“A Sustainable Use For Dried BioSolids”

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ABSTRACT

Lehigh Cement Company has conducted preliminary and in depth testing of Class A dried biosolids (DBS) as a fuel replacement in our cement kiln at Union Bridge, Maryland. Lehigh’s parent company, Heidelberg Cement, has been using DBS in European cement kilns for several years. These programs have proved the safety and environmental soundness of this concept. Lehigh’s ongoing development of these programs in North America will provide long term, sustainable solutions for DBS disposition.

KEYWORDS

Cement Kiln, Sustainable Development, Thermally Dried Class A Biosolids (DBS)

INTRODUCTION

Lehigh Cement Company has served the construction industry in North America for more than 100 years as a leading producer of high quality portland, blended and specialty cements and construction materials. Lehigh cements are widely used by ready-mix concrete suppliers and for numerous highway, architectural, industrial and marine applications. Lehigh is fully owned by HeidelbergCement of Germany and is affiliated with some of the world's most technically advanced cement operations and related construction materials activities. Around the globe, the Group has extensive operations in Europe, Asia, Africa and North America. Lehigh cement owns eleven (11) cement operations in North America including manufacturing facilities in Tehachapi and Redding California.

In 1999 Lehigh Cement and their parent company HeidelbergCement along with nine other major cement companies began The Cement Sustainability Initiative working with the World Business Council For Sustainable Development. The purpose of this initiative is to identify and facilitate actions that companies can take as a group and individually to accelerate the move toward sustainable development. An important aspect of this initiative is the more efficient use of natural resources and energy and to reduce environmental impacts. One way of accomplishing this objective is through process innovations and working with other industries on novel uses of by-products and waste materials in cement production. To learn more about The Cement Sustainability Initiative please consult the web site cement@wbcsd.org.

Lehigh Cement has been conducting studies using dried biosolids from municipal WWTP in the cement manufacturing process in North America. Our parent company HeidelbergCement is currently using this technology in Europe and has a great deal of interest in promoting this initiative in North America.
**PRESENT SITUATION**

For many years municipal wastewater (MWW) sludge has been partially dried (< 50% solids) and used as a compost medium, disposed of in landfills, or incinerated. More recently, mechanically de-watered filter cake (<30% solids) has been thermally dried to >90% solids for use in land applications as a fertilizer. All of these solutions have negative aspects or potentially limiting factors such as adverse public opposition and potential problems associated with metals accumulating in the soil. Utilization of DBS (> 90% solids) material in a cement kiln solves all these disposal problems and is the most environmentally sound option.

**SOLUTION**

The cement manufacturing process has the unique ability to recover the chemical and energy value of DBS while simultaneously closing the environmental loop on this material. A quick review of the cement making process will explain how this is possible.

- **Over 450’ Tall**
- **Consumes 10,000 TPD Raw Materials**
- **Burns 750 TPD Fuel**
- **Produces 2,000,000 TPY Portland Cement**

Cement kilns are the largest pyro-processing devices in the world and have many extreme operating characteristics. A kiln that produces 6,000 tons of product per day will consume 10,000 tons of raw materials and can burn over 750 tons of coal.

The basic function of the cement kiln is to raise the temperature of the raw materials. This is accomplished in a counter current flow process as indicated in Figure 1. The raw materials consist of limestone, sand, clay and iron. These materials enter the process at the top of the pre-heater tower and are heated by the counter flowing gas stream. The raw materials are first dried of free and chemically...
bound water and then as the temperature approaches 1650°F the carbon dioxide is driven from the calcium carbonate (Limestone). The Calciner combustion zone at the base of the pre-heater ensures that sufficient heat is added to the pre-heater tower to drive off most of the carbon dioxide form the limestone before the raw feed enters the rotary kiln. The rotary kiln is a slowly rotating, slightly inclined, refractory line steel tube. The main burner is located at the lower end of the tube. The rotation of the kiln causes the raw feed to move down the incline towards the main burner. As the material is heated to 2640°F, part of the feed melts which allows intimate mixing of the chemical components and formation of the new chemical compounds that are Portland cement.

The rotating motion of the kiln causes the semi molten material to form into balls as it passes under and away from the main burner. These balls are called clinker and fall out of the kiln and into the clinker cooler. The clinker cooler moves huge volumes of ambient air through a bed of clinker to achieve two objectives. Obviously the first objective is to cool the clinker; the second is to produce sufficient super heated air to sustain the intense combustion processes in the main burner and in the Calciner burner. The combustion gases then pass up through the kiln and pre-heater to transfer their heat into the counter flowing raw materials.

This process achieves four main characteristics that are important to the removal of DBS from the environment. The high oxygen content and high temperature of the combustion zones ensure complete oxidation of organic components. The long retention times and turbulent mixing of the raw materials ensures complete chemical incorporation of the inorganic components.
COMPATIBILITY AND LIMITS

As mentioned previously, the raw materials for the manufacture of cement consist of limestone (calcium), sand (silica), clay (alumina), and iron. Coincidentally the ash or inorganic component of DBS is primarily made up of calcium, silica, alumina and iron. This general chemical compatibility allows DBS to be used in considerable amounts before any deleterious effects are noticed in the cement product.

The organic composition of DBS has several interesting characteristics when compared to coal. Table 1 indicates several parameters for these materials.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Coal</th>
<th>DBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>16%</td>
<td>38%</td>
</tr>
<tr>
<td>Combustibles</td>
<td>84%</td>
<td>62%</td>
</tr>
<tr>
<td>Volatiles</td>
<td>35%</td>
<td>91%</td>
</tr>
<tr>
<td>Carbon</td>
<td>83%</td>
<td>53%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>5%</td>
<td>7%</td>
</tr>
<tr>
<td>Heat Value</td>
<td>22 GJ/ton</td>
<td>14 GJ/ton</td>
</tr>
</tbody>
</table>

Table 1

Although DBS has only about two thirds the heat value of coal, it has a very high volatile content. This means that it burns readily. However, due to the extra ambient air that is used to transport the DBS into the combustion zones and the quenching effect of the high ash content, the net heat replacement level is about 50% during full scale utilization.

The physical characteristics of DBS are common to other materials used in cement manufacturing. DBS from several different drying processes has been evaluated. The material is generally spherical to granular in shape and particle sizes from dust to about 6mm maximum. The solids content is above 90% and the material is quite abrasive.

There are two characteristics of DBS that can limit the amount of DBS that is used in a cement kiln. The moisture content in DBS adds to the exhaust gas volume and absorbs heat. This could reduce production rates if a cement kiln does not have much excess fan capacity on their main ID fan. The P2O3 content in the DBS ash ends up in the cement product. When the concentration of phosphorous in the cement clinker approaches 0.6% it can start to retard setting times of concrete made with the cement. To date the moisture contents have not limited usage in any of our tests. Test conducted in Europe have indicated reduced setting times when DBS has replaced more than 35% of the heat requirement of a cement kiln. This can only be used as an estimate of maximum DBS utilization because background levels of phosphorous in the raw materials can also contribute to the reduction of setting times.
FIELD TESTS

In early 2004 the Lehigh Cement Union Bridge facility received permission from the Maryland Department of Environment (MDE) to perform tests on DBS. Test equipment was selected and installed over the summer months to feed DBS into the Calciner combustion zone of the cement manufacturing process. From July to November of 2004 we burnt about 2000 tons of DBS. During the test we reached a maximum utilization rate of 3.0 tons per hour which represented 6% of the system fuel requirements and 11% of the Calciner fuel requirements.

The test results were very encouraging for several reasons. As indicated in Table 2, several emission parameters decreased with the use of DBS. This indicated that the DBS was burning as well as, or better than, the conventional fuel. Second, the use of DBS reduced the amount of coal required. Third, the inorganic ash component of the DBS was readily incorporated into the chemical matrix of the Portland cement product.

<table>
<thead>
<tr>
<th></th>
<th>Heat Input (GJ/MT)</th>
<th>NOx (PPM)</th>
<th>CO (PPM)</th>
<th>THC (PPM)</th>
<th>SO2 (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Only</td>
<td>2.85</td>
<td>436</td>
<td>177</td>
<td>10.8</td>
<td>3.31</td>
</tr>
<tr>
<td>Coal &amp; DBS</td>
<td>3.02</td>
<td>491</td>
<td>172</td>
<td>10.5</td>
<td>2.14</td>
</tr>
<tr>
<td>Change</td>
<td>+6%</td>
<td>+13%</td>
<td>-3%</td>
<td>-3%</td>
<td>-35%</td>
</tr>
</tbody>
</table>

Table 2

Additionally, material characteristic such as abrasiveness and propensity for moisture absorption were noted. The abrasiveness of the material caused the test equipment to wear out very quickly. The wear on the volumetric dosing system caused a loss of precise control of the addition rate of DBS during the later periods of the test burn. This resulted in some erratic results and the desire to conduct further testing with a gravimetric dosing system with abrasion resistant design. The increases in heat input per ton of product and in NOx emission rates were the result of over burning due to the erratic flow of DBS into the Calciner combustion chamber. Over burning can contribute to higher NOx emissions by creating a hotter than required flame and thus producing more thermal NOx generation.

The unloading system used during the test burn had a bin vent design on top of the temporary storage silo to relieve the transport air. This arrangement allowed the ambient air to enter the storage volume. On cool windy nights the higher humidity air inside the temporary storage tank allowed condensation to form on the interior surface of the storage tank.
Based on the results and experience gained during the 2004 test period a full-scale storage and dosing system was designed and constructed. Figure 2 indicates some of the design features that were incorporated into the full-scale system to address the material characteristics that were observed. Different abrasive resistant linings were selected for pneumatic transport lines depending on the expected transport velocities through these lines. The transport air, used to pneumatically unload the transport vehicles, is separated from the DBS before the DBS is deposited into the storage silo to minimize the amount of humid ambient air that enters the storage silo. Additionally, a dry air system is used to keep the storage volume slightly pressurized with dry air to minimize infiltration of ambient air. Finally, the storage silo will also be insulated to further prevent any condensation forming on the inner walls. Provisions have been made to monitoring the exit air from the storage volume for carbon monoxide, oxygen and methane. An increase in the concentration of carbon monoxide or methane in the exit air would be an indication of smoldering combustion. In this event an automated gas inerting system will be activated to flood the filter receiver and storage volume with carbon dioxide. We believe this new system will allow for continuous and safe use of this potentially long-term, renewable supply of energy.
Figure 3 is a photo of the full scale permanent system installed at Union Bridge, Maryland. This system can store approximately 700 metric tons of DBS. Two trucks can unload simultaneously into the filter receiver mounted on top of the storage silo. Trucks can unload in 30 to 45 minutes. The dry air system continuously moves air into the storage silo and can turn over the air inside the silo every 3 to 5 hours. The firing system has a range of 1 to 20 metric tons per hour with a ± 0.5% accuracy. The pneumatic feed system moves the DBS from the dosing system to the top of the Calciner combustion chamber.

In May of 2006 we began conducting further test with the full scale system. Figure 4 indicates several possible firing points for DBS. The initial firing point was used during the 2004 test period. The DBS was mixed with and fired concurrently with the conventional pulverized coal fuel. We believe this configuration may have contributed partly to the high NOx emissions recorded during the 2004 test period. Therefore, we began the 2006 test by using a separate introduction point in the roof of the Calciner combustion chamber. The objective was to get the DBS into a less reactive zone of the combustion chamber which should slow down the combustion rate and lower NOx emissions. Other firing points as indicated in Figure 4 will be tried to maximize the utilization rate of DBS and to minimize the emissions of NOx.
2006 TEST DATA

As previously indicated, the system depicted in Figure 3 went online in mid May 2006. Preliminary tests have been conducted to determine what the maximum utilization rate will be and how the use of DBS as a supplement for coal will affect the stack emissions. To date the experience has been very positive. Utilization rates as high as 15 tons per hour have been achieved with no deleterious affect on the quality of the cement product. Higher utilization rates seem possible and will be tried during stack testing which is scheduled for late July 2006. This data will be presented at the WEFTEC conference in October 2006.

CONCLUSION

Lehigh Cement is committed to developing the use of DBS in our cement kilns across North America. We firmly believe that the cement industry can beneficially use this by-product and effectively remove it from the environment while simultaneously producing a valuable industrial construction material.