OBJECTIVE PERFORMANCE MEASUREMENT OF ACTUAL ROAD SITES TREATED WITH AN ORGANIC SOIL STABILIZER

by

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ABSTRACT

In recent years, a growing number of countries have completed testing and are purchasing fermentation based organic soil stabilizer for stabilization of soils in the base, sub-base and sub-grade for asphalt paved roads or in the wear layer of unsurfaced secondary or rural roads. A growing body of objective evidence supports inclusion of such stabilization programs at the level of local, national and international road rehabilitation and construction programs.

Road engineers in various parts of the world measure performance parameters after road construction and stabilization principally using the Dynamic Cone Penetrometer. The DCP penetration values of a conical probe versus the number of hits of an 8-kg hammer have been correlated with CBR% data by many investigators. This simple, versatile and inexpensive device reliably profiles resistance throughout all layers of a road structure while providing objective measurement of the changes in soil mechanical and resistance properties after stabilization.

While laboratory methods of CBR measurement are useful in establishing free soil baselines, it is not useful for "in situ" road evaluations as the act of removing the stabilized road soil samples destroys the structure that one wishes to test.

This paper will discuss further the soil properties effected by organic soil stabilizers, good engineering practices necessary for successful applications and experiences in road stabilization in such places as Indonesia, Thailand, Malaysia, and the Philippines, to Latin American locations as Brazil, El Salvador and Honduras. Presented briefly will be laboratory study results from BYU and national labs in Chile, Ecuador, Uganda, Philippines, Brazil.

Specific projects in actual road constructions on primary and secondary road surfaces, accompanied by DCP measurements, demonstrate not only the benefits of soil stabilization, but also the utility of DCP usage in portraying resistance by road transverse structure level. Results of pavement projects in Brazil will be presented.

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Soil stabilization is seen to provide important cost savings in the construction of primary, paved roadway in upgrading available and local soils and reducing importation requirements and in the cost of maintenance and repair of secondary, rural, forest, plantation and recreation roads.

Key Words: roads, maintenance, rehabilitation, repair, resurfacing, soil stabilizer, performance, paving, pavements, unsurfaced roads

1. INTRODUCTION

An increasing number of countries have tested and are using organic soil stabilizers for stabilization of soils in the base, sub-base and sub-grade paved roads; or in the wear layer of secondary or rural roads. A growing body of objective performance evidence supports inclusion of such stabilization programs at the level of local, national and international road rehabilitation and construction programs.

The paper explains the benefits of the soil stabilizer additive in improving the function and structure of the roads, in reducing of the incidence of defects on the travel surface that affects comfort of the road users and in increasing in the capacity of the base layer to support weight – CBR%.

The USA Trade and Development Agency (TDA) completed a recent study of road budgets in seven (7) South East Europe countries. "In most countries in the region wholly inadequate amounts are spent on basic road maintenance. Lack of maintenance leads to the requirement of complete replacement, resulting in a more costly lifetime expenditure cycle". (SE Europe Transport and Energy Projects – Conference Briefing Book, Sept. 1, 2000)

Similar conclusions are reached by the United States Agency of International Development (USAID) in their recovery programs focused on Central America (Honduras, El Salvador, Nicaragua, and Guatemala) as a result of the devastation caused in late 1998 by Hurricane Mitch. Their Special Objective states page 5: "Rebuilding Better – The USAID/Honduras reconstruction program should do more than just replace what was lost; it should be an opportunity to transform the country into something better - the development of improved design specifications and use of new technologies in road rehabilitation".

On pg 7: "Major agro-industries considering re-investment in areas where hundreds of millions of dollars of losses have been suffered were questioning whether the principle roads and bridges required to get their products to markets and ports would be reconstructed in a timely and <u>durable way</u>."

The USAID/ El Salvador Hurricane Reconstruction Special Objective states on page 6: "Road repairs made in the short term will be for naught unless there is assurance that the roads will be maintained. The Ministry of Public Works normally can only support the maintenance of 20% of the damaged road network. The lack of road maintenance is exacerbated by the lack of nearby rock quarries, thus requiring the costly transportation of gravel from other parts of the country". "Based on USAID's experience in other parts of the country, the use of a soil stabilizing product creates an all-weather road surface with minimal maintenance requirements".

The following excerpt on soil stabilization is from the October – December 2000 Proyecto RECAP (Emergency Reconstructions of Roads and Bridges Project) Report: "RECAP continued to apply and monitor soil stabilizer use. Many of our stabilized sections experienced their first rainy season. In nearly every instance, stabilized road sections performed better than non-stabilized sections. They had less rutting and surface erosion. There were several instances where road sections were submerged for extended periods and these showed little damage once the water receded".

"In general, RECAP now has sufficient confidence in the design and application of stabilizers to increase their use when funding permits. Given the funding constraints, stabilizer use will be focused on road sections with excessively long over-haul distances, sections with varied gradients and sections passing through villages and towns where dust control is important to public health". See attached RECAP product selection document.

"RECAP will continue monitoring and testing stabilized sections. Other Honduran agencies are interested in using RECAP's procedures and results to design and contract stabilizers for their programs. Next quarter, RECAP plans to prepare and circulate a comprehensive report on its experience using stabilizers".

The World Bank, in recognition of the benefits of soil stabilizers for rural road development and rehabilitation, is currently financing Soil Stabilization Project BIRF 3685-PA in the Republic of Paraguay. The project is for the rehabilitation of 5,000 km of rural roads specifically with soil stabilizers.

Inter-American Development Bank - The office of the President of IDB sent a letter stating that the IDB would support this MOP (Ministério de Obras Publicas) initiative to incorporate the use of soil stabilizers in the specifications of future bids by the Direccion Nacional de Caminos of El Salvador (Jorge Claro de la Maza on behalf of Mr. Enrique Iglesias, President of IDB, August-1999).

Extensive experience in Malaysia with soil stabilizer usage on secondary roads, was reported by PORIM (Palm Oil Research Institute of Malaysia) at the National Seminar on Productivity, June 1998, "the use of soil stabilizer has reduced the maintenance requirements for plantation roads by at least 75%, based on a three (3) year study period, as compared to maintenance costs of adjacent, untreated roads. And much of the treated road costs were clearing ditches of grass. We can do 3 to 4 times as many kilometers of road maintenance work with the same budget".

2. PERFORMANCE MEASUREMENT METHODS

It is important to monitor and confirm the effects of the soil stabilizer treatment with time to show the increase of road strength and bearing improvement. Road engineers in various parts of the world measure performance parameters after road construction and stabilization principally using the Dynamic Cone Penetrometer. This simple and versatile equipment evaluates the improved capacity of the treated soil to support traffic loads. The Dynamic Cone Penetrometer – DCP – determines empirically the CBR% or California Bearing Ratio of soils of the road, without destroying the road structure.

DCP testing was developed in the Union of South Africa and refined by the US Army Corp of Engineers to provide a simple field method for gathering data and determining the soil load carrying capacity at the road site. This developed method has removed the cumbersome, time-consuming and costly methods of the past, while providing a portable, durable, reliable and easy-to-use procedure for measuring road performance. DCP has been adopted by National, State, Municipal and Private contractors in the USA and by many road operations Worldwide to evaluate and manage roads, pavements and airfields.

While laboratory methods of CBR measurement are common in establishing load bearing levels of a particular soil, they are not useful for "in situ" road evaluations, as the act of removing the stabilized road soil samples for lab testing destroys the structure to be measured.

As the penetration in millimeters (mm) of the DCP cone tip per drop is empirically correlated with CBR% values developed in the laboratory, the capacity or road bearing strength of the treated road is measured "in situ And is done without destroying the road structure." The lower the DCP penetration values, the denser or stiffer the soil is and the higher the CBR%.

Experience has shown that soil stabilizer performance on actual roads in the field always exceeds projected results from laboratory analysis. It is believed that this is due to the difficulty of duplication in the lab of the applied loading from traffic and the curing conditions that occur over time (weeks) in the field. The operation of dynamic penetration is repeated as many times as needed to reach or exceed the target depth (stabilization depth is between 150 mm to 200 mm).

3. EXAMPLE ROADS - Brazil

A study began by identifying road sections that exhibited typical soil problems in the base or sub-base layer. Engineers and technicians of the Department of Paving of the Secretary of Municipal Works of Curitiba (SMOP/PMC), State of Paraná, Brasil selected three (3) roads

Street	Suburb	Completed	Length
Marcílio Dias	Alto	07/01/99	100 m
David Tows	Cercado	09/09/99	200 m
Florianópolis	Cajurú	08/13/99	180 m

Tab. 1 - Experimental Sections (15 cm depth of treatment)

in distinct suburbs for project implementation. Table 1 at the side has the names of the roads and suburbs, the dates of product application and road lengths.

After road selection, technicians of the Division of Laboratory and Research characterized soil materials from the experimental sections using plasticity, gradation and CBR. This provided the basis for determining if the bioenzymatic stabilizer would be adequate for the existing soil or if soil amendment would be required to achieve a balanced mix of fine and coarse particles for best stabilization. The product effectiveness in stabilization is associated with its ability to activate strong bonds in fine particulate, to form a dense structure around the coarse material, and to reduce the effects from the contraction and expansion of compacted silt and clay particles.

In the treatment of the streets, all the constructions steps indicated by the manufacturer were followed as best possible. A representative of the manufacturer was present at the time of treatment to assure that necessary instructions were provided. The application of the soil stabilizer was at a treatment depth of about 15 cm.

Figures 1a and 1b give photo information of the DCP equipment in position during the measurement and after the measurement.

(a) DCP in position for measurement on the road

(b) DCP after the measurement

Fig. 1 - DCP equipment being used on Rua David Tows

The manufacturer uses a model developed by AASHTO (American Association of State Highway and Transportation Officials) to calculate the design impact of the increase in CBR in the layers of the stabilized roadbed. The model reveals important potential reductions in the costs of construction and maintenance.

3.1 Results

During the period of more than 165 days of medium traffic (100-200 vehicles/day on David Tows e Florianópolis and 50-100 vehicles/day on Marcílio Dias) at least three (3) evaluations were made of the structural and functional performance of the roads. During this same period more than 650 mm of rain fell on the road surfaces. Table 2 shows the data.

	Jul 99	Aug 99	Sep 99	Oct 99	Nov 99	Dec 99	Jan 00	**Total for period**
Total month (mm)	141,2	12,6	116,2	105,4	70,2	120,0	100,0	**665,6**
Maximum day (mm)	69,2	7,4	52,8	28,8	28,4	31,6	24,2	

Tab. 2 – Data of rain fall in the Metropolitan region of Curitiba (From SUDERHSA).

It was observed that an increase in the capacity of the road layer to support loading (CBR) had occurred on all the roads as they cured. The results are found on Table 3 and Figure 2.

Marcílio Dias				Florianópolis			David Tows		
Days after treatment				Days after treatment			Days after treatment		
0	28	82	166	0	42	127	0	39	165
5	83	117	133	7	108	111	5	106	128
CBR (%)									

Tab. 3 - Increase in CBR of treated soil in road layers of Curitiba.

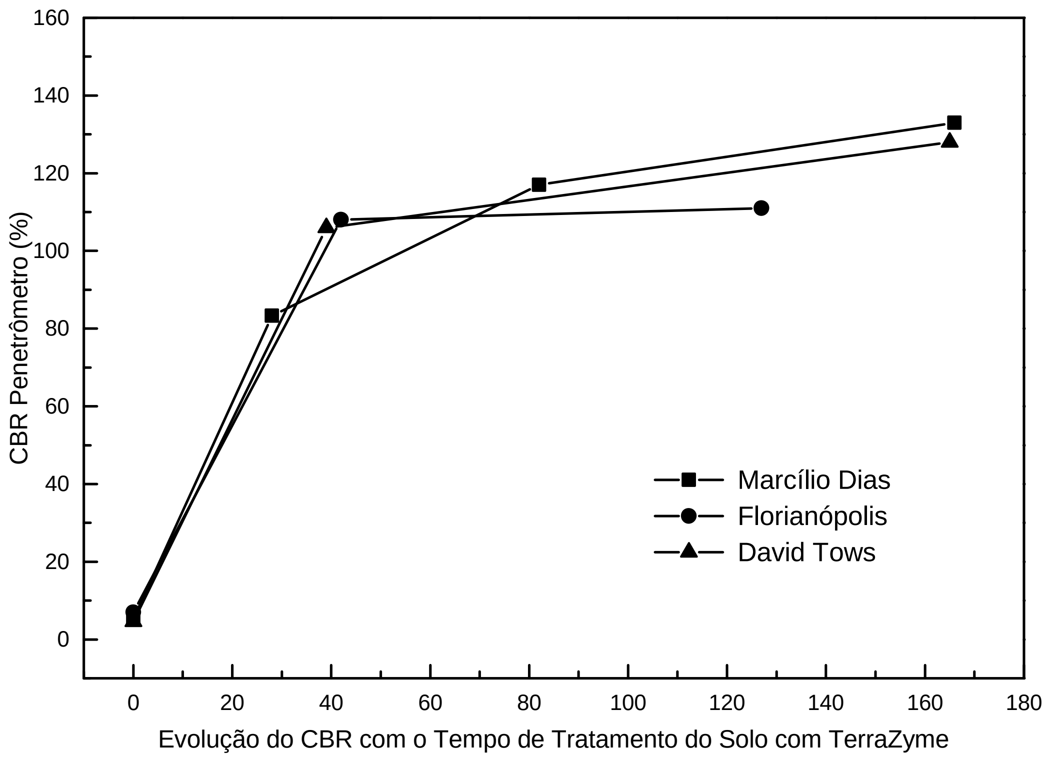

Fig. 2 - Increase of CBR in soil road layers in Curitiba.

Examining Table 3 and Figure 2, it is noted the capacity to support loading by the soils (CBR) increased greatly with the curing time of TerraZyme. In all cases, the bioenzymatic treatment of the soil layers increased the CBR more than fifteen times when compared with the low initial values (5% to 7%) obtained in the laboratory on untreated soil material from the experimental sections.

This increase in the capacity to accept loading creates an increase in the value of the structural coefficient, adopted by the DNER (Departamento Nacional de Estradas e Rodovias) and by AASHTO, which parameters are utilized in calculations in pavement projects. Obviously, the higher CBR values of local soil layers will reflect in a reduction of thickness of the pavement or select material layers, with reduction in construction costs and in future maintenance costs. This avoids the necessity of importing more expensive materials, such as crushed stone or soils with better engineering properties.

The qualitative evaluation of the performance of the bioenzyme stabilizer to improve the incidence of road defects was made from a photographic record taken during the same times as the structural evaluation.

The sequence of photos on Figures 3, 4, and 5 below, respectively on Ruas Marcílio Dias, Florinápolis and David Tows, show the performance of the bioenzyme in improving the comfort of the road users. The lack of vehicles in some photos is because the road evaluations were performed on hours/days outside of peak times to avoid interruptions and possible accidents at the road site.

Marcílio Dias - 28 days after treatment;

Marcílio Dias - 82 days after treatment

Marcílio Dias - (L) 146 days after treatment

Paved with 5 cm of asphalt cement

Fig. 3 – Views of the TerraZyme treated road surface of Rua Marcílio Dias.

Florianópolis - 42 days after treatment;

60 days - note surface quality and the cohesion of base

Florianópolis - 60 days after treatment. No lateral drainage

127 days after treatment - problems of crowning and drainage

Fig. 4 – View of TerraZyme treated road surface of Rua Florianópolis.

David Tows - 39 days after treatment; difficulty in removing the DCP bar due to granular cohesion of the soil base of the layer.

David Tows - 57 days after treatment; photo after rains

165 days after treatment - no crowning and drainage

Fig. 5 View of TerraZyme treated road surface of Rua David Towns

4. CONCLUSIONS OF THE BRAZIL STUDY

After more than 7 months of usage, without any required maintenance, road sections treated with Soil Stabilizer showed the following improvements:

1. Increased the CBR or capacity to support traffic loading to more than fifteen (15) times that of the soil not treated with the soil stabilizer.
2. Preserved the structural integrity of the surface (no permanent deformation or plastic effects) with increased cohesion of the base layer material and consequent increase in CBR.
3. Conserved the initial transverse section, without evidence of loss of material from erosion or abrasion from traffic and with no accumulation of material on the pavement edges.
4. Eliminated the appearance of corrugations or washboard deformations that form principally in areas of acceleration or deceleration of vehicles or in areas of the small surface imperfections.
5. Minimized the creation of dust that causes problems of visibility for the road users, the environment and the health of the neighborhood.
6. Eliminated the occurrence of tire marks or ruts caused by the repeated passage of vehicles and the permanent deformation of the base layer material.

4.1 Other Conclusions

1. A road surface that is not given a proper conformation or slope will accumulate water in any surface depression. This pooled water will act to soften the soil in the depression, allowing further deformation from the weight of passing traffic. During rainy periods depressions will become larger and deeper with the passage of traffic.

Non-treated roads break down rapidly under this softening action. While stabilized roads are resistant to this action and continue to show elevated CBR values, with time depressions will show and degrade the surface. Crowning, slope conformation and drainage are critical design elements for all road surfaces.

2. Road sealing with MC-30 or asphalt emulsion within 24 to 48 hours of road layer stabilization will increase the benefit of stabilization under conditions of rain and inadequate drainage. The application of asphalt paving will protect the treated layer for an indefinite period. The roads have passed more than 7 months without protection, but the stabilized base needs to receive an asphalt wear layer for surface protection. This can be done after correcting slope deficiencies and filling surface depressions with a resistant material such as crushed stone, treated soil or even the paving material.
3. Destructive testing practices of “in situ” collection of material and laboratory measurement of the damaged structure should be avoided in favor of Dynamic Cone Penetrometer (DCP) or another non-destructive test methods for evaluating the CBR of stabilized road layers.

5. RECOMMENDATIONS

1. The usage of soil stabilizers should be broadly expanded for all secondary road rehabilitation and improvements projects to provide the benefits of greatly lowered maintenance problems and costs. Savings of 75% are documented. This allows a limited road maintenance budget to be used on 3 to 4 times more roads.
2. Soil stabilizers should be used more widely in improving road sub-base and base soils and receiving important savings in paved road construction. Savings of 30% are shown.
3. National road ministries and road design consultants need to understand, specify and recommend soil stabilizer usage in national and world funded road projects to achieve economies in construction and maintenance, while improving the transportation networks in their countries. See attachments from the USAID Honduran Report and Uganda “Evaluation of TerraZyme Trial Road Sections”