# CYPHER ENVIRONMENTAL MINING REFERENCE APPENDIX

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# EARTHZYME ALLEVIATES GRAVEL SHORTAGE

Syncrude

*Story by Stephanie Hackett - Photo by Bob Nyers*

***When Base Plant Projects realized Syncrude's road building material was in short supply, they teamed with Mildred Lake Mining to seek a solution.***


**"We knew it was a viable technology, but we didn't know if the construction and application would work."**
**-- Angus Munro**

The heavy equipment operators in the North Mine have compared the road using EarthZyme to paved highway.

"A few years ago we realized our current sand and gravel resource we need for road construction would soon be in short supply," said Jovan Radmanovic with Base Plant Projects. We have to extend the mining roads and build new ones every year to sustain budgeted productivity and maximize available time of the heavy hauler fleet. These roads have to be 40 metres wide and able to support the biggest trucks in the world."

Together, they looked at several options. "The obvious solution was to continue using gravel and start hauling it from public granular pits, but after looking into this, we realized they are 30 kilometres away and would require the use of smaller trucks to transport, which would significantly increase the cost of getting the material to site," said Jovan.

However, a more economical solution was found utilizing the clay that is prevalent throughout the North Mine. "When mixed with clay and water, EarthZyme changes the properties of clay, resulting in a substance similar to rock," said Jovan. "We encounter clay every day in our mines, so we saw the potential."

In 2009, a test section was built by Mine Operations and the product was applied to one-half width of the roads to see how it would perform. "It was tested first on a low-traffic haul road at the Mildred Lake site," said Jovan.

"Trucks capable of carrying 380 tons used on this road and the test were showing promising results. There were no cracks in the road."

In fact, the EarthZyme worked so well that it was tested on a larger scale in 2010.

"We built an entire road, in 2010, using EarthZyme instead of just a 300-metre section," said Angus Munro, operations support with the project.

"We knew it was a viable technology, but we didn't know if the construction and application would work."

Although the use of gravel was almost completely eliminated on this road and replaced with a mixture of clay, EarthZyme and water, there were some issues to work out.

"We soon realized weather can adversely affect the construction of the EarthZyme road," said Angus.

"The product doesn't set well in cold weather and rain. It cures best in warm weather."

An intensive review was completed in 2010, with learnings applied the next year. Base Plant Projects construction specialist George Clark played a significant role said Jovan. "George supervised the contractors, ensuring the road was built properly. There were a lot of unknowns and learnings we were going through and George provided a lot of feedback and guidance."

"We learned that the design, equipment used, and time of year we built roads, all affect its quality," said Ken Bell with Mildred Lake Operations Support.

The objectives for 2011 were to select the right equipment, improve road design and lower the costs.

"The biggest and best road built since starting this project W4 access road. We fully expect it to be in service for many years," said Brayden Kijewski, operations support with the project.

Heavy hauler operators in the North Mine say that it performs better and is harder than conventional roads. "It's a lot smoother and easier to travel on -- similar to driving on pavement," said Angus.

In 2012, all haul roads in the North Mine will be built using EarthZyme.

About two to three kilometres of new haul road in the North Mine is built each year.

## Syncrude

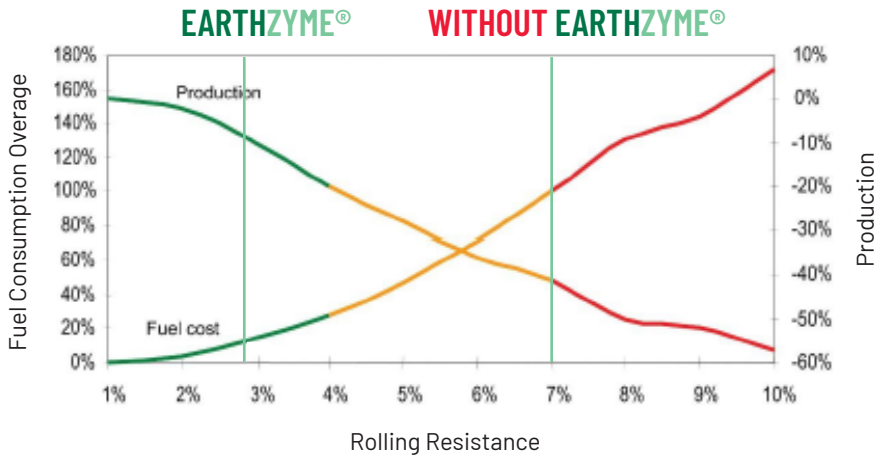
Syncrude Canada Ltd. is one of the largest producers of crude oil from the oils sands in Canada. Based in Fort McMurray, Alberta, Canada, Syncrude's current capacity allows them to supply 15% of Canada's petroleum requirements. In 2011, Syncrude produced 105.3 million barrels of Syncrude Crude Oil.

## Benefits of EarthZyme Application at Syncrude Mine Sites

**Reduces Rolling Resistance**
During this case study, EarthZyme® has proven to reduce the rolling resistance of a haul road from 7% to 2.7%; a reduction of 61%. Referencing the chart below, fuel cost overages were dramatically reduced and fleet productivity increased by 35%.

**Reduction of Materials Costs**
EarthZyme® reduces material costs by utilizing high clay content soils, which are not normally considered quality road building materials, and allows for the reduction or elimination of gravel when building a high-quality road.

**Reduction of Maintenance Requirements**
EarthZyme® treated roads result in reduced maintenance requirements due to the improved engineering properties achieved through the increase in density after treatment, which results in an increase in CBR and a reduction in permeability and swell.




Relationship between rolling resistance and increased fuel consumption and decreased haul fleet productivity.



# DCP Evaluation of EarthZyme Treated Road

June 8 – 9, 2010

**Prepared for:**

Syncrude Canada Ltd.

**Prepared by:**

Cypher Environmental
1149 St. Matthews Avenue
Winnipeg, Manitoba
R3G 0J8

## Executive Summary

In the fall of 2009, a 250m x 20m test section (one lane) of the Sulfur Block Road was treated with EarthZyme soil stabilization product to a depth of 25 cm. During June 8-9 2010, a test was carried out by Cypher using a Dynamic Cone Penetrometer (DCP). Using the DCP, the treated area was compared to the adjacent untreated lane, as well as a gravel haul road. The results of this study showed that the EarthZyme treated section was significantly more consistent in shear strength than the untreated section and the gravel road. Additionally, the average CBR was higher on the EarthZyme treated road than the untreated section and the gravel road. From these results, it is recommended that Syncrude continue with a full haul road construction using EarthZyme to evaluate the product in a real-world scenario.



## Scope of Work

Using the DCP testing instrument, Cypher West compared the shear strength of a gravel haul road, the treated EarthZyme section, and the untreated section adjacent to the EarthZyme section. The test was intended for comparison purposes only; any estimated CBR values should be used with discretion and should not be used for engineering purposes.

## Testing Method

The Dynamic Cone Penetrometer is a standardized instrument that is widely used for measuring the in-situ shear strength of granular materials and particularly subgrade soil for road construction. The apparatus consists of a steel rod fixed with a 20mm diameter 60 degree hardened steel cone tip and an 8 kilogram sliding hammer with a drop height of 575mm. The testing procedure is rapid compared with other procedures, it is relatively non-destructive, offers a strength-depth profile, and is cost-effective. The disadvantage of the DCP instrument is that accuracy decreases in high strength and coarse aggregate soils.

The results from the DCP test can be correlated to a California Bearing Ratio (CBR) value. There is considerable literature which has validated and improved the correlation between DPI (Dynamic Penetration Index, mm/blow) and CBR values. There are several widely accepted relationships between DPI and CBR; the following equations are used frequently around the world for estimating CBR values:

| | | |
|---|---|---|
| Kleyn1 | LogCBR = 2.438 – 1.065*LogDPI | (1) |
| Livneh2 | LogCBR = 2.14 – 0.69*(LogDPI)1.5 | (2) |
| US Army3 | LogCBR = 2.465 – 1.12LogDPI | (3) |
| South Africa4 | | |
| For DPI > 2 | CBR = 410*(DPI)-1.27 (4a) | |
| For DPI < 2 | CBR = (66.66*DPI2) – (330*DPI) + 563.33 | (4b) |

In the following chart, these relationships are plotted for a range of DPI values. It can be seen that the relationships diverge for very small DPI values, but converge well at the DPI value of 3 mm/blow. The Livneh (2) relationship is the most conservative for smaller DPI values; therefore this relationship will be used in the data analysis.

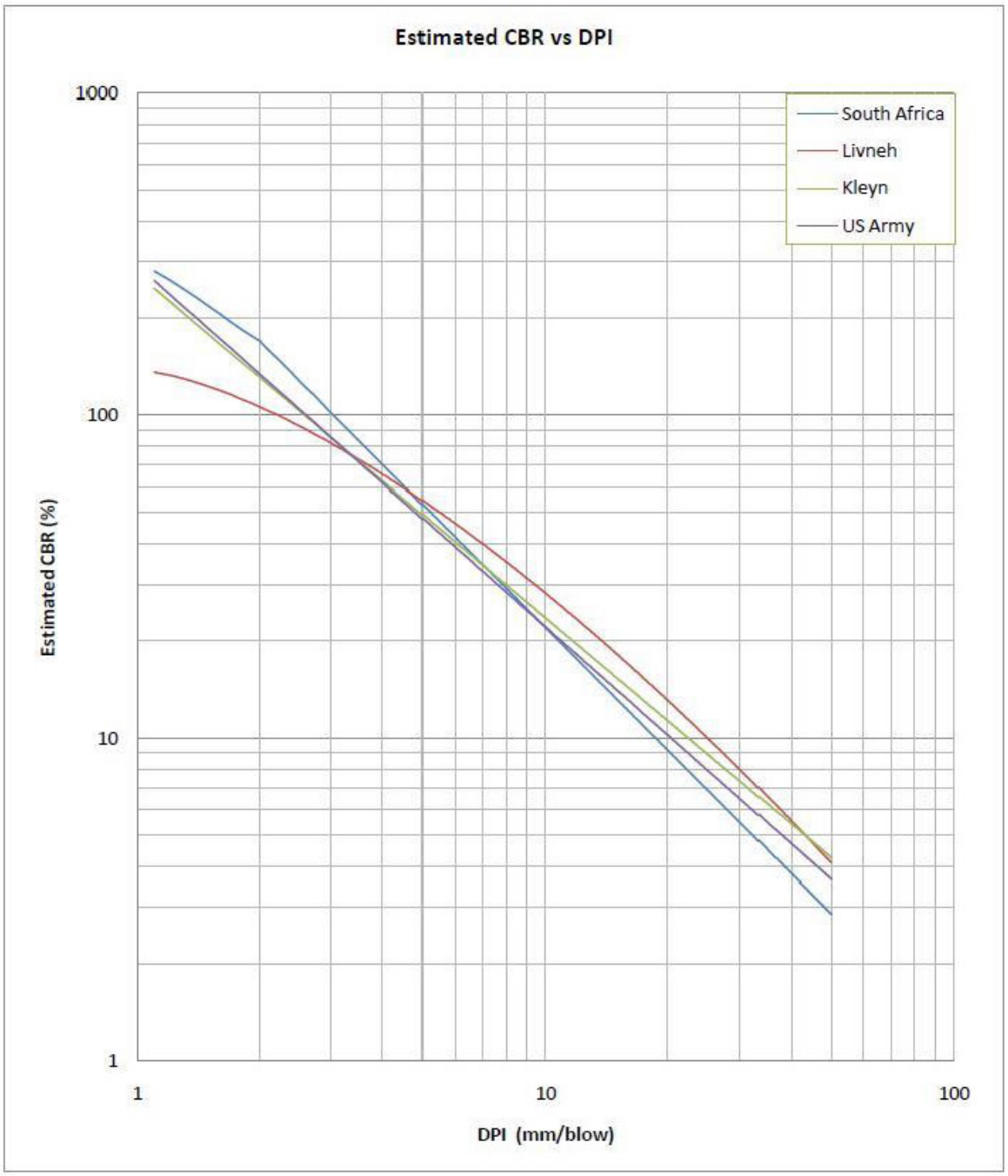



Figure 1: Comparison of accepted CBR - DPI relationships

## Observations and Results

Some of the initial observations included:

**EarthZyme road:**
- Consistently flat with no potholes, ruts, or water accumulation
- Smooth running surface
- Minimal deflection from haul trucks

**Untreated road adjacent to EarthZyme section:**
- Undulated road surface
- Settled water in low spots
- Deflection was noticeable from haul trucks
- Cracking in road surface

**Gravel road (#702 & N. Mine Expressway):**
- Undulated road surface
- Considerable amount of road gravel was scraped into berm
- Road had extremely hard spots, but also very soft spots with loose material
- Cracking in road surface

**Testing Procedure**
DCP testing was carried out at least four meters from the berm towards the center of the road and the interval between each test was approximately 10-20 meters. Proper procedure for using DCP instrument was carried out to ensure consistency. Conditions were dry for duration of test.

**Summary of Test Results**
Results show that the EarthZyme treated section is significantly more consistent in shear strength than the untreated road and gravel roads. The following charts highlight the results of the DCP testing. It can be seen that the average strength of the EarthZyme treated road is higher than the untreated road and the gravel roads. The range of values is substantially lower for the EarthZyme tests when compared with the untreated section and the gravel roads.

| Section | Average DPI (mm/blow) | | | |
|---|---|---|---|---|
| | Mean | Max | Min | Range |
| EarthZyme® treated section | 2.49 | 2.93 | 1.98 | 0.95 |
| Untreated adjacent section | 3.00 | 4.87 | 1.86 | 3.01 |
| Gravel Road (#702 & N. Mine Express) | 3.23 | 6.47 | 1.45 | 5.02 |

| Section | Estimated CBR(%) | | | |
|---|---|---|---|---|
| | Mean | Max | Min | Range |
| EarthZyme® treated section | 95 | 109 | 84 | 25 |
| Untreated adjacent section | 80 | 111 | 57 | 54 |
| Gravel Road (#702 & N. Mine Express) | 87 | 125 | 45 | 80 |

**Table 1: Comparison of test results**

### Consistency of Test Results

In Figure 2 the results of each test are compared. It can be seen that the estimated CBR values of the EarthZyme road remains relatively consistent compared to the untreated conventional road and gravel roads. The range of estimated CBR values for each road can be seen in Table 1.

Figures 3 and 4 show the DPI and CBR values at their recorded depths. These charts show that the data is not skewed from variations in shear strength with increasing depth. The EarthZyme treated road shows a consistent, narrow range of values for increasing depth. The untreated conventional road and the gravel roads show a consistently high range of values for increasing depth.

### Limitations of Test Results

The tests were usually limited to a depth of 200 mm, due to the difficulty of removing the instrument and time limitations. During testing it was seen that shear strength remained relatively constant with increasing depth (this can be seen from Figures 3 and 4). Therefore, it was decided that a wider sample of test data was preferred over deeper tests.

The correlation of DPI to CBR decreases in accuracy for DPI values less than 3mm/blow. The conservative Livneh relationship was used in order to avoid over estimation of CBR, but the CBR values could be higher based on other accepted relationships.was carried out to ensure consistency. Conditions were dry for duration of test.

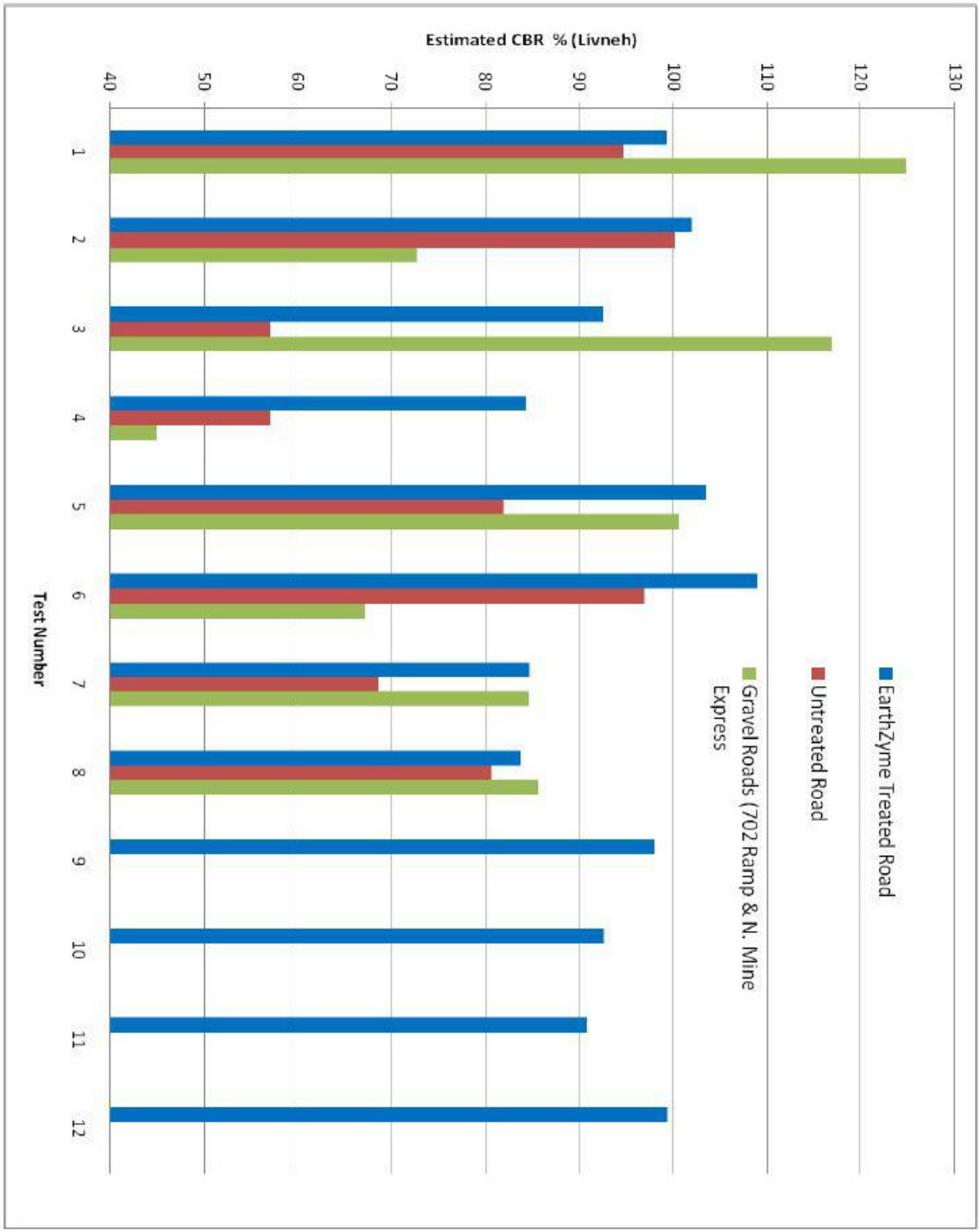



Figure 2: Comparison of estimated CBR values

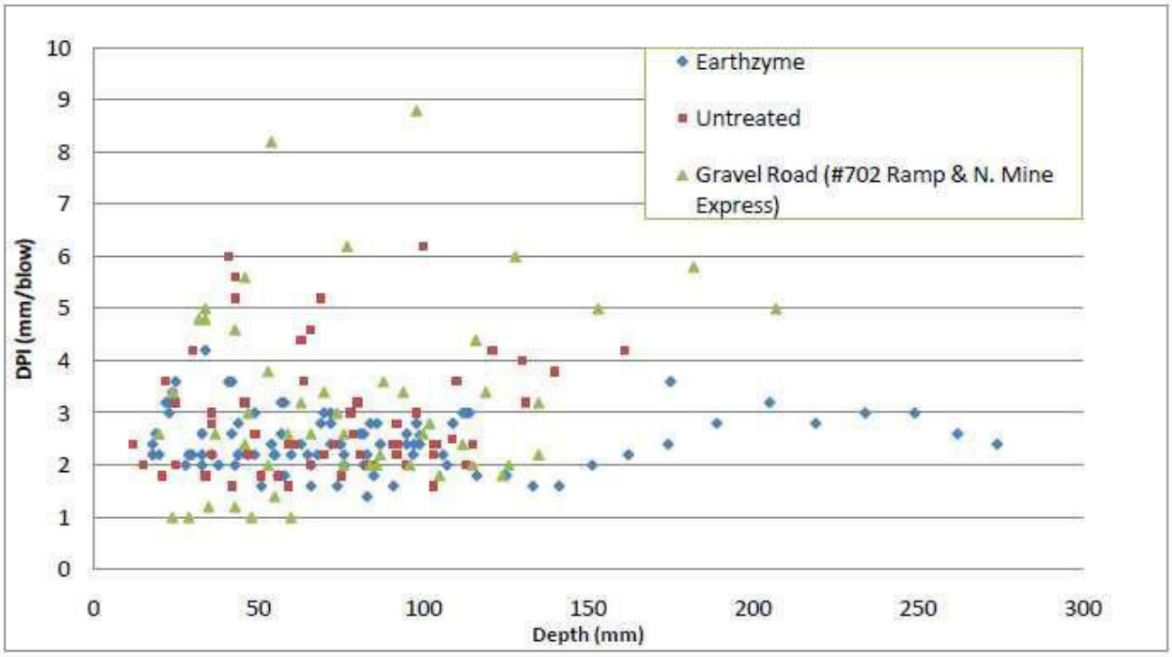



Figure 3: DPI (Dynamic Penetration Index, mm/blow) versus Depth

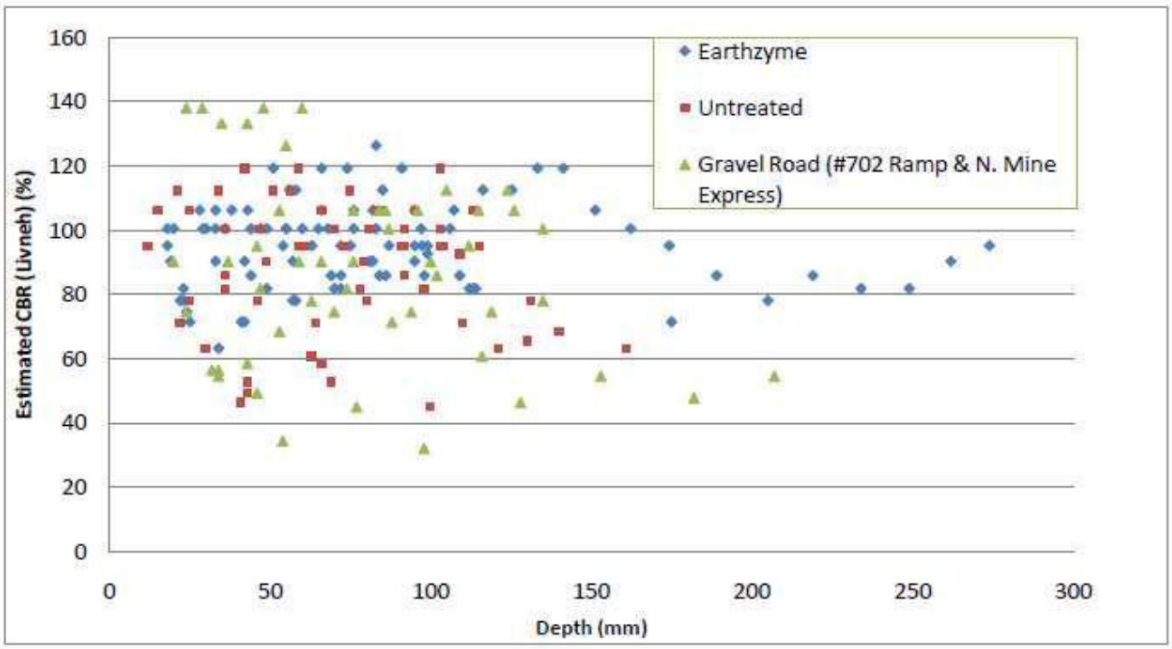



Figure 4: Estimated CBR (California Bearing Ratio) versus Depth

## Conclusions and Recommendations

From the results, it can be concluded that the EarthZyme treated road is considerably more consistent in shear strength than the adjacent untreated road, as well as the tested gravel roads (#702 and North Mine Expressway). It is speculated that the inconsistencies in shear strength of the untreated section and the gravel roads contribute to the surface undulations of these roads. These same undulations were not observed on the EarthZyme treated section. It can be assumed from the test results that the consistency in shear strength achieved through arthzyme treatment has prevented undulations from forming.

These test results provide an explanation for the observable consistency of the EarthZyme road; however, construction and monitoring a full haul road will be the true test for determining if EarthZyme suits the needs of Syncrude.

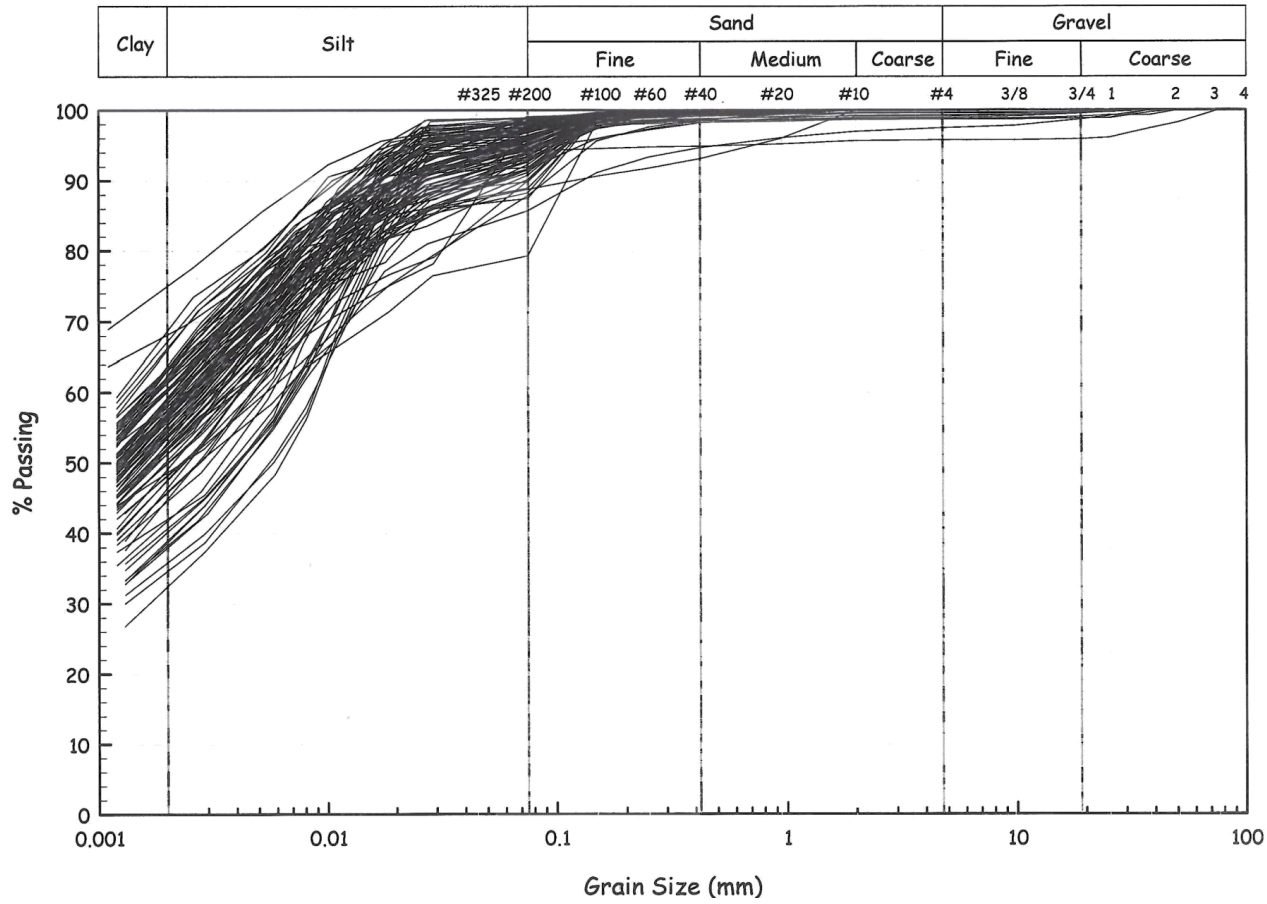
## References

[1]Kleyn, E.G. "The Use of the Dynamic Cone Penetrometer," Report L2/L4, Transvaal Roads Department, Pretoria, South Africa, 1975.
[2] Livneh, M. Ishai, I. And Livneh N. "Effect of Vertical Confinement on Dynamic Cone Penetrometer Strength Values in Pavement Subgrade Evaluation," Transportation Research Record 1473, 1995.
[3] Webster, S.L.,Grau, R.H. and Williams, R.P. "Description and Application of Dual Mass Dynamic Cone Penetrometer," U.S. Army Engineer Waterways Experiment Station, Report No. GL-92-3, 1992.
[4] Session 6, Pavement/Material Evaluation, "RSA/US Pavement Technology Workshop," the University of California, Berkeley, March 20th – 23th, 2000.

Syncrude

Proctor Summary

Composite Grain Size Distribution : Kc Clay



Crew Gold

23 May, 2012

Dear Mr. Burns,

**Re: Dust Stop**

Recently, we tried the Dust Stop on our site at the Lefa Gold mine in Guinea West Africa. The results obtained were very satisfactory for us and have brought us to the conclusion that we will introduce Dust Stop on all of our haul roads. With the recent taxes being imposed by the Guinea Government on water usage, this makes this even more attractive for our site to introduce in as a process.

We had a recent visit from the head office in Moscow and discussed the results obtained with Dust Stop. It was perceived as a definite cost savings and definite improvement idea for our production. Treating our roads would permit us to get going much sooner after heavy rain due to the fact that its stabilizing effect would allow us to maintain the proper profiling and allow rain water to run off. Quicker drying would occur, resulting in increased production.

We are presently looking at completing our mixing tank to allow for a more efficient and effective means of applying Dust Stop throughout the vast areas needing treatment.

I would also like to confirm that I will be travelling to Canada in early June and will be able to attend the MassMine Conference in Sudbury Ontario as per your invitation to discuss further on your full product range.

Please feel free to use this letter as reference, if you so wish.

We look forward in doing business with your company.

Best regards,

Mr. Mike Proulx, Acting Mine Manager
SMD Lefa Gold
Guinea, West Africa
00224 62 35 11 27
Michel.proulx@smdlefa.com



## Results from Mining Haul Road Project in Mali, Africa (Nov. 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, 4,200 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 an 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 combine CBR improvement of 159.91%.

Table 1 – 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 |
| **Improved in CBR** | | | **184.45%** | **135.38%** |
| **Combine CBR Improvement** | | | **159.91%** | |

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



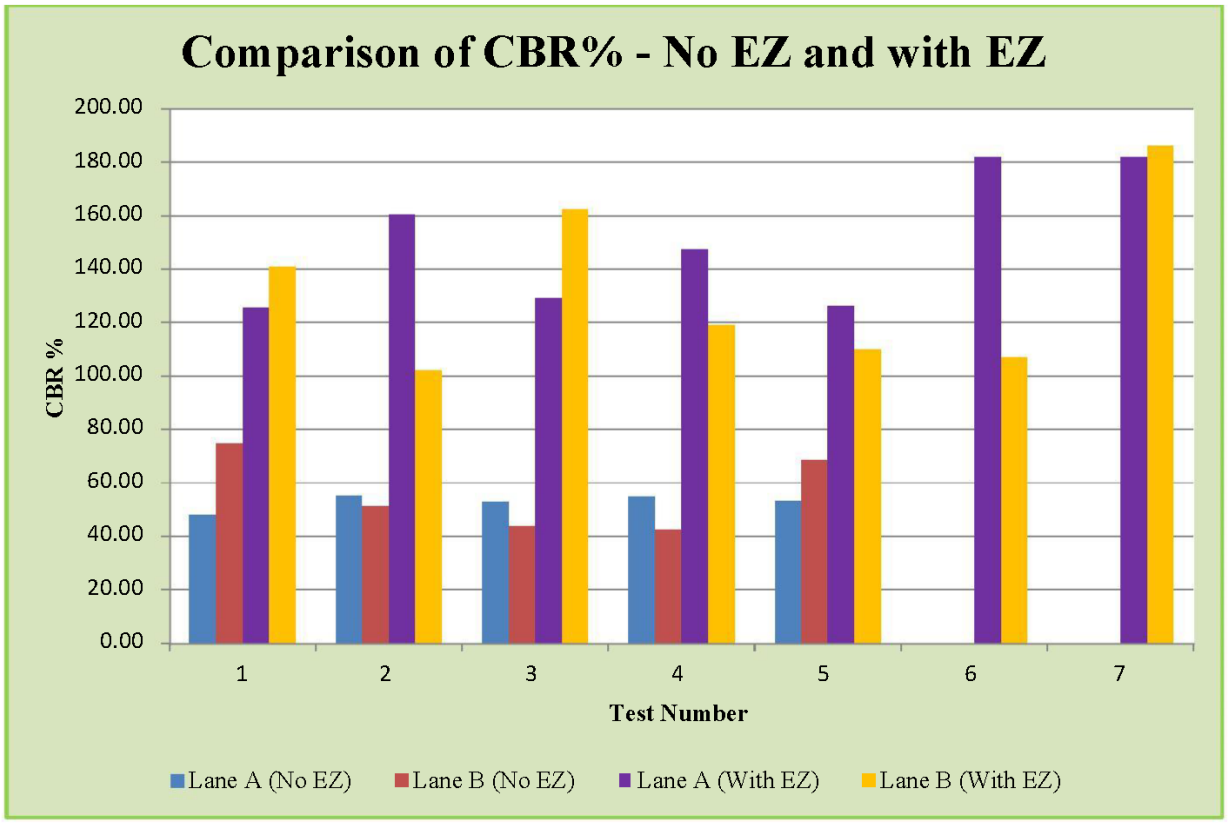



Figure 1 – Comparison of treated and untreated CBR in Mali, Africa

On the following page is a letter of recommendation that was sent to our distributor in Mali from the Site Manager of the mine, stating that the results observed on the EARTHZYME® treated road has exceeded their expectations.

## Letter of Recommendation from SFTP Mining (Verdoes, 2013)

"To Whom is May Concern,

This letter serves to confirm that Enviromax Innovations from Johannesburg South Africa, distributors of Cypher Environmental Ltd. in Canada, conducted a soil stabilization project with SFTP and Randgold on the Gounkoto haul road at Gounkoto Mine in Mali.

We treated a one kilometre section of road in November 2013. To date, the treated road has exceeded all expectations.

The purpose of the project was to reduce dust emissions and to improve road conditions. See pictures below, taken on 05.12.2013:

On the close up picture, you see that the stones in the laterite are bonded with the fines and not coming lose what you see is as hard as concrete, this part was done about 4 weeks ago and since then 3500 trucks with a total weight of 65 ton has passed without losing stones, there is very little dust coming from the road.

The treated road is a lot smoother and easier to drive on, similar to driving on a paved road.

The treatment of this road with EarthZyme has given me a far better result than expected.

Martin Verdoes
Site Manager"

**Safety in Coal Mines ***
Translated to English
by Translation Agency of Manitoba
Vol. 46 No. 5 May 2015
238

DOI: 10.13347 / j.cnki.mkaq 2015.05.067

# Application of EarthZyme® Biological Enzyme Road Building Technology in Field Management of Shengli Open-pit Coal Mine

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**ABSTRACT:** Road building plays a very important role in the production of open-pit mines, technical conditions of road transportation is not only directly related to the production safety and efficiency of the mine, but also an important symbol to measure the field management level of the mine. EarthZyme® is a new road building material that is applicable to the clay-based soil. The surfactant, electrolyte, and the enzyme of EarthZyme® can react with clay composition of the soil, discharge the water by transforming the bound water to free water, and bond the soil particles and sand closely together so as to render the clay soil weakened in water absorption and achieve the effect of road hardening. Encouraged by the success of the demo road in 2013, we built up 10 km EarthZyme® mine road in 2014. It has been shown that the road works well in flatness, strength and other performance indexes. It is a benefit for resuming production after the rain and reducing the operation cost. Meantime, it is significant in cost control, energy conservation and environment protection.

Keywords: EarthZyme® biological enzyme; road building; field management; open-pit coal mine; safety production

Chinese Library Code: TD228 Literature label: BArticle No.: 1003-496X (2015) 05-0238-03

The road of an open-pit mine is an important infrastructure of the mine production system. The technical status of the transport roads is closely related to the safety and the efficiency of mine's production; it is also a measure of the level of mine site management[1]. Road building plays an important role in the operation of an open-pit mine. Following the expansion of production scale and the increase of the transport vehicles, the road quality becomes a critical factor that affects the operation cost[2]. EarthZyme®, a biological enzyme, is a new road building material that is applicable to the clay-based soil. The surfactant, electrolyte, and the enzyme of EarthZyme® can react with clay composition of soil , discharge the water by transforming the

bound water into the free water, and bond the soil particles, sands, and gravels closely together so as to render the clay-soil weakened in water absorption and eliminate the strong hydrophilicity of clay due to its negative charge, achieving an effect of road hardening. In 2013, Shengli Open-pit Coal Mine tested a 500 m road with the use of EarthZyme®. After one year of the field trial, it has been proved that the strength, flatness and other indicators of the EarthZyme® road are all satisfactory. In the first half of 2014, Shengli Open-pit Coal Mine purchased EarthZyme® through bidding and implemented 10 km EarthZyme® road transformation by the end of September. Short after the use of EarthZyme® road, it has been demonstrated a significant decrease in the vehicle fuel consumption and tire consumption, according to the cost analysis of the third quarter. The economic advantage is very obvious.

**1. Introduction of Shengli Open-pit Coal Mine**

Shengli Open-pit Coal Mine is located in the central-western part of Shengli coalfield area, 6 km from the city of Xilinhot, possessing the rich reserves, reliable resources, and favorable mining conditions. The coal is lignite of low ash, low sulfur, low phosphorus, and medium calorific value of combustion. Infrastructure construction of the mine was started on April 20, 2004, with a scale of 20 Mt / a, and completed in 2011. At Shengli Open-pit Coal Mine, above the #5 coal seam roof, the stones mainly consist of gray, gray-white, gray-green, gray-purple, purplish red glutenins and conglomerates, including some thin layers of mudstone, siltstone, fine sandstone, and coarse sandstone; the average thickness of that is around 45.9 m.

The rock layers sandwiched between in #5 Seam and #6 seam are mainly the gray, dark gray mudstone and siltstone; with an average thickness of 59.7 m. The rock stripping above the #5 seam and between the #5 ~ #6 seams are all using the Single Bucket - Truck technology.

The rocky overburden and coal are mainly of soft rock, in which the soft rock of compressive strength <6. 0 MPa accounted for 89%. The mineral composition of mudstones from the bottom of #6 seam was inspected by Infrared Spectroscopy test, revealing montmorillonite content of 13% to 63%, generally 40%; kaolinite content of 12% to 25%; illite content of 5% ~20%. Because of the high hydrophilicity of montmorillonite, poor water stability, and the swelling-contracting property with/without water, to maintain the stability of the slope is a serious challenge.

**2. Current Road Building Technologies**

a) *The main road building* – The main road shall be in service for intense traffic flow for a long time. The quality requirement of the main road is high. The overburden of the open-pit mine composed principally of mudstones, the main road building adopts the single-story pavement structure, see Figure 1. First, CAT D10T bulldozer levels down the ragged field produced after the excavator shoveling. Then, with the aid of dump truck, CAT D10T bulldozer lays a layer of overburden 30 ~ 50 cm in thickness. The gradation

is the natural grading of the overburden blasting. Finally, the grader modifies and compacts the road surface.

b) *Temporary ramp building* – The temporary ramp is the 200 m sections from the shoveling face to the main road and from the main road to the dumping face. These two branches' construction uses the tracking method[3]. At the dumping site, make use of the roadbed when CAT D10T bulldozers reserved when dumping, followed by a grader for leveling. When the power shoveling face advances, the CAT D10T bulldozer is following up to ensure the quality of the two sections.

**3. EarthZyme® Road Building**

3.1 EarthZyme® Introduction

Adding EarthZyme® to the clay-based soil can increase the density of the soil, reduce free water in the compacted soil matrix. EarthZyme® consists mainly three components:

a) Ion solution. It reacts with the clay minerals, reducing the water portion that has relatively weak linkage force with the clay particles. The ionic solution helps to shrink the diffuse double layer and to get higher soil density under the same pressure.

b) Surfactant. It reduces the viscosity of water and improves the water lubrication in the compaction process. The upshot is a denser and drier status of the soil. Moreover, it makes the clay particles arranged more neatly, so as to diminish the permeability of compacted soils. The surfactant is also the carrier of the ion solution and the enzymes.

c) Enzymes mixture. They promote the ion exchange between the clay particles and the ion solution. These three components work together on the clay component of the soil during road construction. Compared with the soil without EarthZyme® treatment, using EarthZyme® is easy to make the soil to achieve a high density with conventional construction equipment. The high density, in turn, will make the clay particles arranged more neatly and bonded more closely so as to significantly improve the road strength, wear resistance, endurance, and other indicators.

3.2 EarthZyme® Work Principal

Clay particles are negatively charged, the positively charged part of a polarized water molecule is therefore likely attracted to the surface of negatively charged clay particles. A weak ionic bond is formed between the polarized water and the clay particle.

This is the mechanism why the free-water-bearing, clay-based soil tends to swell and the strength of which decreased[4]. The thickness of the diffusion double layer depends on the chemical reaction of clay minerals and the water in pores. Through manipulation of the chemical reaction between the clay and the polarized water can shrink the thickness of the diffusion double layer[5].

EarthZyme® takes advantage of its huge ion exchange potential to shrink the diffuse double layers, abating the water absorption capacity of the soil, descending the water content in clay-based soil, and boosting the density of compacted soil. The surfactants facilitate the ionic solution to penetrate into the soil capillary structure, thereby promote the ion exchange process. The surfactant also acts as the carrier for the enzymes. Enzymes help to enhance ion exchange between different clay minerals, ensuring the EarthZyme®'s versatility. When the EarthZyme® is mixed with clay-based soil, the bound water in the soil will be transformed into the free water and be discharged, resulted from the ion exchange mechanism, and then be discharged. The clay in the soil bonds the soil particles, sand and others closely together. The surfactant in EarthZyme® plays a dual role in soil stabilization. It can temporarily reduce the surface tension and the viscosity of water, conducive to the compaction process. This lubrication effect is leading to get the distributed soil structure where the soil porosity minimized. The effect on the clay molecules by EarthZyme® road building material is demonstrated in Figure 2. The reduction of surface tension also lessens the requirement on the water-bearing condition for achieving the best soil compaction. The combination of the shrinkage of diffusion double layer and the reduction of surface tension ameliorates the best soil moisture content by about 1% ~2%. Therefore, it is the surfactant that significantly eliminates the porosity and gets a dense fine grain soil structure where the particles attach more closely.

The combination of high compaction (porosity and capillary structure reduction) and distributed soil structure (parallel distribution) greatly decreases the soil permeability and greatly increases soil strength (bearing capacity). The biological degradation of EarthZyme® engenders the surfactant decomposition and rebuild the surface tension of water, making the binding water (liquid bridge) more compact. This will result in a stronger inward compression pressure to augment the soil matrix structure strength, to reduce the gap between clay particle, to strengthen the covalent bond and ionic bond, and finally bring about the hardening and solidifying of the compacted soils so that the EarthZyme® road surface holds a long service time. This process most occurred in the first 5 ~ 7 d, and lasting for 28 d. A reduction in porosity also helps to increase the adhesion and the Van der Waals forces between the clay molecules[5]. Increased density and accompanying adhesion enhancement of the clay structure, combined with clay particles parallel distribution created a support surface that improves not only the strength but also the uniformity. This synchronism prevents the clay particles from re-adsorbing water to impair the soil strength. Soil matrix distribution further enhances this effect. Distributed soil structure is beneficial in reducing the permeability, the number of interconnected pores, thus restricts the water transportation in the soil and makes the compacted soil more stable[6], so that the road is more enduring with its low water absorption and high uniformity. The EarthZyme® implements the soil structure improvement within 28 days. After

then, EarthZyme® will degrade, leaving no residue in the soil, no influence on the chemical composition of the soil itself. It is completely green and environment-friendly material.

3.3 EarthZyme® Road Building

Shengli Open-pit Coal Mine uses local soil in site for road building which saves the cost of materials transportation in current road building process. First, the grader-scrapper loosens the road surface (rough loosening), and then the Wirtgen W2200 - 3800SM surface mining machine executing the further loosening (fine loosening). After the loosening, EarthZyme® is sprayed over the road surface, following further loosening; spraying again, and loosening again. Finally, modifying and compacting.

**4. EarthZyme® Road Building**

Since the third quarter of 2014, Shengli Open-pit Coal Mine has built 10 km of EarthZyme® road (pavement width of 30 m). After the construction of EarthZyme® road, the fuel consumption of trucks decreased by 17. 4%. Based on the fact that the comprehensive transporting distance of the overburden is about 3. 2 km, if 80% of the overburden transportation is using EarthZyme® road, the annual savings of fuel is 3.9 million L. Given the price of 6 yuan per liter, the annual savings of fuel costs could be 23.4 million yuan.

The road maintenance costs, tire loss, etc. will also be significantly diminished. Using the soil at the field for road building, saves the direct costs of construction. EarthZyme® road is of high hardness and high bearing capacity. Smooth road surface needs only limited maintenance workload. The muddy situation of the road in rainy days has been significantly ameliorated. The road seepage rate is greatly reduced and the resuming time after rain is shortened. Moreover, the dust of EarthZyme® road surface is less than ever.

EarthZyme® road significantly improves the surficial roughness of the mine road, helps the vehicle moving more stable by saving the frequent vehicle braking and vehicle vibration owing to the poor roughness condition in the traditional roads. The safety issue and the transportation accidents induced by the vehicle mechanical damage are also restricted. Thanks to the excellent pavement strength, density and other properties of the EarthZyme® road, the load scatter of vehicle transportation is limited. There is rarely the mud boiling and the formation of obvious ruts. The dust in the opencast decreased more than 60%, significantly reducing the concentration of dust on the production site, improving the visibility of the site; thereby reducing the risk of occupational diseases and potential safety hazards or accidents due to the high concentration of dust and dust-raising.

## 5. Conclusion

Conclusion EarthZyme® is a new biological enzyme road building material that is applicable to the clay-based road. Encouraged by the EarthZyme® field test, Shengli Open-pit Coal Mine carried out a large-scale transformation of mine road with EarthZyme®. In spite of the short history in service of the EarthZyme® road, a significant economic and environmental advantage have been demonstrated. EarthZyme® road construction process is an important innovation for the existing mud-rock mine road construction technology. It can be widely used in mudstone-based mine road building.

## References

[1] Li Wenbin, Discussion on Quality and Benefit of Large Opencast Mine Transportation Road Engineering, [J]. Jiangxi NonferrousMetals, 2004 (12): 28 – 30 (in Chinese).
[2] Wu Zhankuan, Chang Shengquan, Liu Yufu. Heidaigou Opencast Coal Mine Road Construction and Management, [J]. OpencastMining Technology, 2001 (3): 19-21(in Chinese).
[3] Zhao Jianjun. Talking about the Construction and Maintenance of Antaibao Coal Mine Dumping Ground and Road, [J].Opencast Mining Technology, 2005 (5): 15 – 16 (in Chinese).
[4] Das, B. Fundamentals of Geotechnical Engineering [M]. 2008 by Stamford, CT: Cengage Learning Incorporated.
[5] Mitchell, J. & Soga, K. Fundamentals of Soil Behavior [M]. New Jersey: John Wiley & sons, 2005.
[6] Bowles, J. Engineering properties of soils and their measurement [M]. New York: Tata McGraw - Hill Education Private Limited,1992.

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(Received: 2015-03-03; Editor: Liang Shaoquan)

中国神华
CHINA SHENHUA

# CERTIFICATION

November 9th, 2015

Based on the success of the demo road in 2013, Shengli Open-pit Coal Mine built another 19.8km EARTHZYME mine road in 2014. So far, the road has been subjected to heavy traffic including Komatsu 830E which average 320 T in weight over a year.

And also, it has been approved that the road performs well in flatness, strength and other performance indexes, it is benefit for the recovery of production after the rain and the reduction of cost, it has great significance in cost control, energy conservation and environment protection.

We hereby certify !

Engineering in charge:

Shenhua Beidian Shengli Energy Co. , Ltd

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