CHAPTER 1 – INTRODUCTION AND BACKGROUND

THE DUST ISSUE

Dust is most always unwanted. In manufacturing, dust can seriously affect the quality of production. Without proper air filters, automobile engines wear down from the abrasive friction of dust particles. In dusty regions, people find it difficult to breath, and their body's reaction to dust is to cough and sneeze. Dust can create major economic disasters like what happened during the dust bowl era of the 1940's where uncontrolled farming practices exposed wide areas of soil to blowing wind, and dust storms of epic proportions choked entire states like Oklahoma and Kansas.

Today on unsurfaced roads or on road construction projects or travel ways adjacent to fields with loose material, blowing dust, as shown in Figure 1, is an irritant and obstacle that slows travel times and decreases driver safety due to loss of visibility. Several western State Department of Transportations (DOTs) now post signs on their roadways warning travelers to beware of dust.

Dust is defined as fine particulate material that can pass through a 75 µm (No. 200) sieve. It is material that has broken free from an unpaved roadway surface and floats in the air, carried by wind currents, until it finally settles to the ground. Road dust can be controlled, managed, reduced or even eliminated depending on the application strategy selected for the roadway.

Figure 1. Photo[1]. Dust typical of untreated roadway.

A number of factors can contribute to the occurrence of dust. These include road material properties such as gradation, cohesion/bonding, and durability; construction controls such as the level of compaction applied to the material and moisture (or lack there of) in the material; road use factors such as vehicle speed, number, weight, and wheels per vehicle; and environmental factors such as dry climate.

Controlling dust is an issue that concerns both private and public sectors, and many improvements have become standard practice. Strip farming practices and tree rows now prevent the reoccurrence of the dust bowls. Large building demolition projects now have requirements to use sprinklers to moisten the area. The Occupational Safety and Health Administration requires safety masks for workers exposed to dust. Sweeping compounds that attract fine particulate matter are now used in factories. Keeping haul road dust controlled is a constant effort, and roadway construction contractors are required to keep exposed areas moistened or covered with some kind of tackifier.

The owners of unsurfaced roadways probably face one of the biggest challenges today. There are approximately 6,359,568 km (3,950,042 mi[2])of road in the United States. Of this total, about 2,327,332 km (1,445,548 mi), or 37% are unpaved. More specifically as Table 2 shows, 987,518 km (613,365 mi) of roads that serve Federal and Indian lands, 825,247 km (512,576 mi) or 83.6% are unpaved.

While this information is derived from a FHWA document [3] published in 2000 and current lengths may vary slightly, it still shows the relative percentage of unpaved roads for each agency and how each one shares in the problem of dust generation due to the road user traffic. Thus, a high priority for each Federal Land Management Agency is to find economical and long lasting ways to control road dust. The challenge is amplified as maintenance budgets continue to be woefully inadequate, environmental concerns become more prevalent, and as quality road building materials are depleted and harder to procure. For these reasons, identifying methods to effectively control dust on unsurfaced roads is a goal of the Federal Highway Administration (FHWA), Federal Lands Highway (FLH) and was the focus of this study conducted by the Central Federal Lands Highway Division (CFLHD).

DUST STABILIZATION

Roads constructed of native borrow materials typically do not have the ideal range and distribution of particle sizes to have a good load bearing capacity. Dust palliative products applied for in-depth stabilization can enhance the strength or load bearing capacity of the native road. Gravel road materials typically have been engineered for strength, yet all gravel roads suffer surface abrasion loss when dry. Application of a dust palliative can preserve adhesion between fine particles which reduces dusting. If adhesion is not preserved, the fine loose material in the road blows away in the wind or washes away under heavy rain. Over time, the amount of fine binding soil in the road is reduced, and gradually, more and larger particles break away. The loose surface material becomes prone to increased dusting, potholing, and corrugation making road travel uncomfortable and less safe.

There are several reasons to stabilize soil. The first is strength improvement to enhance load-bearing capacity. The second is dust control. The third is waterproofing to preserve the natural or constructed strength of a soil and to minimize the entry of surface water.

Soil stabilization materials can be applied by an admixture process or topically through surface penetration. In the admixture process, aggregate and soil materials are combined with the stabilizer product in one of three ways: 1) In-place mixing (blending the soil and stabilization materials with a reclamation machine), 2) Off-site mixing using stationary mixing plants, and 3) Windrow mixing using a grader. The second method of application is topical; that is, spraying a soil treatment material directly onto the existing roadway and allowing the palliative to penetrate.

Table 2. Summary of Federal Roads

Federal Lands Served	Road Category	Owner	Length Miles	Unpaved Miles	Percent Unpaved
Department of Agriculture					
National Forests	Forest Highways	State and Local	29,200	7,800	26.7%
	Forest Development Roads (60,000 miles Public Roads)	Forest Service	385,000	357,000	92.7%
Department of Interior					
National Parks	Park Roads and Parkways	National Park Service	8,127	2,988	36.8%
Indian Lands	Indian Reservation Roads	Bureau of Indian Affairs and Tribes	23,000	17,500	76.1%
	Indian Reservation Roads	State and Local	25,600	15,450	60.4%
Wildlife Refuges	Wildlife Refuge Roads	Fish and Wildlife Service	5,900	5,400	91.5%
	Administrative Roads	Fish and Wildlife Service	3,100	3,100	100%
Public Lands (BLM lands)	Land Management Highways	State and Local	7,200	3,600	50.0%
	Public Lands Development Roads (Administrative Roads)	Bureau of Land Management	83,000	81,300	98.0%
Reclamation Projects	Reclamation Roads (Intended for Public Use)	Bureau of Reclamation	1,980	980	49.5%
	Administrative Roads	Bureau of Reclamation	8,000	7,200	90.0%
Department of Defense					
Military Installations	Military Installation Roads	Department of Defense	23,000	0	0%
	Missile Access Defense (Malmstrom, Minot, and Warren)	State and Local	1,858	1,858	100%
U.S. Army Corps of Engineers					
Corps of Engineers Recreation Areas	Corps Recreation Roads	Corp of Engineers	4,800	4,800	100%
	Corps Leased Roads	State and Local	3,600	3,600	100%
		TOTAL	613,365	512,576	83.6%

STABILIZATION AND DUST ABATEMENT MATERIALS

There are numerous products on the market today for stabilization and dust abatement purposes. Currently these products are classified by the United States Forest Service (USFS)[4] into seven basic categories each with different attributes, applications, and limitations:

1. **Water** acts to bind material together by surface tension. As such, dust will not float into the air while attached to larger particles. Water is easy to apply but it tends to dry or evaporate quickly. When the material loses its surface tension, dusting and other surface deterioration will occur.
2. **Water Absorbing** products include various chlorides of salt. These materials have the ability to absorb moisture from the air and retain that moisture in the soil. Aggregates treated with these products can be re-wetted and re-worked. Their effectiveness is a function of the air temperature and relative humidity.
3. **Organic Petroleum** products include asphalt emulsions, cutback asphalts, and dust oils. These tend to bind particles together through adhesion, and can waterproof the road. They are relatively insensitive to moisture but under dry conditions may not retain their resilience. In thin layers, they may form a crust and fragment under traffic and could be difficult to maintain.
4. **Organic Non-Petroleum** products include lignin derivatives, tall-oil derivatives, sugar beet extracts, and vegetable oils. These products bind aggregates in much the same way that petroleum products do, but they may be less effective because they are more water-soluble and oxidize more rapidly. These products are more environmentally friendly than the Organic Petroleum products.
5. **Electrochemical** products include enzymes, ionic compounds and sulfonated oils. Their performance depends on the clay mineralogy, and they need time to react with the clay fraction. Some of the products are highly acidic in their undiluted form.
6. **Synthetic Polymer** emulsions include polyvinyl acetate, vinyl acrylic, and polymer combinations. These emulsions bind aggregates together through the polymer’s adhesive properties. These too, once applied and set in place as thinner layers, may crust and fragment under traffic and be difficult to maintain.
7. **Clay Additives** are natural clays such as bentonite and montmorillonite. These materials gather together the fine dust particles of the aggregate. They tend to increase the dry strength of the aggregate under dry conditions. However, if too much product is applied, the roadway surface may become slippery when wet.

The evaluation team found this USFS *Dust Palliative Application and Selection Guide* to be a very valuable resource in that it not only presents Dust Suppressant Category information - Attributes, Limitations, Applications, Origin, and Environmental Impact - but also shows the various types of suppressants within each category and offers a list of specific product names and manufactures. The guide also advises that these products be applied as recommended by the supplier for the soil type and conditions specific to the project with a review of the products’ Material Safety Data Sheets (MSDS) to identify and address any applicable environmental concerns. A product selection flowchart is also included in this publication.

OTHER DUST STUDIES

A literature search reveals that many studies have been conducted to investigate effective methods to control dust, or to categorize the numerous dust control products. The ones discussed below are in chronological order and have significantly contributed to the overall effort of documenting solutions to the dust problem.

Non-Standard Stabilizers

In 1992 prior to the USFS study discussed above, the FHWA prepared a similar work entitled *Non-Standard Stabilizers* [(5)] to summarize dust stabilization products. As its title suggests, this work listed new and emerging products, their applications, the manufacturers and suppliers, and relative costs. Now a decade or more later, this work is somewhat dated in that many of the non-standard products are either now standard or unavailable, and many of the suppliers and product names have changed. Nevertheless, it still is a good reference for overall product categories and for finding recommendations on matching the best product with the specific site condition.

Gravel Roads Maintenance and Design Manual

In 2000, the South Dakota Local Technical Assistance Program (LTAP) produced a *Gravel Roads: Maintenance and Design Manual* [(6)]. The majority of this publication deals with designing and maintaining gravel roads, however one chapter is devoted to controlling dust. It makes general recommendations for the applicability, selection, and use of various products. While this information is not as detailed as some of the other studies, it is unique in that it links recommendations for dust control with the routine roadway maintenance activities.

Dust Control on Low-Volume Roads

In 2001, the FHWA in cooperation with the LTAP produced *Dust Control on Low-Volume Roads, a Review of Techniques and Chemicals Used*[(7)]. This document was very similar to the USFS and FHWA publications noted earlier and presented updated information on products, prices, application rates, and performance.

The World Bank Study

In September 2002 a World Bank sponsored study was completed by the Brazil's National Department of Roads and Highways that reported results in a document, *A Comparative Study of the Performance of the Soil Stabilizers in Secondary Unsurfaced Roads in Paraguay*[(8)]. Under this study nine different products from three stabilizer categories were installed on seven experimental sites with seven to ten products per site. Two products could be categorized as Organic Non-Petroleum, six products as Electrochemical, and one as Synthetic Polymer Emulsion. The roadway material compositions varied from sandy to clayey soils with low to high Plasticity Indices. No sites were categorized as having Non Plastic material. During the installation at each site, the roadway surface was scarified to a depth of 20 mm (¾ in), and re-compacted after the each product application.

The study used three monitoring methods, the Dynamic Cone Penetrometer (DCP), the Clegg Impact Soil Tester, and the Unsurfaced Road Condition Assessment. While these three methods all produced different results, they still found that five of the seven stabilized sites performed better than the adjacent untreated sites. They also found that product performance varied with soil type. They noted that the electrochemical enzymes worked best on clayey, sandy clay, and silty sand type soils, and the electrochemical sulfonated oils worked best on clayey type soils.

The usefulness of this study is its contribution to understanding what kind of soils might be enhanced by a given product. However, the results are not conclusive on which classes of products work best for a particular kind of soil – for example, soils that are Non Plastic.

The HITEC Pool Fund Study

In 2002, the Highway Innovative Technology Evaluation Center (HITEC) initiated a long-term study entitled *Evaluation Plan for the Group Evaluation of Soil Stabilization and Dust Suppression Products* [9].

The primary objective of this study was to perform well-defined field and laboratory tests of dust suppressant and soils stabilizer products that would provide performance and baseline environmental data. Performance data would be related to soil type, level of traffic, and climate. This data would answer questions such as:

- Do the products perform as claimed or intended?
- How do they perform in relation to various climatic conditions?
- How long do the products remain effective?

Baseline environmental data would focus on how friendly the products are to people and the environment:

- Do the products have any characteristics of hazardous waste?
- Do the products impact water quality?
- Do the products impact air quality?
- Are the products easy and safe to use?

Finally, the cost effectiveness issue would be explored.

To date only four vendors have participated and no results are yet available. When conclusions are documented, they will be posted at the HITEC website.

STUDY JUSTIFICATION AND GOALS

The FLH designs, administers, and oversees an increasing amount of aggregate surfacing roadwork for clients in remote locations throughout the western United States. The CFLHD specifically, oversees the construction of highways on Federal Lands in 14 western states as shown in Figure 2.

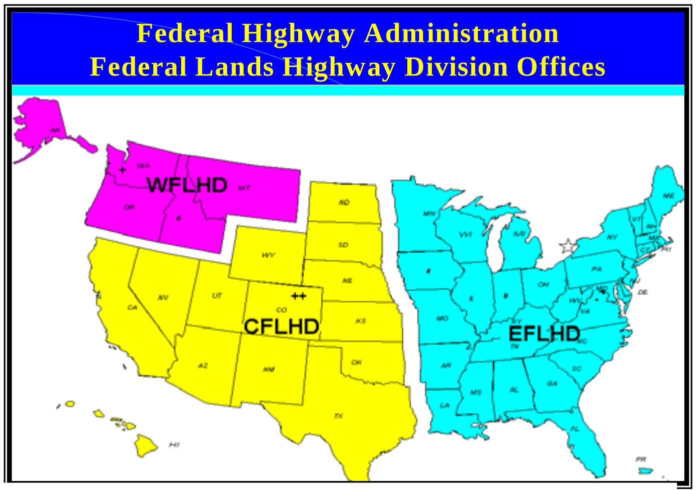

Figure 2. Map. FHWA FLHD regions.

FLH's clients, such as the National Park Service, USFS, Bureau of Indian Affairs, Department of Defense, and US Fish and Wildlife Service (F&WS) often have limited budgets for construction and maintenance on their low volume roads. To save money they often request their roads be surfaced with native materials. While many of these materials are adequate for their intended use, at times additional processing is required to add stabilizing and dust control components.

Currently in the FHWA FLH's FP-03 Standard Specifications for Highway Construction[10] the dust abatement options provided are water, magnesium chloride, Lignosulfonate, calcium chloride, and emulsified asphalt. The FLH recognizes that there are many other options available that may be viable solutions for controlling dust and reducing maintenance costs.

As discussed above, there are many completed and ongoing studies on the topic of stabilization and dust control. However, no studies specifically addressed the products readily available in CFLHD's 14-state oversight area or the specific soil conditions found at the project site. In addition, long-term performance data and cost comparison data was unavailable. Thus, a practical study covering commonly available products, their method of application, long-term performance, and relative costs was needed. Results of such a study would not only provide valuable information to the owner agency, but would also add to a growing knowledge base on product performance related to various soil types and climates.

The primary objective of this project was to incorporate six different road stabilizers and dust palliatives on one of the CFLHD's construction projects, to evaluate the products for long-term performance, and to recommend those products with acceptable performance for use on other CFLHD projects. The evaluation addressed each product's performance for dust control, rutting, washboarding, raveling and material stabilization over a 24-month period.

While visual observations for product leaching were done, no other physical monitoring such as ground water quality, fresh water aquatic environment, or plant community was conducted to document any environmental effect of the products. Still, it continues to be a point of concern as subsequent to the completion of this study, one of the FLMAs issued direction that any further projects using dust stabilizers on their lands must include a minimum 3-year environmental monitoring plan to include monitoring during the year prior to application, the year of application, and a year following the application.

It was anticipated that all of the products selected for this study would effectively stabilize the roadway material thereby controlling dust for at least twelve months. If over this period, the stabilization significantly saved the owner agency manpower, machinery, and material costs equal to or more than the cost of the stabilization, then the study would be considered a success.

The tables, figures, and discussions in subsequent chapters show how each of the products performed in relation to each other. It is not the intent of this study to imply that any one product failed to adequately perform simply because its subjective visual rating values gave it a relative rank lower than another product. Each product's performance was fully acceptable throughout the 24-month study, although based on the levels of observed washboarding; some sections required a reapplication of the product to reestablish an acceptable ride surface. Before the stabilization project, the owner agency had to grade, blade, or work the roadway at least every three months. During the entire 24-month study, they were requested not to maintain the roadway surface at all. By the end of this 24-month study, some sections did need to be graded; however the owner agency had been saved from performing six to seven grading maintenance events.
Therefore, this project was considered a success for all products and for the owner agency.

Figure 3. Map. Buenos Aires NWR site location.

PROJECT BACKGROUND

The project site selected for this evaluation is located in the Buenos Aires National Wildlife Refuge (NWR) in south central Arizona as shown in Figure 3. Buenos Aires NWR is a 46,575 ha (115,000 ac) refuge established to preserve the endangered masked bobwhite quail. It also is home to 300 other species of birds, including hawks, herons, gray hawks, vermilion flycatchers and golden eagles. Resident mammals include coyotes, deer, foxes, and pronghorn antelope.

The Refuge contains extensive semi-desert grasslands, various types of cacti, and groves of small trees. Due to the desert climate, the land is mostly dry; but during the monsoon season there are streams and a lake that fill with water. Several popular hiking trails are located on the eastern side of the Refuge near the town of Arivaca. However, the vehicular tour roads are the most popular access route to view all of the flora and fauna. Improving the visitors' experience on these travel ways was an important rationale for upgrading the roads.

The original Buenos Aires NWR Tour Roads were constructed using local materials from a nearby borrow source. The sections suffered from severe raveling, potholing, and dusting. The Refuge reported that the average daily traffic was low, ranging from 8 to 25 vehicles per day depending on the season of the year. The FLH also measured traffic volumes at various locations on the route, and confirmed these estimates. However, even these low traffic volumes generated dust, created visual and air quality concerns for Refuge visitors and wildlife, and also covered vegetation along the roadway.

The resulting reconstruction project, Arizona RRP BUAI 10(2) Auto Tour Roads [11], was designed and administered by the CFLHD. The CFLHD Construction Branch was responsible for contract negotiations and project layout, and also provided the construction inspection, reporting and initial materials sampling. The stabilization portion of the project was primarily financed under the FLH Technology Deployment Initiatives and Partnership Program that promotes deployment of transportation-related research and technology, and the monitoring was funded by the Coordinate Technology Implementation Program. The construction contractor was A&S Paving, Tucson, Arizona. Construction of the project, including the application of the roadway dust stabilizers, was completed in August 2002.

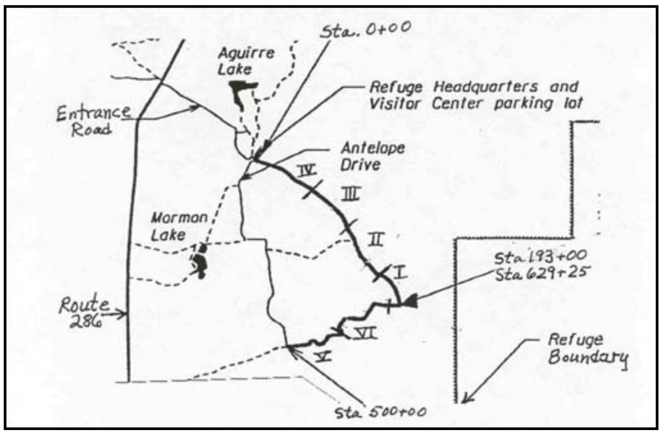

Figure 4. Map. Buenos Aires NWR site and test locations.

PROJECT LAYOUT AND PRODUCTS

Figure 4 shows the layout of the project. Six types of roadway dust stabilizers and palliatives were applied 15.2 cm (6 in) deep in 1.6 km (1 mi) long sections throughout the 9.6 km (6 mi) long reconstruction project. The selected products, as shown in Table 3, represent most of the major categories of stabilizers or dust suppressants. The products chosen were based on those products most commonly used and available in the CFLHD 14-state oversight region.

A seventh, 6.0 km (3.7 mi) long section, was also monitored and included in the study. This section was the north-south segment between Mileposts 6.2 and 0.0 on which Magnesium Chloride was surface-applied as a dust suppressant only. Since Magnesium Chloride is one of CFLHD's conventional dust abatement products, it was included in the evaluation for comparison with the other six-roadway dust stabilizers and palliative products that are not current options in the standard FP-03 specifications**.**

GENERAL PRICE ANALYSIS AND SAVINGS

The cost and application rate of each product used in this study varied widely. No two manufactures recommended the exact same application rate. Because manufactures typically quote prices by the job depending upon the total quantity of product required, a simple price per gallon figure is difficult to pin point. In other words, price often will be reduced as the product quantity increases. A comparison using price per gallon is nearly impossible because price depends on varying market conditions as well as project location. Due to all of these factors, it is difficult to provide a detailed comparison of product costs. Finally, it should be noted that for this study, several manufactures either donated their products or sold them at a substantially reduced price to gain exposure from the work.

With this stated, a general comparison of product costs can be made using overall market prices and general cost data. The electrochemical enzyme products (Terrazyme and Permazyme in this study) are sold on the market at a cost significantly less than all the other products used in this study. In a general comparison for a standard application, the enzyme products might cost approximately one-third the cost of the chloride and sulfonated products (DC Caliber 2000, Mag/Lig, and the Lignosulfonate) and one-fourth to one-fifth the cost of the Soil Sement. Again, it is noted that these comparisons are suggestions based on general cost data and are subject to many variations. Contractors or other agencies that use the results of this study should perform their own market analysis of products costs based on the proposed application, climate, specifications requirements, availability, and project location.

Table 3. Test sections, locations, products, and suppliers.

Test Section	Approximate Milepost Locations	Product and Category	Manufacturer's Undiluted Application Rate	Supplier
I	3.0 – 4.0	Magnesium/Lignosulfonate (Mag/Lig) *(Water absorbing + Organic non-Petroleum)*	6 gal/yd^3	Desert Mountain P.O. Box 163 Kirtland, NM
II	2.0 – 3.0	Caliber DC 2000 (Caliber) *(Organic non-Petroleum (vegetable corn oil) + water absorbing (Mag/Cl))*	6 gal/yd^3	Desert Mountain P.O. Box 163 Kirtland, NM
III	1.0 – 2.0	Soil Sement *(Synthetic Polymer Emulsion Vinyl Acrylic)*	1.1 gal/ yd^3	Earth Care Consultants P.O. Box 8431 Canton, OH
IV	0.0 – 1.0	Permazyme *(Electrochemical enzyme)*	0.006 gal/ yd^3 (0.77 oz/ yd^3)	International Enzymes, Inc 1706 Industrial Road Las Vegas, NV
V	5.2 – 6.2	Terrazyme *(Electrochemical enzyme)*	0.006 gal/ yd^3 (0.77 oz/ yd^3)	Nature Plus, Inc 555 Lordship Blvd. Stratford, CT
VI	4.0 – 5.2	Lignosulfonate *(Organic non-Petroleum)*	6 gal/yd^3	Desert Mountain P.O. Box 163 Kirtland, NM
VII	6.2 – 0.0	Magnesium/Chloride (Mag/Cl) *(Water absorbing)*	0.25 – 0.50 gal/yd^2	Desert Mountain P.O. Box 163 Kirtland, NM

Since the Refuge did not need to conduct routine maintenance on the roadway throughout this study, there was a definite benefit in maintenance cost savings. Unfortunately, the annual roadway maintenance costs were not recorded at the Refuge for previous years. Other cost estimates however can be found in a 2003 study(13) of gravel roads in four Minnesota counties where the average annual cost to maintain the gravel roads varied from $857 to $3,386 per km ($1,380 to $5,452 per mi). For the total 15.6 km (9.7 mi) of gravel road in this study, and assuming a higher cost of $3,105/km ($5,000/mi) for the Refuge due to its remoteness, the savings could be estimated at $97,000. As discussed earlier, since this was an evaluation study with some but not all of the costs borne by some of the suppliers, the overall true cost of the study was not determined. What can be noted is that the construction contractor was paid $83,168.28[(11)] to procure and install the products. As a result, the benefit to cost ratio for this study can be estimated as approaching 1 or just slightly higher.