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Base Stabilization and Dust Control Using Calcium Chloride and Fly Ash

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ABSTRACT

Field trials were conducted at the TETRA Technologies, Inc. plant site in Lake Charles, Louisiana. A filter cake generated as a by-product in the production of calcium chloride at this plant was investigated for its potential as a dust-controlling agent and for the stabilization of low-volume dirt roads. A laboratory study was initiated prior to the field trials to develop mix designs in which this filter cake could be blended with a class C fly ash and a crushed limestone base obtained from the construction site located at the plant grounds. Two mix designs were developed in the laboratory for incorporating the filter cake, which contained about 30 to 33 wt% of $CaCl_2$, into a series of field sections. One mixture was blended so as to contain a dry $CaCl_2$ content (i.e. percent of dry solids in the base) of 1.3 wt%. A second mix was designed for a dry $CaCl_2$ content of 1.7 wt%. A locally available ASTM designated Class C fly ash was added to both mixtures to control fines, porosity, and moisture-density characteristics. Five test sections were built as a part of the construction phase of the project. Along with a control section represented by the untreated, existing crushed limestone base and two sections containing filter cake, two other sections were built in which the base was treated with ROADMASTER™ calcium chloride, a commercial, 38 wt% aqueous solution of $CaCl_2$ marketed by TETRA Technologies, Inc. of The Woodlands, Texas as a dust palliative. Of the two sections containing ROADMASTER calcium chloride, only one incorporated fly ash. Both ROADMASTER calcium chloride treated sections were designed to have 1.3 wt% dry $CaCl_2$ content. Following construction, the five sections were subjected to traffic to qualitatively compare their ability to minimize dust erosion. All four treated sections performed extremely well, whereas the control sections created considerable dust clouds at vehicle speeds typical of those anticipated at the plant. Limitations in the construction equipment used in this project had an effect on the surface characteristics of the test sections containing filter cake and on their ability to provide a uniformly homogenized blend within the thickness of the base. Recommendations for dealing with these construction problems are presented for consideration in planning future projects utilizing this filter cake.

INTRODUCTION

The work discussed in this paper is part of an ongoing effort at Texas A & M University to establish the effectiveness of calcium chloride as an additive for low-volume roadway construction. The first study examined the relative effectiveness of $CaCl_2$ and $MgCl_2$ to control dust erosion of selected roadway aggregates used in Texas, Arizona, and Wyoming[1].

In a subsequent project, the use of $CaCl_2$ to enhance full-depth recycling of asphalt roads was investigated[2,3]. This study involved a laboratory effort and a field demonstration projected conducted to establish if $CaCl_2$ could be used for reclamation and dust control on secondary roads in Texas by building upon the encouraging results experienced in Pennsylvania[4], New Hampshire[5], New York[6], Michigan[7], and Canada[8].

A field trial, involving three test sections, was conducted during May 1998 at the Texas A & M University Riverside Campus, College Station, Texas[2,3]. The objective of this project was to evaluate a 38 wt% aqueous solution of $CaCl_2$ produced by TETRA Technologies, Inc. of The Woodlands, Texas under the trade name ROADMASTER for dust control and to establish a working platform during full-depth recycling asphalt roads.

Of the three test sections constructed under this project the two which did not contain ROADMASTER calcium chloride showed considerable dust erosion and little or no structural improvement under traffic throughout a seven month post-construction evaluation period. The strength of the test section treated with ROADMASTER calcium chloride began to improve within days following application and continued for about three months. The treated section remained dust free well beyond the evaluation period of the test sections.

Early in April 2001, Texas A & M University was asked by TETRA Technologies, Inc. to develop a use of a by-product of one of their calcium chloride production plants. During purification, a filter cake containing about 30 to 33 % by weight of $CaCl_2$ was generated. A laboratory study was initiated to determine if this filter cake, once suitably dried and blended into a road base, could provide both dust control and stability to the road base comparable to that achieved with ROADMASTER calcium chloride. The results of this laboratory investigation were incorporated into a second field trial, which was conducted during May 2001 at the TETRA Technologies, Inc. plant site in Lake Charles, Louisiana. The results of this investigation are discussed below.

OVERALL OBJECTIVES

The overall objective of the study was to determine the extent to which the filter cake generated at the TETRA's calcium chloride production facility in Lake Charles, Louisiana could provide dust abatement as well as base stabilization in low volume roadways comparable to ROADMASTER calcium chloride.

SPECIFIC OBJECTIVES

The achievement of the overall objective stated above involved following specific objectives:

- Produce mix design(s) utilizing a by-product filter cake generated at TETRA's Lake Charles, Louisiana plant for treating on-site, unsurfaced roads.
- Determine construction procedures for incorporating the mix design(s) into the base material.
- Provide a qualitative comparison of the relative dust abatement and stability achieved in base materials treated with filter cake and those treated with ROADMASTER calcium chloride.
- Carry out a 6-month post-construction evaluation of the in service performance of ROADMASTER calcium chloride and filter cake stabilized test sections.
- Establish recommended mixed designs, construction procedures and service-life expectancy for road bases stabilized with filter cake.

TECHNICAL APPROACH

The project consisted of a laboratory effort and the construction of five test sections. In the laboratory, mix designs comprised of a crushed limestone base, $CaCl_2$-containing filter cake and an ASTM Class C fly ash were generated and optimized. In the preparation of the mix designs, two calcium chloride concentrations were studied (a 1.3 and a 1.7 percent by weight of dry $CaCl_2$). Because of the significant amount of residual water in the filter cake, a locally available ASTM Class C fly ash was incorporated into the mix for drying purpose as well as for any cementitious benefits, which might be derived. Once the mix designs were generated, they were incorporated into 4-test sections of the experimental field trial at the Lake Charles plant site. A fifth section was left untreated and designated as a control. Construction took place on the 17th and 18th of May 2001.

Materials

The mix designs generated in the laboratory activity of the study involved three materials: crushed limestone; filter cake; and fly ash.

Crushed Limestone Base: The crushed limestone base used in the mix designs was obtained from the site of the test sections at TETRA's Lake Charles, Louisiana, plant. The gradation of the base material is given in Figure 1. Laboratory tests revealed an average moisture content of 4.6 wt%. The Material Data Sheets for the limestone base furnished by Martin Marietta Aggregates of Lake Charles, Louisiana is given in Table 1.

Filter Cake: The filter cake was obtained from TETRA's calcium chloride production facility in Lake Charles, Louisiana. The filter cake resembled a black, soggy clay. The calcium chloride and moisture contents of the filter cake were measured to be about 30 and 40 wt%, respectively. Additional data reflecting the chemical makeup of the filter cake is given in Table 2.

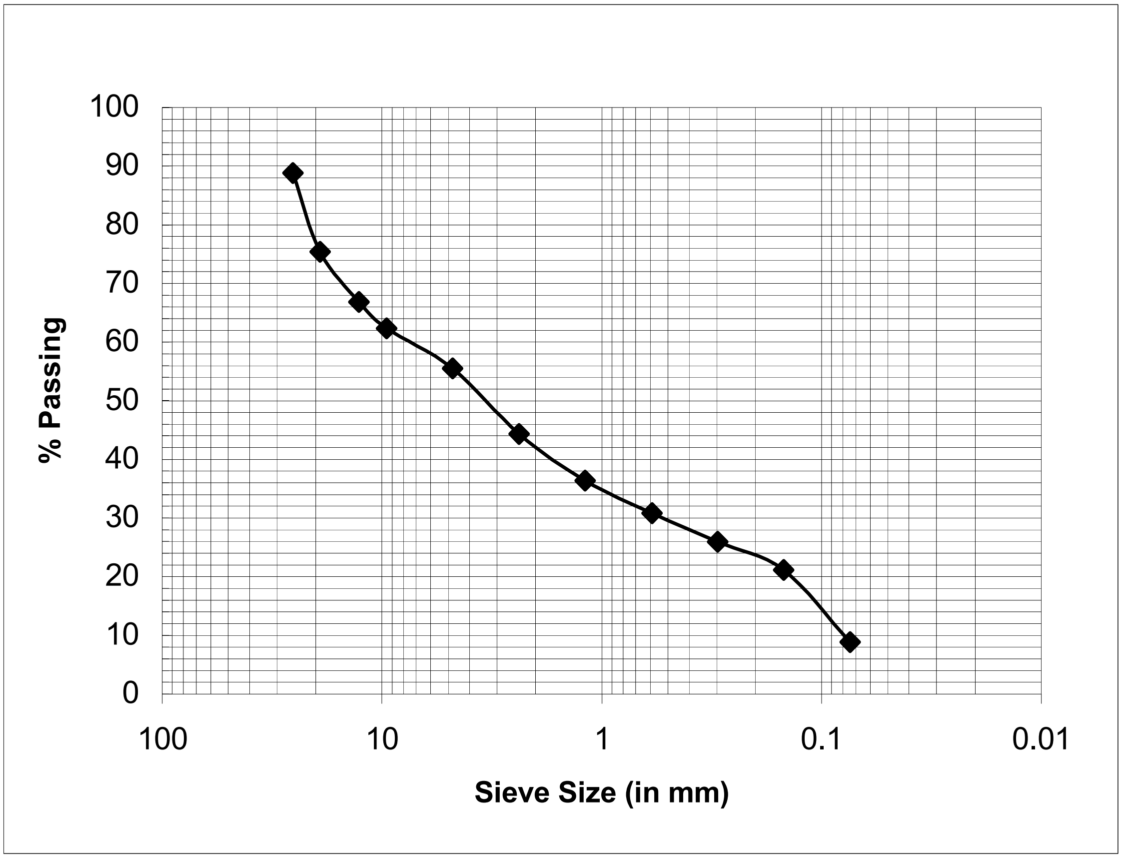


Figure 1. Grain Size Distribution Curves of Crushed Limestone Base

MOISTURE DENSITY DATA ASTM D 698-C	Maximum Density, pcf	135.7
	Optimum Moisture, %	8.8
LOS ANGELES ABRASION ASTM C 131, AASHTO T-96	Grading	A
	% Loss	29
FLAT & ENLONGATED ASTM D 4791	0	
UNIT WEIGHT (pcf) ASTM C 29, AASHTO T-19	Dry Loose	102
	Dry Rodded	116
SODIUM SULFATE SOUNDESS ASTM C 88, AASHTO T-104	% Loss	9.5
PLASTIC INDEX ASTM D 4318	Liquid Limit	16.3
	Plastic Limit	0

Table 1. Material Data Sheets for Crushed Limestone Base
(Furnished by Martin Marietta Aggregates of Lake Charles, Louisiana)

Parameter	Water Soluble	Total
Calcium, %	13.9	14.8
Chloride, %	21	21
% $CaCl_2$ based on Chloride (1)	32.8	32.9
% $Ca(OH)_2$ based on Calcium (2)	3.9	5.4
Magnesium, %	0.1	5.2
% $Mg(OH)_2$ based on magnesium (3)	0.3	12.4
Moisture, %	38.6	
pH	6.1	
Bulk specific gravity, g/ml	1.4	
The following assumptions were made in calculating % $CaCl_2$, $Ca(OH)_2$ and $Mg(OH)_2$: (1) All chloride is present as $CaCl_2$. (2) The calcium not accounted for by $CaCl_2$ is present as $Ca(OH)_2$. (3) All magnesium is present as $Mg(OH)_2$. Based on these assumptions, the filter cake sample contains 38.6% moisture, 32.9% $CaCl_2$, 12.4% $Mg(OH)_2$ and 5.4% $Ca(OH)_2$ on a total basis. On a water-soluble basis, The sample contains 32.8% $CaCl_2$, 0.3% $Mg(OH)_2$ and 3.9% $Ca(OH)_2$		

Table 2. Analysis of TETRA Lake Charles, Louisiana Filter Cake Sample

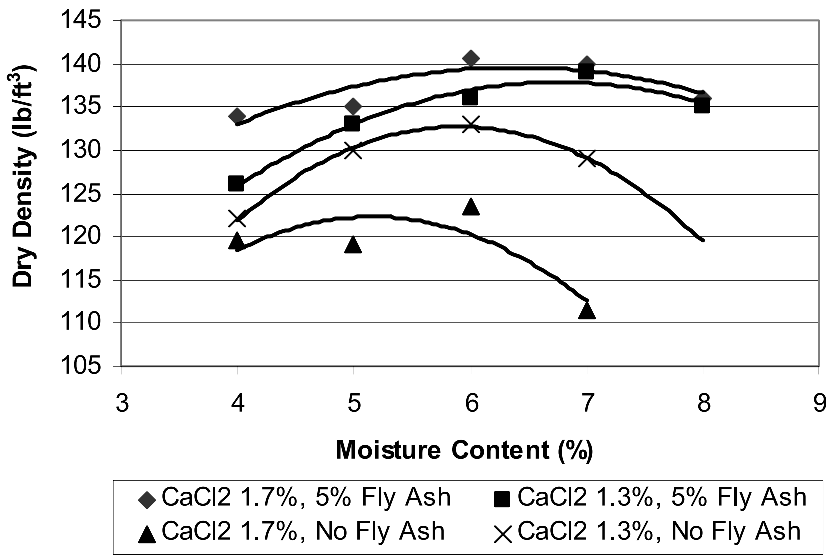


Figure 2. Density vs. Moisture Content

Fly Ash: The fly ash utilized in the mix design was a Class C ash as designated by the requirements of ASTM C-618-99, with the CaO content being 25.74 wt%. The original intent for incorporating the fly ash into the mix was for drying out the filter cake. However, during laboratory mix preparations it was determined that the necessary moisture reduction was achieved by the base material, alone. In addition, it was subsequently shown that the fly ash produced mixtures that had higher compaction densities and lower porosity. Typically, higher compaction densities tend to indicate higher load-bearing strengths.

Mix Design Evaluation
Four combinations of road base mix designs were generated and optimized, one with and one without fly ash and two incorporating filter cake at 1.3 and 1.7 percent by dry weight of $CaCl_2$, respectively. At the outset, an arbitrarily selected target for fines content (i.e. minus 200-mesh sieve) of 16 wt% was made part of the mix design criteria. The optimum mix designs for each of the four blends were chosen from the moisture content at the maximum dry densities as given in Figure 2.

It can be noted from Figures 2 and 3(a) that all but the mix design with 1.7 wt% $CaCl_2$ and 5 wt% fly ash met the target fines content. As shown in Figure 3(c), fly ash appears to have a more dramatic effect on dry density in the 1.7 wt% $CaCl_2$ mixture.

In addition to the criteria mentioned above, the final mix design selection was also based on maximum density and the reduced porosity of the two mixtures containing the fly ash. In the absence of compression strength data, which could not be generated within the time constraints necessary to go the field by the 17th May 2001, a joint decision with the sponsor favored the designs with the higher compaction capability and reduced porosity.

CONSTRUCTION OF TEST SECTIONS

Equipment
The construction of the test sections was carried out by an outside contractor. During the course of the project, the following equipment was utilized:

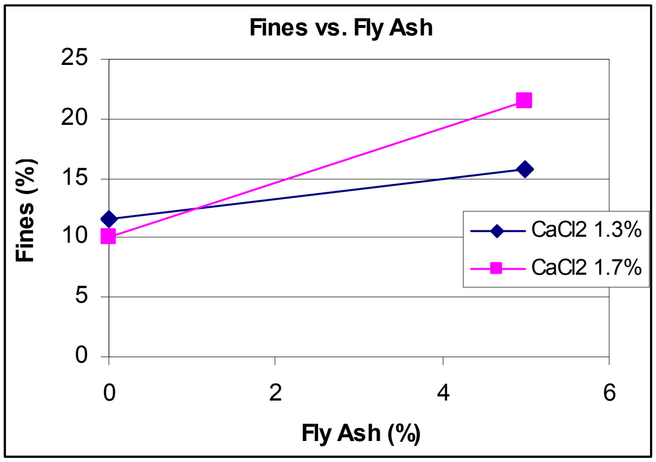
- Scarifier/ Grader – Champion X8076/CBOA C-Series
- Pulverizer – Caterpillar: 55-25
- Padded foot Compactor – Dynapac Mfg Co: CA-15 (15 tons)
- Steel Wheel Compactor – Ingersol Rand: DD-24 (4 tons)
- Front end Loader/ Maintainer – New Holland 555E

A 2,000 gal water truck with front and rear-end spray nozzles was used to apply both water and ROADMASTER calcium chloride to the test sections. A Troxler Nuclear Density Gage was utilized for obtaining both moisture content and compacted field densities during and after construction.

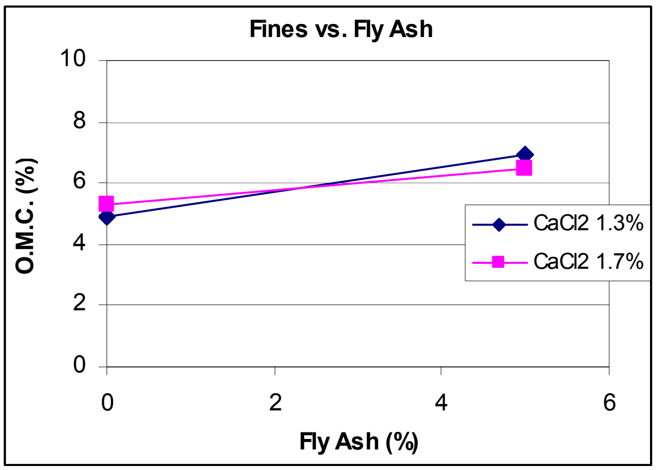
About 15 tons of Class C fly ash from ISG Resources, Inc. of West Lake, Louisiana was delivered in a 3-trough truck. The truck had a rear-end spreader bar. Each trough contained 5 tons of ash. The ash was spread uniformly on the road.

About 20 tons of filter cake was transported in a 20 ton dump truck from a storage location at the plant site and stockpiled at an area in the vicinity of the test sections.

About 4 tons of ROADMASTER calcium chloride (38% solution) was provided by TETRA's Lake Charles, Louisiana, plant and delivered in a 2,000 gal tank truck with rear end spray nozzles. This vehicle was also used as a water truck for adjusting the moisture content of the test sections.



(a)



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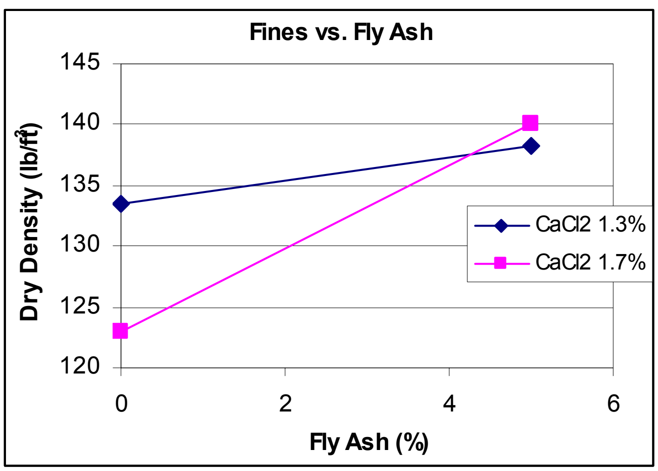

(c)

Figure 3. Fines, Optimum Moisture Content, and Dry Density vs. Fly Ash Content

Test Section Mix Designs and Material Requirement
Five test sections (150 ft x 20 ft), designated A through E, were built as a part of the construction phase of the project. Along with a control section, represented by the untreated, existing crushed limestone base and two sections containing filter cake and fly ash, two other sections were built in which the base was treated with ROADMASTER calcium chloride. Of the two sections treated with calcium chloride, only one incorporated 5% class C fly ash. Both calcium chloride treated sections were constructed to have a 1.3 wt% dry $CaCl_2$ content. A listing of the mix designs and materials required for each section is given as follows:

Section A: Control section consisting of 8 in. of crushed limestone base.

Section B: Crushed limestone base treated to a depth of 8 in. with 3.54 tons (616 gal.) of ROADMASTER calcium chloride to achieve a dry $CaCl_2$ content of 1.3 wt%.

Section C: Same as Section B, except the base was blended with 5 tons of Class C fly ash and treated with 3.72 tons (647 gal.) of ROADMASTER calcium chloride to achieve a % dry $CaCl_2$ / % Fly Ash content of 1.3 / 5.0.

Section D: 8 in. of crushed limestone base blended with 5 tons of Class C fly ash and 4.33 tons of filter cake to achieve a dry $CaCl_2$ content of 1.3 wt% (i.e., $CaCl_2$ 1.3 wt% and Fly Ash 5 wt%).

Section E: 8 in. of crushed limestone base blended with 5 tons of Class C fly ash and 5.73 tons of filter cake to achieve a dry $CaCl_2$ content of 1.7 wt% (i.e., $CaCl_2$ 1.7 wt% and Fly Ash 5 wt%).

Targeted moisture contents for all five (5) sections was 6.5 wt%.

Construction Sequence
17 May, 2001: Construction began at around 8 am, and carried out from Section A to Section E. The sequence of operations for each is given as follows:

Sections A - Control

1. The entire length of the section was scarified and pulverized to a depth of 8 in.
2. Water was added to the surface in an amount to achieve proper moisture content and mixed into the base with the pulvermix.
3. The section was graded and crowned to ensure proper surface water run-off.
4. The section was initially compacted with a padded foot roller and final compaction was achieved using a 4-ton steel wheel roller.

Section B

1. Same as (1) for Section A.
2. about 3.54 tons (646 gal.) of ROADMASTER calcium chloride (38% solution) was sprayed on to the surface using multiple passes.
3. Items (2) and (4) as for Section A were repeated.

Section C

1. Item (1) for Section A was repeated.
2. About 3.72 tons (647 gal.) of ROADMASTER calcium chloride (38% solution) was sprayed onto the surface using multiple passes.
3. About 5 tons of Class C fly ash was evenly distributed across the test strip.
4. Items (2) through (4) as for Section A were repeated.

Section D

1. Item (1) for Section A was repeated.
2. About 4.33 tons of filter cake was spread across the test strip using a front end loader.
3. About 5 tons of Class C fly ash was evenly distributed across the test strip previously covered with filter cake.
4. Items (2) through (4) as for Section A was repeated.

Section E

1. Item (1) for Section A was repeated.
2. About 5.73 tons of filter cake was spread across the test strip using a front end loader.
3. About 5 tons of Class C fly ash was evenly distributed across the test strip previously covered with filter cake.
4. Items (2) through (4) as for Section A were repeated.

Grading and slope of all drainage ditches were completed. All standing water remaining in ditches was removed. Final check of moisture content and compacted density of all five sections was initiated. These measurements are discussed in the section Post Construction Evaluation.

Climate

The average wind velocity, temperature, dew point, and relative humidity during the morning and afternoon hours of construction on 17 May 2001 are shown in Table 3

	Morning	Afternoon
Wind Velocity	10 mph	5 mph
Temperature	80^{o}F	71^{o}F
Dew Point	66^{o}F	68^{o}F
Relative Humidity	62%	90%

Table 3. Climatic Conditions

POST CONSTRUCTION EVALUATION

The initial post construction activity took place during the morning of the 18th of May 2001, and involved three types of evaluation.

- Visual
- Dust Abatement
- Moisture Content and Density of Treated Surface

Visual

All test sections were suitably shaped and crowned. Drainage ditches appeared adequate to handle surface water run-off. The control section (Section A) appeared much drier and dustier than the treated surfaces with very little resistance to penetration with a screw driver. The surfaces of Sections B and C were darker in color, indicating moisture content higher than the control section and relatively smooth with some random dimples caused by the padded foot roller. Most of the dimples occurred along the outer edges of the entire length of the treated sections. This was most likely due to over watering at the edges caused by the extended width of the spraying from the nozzles on the water truck. Most of these surface anomalies might have been minimized or eliminated by using a heavier steel wheel roller. Sections D and E containing filter cake appeared darker in color, moist and free of loose dust particles. As was observed in Sections B and C, the outer edges appeared damper than the middle portion which, again, was attributed to additional water received during the application of water to adjacent sections. The drainage ditches for all sections contained isolated puddles of water from the run-off caused by spraying. Sections D and E appeared quite cohesive and offered the most resistance to penetration by a screw driver. It is anticipated that as the fly ash begins to cure, Sections C, D and E will become stiffer.

Dust Abatement

The ability of the treated sections to minimize dust erosion was demonstrated by running a pickup truck over each section at approximately 30-33 mph. While the untreated control section generated considerable dust from the vehicle tires (see Figure 4a), none was observed in any of the treated sections (see Figure 4b). In addition, no tire tracks were created on any of the treated surfaces after passage of the vehicle.

Moisture Content and Field Density Results

Moisture content and compacted field density were measured using a Troxler Nuclear Density Meter at nine (9) locations along each test section. A tabulation of data for all five (5) test sections is given in Table 4.

(a)

(b)

Figure 4. Typical Comparison of Dust Generated at 35 mph in Untreated Control (a) and Treated (b) Sections

SECTION	A		B		C		D		E	
Data Point No.	Moisture Content, %	Density	Moisture Content, %	Density	Moisture Content, %	Density	Moisture Content, %	Density	Moisture Content, %	Density
1	4.1	126.1	6.8	128.5	5.3	129.5	6.0	122.4	5.7	113.3
2	5.1	126.9	7.4	131.1	6.4	132.8	5.2	119.4	6.8	122.1
3	4.7	125.9	8.0	131.1	6.3	128.9	6.7	122.1	6.7	124.4
4	4.0	127.5	6.2	130.7	5.9	127.8	9.5	117.3	6.8	120.3
5	3.3	127.6	6.7	131.3	5.4	125.8	5.8	118.0	7.1	124.3
6	4.8	121.4	7.3	131.6	6.1	127.2	7.2	121.4	8.4	122.8
7	3.9	119.2	6.2	124.4	5.5	121.7	6.3	127.9	6.7	116.3
8	4.6	119.8	7.5	124.1	5.5	124.4	6.5	123.9	6.8	121.2
9	6.7	118.4	7.5	123.0	5.4	125.4	7.5	122.9	7.9	126.3
Average	4.6	123.6	7.1	128.4	5.8	127.1	6.7	121.7	7.0	121.2
% of Laboratory @ 6.5% Moisture Content and 138 pcf Density							**103**	**88.2**	**92**	**86**

Table 4. Test Section Post Construction Field Data

The lowest moisture content was measured in the control section (Section A), which averaged about 4.6 percent. This moisture content was similar to that measured on laboratory samples furnished by TETRA (i.e. 4.6 percent).

Field densities of the section treated with ROADMASTER were consistently higher than the control as well as for those sections containing the filter cake. The densities of sections D and E were around 88 and 86 percent of laboratory generated density values, respectively. No laboratory densities were generated for the base represented by Sections A, B and C.

Two factors may have contributed to lower than expected field density results in Sections D and E: non-homogeneous distribution of filter cake and inadequate compaction. As was discussed above, the manner in which the wet filter cake was distributed onto the surface of each section using a front-end loader made it difficult to achieve homogeneous blending with the base and fly ash. This was further compounded by the extreme variations in moisture content of the filter cake within the stockpile. Future construction projects will require a better means for pre-blending the filter cake that will ensure its even distribution across the width of the sections and uniform moisture content.

The second factor was attributed to inadequate compaction that was provided by the 4-ton steel wheel roller. A 15-ton capacity would have been preferred to achieve higher densities and permit compaction to the full depth of 8 inches.

It should be noted that field densities are not necessarily a true measure of the roadway's ability to carry traffic. Samples of base materials from each section were collected following construction for laboratory evaluation of the as-constructed and post-cure of the various mix designs. Compressive strengths were determined over 100 days. Samples were prepared in accordance with ASTM D1557 and tested using ASTM D2166. Samples were cured in plastic bags in a damp room prior to testing. Section E (i.e. filter cake @ %$CaCl_2$ / fly ash ratio of 1.7/5.0) maintained the highest strength throughout the 100 days testing program. The strength in Section E rose to around 200 psi after seven days and maintained this value out to 28 days. The strength eventually dropped off to about 150 psi after 100 days. Section D (i.e. filter cake @ %$CaCl_2$ / fly ash ratio of 1.3/5.0) reached its maximum value of 150 after 14 days. After 100 days the strength of the mixture is Section D leveled out at about 75 psi. After 28 days, the strength in the two sections containing ROADMASTER (Sections B and C) appeared to maximize at around 90 psi and gradually dropped off to 25 psi after 100days. As was expected the control section performed the poorest of all sections, never increasing beyond 20 psi throughout the testing period.

Figure 5 shows the change in compressive strength of each section measured over the 100-day test program. Except for the anomaly reflected in the 28-day strength of Section D, it appears that the sections containing filter cake consistently outperformed those containing ROADMASTER. The results also indicate that Section E, which contained 1.7 percent calcium chloride, was the stronger mix design.

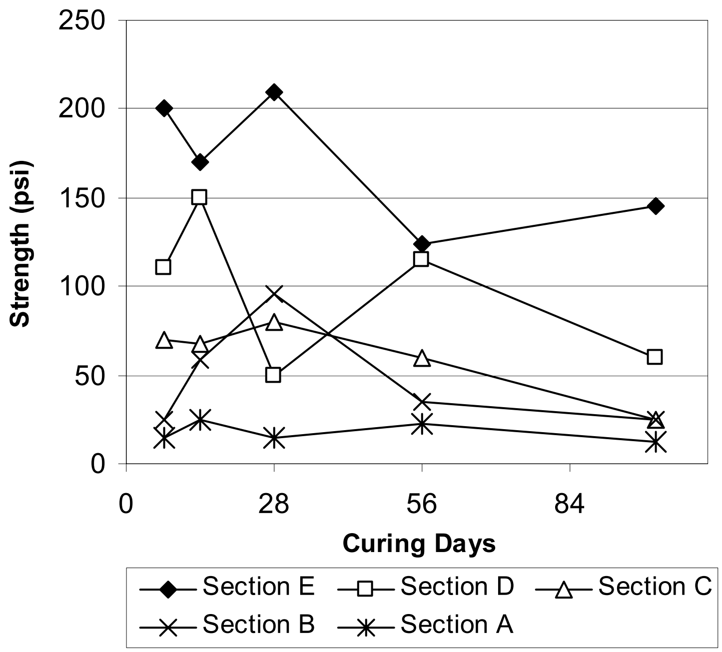

Figure 5. Curing Days vs. Compressive Strength

The Dynamic Cone Penetrometer (DCP) was utilized to derive California Bearing Ratio (CBR) and Texas Triaxial Classification (TTC) values over the three months following construction to better assess the anticipated in-service quality of the test sections[9]. This device was also employed in the evaluation of an earlier field test section[2]. The test method employed in this effort involves dropping a 6.8 kg (15 lb) ring weight on a spike with graduated markings. The relationship between number of blows and depth of penetration (in mm) is plotted and the resulting slope referred to as the Penetration Index (DCP in millimeters per blow) is generated.

The CBR is related to DCP as follows:

$$\text{Log CBR} = 2.46 - 1.12 \log(\text{DCP}) \quad (1)$$

The relationship between CBR and TTC as it relates to quality and recommended use of a roadway is given in Table 5.

CBR	TTC	Quality/Use
150+	1	High Volume Traffic
85	2	Low Volume Traffic
38	3	Subgrade
14 and lower	4 and below	Poor

Table 5: CBR and TTC for Different Road Quality/ Use

The Penetration Index from the Dynamic Cone Penetrometer tests for different test sections at 1, 2 and 3 months after the treatment are shown in Figure 6. As can be noted, the treated sections have low Penetration Index and they have out-performed the control section. The CBR values computed from the DCP data are presented in Figure 7. The CBR results of Sections B through E with 100+ values indicate that the roadway is more than capable of handling the low volume traffic loads, which are anticipated at the plant site.

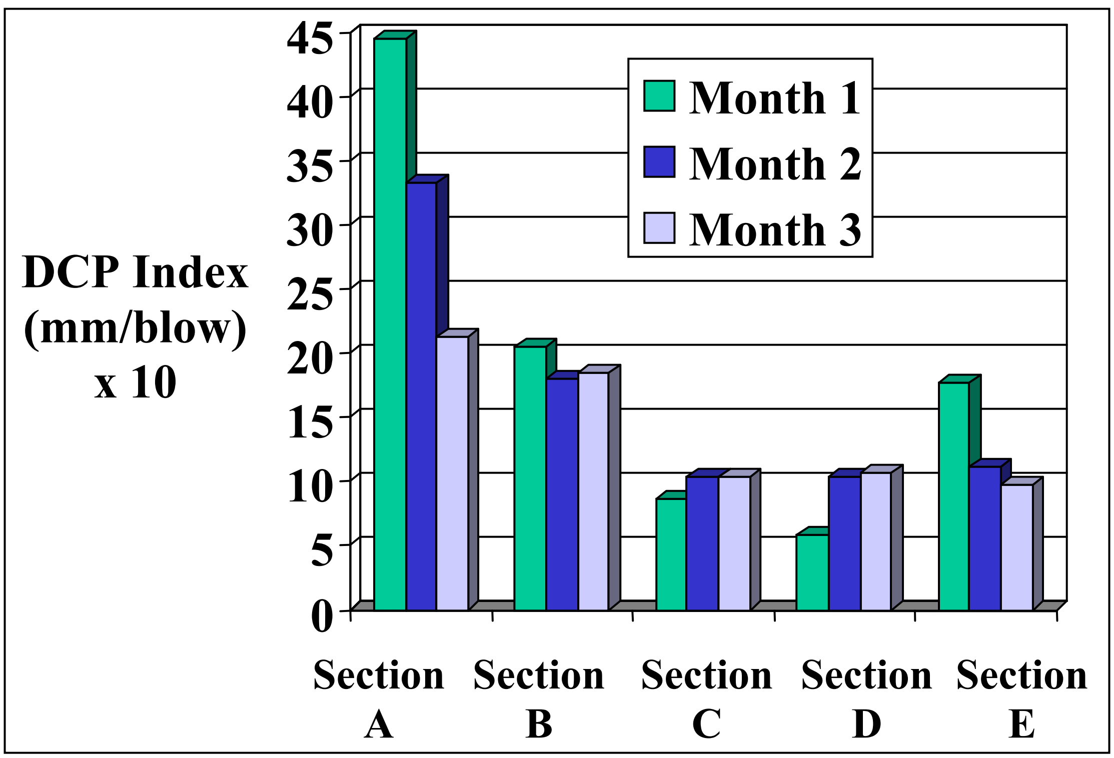

Figure. 6. Dynamic Cone Penetrometer Index for
Lake Charles Unpaved Surfaces with Different Full Depth Treatments

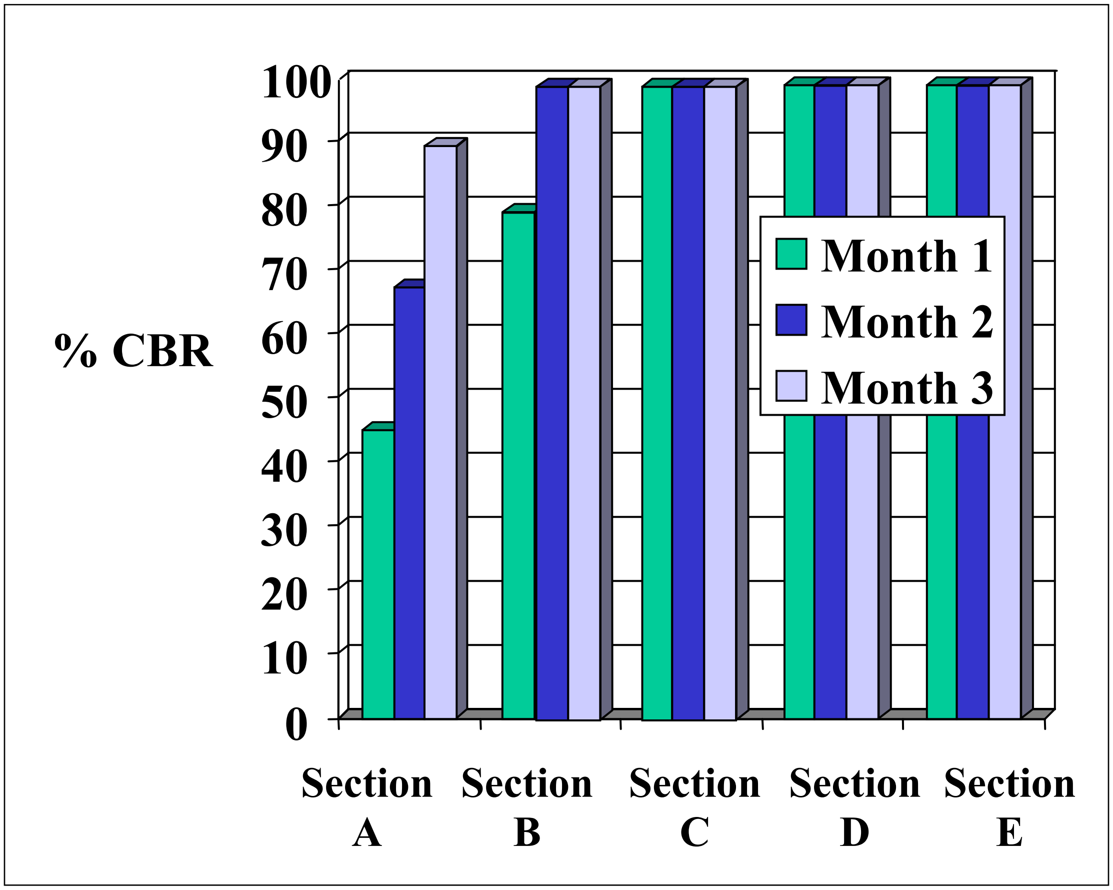

Figure. 7. California Bearing Ratio for Lake Charles Unpaved Surfaces
with Different Full Depth Treatments

CONCLUDING REMARKS

In summary, it can be stated that the filter cake, when evenly distributed, has the potential to provide a low-cost alternative to ROADMASTER calcium chloride as a dust control and stabilization agent for the unpaved surfaces. However, the operations required for placing the filter cake may add to labor and construction costs that are not involved in the application of ROADMSTER calcium chloride. In order to achieve the same mixture properties in the field as was demonstrated in the laboratories, the construction problems discussed above need to be addressed.

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