0
8/3/1999	DM	158+50	15' RT	6	8/6/1999	97.5	25.3	115.9	106.8	9.1	8.5	20.5	96.2	98.6
8/3/1999	DM	156+50	12' LT	6	8/6/1999	97.5	25.3	116.2	107.7	8.5	7.9	18.7	97.9	100.4
8/3/1999	DM	154+50	10' RT	6	8/6/1999	97.5	25.3	112.9	104.7	8.2	7.8	16.2	97.2	99.7
8/3/1999	DM	152+50	10' LT	6	8/6/1999	97.5	25.3	108.6	101.5	7.1	7.0	17.2	92.7	95.0
8/4/1999	DM	150+50	8' LT	6	8/6/1999	97.5	25.3	111.8	102.9	8.9	8.6	16.6	95.9	98.3
8/4/1999	DM	148+50	12' LT	6	8/6/1999	97.5	25.3	110.3	101.7	8.6	8.5	17.4	94.0	96.4
8/4/1999	DM	146+50	15' RT	6	8/6/1999	97.5	25.3	116.3	107.1	9.2	8.6	22.8	94.7	97.1
8/4/1999	DM	144+50	7' LT	6	8/6/1999	97.5	25.3	113.3	104.9	8.4	8.0	15.1	98.4	101.0
8/4/1999	DM	142+50	Centerline	6	8/6/1999	97.5	25.3	113.6	104.9	8.7	8.3	18.6	95.8	98.2
8/4/1999	DM	140+50	Centerline	6	8/6/1999	97.5	25.3	113.1	104.4	8.7	8.3	18.6	95.4	97.8
8/5/1999	DM	138+50	12' LT	6	8/6/1999	97.5	25.3	112.6	102.8	9.8	9.5	23.4	91.2	93.6
8/5/1999	DM	136+50	10' RT	6	8/6/1999	97.5	25.3	111.1	102.0	9.1	8.9	19.1	93.3	95.7
8/5/1999	DM	130+50	15' LT	6	8/6/1999	97.5	25.3	113.9	106.0	7.9	7.5	16.4	97.9	100.4
8/5/1999	DM	128+50	8' RT	6	8/6/1999	97.5	25.3	110.8	102.8	8.0	7.8	22.1	90.7	93.1
8/5/1999	DM	126+50	10' RT	6	8/6/1999	97.5	25.3	125.3	113.1	12.2	10.8	23.1	101.8	104.4
8/5/1999	DM	124+50	Centerline	6	8/6/1999	97.5	25.3	116.7	107.4	9.3	8.7	20.4	96.9	99.4
8/5/1999	DM	122+50	5' RT	6	8/6/1999	97.5	25.3	117.9	107.9	10.0	9.3	23.0	95.9	98.3
8/9/1999	DM	134+50	15' RT	6	8/6/1999	97.5	25.3	118.6	107.2	11.4	10.6	23.5	96.0	98.5
8/9/1999	DM	132+50	15' RT	6	8/6/1999	97.5	25.3	123.1	114.0	9.1	8.0	20.0	102.6	105.2
8/9/1999	DM	120+50	15' RT	6	8/6/1999	97.5	25.3	111.8	102.4	9.4	9.2	26.7	88.2	90.5
8/9/1999	DM	118+50	Centerline	6	8/6/1999	97.5	25.3	114.6	104.8	9.8	9.4	22.5	93.6	95.9
8/10/1999	DM	116+50	10' LT	6	8/6/1999	97.5	25.3	119.9	109.4	10.5	9.6	24.7	96.2	98.6
8/10/1999	DM	114+50	15' LT	6	8/6/1999	97.5	25.3	122.9	112.7	10.2	9.1	23.1	99.8	102.4
8/10/1999	DM	112+50	15' RT	6	8/6/1999	97.5	25.3	119.0	107.8	11.2	10.4	25.8	94.6	97.0
8/16/1999	DM	98+00	15' LT	6	8/6/1999	97.5	25.3	111.8	102.7	9.1	8.9	20.8	92.5	94.9
8/16/1999	DM	100+15	12' LT	6	8/6/1999	97.5	25.3	112.6	104.3	8.3	8.0	20.6	93.4	95.8
8/16/1999	DM	102+30	15' RT	6	8/6/1999	97.5	25.3	115.5	106.4	9.1	8.6	23.6	93.4	95.8

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Nuclear Density Tests - ASTM D 2922 Spring 1999

					Standard Proctor			Nuclear Density						
Date	Tech	Station	Location	Depth (inches)	Date	g_d (pcf)	w (%)	WD (pcf)	DD (pcf)	M (pcf)	Moisture (%) (Measured)	Moisture (%, Oven)	Computed g_d (pcf)	Compaction (%)
8/16/1999	DM	104+50	15' RT	6	8/6/1999	97.5	25.3	112.9	103.6	9.3	9.0	18.7	95.1	97.6
8/16/1999	DM	106+50	15' RT	6	8/6/1999	97.5	25.3	118.0	108.0	10.0	9.3	23.0	95.9	98.4
8/16/1999	DM	108+50	10' RT	6	8/6/1999	97.5	25.3	114.3	103.4	10.9	10.5	21.5	94.1	96.5
8/16/1999	DM	110+50	12' LT	6	8/6/1999	97.5	25.3	111.4	100.9	10.5	10.4	22.5	90.9	93.3
												Averages	95.3	97.8
												Standard Deviations	2.9	3.0

Dynamic Cone Penetration Tests on Select Fill Material Placed Fall 1998 - Tested Fall 1998

Date	Station	Location	Average C-Stone CBR (from DCP)			Average Subgrade CBR (from DCP)			Average C-Stone DPI (mm/blow)			Average Subgrade DPI (mm/blow)		
			Top 6"	Bottom 6"	Average	0-6"	6-12"	Average	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average
10/30/98	19+50	15' RT	15	17	16	12	7	9.5	14.2	12.7	13.4	17.3	28.0	21.3
10/30/98	25+10	10' LT	31	30	30.5	11	9	10	7.4	7.6	7.5	18.7	22.3	20.3
10/30/98	30+00	15' RT	26	19	22.5	11	8	9.5	8.7	11.5	9.9	18.7	24.8	21.3
10/26/98	32+70	12' RT	29	26	27.5	16	10	13	7.9	8.7	8.2	13.4	20.3	16.1
10/24/98	34+00	Centerline	20	23	21.5	14	10	12	11.0	9.7	10.3	15.1	20.3	17.3
10/30/98	35+00	12' RT	30	35	32.5	14	8	11	7.6	6.6	7.1	15.1	24.8	18.7
10/24/98	37+50	15' RT	18	12	15	5	4	4.5	12.0	17.3	14.2	37.8	46.1	41.5
10/23/98	38+40	8' LT	25	25	25	10	5	7.5	9.0	9.0	9.0	20.3	37.8	26.3
10/23/98	39+60	12' LT	25	23	24	8	7	7.5	9.0	9.7	9.3	24.8	28.0	26.3
10/23/98	41+45	18' RT	32	26	29	9	4	6.5	7.2	8.7	7.9	22.3	46.1	29.9
10/30/98	43+50	10' RT	46	25	35.5	11	3	7	5.2	9.0	6.6	18.7	59.6	28.0
10/22/98	46+50	Centerline	27	21	24	13	9	11	8.4	10.5	9.3	16.1	22.3	18.7
10/22/98	48+30	8' LT	23	22	22.5	4	11	7.5	9.7	10.1	9.9	46.1	18.7	26.3
10/28/98	49+70	12' LT	20	11	15.5	8	8	8	11.0	18.7	13.8	24.8	24.8	24.8
10/22/98	50+50	8' RT	20	19	19.5	7	18	12.5	11.0	11.5	11.2	28.0	12.0	16.7
10/28/98	52+00	5' LT	44	25	34.5	7	12	9.5	5.4	9.0	6.7	28.0	17.3	21.3
10/20/98	53+30	18' LT	15	6	10.5	8	8	8	14.2	32.1	19.5	24.8	24.8	24.8
10/20/98	53+40	20' RT	17	5	11	11	9	10	12.7	37.8	18.7	18.7	22.3	20.3
10/20/98	53+75	12' LT	16	7	11.5	6	5	5.5	13.4	28.0	18.0	32.1	37.8	34.7
10/20/98	53+85	12' RT	8	5	6.5	5	5	5	24.8	37.8	29.9	37.8	37.8	37.8
10/21/98	54+50	10' LT	18	14	16	8	5	6.5	12.0	15.1	13.4	24.8	37.8	29.9
10/21/98	55+00	5' RT	20	19	19.5	15	6	10.5	11.0	11.5	11.2	14.2	32.1	19.5
10/21/98	55+75	15' RT	23	17	20	9	4	6.5	9.7	12.7	11.0	22.3	46.1	29.9
Averages			23.8	18.8	21.3	9.7	7.6	8.6	10.5	15.0	12.0	23.5	30.1	24.9
Standard Deviations			8.7	8.0	7.4	3.3	3.4	2.4	3.9	9.3	5.3	8.3	11.4	6.7

Dynamic Cone Penetration Tests on Select Fill Material Placed Fall 1998 - Tested Spring 1999

Date	Station	Location	Average C-Stone CBR (from DCP)			Average Subgrade CBR (from DCP)			Average C-Stone DPI (mm/blow)			Average Subgrade DPI (mm/blow)		
			Top 6"	Bottom 6"	Average	0-6"	6-12"	Average	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average
5/26/99	1+20	15' RT	31	21	26	5	5	5	7.4	10.5	8.7	37.8	37.8	37.8
5/26/99	3+45	15' RT	48	30	39	6	11	8.5	5.0	7.6	6.0	32.1	18.7	23.5
5/26/99	5+30	15' LT	37	25	31	14	6	10	6.3	9.0	7.4	15.1	32.1	20.3
5/26/99	8+00	15' LT	56	25	40.5	61	2	31.5	4.4	9.0	5.8	4.0	85.6	7.3
5/26/99	10+00	15' RT	43	20	31.5	16	12	14	5.5	11.0	7.3	13.4	17.3	15.1
5/26/99	12+00	15' RT	58	15	36.5	12	6	9	4.2	14.2	6.4	17.3	32.1	22.3
5/26/99	14+00	15' LT	55	31	43	16	10	13	4.4	7.4	5.5	13.4	20.3	16.1
5/26/99	16+00	15' LT	42	6	24	4	6	5	5.6	32.1	9.3	46.1	32.1	37.8
5/26/99	18+00	15' RT	60	40	50	34	10	22	4.1	5.9	4.8	6.8	20.3	10.1
5/26/99	19+50	15' RT	51	29	40	37	11	24	4.7	7.9	5.9	6.3	18.7	9.3
5/26/99	25+10	12' LT	46	35	40.5	15	9	12	5.2	6.6	5.8	14.2	22.3	17.3
5/26/99	30+00	15' RT	39	15	27	7	11	9	6.0	14.2	8.4	28.0	18.7	22.3
5/26/99	32+70	12' RT	46	36	41	11	14	12.5	5.2	6.5	5.8	18.7	15.1	16.7
5/26/99	34+00	10' LT	45	32	38.5	41	13	27	5.3	7.2	6.1	5.8	16.1	8.4
5/26/99	35+00	12' RT	67	27	47	18	13	15.5	3.7	8.4	5.1	12.0	16.1	13.8
5/26/99	37+50	15' RT	47	14	30.5	4	5	4.5	5.1	15.1	7.5	46.1	37.8	41.5
5/26/99	38+40	10' LT	46	70	58	30	8	19	5.2	3.6	4.2	7.6	24.8	11.5
5/26/99	39+60	12' LT	89	55	72	7	11	9	2.9	4.4	3.5	28.0	18.7	22.3
5/26/99	41+45	12' RT	82	69	75.5	50	5	27.5	3.1	3.6	3.3	4.8	37.8	8.2
5/26/99	43+50	15' RT	79	45	62	28	6	17	3.2	5.3	4.0	8.1	32.1	12.7
5/26/99	46+50	8' RT	60	62	61	12	4	8	4.1	4.0	4.0	17.3	46.1	24.8
5/26/99	48+30	8' LT	101	50	75.5	64	10	37	2.6	4.8	3.3	3.9	20.3	6.3
5/26/99	49+70	12' LT	68	43	55.5	12	10	11	3.7	5.5	4.4	17.3	20.3	18.7
5/26/99	50+50	8' RT	68	72	70	40	17	28.5	3.7	3.5	3.6	5.9	12.7	8.0
5/26/99	52+00	10' LT	53	22	37.5	5	10	7.5	4.6	10.1	6.2	37.8	20.3	26.3
5/26/99	53+80	12' RT	59	26	42.5	7	7	7	4.2	8.7	5.6	28.0	28.0	28.0
5/26/99	54+50	10' LT	67	11	39	6	7	6.5	3.7	18.7	6.0	32.1	28.0	29.9
5/26/99	55+75	12' RT	56	33	44.5	13	8	10.5	4.4	7.0	5.4	16.1	24.8	19.5
		Averages	57.1	34.3	45.7	20.5	8.8	14.7	4.6	9.0	5.7	18.7	27.0	19.1
		Standard Deviations	16.2	18.2	15.0	17.5	3.4	9.0	1.1	5.9	1.6	12.9	14.2	9.7

Dynamic Cone Penetration Tests on Select Fill Material Placed Fall 1998 - Tested Summer 1999

			Average C-Stone CBR (from DCP)			Average Subgrade CBR (from DCP)			Average C-Stone DPI (mm/blow)			Average Subgrade DPI (mm/blow)		
Date	Station	Location	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average
8/10/99	1+25	18' LT	14	23	18.5	3	4	3.5	15.1	9.7	11.7	59.6	46.1	51.9
8/10/99	5+53	15' LT	76	84	80	42	5	23.5	3.3	3.0	3.2	5.6	37.8	9.5
8/10/99	10+00	15' RT	121	146	133.5	15	9	12	2.2	1.9	2.0	14.2	22.3	17.3
8/10/99	15+00	15' RT	117	61	89	8	18	13	2.3	4.0	2.9	24.8	12.0	16.1
8/10/99	19+51	15' LT	103	83	93	15	6	10.5	2.5	3.1	2.8	14.2	32.1	19.5
8/10/99	24+50	15' LT	176	115	145.5	23	4	13.5	1.6	2.3	1.9	9.7	46.1	15.6
8/10/99	29+00	18' RT	59	23	41	13	14	13.5	4.2	9.7	5.8	16.1	15.1	15.6
8/10/99	33+61	15' RT	76	48	62	11	13	12	3.3	5.0	4.0	18.7	16.1	17.3
8/19/99	38+60	15' LT	43	36	39.5	9	8	8.5	5.5	6.5	6.0	22.3	24.8	23.5
8/19/99	43+50	15' RT	75	46	60.5	15	12	13.5	3.4	5.2	4.1	14.2	17.3	15.6
8/19/99	48+50	15' RT	182	132	157	38	10	24	1.5	2.0	1.7	6.2	20.3	9.3
8/19/99	52+00	15' LT	66	30	48	6	5	5.5	3.8	7.6	5.0	32.1	37.8	34.7
		Averages	92.3	68.9	80.6	16.5	9.0	12.8	4.1	5.0	4.3	19.8	27.3	20.5
		Standard Deviations	50.3	43.0	44.7	12.2	4.5	6.1	3.6	2.8	2.8	14.7	12.2	11.9

Dynamic Cone Penetration Tests on Select
Fill Material Placed Summer 1999 - Tested Summer 1999

			Average C-Stone CBR (from DCP)			Average Subgrade CBR (from DCP)			Average C-Stone DPI (mm/blow)			Average Subgrade DPI (mm/blow)		
Date	Station	Location	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average
7/13/99	228+50	15' RT	20	15	18	9	4	7	11.0	14.2	12.3	22.3	46.1	29.9
7/13/99	230+15	12' RT	21	22	22	9	2	6	10.5	10.1	10.3	22.3	85.6	34.7
7/14/99	230+50	12' LT	17	20	19	19	30	25	12.7	11.0	11.7	11.5	7.6	9.1
7/14/99	228+00	10' LT	18	16	17	24	5	15	12.0	13.4	12.7	9.3	37.8	14.6
7/14/99	227+30	Centerline	21	24	23	22	4	13	10.5	9.3	9.9	10.1	46.1	16.1
7/14/99	226+50	10' RT	18	26	22	15	8	12	12.0	8.7	10.1	14.2	24.8	18.0
7/15/99	209+50	10' RT	22	25	24	11	17	14	10.1	9.0	9.5	18.7	12.7	15.1
7/15/99	208+50	15' LT	19	18	19	15	13	14	11.5	12.0	11.7	14.2	16.1	15.1
7/15/99	218+30	5' RT	26	17	22	7	3	5	8.7	12.7	10.3	28.0	59.6	37.8
7/15/99	219+50	12' RT	33	16	25	32	7	20	7.0	13.4	9.1	7.2	28.0	11.2
7/19/99	212+50	15' LT	28	23	26	24	5	15	8.1	9.7	8.8	9.3	37.8	14.6
7/19/99	214+00	15' RT	12	17	15	28	9	19	17.3	12.7	14.6	8.1	22.3	11.7
7/19/99	215+50	15' RT	25	23	24	38	5	22	9.0	9.7	9.3	6.2	37.8	10.3
7/19/99	217+00	15' RT	12	11	12	7	6	7	17.3	18.7	18.0	28.0	32.1	29.9
7/20/99	204+00	10' RT	34	26	30	33	22	28	6.8	8.7	7.6	7.0	10.1	8.2
7/20/99	205+50	7' LT	22	22	22	25	11	18	10.1	10.1	10.1	9.0	18.7	12.0
7/20/99	207+00	15' RT	41	26	34	15	10	13	5.8	8.7	6.9	14.2	20.3	16.7
7/20/99	211+00	15' LT	60	41	51	5	12	9	4.1	5.8	4.8	37.8	17.3	23.5
7/21/99	197+25	7' LT	21	22	22	29	11	20	10.5	10.1	10.3	7.9	18.7	11.0
7/21/99	198+75	4' LT	23	23	23	26	7	17	9.7	9.7	9.7	8.7	28.0	13.0
7/21/99	200+75	Centerline	44	24	34	26	10	18	5.4	9.3	6.8	8.7	20.3	12.0
7/21/99	202+50	10' RT	17	20	19	21	12	17	12.7	11.0	11.7	10.5	17.3	13.0
7/22/99	221+00	10' RT	15	25	20	16	14	15	14.2	9.0	11.0	13.4	15.1	14.2
7/22/99	222+75	10' LT	42	56	49	55	14	35	5.6	4.4	4.9	4.4	15.1	6.7
7/22/99	224+50	10' LT	55	22	39	25	5	15	4.4	10.1	6.1	9.0	37.8	14.2
7/22/99	225+80	10' RT	54	35	45	42	24	33	4.5	6.6	5.4	5.6	9.3	7.0
7/26/99	190+25	10' LT	29	26	28	16	4	10	7.9	8.7	8.2	13.4	46.1	20.3

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Dynamic Cone Penetration Tests on Select
Fill Material Placed Summer 1999 - Tested Summer 1999

			Average C-Stone CBR (from DCP)			Average Subgrade CBR (from DCP)			Average C-Stone DPI (mm/blow)			Average Subgrade DPI (mm/blow)		
Date	Station	Location	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average
7/26/99	192+25	15' RT	41	31	36	17	16	17	5.8	7.4	6.5	12.7	13.4	13.0
7/26/99	194+25	18' RT	58	28	43	10	14	12	4.2	8.1	5.5	20.3	15.1	17.3
7/26/99	196+10	17' LT	65	36	51	55 - Rock	Rock	-	3.8	6.5	4.8	-	-	-
7/27/99	182+50	16' LT	17	27	22	27	10	19	12.7	8.4	10.1	8.4	20.3	11.7
7/27/99	186+40	17' LT	37	28	33	15	2	9	6.3	8.1	7.1	14.2	85.6	23.5
7/27/99	180+75	10' RT	32	36	34	23	12	18	7.2	6.5	6.8	9.7	17.3	12.3
7/27/99	188+30	15' RT	28	30	29	45	11	28	8.1	7.6	7.9	5.3	18.7	8.1
7/27/99	179+00	15' LT	19	20	20	27	15	21	11.5	11.0	11.2	8.4	14.2	10.5
7/27/99	184+50	18' RT	31	32	32	23	13	18	7.4	7.2	7.3	9.7	16.1	12.0
7/27/99	177+00	10' LT	18	21	20	20	10	15	12.0	10.5	11.2	11.0	20.3	14.2
7/27/99	175+00	10' RT	20	14	17	21	13	17	11.0	15.1	12.7	10.5	16.1	12.7
7/27/99	173+50	12' LT	43	35	39	18	15	17	5.5	6.6	6.0	12.0	14.2	13.0
7/27/99	171+50	6' RT	23	43	33	41	16	29	9.7	5.5	7.0	5.8	13.4	8.0
7/27/99	170+00	5' LT	37	59	48	23	7	15	6.3	4.2	5.0	9.7	28.0	14.2
8/2/99	168+20	15' RT	36	38	37	20	11	16	6.5	6.2	6.3	11.0	18.7	13.8
8/2/99	166+35	12' LT	71	44	58	13	9	11	3.5	5.4	4.3	16.1	22.3	18.7
8/2/99	164+50	8' RT	149	66	108	17	14	16	1.8	3.8	2.4	12.7	15.1	13.8
8/2/99	162+50	8' LT	47	72	60	27	12	20	5.1	3.5	4.1	8.4	17.3	11.2
8/3/99	160+50	15' RT	66	96	81	27	26	27	3.8	2.7	3.1	8.4	8.7	8.5
8/3/99	158+50	15' RT	19	20	20	8	9	9	11.5	11.0	11.2	24.8	22.3	23.5
8/3/99	156+50	12' LT	49	26	38	16	10	13	4.9	8.7	6.2	13.4	20.3	16.1
8/3/99	154+50	10' RT	52	31	42	13	5	9	4.7	7.4	5.7	16.1	37.8	22.3
8/3/99	152+50	10' LT	51	35	43	18	16	17	4.7	6.6	5.5	12.0	13.4	12.7
8/4/99	150+50	8' LT	26	27	27	15	9	12	8.7	8.4	8.5	14.2	22.3	17.3
8/4/99	148+50	12' LT	25	26	26	26	29	28	9.0	8.7	8.8	8.7	7.9	8.2
8/4/99	146+50	15' RT	54	24	39	23	31	27	4.5	9.3	6.0	9.7	7.4	8.4
8/4/99	144+50	7' LT	35	23	29	20	16	18	6.6	9.7	7.9	11.0	13.4	12.0
8/4/99	142+50	Centerline	24	28	26	29	16	23	9.3	8.1	8.7	7.9	13.4	9.9

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Dynamic Cone Penetration Tests on Select
Fill Material Placed Summer 1999 - Tested Summer 1999

			Average C-Stone CBR (from DCP)			Average Subgrade CBR (from DCP)			Average C-Stone DPI (mm/blow)			Average Subgrade DPI (mm/blow)		
Date	Station	Location	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average	Top 6"	Bottom 6"	Average	0-6"	6-12"	Average
8/4/99	140+50	Centerline	23	17	20	19	13	16	9.7	12.7	11.0	11.5	16.1	13.4
8/5/99	138+50	12' LT	31	31	31	21	25	23	7.4	7.4	7.4	10.5	9.0	9.7
8/5/99	136+50	10' RT	25	28	27	47	21	34	9.0	8.1	8.5	5.1	10.5	6.8
8/5/99	130+50	15' LT	27	21	24	28	25	27	8.4	10.5	9.3	8.1	9.0	8.5
8/5/99	128+50	8' RT	24	19	22	16	6	11	9.3	11.5	10.3	13.4	32.1	18.7
8/5/99	126+50	10' RT	24	33	29	12	4	8	9.3	7.0	8.0	17.3	46.1	24.8
8/5/99	124+50	Centerline	30	20	25	13	4	9	7.6	11.0	9.0	16.1	46.1	23.5
8/5/99	122+50	5' RT	13	24	19	19	6	13	16.1	9.3	11.7	11.5	32.1	16.7
8/9/99	134+50	15' RT	63	117	90	95	24	60	3.9	2.3	2.9	2.7	9.3	4.1
8/9/99	132+50	15' RT	66	28	47	15	20	18	3.8	8.1	5.1	14.2	11.0	12.3
8/9/99	120+50	15' RT	18	14	16	8	3	6	12.0	15.1	13.4	24.8	59.6	34.7
8/9/99	118+50	Centerline	20	20	20	19	9	14	11.0	11.0	11.0	11.5	22.3	15.1
8/10/99	116+50	10' LT	46	50	48	17	18	18	5.2	4.8	5.0	12.7	12.0	12.3
8/10/99	114+50	15' LT	50	48	49	14	22	18	4.8	5.0	4.9	15.1	10.1	12.0
8/10/99	112+50	15' RT	30	41	36	19	44	32	7.6	5.8	6.6	11.5	5.4	7.3
8/16/99	98+00	15' LT	17	19	18	17	5	11	12.7	11.5	12.0	12.7	37.8	18.7
8/16/99	100+15	12' LT	26	18	22	21	14	18	8.7	12.0	10.1	10.5	15.1	12.3
8/16/99	102+30	15' RT	48	24	36	11	4	8	5.0	9.3	6.5	18.7	46.1	26.3
8/16/99	104+50	15' RT	34	40	37	30	4	17	6.8	5.9	6.3	7.6	46.1	12.7
8/16/99	106+50	15' RT	29	22	26	15	7	11	7.9	10.1	8.8	14.2	28.0	18.7
8/16/99	108+50	10' RT	37	28	33	12	22	17	6.3	8.1	7.1	17.3	10.1	12.7
8/16/99	110+50	12' LT	57	62	60	31	29	30	4.3	4.0	4.1	7.4	7.9	7.6
8/19/99	236+00	10' RT	20	17	19	4	4	4	11.0	12.7	11.7	46.1	46.1	46.1
8/19/99	234+00	5' LT	19	31	25	23	3	13	11.5	7.4	9.0	9.7	59.6	16.1
8/19/99	232+00	Centerline	19	29	24	31	15	23	11.5	7.9	9.3	7.4	14.2	9.7
Averages			34.0	30.5	32.2	21.9	12.6	17.2	8.3	8.8	8.4	12.8	24.6	15.3
Standard Deviations			19.9	17.3	16.6	12.8	8.2	8.6	3.3	3.0	2.9	7.0	16.9	7.6

Dynamic Cone Penetration Tests on Control Section
Fall 1998

			Average Subgrade CBR				
Date	Station	Location	0-6"	6-12"	12"-18"	18"-24"	Average
11/6/1998	58+00	12' RT	3	7	13	12	9
11/6/1998	60+00	12' RT	3	6	15	Rock?	8
11/6/1998	62+00	10' LT	25	25	11	15	13
11/6/1998	64+00	10' RT	9	15	18	11	13
11/6/1998	66+00	15' RT	7	9	10	7	8
11/6/1998	68+00	12' LT	3	6	6	7	6
11/6/1998	70+00	10' LT	6	7	12	10	9
11/6/1998	72+00	14' RT	8	7	9	11	9
11/6/1998	76+00	12' LT	7	12	14	10	11
11/6/1998	78+00	15' RT	6	9	7	7	7
11/11/1998	79+50	12' LT	3	2	2	3	3
11/11/1998	81+50	12' RT	2	8	4	5	5
11/11/1998	83+50	10' RT	3	4	7	8	6
11/11/1998	85+50	12' RT	3	5	6	10	6
11/11/1998	87+50	12' LT	7	8	7	9	8
11/11/1998	89+50	12' RT	5	7	11	15	10
11/11/1998	91+50	15' RT	8	9	11	11	10
11/11/1998	93+50	15' LT	5	10	12	15	11
11/11/1998	95+50	15' RT	4	5	6	12	7
11/11/1998	97+50	12' LT	3	5	8	8	6
11/11/1998	99+50	15' RT	5	3	4	2	4
11/11/1998	101+50	10' LT	5	8	15	15	11
		Averages	5.0	7.2	9.5	9.7	8.0
		Standard Deviations	2.0	2.9	4.0	3.7	2.7

Dynamic Cone Penetration Tests on Control Section
Spring 1999

			Average Subgrade CBR				
Date	**Station**	**Location**	**0-6"**	**6-12"**	**12"-18"**	**18"-24"**	**Average**
5/27/1999	58+00	12' RT	5	7	7	10	7.3
5/27/1999	60+00	12' RT	6	4	3	2	3.8
5/27/1999	62+00	10' LT	2	2	4	6	3.5
5/27/1999	64+00	12' RT	4	2	11	47?	5.7
5/27/1999	66+00	12' RT	9	15	9	9	10.5
5/27/1999	68+00	10' LT	4	6	6	10	6.5
5/27/1999	70+00	12' LT	5	6	13	12	9.0
5/27/1999	72+00	15' RT	5	7	14	14	10.0
5/27/1999	76+00	12' LT	4	4	4	6	4.5
5/27/1999	78+00	15' RT	5	4	7	9	6.3
5/27/1999	79+50	12' LT	4	5	6	7	5.5
5/27/1999	81+50	12' RT	7	4	5	8	6.0
5/27/1999	83+50	15' RT	3	3	4	4	3.5
5/27/1999	85+50	12' RT	4	4	7	12	6.8
5/27/1999	87+50	15' LT	4	2	2	3	2.8
5/27/1999	89+50	15' RT	3	1	5	4	3.3
5/27/1999	91+50	15' RT	2	3	3	4	3.0
5/27/1999	93+50	12' LT	4	8	10	10	8.0
5/27/1999	95+50	12' RT	2	2	2	21	6.8
5/27/1999	97+50	15' LT	3	4	5	5	4.3
5/27/1999	99+50	15' RT	4	4	6	9	5.8
5/27/1999	101+50	12' LT	3	3	4	4	3.5
Averages			4.2	4.5	6.2	8.0	5.7
Standard Deviations			1.7	3.0	3.3	4.4	2.3

Dynamic Cone Penetration Tests on Control Section
Fall 1999

			Average Subgrade CBR				
Date	**Station**	**Location**	**0-6"**	**6-12"**	**12"-18"**	**18"-24"**	**Average**
9/9/1999	58+00	16' LT	15.0	9.0	6.0	4.0	8.5
9/9/1999	63+00	15' RT	22.0	14.0	12.0	10.0	14.5
9/9/1999	68+00	15' RT	24.0	20.0	13.0	14.0	17.8
9/9/1999	73+00	15' LT	26.0	21.0	12.0	7.0	16.5
9/9/1999	78+00	15' RT	18.0	13.0	9.0	7.0	11.8
9/9/1999	83+00	15' LT	12.0	9.0	9.0	9.0	9.8
9/9/1999	88+00	15' RT	15.0	20.0	24.0	18.0	19.3
9/9/1999	93+00	15' LT	26.0	23.0	19.0	5.0	18.3
Averages			19.8	16.1	13.0	9.3	14.5
Standard Deviations			5.5	5.6	5.9	4.7	4.1

Field CBR Summary - Summer 1999

Date	Station	Location	CBR at 0.100" (%)	CBR at 0.200" (%)
7/22/1999	222+75	10' LT	26.7	23.4
7/22/1999	224+50	10' LT	25.3	31.9
7/22/1999	225+80	10' RT	53.4	86.3
8/2/1999	168+20	15' RT	68.9	63.8
8/2/1999	166+35	12' LT	50.6	52.5
8/2/1999	164+50	8' RT	74.5	83.4
8/2/1999	162+50	8' LT	54.8	53.4
8/3/1999	160+50	15' RT	60.5	63.8
8/3/1999	158+50	15' RT	39.4	48.8
8/3/1999	156+50	12' LT	36.6	36.6
8/3/1999	154+50	10' RT	50.6	52.4
8/3/1999	152+50	10' LT	40.8	41.3
8/4/1999	150+50	8' LT	22.5	20.6
8/4/1999	148+50	12' LT	36.6	30.9
8/4/1999	146+50	15' RT	29.5	27.2
8/4/1999	144+50	7' LT	50.6	53.4
8/4/1999	142+50	Centerline	36.6	32.8
8/4/1999	140+50	Centerline	30.9	30.0
8/5/1999	138+50	12' LT	30.9	32.8
8/5/1999	136+50	10' RT	30.9	30.0
8/5/1999	130+50	15' LT	29.5	25.3
8/5/1999	128+50	8' RT	36.6	33.8
8/5/1999	126+50	10' RT	26.7	27.2
8/5/1999	124+50	Centerline	38.0	42.2
8/5/1999	122+50	5' RT	26.7	25.3
8/9/1999	134+50	15' RT	49.2	56.3
8/9/1999	132+50	15' RT	43.6	54.4
8/9/1999	120+50	15' RT	35.2	35.6
8/9/1999	118+50	Centerline	28.1	24.4
8/10/1999	116+50	10' LT	39.4	47.8
8/10/1999	114+50	15' LT	53.4	68.4
8/10/1999	112+50	15' RT	38.0	41.3
8/16/1999	98+00	15' LT	48.1	25.3
8/16/1999	102+30	15' RT	38.0	40.3
8/16/1999	106+50	15' RT	43.6	42.2
8/16/1999	110+50	12' LT	54.8	60.0
8/19/1999	236+00	10' RT	25.3	22.5
8/19/1999	234+00	5' LT	21.1	19.7
		Averages	40.2	41.8
		Standard Deviations	12.8	17.0

Clegg Impact Testing - ASTM D 5874
Fall 1998

Date	Station	Location	Clegg Impact Value (CIV)
10/20/1998	53+30	18' LT	16
10/20/1998	53+40	20' RT	41
10/20/1998	53+50	22' RT	19
10/20/1998	53+75	12' LT	27
10/20/1998	53+85	12' RT	14
10/20/1998	53+90	12' RT	23
10/20/1998	53+80	12' RT	21
10/20/1998	53+20	Centerline	25
10/20/1998	53+40	Centerline	40
10/20/1998	53+60	Centerline	42
10/20/1998	53+80	Centerline	46
10/20/1998	53+90	Centerline	43
10/20/1998	53+30	18' LT	16
10/20/1998	53+30	20' LT	17
10/20/1998	53+40	20' RT	41
10/20/1998	53+40	22' RT	19
10/20/1998	53+85	12' RT	14
10/20/1998	53+85	16' RT	23
10/20/1998	53+85	18' RT	21
10/31/1998	55+75	15' RT	38
10/31/1998	55+00	5' RT	33
10/31/1998	54+50	10' LT	29
10/31/1998	50+50	8' RT	34
10/31/1998	48+30	8' LT	46
10/31/1998	46+50	Centerline	43
10/31/1998	43+50	10' RT	39
10/31/1998	41+45	18' RT	36
10/31/1998	39+60	12' LT	37
10/31/1998	38+40	8' LT	45
10/31/1998	35+00	12' RT	28
10/31/1998	32+70	12' RT	34
10/31/1998	30+00	15' RT	28
10/31/1998	25+10	10' LT	31
10/31/1998	19+50	15' RT	27
10/31/1998	15+00	Centerline	32
10/31/1998	10+00	10' LT	23
10/31/1998	5+00	Centerline	27
		Average	30.2
		Standard Deviation	9.8

Clegg Impact Testing - ASTM D 5874
Summer 1999

Date	Station	Location	Clegg Hammer Readings				Average	Median	Standard Deviation
7/14/1999	230+50	12' LT	19.6	19.5	15.0	19.5	18.4	19.5	2.27
7/14/1999	228+00	10' LT	17.0	18.0	21.2	19.2	18.9	18.6	1.81
7/14/1999	227+30	Centerline	29.8	21.1	24.5	24.0	24.9	24.3	3.62
7/14/1999	226+50	10' RT	22.3	20.8	19.0	22.9	21.3	21.6	1.74
7/15/1999	209+50	10' RT	20.6	28.7	19.0	20.2	22.1	20.4	4.44
7/15/1999	208+50	15' LT	20.2	26.0	21.6	25.1	23.2	23.4	2.77
7/15/1999	218+30	5' RT	21.2	22.6	18.8	24.7	21.8	21.9	2.48
7/15/1999	219+50	12' RT	25.4	18.5	18.9	24.6	21.9	21.8	3.66
7/19/1999	212+50	15' LT	21.2	32.4	23.4	22.8	25.0	23.1	5.05
7/19/1999	214+00	15' RT	12.3	19.2	29.6	19.5	20.2	19.4	7.12
7/19/1999	215+50	15' RT	21.7	36.5	32.4	16.6	26.8	27.1	9.23
7/19/1999	217+00	15' RT	10.8	17.2	16.5	10.7	13.8	13.7	3.53
7/20/1999	204+00	10' RT	30.5	26.0	25.1	31.7	28.3	28.3	3.26
7/20/1999	205+50	7' LT	21.8	24.3	19.4	22.5	22.0	22.2	2.03
7/20/1999	207+00	15' RT	46.6	24.6	48.3	36.1	38.9	41.4	10.95
7/20/1999	211+00	15' LT	33.3	41.3	26.3	26.3	31.8	29.8	7.14
7/21/1999	197+25	7' LT	26.8	28.3	25.3	30.0	27.6	27.6	2.01
7/21/1999	198+75	4' LT	27.8	25.2	21.6	28.4	25.8	26.5	3.10
7/21/1999	200+75	Centerline	50.6	43.9	46.8	27.2	42.1	45.4	10.32
7/21/1999	202+50	10' RT	23.1	22.6	20.3	20.9	21.7	21.8	1.34
7/22/1999	221+00	10' RT	19.0	20.3	27.4	24.1	22.7	22.2	3.81
7/22/1999	222+75	10' LT	23.2	28.7	25.9	29.5	26.8	27.3	2.87
7/22/1999	224+50	10' LT	31.8	29.1	25.0	33.4	29.8	30.5	3.67
7/22/1999	225+80	10' RT	56.3	46.7	34.6	49.0	46.7	47.9	9.02
7/26/1999	190+25	10' LT	34.1	29.0	29.1	30.2	30.6	29.7	2.40
7/26/1999	192+25	15' RT	43.7	29.5	36.7	44.4	38.6	40.2	6.98
7/26/1999	194+25	18' RT	45.5	44.3	33.7	39.8	40.8	42.1	5.35
7/26/1999	196+10	17' LT	50.2	39.4	29.8	46.6	41.5	43.0	9.00
7/27/1999	182+50	16' LT	24.4	25.9	25.9	22.1	24.6	25.2	1.80
7/27/1999	186+40	17' LT	35.4	33.4	19.8	24.3	28.2	28.9	7.41
7/27/1999	180+75	10' RT	34.2	21.7	39.3	29.3	31.1	31.8	7.49
7/27/1999	188+30	15' RT	27.6	26.0	22.8	25.5	25.5	25.8	2.00
7/27/1999	179+00	15' LT	22.8	23.1	25.3	25.5	24.2	24.2	1.42
7/27/1999	184+50	18' RT	24.7	23.9	30.7	28.8	27.0	26.8	3.26
7/27/1999	177+00	10' LT	21.3	15.7	23.6	24.6	21.3	22.5	3.98
7/27/1999	175+00	10' RT	33.0	24.8	33.7	31.8	30.8	32.4	4.09
7/27/1999	173+50	12' LT	28.2	46.9	43.4	25.9	36.1	35.8	10.59
7/27/1999	171+50	6' RT	23.4	23.2	23.6	18.3	22.1	23.3	2.56
7/27/1999	170+00	5' LT	28.1	28.7	14.8	29.8	25.4	28.4	7.07
8/2/1999	168+20	15' RT	38.2	29.0	35.1	49.4	37.9	36.7	8.55

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Continued
Clegg Impact Testing - ASTM D 5874
Summer 1999

Date	Station	Location	Clegg Hammer Readings				Average	Median	Standard Deviation
8/2/1999	166+35	12' LT	40.1	36.3	39.5	32.3	37.1	37.9	3.58
8/2/1999	164+50	8' RT	68.0	76.0	67.7	73.6	71.3	70.8	4.13
8/2/1999	162+50	8' LT	31.1	28.4	35.2	25.6	30.1	29.8	4.09
8/3/1999	160+50	15' RT	40.9	29.0	41.0	57.2	42.0	41.0	11.58
8/3/1999	158+50	15' RT	27.8	33.7	49.9	36.9	37.1	35.3	9.34
8/3/1999	156+50	12' LT	28.6	45.3	43.7	27.4	36.3	36.2	9.56
8/3/1999	154+50	10' RT	43.4	34.1	37.6	32.5	36.9	35.9	4.83
8/3/1999	152+50	10' LT	35.4	26.6	33.4	32.3	31.9	32.9	3.77
8/4/1999	150+50	8' LT	30.8	24.5	31.6	20.3	26.8	27.7	5.37
8/4/1999	148+50	12' LT	27.9	27.2	23.2	25.1	25.9	26.2	2.13
8/4/1999	146+50	15' RT	32.4	34.2	34.4	26.7	31.9	33.3	3.60
8/4/1999	144+50	7' LT	38.8	29.9	32.3	34.6	33.9	33.5	3.79
8/4/1999	142+50	Centerline	31.4	21.4	31.8	23.8	27.1	27.6	5.29
8/4/1999	140+50	Centerline	23.5	26.6	24.4	25.0	24.9	24.7	1.30
8/5/1999	138+50	12' LT	38.0	46.1	42.8	31.0	39.5	40.4	6.56
8/5/1999	136+50	10' RT	27.0	29.4	30.8	27.0	28.6	28.2	1.88
8/5/1999	130+50	15' LT	23.7	22.8	22.5	26.4	23.9	23.3	1.77
8/5/1999	128+50	8' RT	29.1	21.4	20.4	25.0	24.0	23.2	3.95
8/5/1999	126+50	10' RT	22.7	33.1	14.0	32.7	25.6	27.7	9.12
8/5/1999	124+50	Centerline	31.5	21.9	40.0	26.4	30.0	29.0	7.76
8/5/1999	122+50	5' RT	20.2	23.2	15.3	20.9	19.9	20.6	3.32
8/9/1999	134+50	15' RT	52.5	45.7	46.1	34.3	44.7	45.9	7.57
8/9/1999	132+50	15' RT	43.0	61.8	63.3	42.1	52.6	52.4	11.57
8/9/1999	120+50	15' RT	28.4	33.6	36.9	23.2	30.5	31.0	6.01
8/9/1999	118+50	Centerline	25.8	27.5	25.0	28.4	26.7	26.7	1.55
8/10/1999	116+50	10' LT	26.9	53.2	40.3	27.7	37.0	34.0	12.41
8/10/1999	114+50	15' LT	53.2	50.7	53.0	46.6	50.9	51.9	3.07
8/10/1999	112+50	15' RT	36.4	46.6	43.0	41.2	41.8	42.1	4.24
8/16/1999	98+00	15' LT	31.6	27.3	20.8	26.1	26.5	26.7	4.45
8/16/1999	100+15	12' LT	27.5	24.6	26.1	25.5	25.9	25.8	1.22
8/16/1999	102+30	15' RT	31.7	32.3	27.8	32.3	31.0	32.0	2.17
8/16/1999	104+50	15' RT	36.2	32.0	34.4	30.6	33.3	33.2	2.49
8/16/1999	106+50	15' RT	36.9	33.4	34.0	39.6	36.0	35.5	2.86
8/16/1999	108+50	10' RT	56.5	50.6	45.3	51.2	50.9	50.9	4.58
8/16/1999	110+50	12' LT	50.2	53.1	50.0	48.7	50.5	50.1	1.86
8/19/1999	236+00	10' RT	18.2	18.9	17.2	19.3	18.4	18.6	0.92
8/19/1999	234+00	5' LT	20.7	25.9	22.3	22.1	22.8	22.2	2.22
8/19/1999	232+00	Centerline	23.4	22.0	22.8	21.3	22.4	22.4	0.92
						Averages	30.7	30.9	4.72
						Standard Deviations	9.7	9.9	