EARTHZYME – PAVING A NEW WAY FOR HAUL ROAD CONSTRUCTION

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KEYWORDS

EarthZyme, soil stabilization, roads, road construction, haul roads, haul road stabilization, clay soil stabilization, environmentally friendly road building, mining solutions, sustainable engineering, mine roads

ABSTRACT

The following is a technical summary of some examples of the past 15 years of Cypher Environmental Ltd.'s work with EarthZyme soil stabilizer.

The use of environmentally friendly EarthZyme soil stabilizer can dramatically reduce costs associated with the construction and maintenance of new haul roads and the stabilization of existing haul roads. EarthZyme is a concentrated blend of enzymes, electrolytes and surfactants that produce fantastic results on suitable soils. After an application of EarthZyme, treated soils have shown to yield higher densities, increase California bearing ratio (CBR) values, and reduce permeability and swell. EarthZyme works on clay based soils, stabilizing them to comparable strengths of traditional aggregate haul roads. This results in a significant cost savings in expensive raw material inputs such as coarse sand and gravel, which are not required when a soil is stabilized with EarthZyme. EarthZyme soil stabilization has been successfully used in a variety of road construction projects. Specifically in a thoroughly studied project in Ecuador, EarthZyme treated soils were determined to yield a significant reduction in swell (170 %) and an increase in CBR (51 %). These modifications in soil properties, due to stabilization with EarthZyme, are consistently reported and long-lasting even though the product biodegrades (> 90 %) within 28 days. This report will go into greater detail regarding the advantages that EarthZyme can provide when introduced to any mine site. Further to the cost savings in raw materials, emphasis will be placed on the reduced maintenance requirements and costs that introducing EarthZyme to a road construction project exhibits through the long term stabilization and improved engineering characteristics of a stabilized soil. EarthZyme has a diverse application history; from humid climates like Southern China, and tropical Latin America to the arid Gobi Desert of Mongolia, or the extreme climates of West Africa, and Northern Alberta, Canada. The most challenging of these, in terms of climate and road requirements, has been the Athabasca oil deposits of Northern Alberta, Canada. The consistently low temperatures and high levels of precipitation combined with the extreme weight of haul trucks, 400-700 tonne loaded weights, required to mine the deposit was put to Cypher Environmental Ltd. as a challenge in 2009. Cypher Environmental Ltd. eagerly met this challenge and together with our Western Canadian distributor, Frontline Integrated Services Limited, and our other industry partners, have successfully reduced the cost of all-weather haul road construction while exceeding industry standards in the Athabasca Oil Sands and around the world.

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INTRODUCTION

Cypher Environmental Ltd. has been developing and applying EarthZyme liquid soil stabilizer for over a decade. In our extended time applying and developing EarthZyme we have successfully utilized the product in diverse projects and global settings. For the past 5 years Cypher Environmental Ltd. has been working closely with the mining industry in the Athabasca oil sands to construct haul roads that outperform dated and costly aggregate construction methods. These EarthZyme stabilized roads have displayed both short and long term cost savings. Due to the competitive nature of the mining industry this summation of works completed will not specifically reference our clients or their projects. Differentiation will be made between road type and project location.

ECONOMIC BENIFTS OF EARTHZYME CONSTRUCTION PROJECTS

Currently aggregate material is becoming scarce on many mine sites, particularly in the Athabasca oil sands. Typically haul road construction requires a well graded aggregate to achieve desired characteristics: high load bearing capacity, wear resistance, and weather resistance. Constructing haul roads with EarthZyme utilizes fine grain clayey soils and standard equipment. These clayey soils are traditionally considered mine waste or over burden. EarthZyme haul roads in the Athabasca oil sands have been studied in comparison to aggregate all-weather haul roads and have consistently produced comparative, if not superior results. These haul roads have shown to be faster to build, exhibit reduced rolling resistance and rack events, and cost less to construct.

EarthZyme road construction methods, whether for heavy mining trucks or municipal traffic, are quite similar. The difference between constructing a haul road (40 metre width) or a municipal road (7 metre width) is equipment selection. For haul road construction Cypher Environmental Ltd. recommends utilizing 1-2 large haul trucks (ex. Caterpillar 793) or steel drum rollers (ex. Caterpillar CS64) depending on availability, to compact the soil, 1-2 large water trucks (40-100 tonnes), a large grader (ex. Caterpillar 16M or 24M), and 2 reclaimers (ex. Caterpillar RM500 Reclaimer). For municipal road construction Cypher Environmental Ltd. recommends utilizing 1 steel drum vibratory compactor and a pneumatic roller (ex. Caterpillar CS64, Caterpillar PS360C), 1-2 graders (ex. Caterpillar 14M) or 1 grader and 1 reclaimer (ex. Caterpillar RM300), and a 10-20 tonne water truck. A major similarity between EarthZyme road construction projects in different industry settings is the associated short and long term cost savings.

As a result of the similarities in construction techniques and effort, and the competitive nature of the mining industry, a well-studied comparative municipal construction project will be utilized to display the short term cost saving nature of EarthZyme road construction.

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Short Term Economic Benefits of EarthZyme

An empirical review of a municipal road construction project in Ecuador was conducted by Eco-Road Solutions, Quito, Ecuador (Helberth, 2012, June). This review encompassed several aspects of the project, including a cost comparison between two equal sections of road; one constructed with standard aggregates, the other using clayey soil and EarthZyme. This study determined that the EarthZyme stabilized road was completed more efficiently on all measurement criteria (Table I).

Table I - Economic savings of EarthZyme municipal road construction, Quito Ecuador

Action	Savings with EarthZyme
Material transported	95 %
Use of machinery	59 %
Material	27 %
Labour	33 %
Total Project Savings	**47 %**

The largest saving resulting from this study was in material transportation. Material and transportation cost savings result from EarthZyme projects because raw material inputs for EarthZyme road construction are considered waste by many industries and therefore inexpensive to acquire. It is worth noting that prior to this project the contractor had not previously worked with EarthZyme, but they had received mandatory training from a Cypher Environmental Ltd. representative. Also, constructing roads with EarthZyme reduces machine hours and labour, which results in increased contractor capacity.

Long Term Economic Benefits of EarthZyme

Reduced Rolling Resistance

Reducing the rolling resistance of a haul road directly results in reduced fuel cost and increases haul fleet productivity of a road segment (Regensburg & Tannant, 2001). Using EarthZyme to construct fine grain clayey haul roads has shown to reduce rolling resistance. A rolling resistance study conducted in the Athabasca oil sands determined the average rolling resistance of an EarthZyme treated haul road constructed with Clearwater Clay Shale overburden

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of medium to high plasticity. This study determined that the average rolling resistance was 2.7 % with a standard deviation of 0.5 %. This is well within the boundary requirements of many Athabasca oil sands companies, 3-5 % for permanent road surfaces (Regensburg & Tannant, 2001).

Haul roads constructed with similar material and not stabilized with EarthZyme exhibit considerably different characteristics than an EarthZyme stabilized haul road. Common rolling resistance values for similar material, in-situ benonitic clay shale of medium to high plasticity, range from 7-13 % with an addition of 1.5 % for every inch (2.54 cm) of penetration (Dionne 1987). Increased rolling resistance directly relates to increased fuel consumption and reduced haul fleet productivity (Figure I).

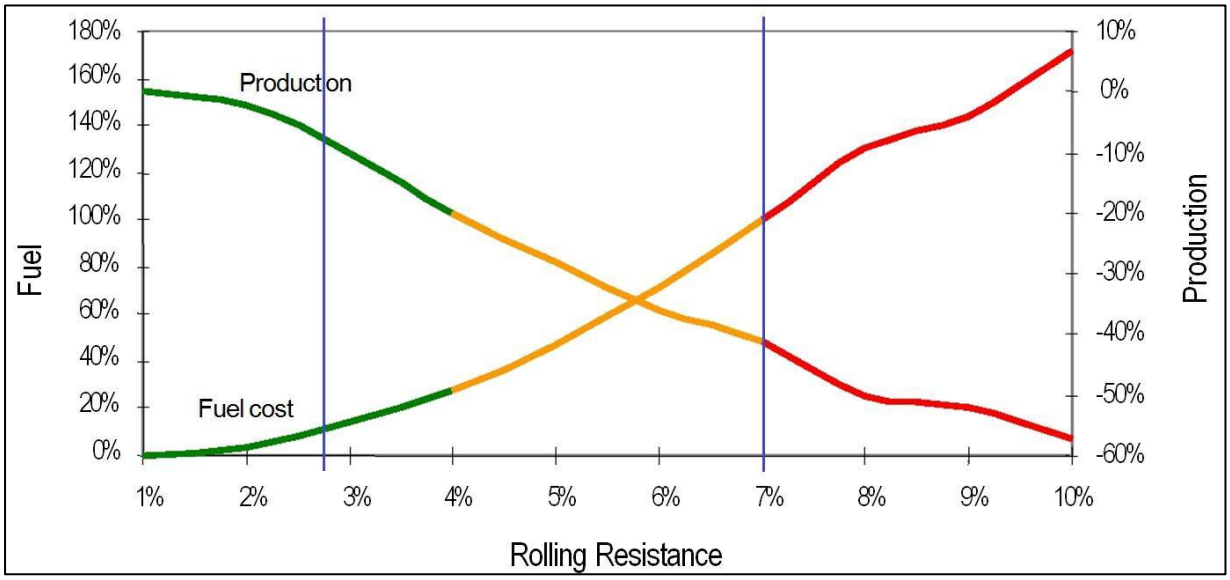

Figure I - Relationship between rolling resistance and increased fuel consumption and decreased haul fleet productivity (Holman, 2006).

Figure I was used to forecast potential economic benefit of reducing rolling resistance on a mine site. It was determined that reducing rolling resistance of a haul road from 7 % to 2.7 %, 1 deviation above average was determined to be 3.2, will increase haul fleet productivity by 35 % and decrease fuel cost by 90 % percent (Table II).

Table II - Potential savings resulting from reduced rolling resistance

Rolling Resistance (%)	**Production (%)**	**Fuel Cost (%)**
Clay Shale; 7.0	- 47	100
Clay Shale + EarthZyme 3.2	- 7	10
Savings (%)	**35**	**90**

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From Table II and Figure I it is evident that reducing rolling resistance on haul roads using EarthZyme can yield extensive savings in fuel consumption and significantly increase the productivity of a mining operation.

Reduced/Eliminated Racking Events

To date the cost reductions associated with the reduced maintenance and racking events on EarthZyme haul roads has not been quantified. This is an area Cypher Environmental Ltd. plans to focus on in the future to further display the economic benefits of EarthZyme haul roads. The study previously referred to with respect to rolling resistance also determined that no trucks passing over the EarthZyme stabilized haul roads exhibited racking events. RAC events as defined by Caterpillar Inc. (2012), "RAC measures the frame's rack and pitch. Rack is the lateral twisting of the frame due to uneven loading on the diagonal tires. Pitch is the force on the frame from front to rear which occurs when the truck crosses a bump or dip perpendicular to the line of travel, hard braking or turns." (para. 2). These trucks were monitored daily. Traffic was considered high for an average mine in the Athabasca oil sands and travel speeds were consistently greater than 40 km/hr.

Reduced Maintenance

Quantifying reductions in maintenance of roads is a costly task, in both time and funds. Further complicating this task is the competitive nature of the mining industry. Through experience in road construction, Cypher Environmental Ltd. determined that reduced maintenance on haul roads can be objectively measured in grading requirements. To date EarthZyme haul roads require minimal grading, generally only to clear spillage from haul trucks. Furthermore, the high volume of traffic and loading subjected to EarthZyme treated haul roads enables the roads to maintain the high levels of density achieved during the initial compaction process carried out during construction. Due to the homogeneous nature of the soil structure, EarthZyme haul roads exhibit negligible rutting and remarkable reductions in common maintenance issues. These issues frequently result from imperfections in road surfaces or bearing layers: wash boarding, rutting, potholing.

Although not quantified, reduced maintenance requirements have been consistently reported on EarthZyme soil stabilization projects in diverse work site application settings. The cohesive nature of the fine particles, and the improved binding and strengthened clay bonds facilitated by EarthZyme makes possible the reduced maintenance of the haul roads. To ensure that the wear surface of an EarthZyme haul road achieves the required level of water and wear resistance, a slurry coat is applied to the final lift during construction. A slurry coat is applied using approximately 1:1000 ratio of EarthZyme to water, with an application rate of 1 litre of

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EarthZyme to 1000 square metres of compacted surface. Contractors apply this mixture topically to the road and allow it to soak into the compacted surface. Once the moistened surface is no longer tacky, fully loaded haul truck(s) compact the surface. They make several passes until the road dries and requires rewetting or until the surface seals. This process forces the larger granular particles down and the cohesive fines to the surface, creating a tightly sealed road that effectively repels and sheds water (Figure II, A., B.).

Figure II - Coal mine haul road; Indonesia
A. Sealed surface after slurry coat is finished
B. Close-up of haul road surface

It should be noted that tightly bound surface of EarthZyme treated haul roads have significantly reduced dust production. Reduced fugitive dust is of high value to mine sites as increased dust levels can result in reduced haul fleet productivity. The reduced productivity results from reduced visibility due to fugitive dust. Reduced visibility by dust is a safety hazard and requires haul trucks to slow down and in some cases stop to prevent accidents. Reducing dust caused by haul truck traffic on EarthZyme treated haul roads can allow for faster operating speed and increased efficiencies of haul fleet operations. Reducing dust can also help to reduce wear caused by dust particulates to the moving parts of haul trucks, extending part life. The overall reduction in dust also provides cleaner air for workers.

These reductions in common maintenance issues directly result from an increased homogeneity of a bearing layer and surface with increased strength and durability. These reductions in overall maintenance have been reported as a result of EarthZyme stabilization in a diverse climate setting from Northern Alberta, Canada to Columbia and Indonesia. Other examples of diverse climates that achieve similar results include: West Africa, Southern China,

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Dominican Republic, Ecuador, Mongolia, Peru, Romania, South Korea, Turkey, and the Southern United States.

To achieve these desirable cost savings, a client must first test the soil for compatibility with EarthZyme.

SOIL REQUIREMENTS

EarthZyme is not effective at stabilizing all soils. Before treating a soil with EarthZyme, Cypher Environmental Ltd. recommends several standard soil tests be conducted: Particle Size Distribution-ASTM D422, Atterberg Limits liquid and plastic-ASTM D4318.

This testing verifies that the soil contains fines in excess of 20 % by weight passing the 75 micron sieve (# 200 sieve), and a plasticity index above 8. The A-line on the Casagrande Chart determines soil acceptability for treatment. A soil that plots on or above the A-line is considered acceptable and exhibits the short and long-term gains in engineering properties associated with EarthZyme stabilization. A soil that plots below the A-line can still be treated with EarthZyme, but will exhibit only short term gains in engineering properties. The difference in the length of effective treatment relates to the non-organic clay content and chemistry of the soil. The long-lasting stabilization of EarthZyme directly relates to the use of clay as the binding agent. This is because the clay is indigenous to the soil and not an additive that will leach out of the soil or degrade through soil microbes and soil chemistry. This combined with the increased cohesive nature of the treated clay and the permanent alteration of the chemistry of the soil, results in haul roads that exhibit minimal maintenance and increased load carrying capacity for many years.

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EARTHZYME

What It Is

EarthZyme is added to clay-mineral soils to increase compactability and decrease the mobility of water in the compacted soil matrix. EarthZyme consists of these three primary elements:

1. An ionic solution that interacts with the clay minerals in the fill to reduce the proportion of water that is weakly bonded to the clay particles. The ionic solutions serve to reduce the diffuse double-layer, which allows greater densities to be achieved under a constant compaction force.

2. A strong surfactant that serves to reduce the viscosity of the water, increasing the lubricating effect of the water during compaction. This ultimately achieves greater densities at lower moisture contents while enhancing alignment of the clay particles, which reduces the permeability of the compacted mass. The surfactant also serves as a carrier fluid for the enzymes and ionic solution.

3. A combination of enzymes that facilitate ion exchange between clay particles and the ionic solution.

These three compounds work in harmony during haul road construction enabling conventional construction equipment to achieve higher densities than with untreated compacted clay fill. The higher densities, in turn, create a compacted mass with greater clay particle alignment and binding. This results in significantly higher strength, durability, and bearing resistance. The combined affect renders the treated compacted fill hard, improving water replant characteristics, making it suitable for road surface and base construction.

How It Works

Clay minerals are negatively charged. As a result, the positively charged portions of the polar water molecules are attracted to the negatively charged surfaces of the clay particles, forming weak ionic bonds between the clay minerals and the polar water. Soil scientists referred to this as the diffuse double layer, and is the mechanism that causes clay soils to swell and lose strength in the presence of free water (Das, 2008, Ch. 4). The thickness of the diffuse double layer depends on the chemistry of the clay minerals and the pore water (Michael & Soga, 2005, P. 158). The diffuse double layer thickness can be reduced by altering the clay and pore water chemistry (Michael & Soga, 2005, P. 158). EarthZyme utilizes an enormous ionic exchange potential to shrink the diffuse double layer, which reduces the soils ability to adsorb water, reducing the optimum moisture content of the treated clay soil, and allowing higher compaction

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densities. Surfactants enhance this ion exchange by increasing the penetration of the ion solution into the capillary structure of the soil. The surfactants also serve as a carrier fluid for the enzymes. These enzymes facilitate increased ion exchange between different clay mineralogy; enabling EarthZyme to be diversely effective. These combined effects permanently reduce the clays affinity to water.

The EarthZyme surfactants have a dual purpose during the soil stabilization process. The EarthZyme surfactants have the temporary effect of decreasing surface tension and water viscosity, acting to encourage compaction. This lubrication results in achieving a dispersed soil structure and reduced pore spacing. This reduction in surface tension further reduces the moisture requirements of the soil for optimal compaction. The combined effect of the shrunken diffuse double layer and reduction in surface tension reduces the optimum moisture content of the soil in combination by approximately 1-2 %. This process creates a fine grained soil structure with significantly reduced pore space and increased platelet to platelet contact.

The combination of the high degree of compaction (reduced pore space and capillary structure) and dispersed (parallel) soil structure vastly reduces the permeability of the soil and vastly increases the strength (bearing capacity). As EarthZyme biodegrades the surfactants breakdown, and re-establish the surface tension of the water. This triggers the bound water (liquid bridges) to tighten, creating greater internal compression forces. This results in increased suction and skeletal forces in the soil matrix, further reducing space between cohesive clay particles, and increasing covalent and ionic bonding. Ultimately, this causes the hardening or curing of the compacted clay fill, resulting in the completed surface exhibiting increasing strength overtime. The majority of this process happens in the first 5-7 days, continuing until day 28.

The reduced void ratio also facilitates increased natural binding via chemical bonding, and Van Der Waals bonding between clay structures (Michael & Soga, 2005, Ch. 7). The increased density and subsequent increased bonding of clay fabric in combination with their parallel orientation works to create a bearing surface that exhibits not only increased strength properties, but, increased homogeneity. Combined, the effect is to resist re-adsorption of water that would otherwise reduce strength. The dispersed nature of the soil matrix further increases this effect. This dispersed soil structure also assists to reduce permeability, a result of a reduction in interconnected pores that otherwise aid in water transmission and a reduced inclination for the compacted soil to exhibit brittle failures (Bowles, 1992). This creates a strong more durable road, with a reduced inclination to water and increased uniformity of strength gains.

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PAST PROJECTS

The diversely applicable design of EarthZyme enabled Cypher Environmental Ltd. to effectively stabilize road construction projects around the world and across the industrial/municipal sectors. EarthZyme's highly concentrated design, 1 liter of EarthZyme required to treat 33 cubic metres of compacted soil, makes EarthZyme cost effective on a global scale. Common links between all of these projects include increased bearing capacities and reduced susceptibility to water permeation and degradation. Cypher Environmental Ltd. developed alterations to the CBR test to predict the effectiveness of EarthZyme on particular soil types. Traditionally determining road design requirements utilizes the CBR test (Bowles, 1992). The CBR test is a well-known test that can be conducted in the majority of soils laboratories in both developed and developing countries. Because of this Cypher Environmental Ltd. utilized the CBR test for years to predict the strength gains and stability of foundations stabilized with EarthZyme. Reduced infiltration of and affinity to water is an important aspect of road construction with fine grained, traditionally highly expansive soils. EarthZyme effectively reduces the expansive characteristic of normally expansive soils yielding a low cost, stable construction material (Table III).

Table III - Swell reduction of fine grain soils treated with EarthZyme; 96 hour test

Project Type	Location	EarthZyme*	Untreated*	Swell (% Reduction)
Municipal Paved Road	Caupicho Quito Ecuador	0.3	0.81	**63%**
Secondary Unpaved Road	Hainan Province China	0.08	0.26	**69%**
Primary Unpaved Road	Hainan Province China	0.06	0.28	**79%**
Municipal Paved Road	Metropolitan District of Quito Ecuador	0.01	0.32	**97%**
Highway	Cajamarca Peru	0.88	1.8	**51%**

*(percentage; vertical deflection divided by initial thickness/height of compacted soil)

The significant strength gains exhibited as a result of compacting soils with EarthZyme is an important added benefit of constructing haul roads with EarthZyme and fine grained soils (Table IV).

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Table IV - Increased bearing capacity of fine grained soils compacted with EarthZyme

Project Type	Location	CBR No EZ	CBR With EZ	Increase in CBR (Avg. % Change)
Primary Unpaved Road	Puerto Plata Dominican Republic	43	196	**353%**
Primary Unpaved Road	Peru	12	37	**208%**
Secondary Unpaved Road	Huiyang District China	37	135	**265%**
Haul Road	Pallancata Silver Mine, Peru	55	102	**85%**
Municipal Road	Ghana	69	296	**328%**
Highway	Cajamarca Peru	14	41	**192%**
Paved Parking Lot	Guangdong Province China	64	286	**347%**
Municipal Paved Road	Metropolitan District of Quito Ecuador	61	92	**51%**

These strength gains are a result of EarthZyme's unique ability to increase the bonding of the parallel oriented clay platelets while reducing the void ratio in fine grained soil at a moisture content below optimum (OMC). This is important in both increasing the overall strength of the soil and the uniformity of the engineering properties of a haul road. This bound particle orientation causes the soil to behave in a consolidated, sheet like elastic fashion; enabling the fine grained soils to tolerate higher loads with minimal breakdown of the consolidated soil structures. Generally, a haul road behaving in an elastic fashion is not beneficial to mine economics because it results in increased rolling resistance. The constant deflection of the haul road causes this increased rolling resistance resulting in a constant up-hill effect. This increased rolling resistance is due to the constant deflection of the haul road, which produces the constant up-hill effect previously mentioned (Regensburg & Tannant, 2001). This constant up-hill effect is not exhibited on fine grain EarthZyme stabilized haul roads because of large increases in CBR number. The combined strength gains and dispersed particle orientation of EarthZyme stabilized soils greatly increases their durability and bearing capacities. This creates a superior haul road using economical material inputs that can withstand repeated substantial loading with minimal maintenance or resurfacing.

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Results from a recent Mining Haul Road Project in Mali, Africa (November 2013):

A stabilization project was carried out at the Randgold Somilo site on the haul road connecting the Gounkoto and Loulo mines. EarthZyme was used to stabilize the road to a 20 cm depth, treating the in-situ soil. On an average month, 4200 trucks weighing 65 tons each use the haul road and after one month of operation, Randgold reported the following test results. CBR data from the road was collected before and after treatment with EarthZyme (Table V and Figure III). Samples were taken from both lanes of the road, lane "A" being the lane the empty trucks travel on and lane "B" the one the loaded trucks travel on. As shown below there was a combined CBR improvement of 159.91%.

Table V – CBR Data from EZ treated mining road in Mali, Africa

Test #	CBR% No EZ		CBR% With EZ	
	Lane A	Lane B	Lane A	Lane B
1	48.00	75.00	125.62	140.96
2	55.11	51.43	160.61	102.15
3	53.00	44.06	129.33	162.35
4	55.00	42.67	147.42	119.16
5	53.44	68.44	126.33	109.94
6			182.09	107.04
7			182.09	186.35
Mean	**52.91**	**56.32**	**150.50**	**132.56**
Var.	6.72	171.33	537.02	874.12
Std Dev.	2.59	13.09	23.17	29.57
Improvement in CBR			**184.45%**	**135.38%**
Combine CBR Improvement			**159.91%**	

**Lane A: Empty trucks lane; Lane B: Loaded trucks lane*

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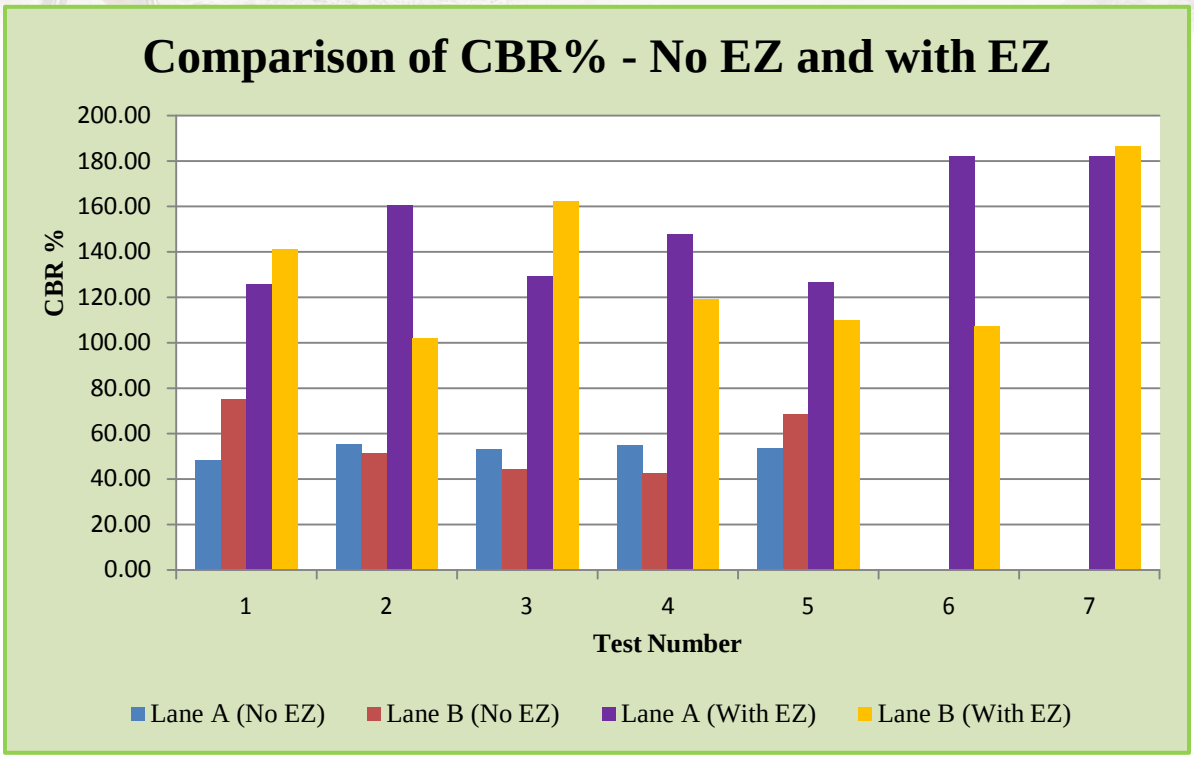

Figure III – Comparison of treated and untreated CBR in Mali, Africa

Below are photos of the road one month after being treated with EarthZyme. (Figure IV, A., B.).

Figure IV - Gold mine haul road; Mali
A. Surface after one month of traffic
B. Close-up of haul road surface

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SUMMARY OF BENEFITS

As a result of Cypher Environmental Ltd.'s commitment to providing the most cost effective, highly functional and environmentally friendly solution, Cypher Environmental Ltd. has been able to reduce the industrial foot print of road construction, while simultaneously reducing project costs. These reductions in cost are seen not only as a result of reduced costly raw material inputs, labour and machine hours, but throughout the extended life of the road. In the past 5 years EarthZyme has been integrated more and more into the mining industry as an effective additive to all-weather road construction projects. Studies of these all-weather haul roads have determined that EarthZyme stabilized haul roads exhibit reduced rolling resistance, racking events, and reduced grading requirements. This results in increased productivity and reduced fixed costs of road networks, increasing overall efficiencies at mine sites utilizing the EarthZyme product.

For further details on EarthZyme or Cypher Environmental Ltd. products see www.cypherenvironmental.com or contact info@cypherenvironmental.com.

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