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P a r t 3

ASH AND SLAG HANDLING

3.5. Applications of ash and slag from power coals

3.5.3. Combined processing of ash, slag and wastes from other industries

3.5.3.1. Environmentally friendly uses of none coal ashes in Sweden

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ABSTRACT

The Thermal Engineering Research Institute of Sweden, Värmeforsk, have since 2002 had a research program: Environmentally friendly uses of ashes, other than coal-based ashes. It is supported by about 40 organizations both private and authorities.

There have been about 50 interesting projects about uses of ashes from both bio energy boilers and incinerators in the program. The program has been divided into four areas:

- recycling of ashes to forests;
- geotechnical uses;
- uses in landfilling;
- environment and Chemistry.

1. BACKGROUND

1.1. Ashes

Totally we are producing about 1 Mton of ashes dry weight in Sweden per annum. Its not only ashes from the pure fuels but also minerals etc that the follows the fuels. There are about 25 % of ashes in municipal wastes, about 5 % in peat for fuel, 50…90 % in sludge from the paper industry, 2…4 % in bark and 0,3…0,5 % in pure wood. To that shall be added clay and sand that follow e.g. both peat and woodchips. For fluid beds, FBC:s, the bottom ashes consists mainly of sand and in circulating fluid beds, CFBC:s the fly ash will hold some sand. There are some different streams of ashes in the boilers and some of them can alternatively go to the bottom ashes or to the fly ashes.

1.2. Boilers and incinerators

In Sweden we have a lot of different rooster boilers and incinerators for most different fuels like wastes from households and industry, waste building materials, sludge from the paper industry, peat, bark, woodchips and chipped tyres. Elderly boilers have a lot of unburnt in their ashes but ashes from modern roosters hold only 3…5 %. Burning temperature is about 1100 ^oC. With MSWI I mean in this paper a rooster for burning wastes, mostly from households.

Powder boilers burn less and less coal and more and more peat, pellets from the sawing industry and woodchips. Due to the high taxes on nitrogen oxides the content of air are hold to a minimum during the combustion. Therefore the Powder boiler ashes can contain a lot of unburnt. The temperature is about 1200^oC.

Fluid beds are flexible boilers and incinerators. The content of unburnt are mostly very low.

Temperature of combustion is about 850 ^oC.

1.3. Unburnt

Loss of ignition, LOI is not a good method for measuring unburnt for ashes that can hold chemically bonded water e.g. in $Ca(OH)_2$ or CO_2 in form of carbonates as in $Ca(CO)_3$.

One ongoing project analyses different ashes with different methods and the results will be presented at the conference [1].

2. ASHES TO FORESTS

2.1. Acid rains and low buffering capacity

In Sweden we are very concerned by acidification of the ground from sulphuric acid and nitric acid containing rains especially in the Southwest part of Sweden. The outtake of timber and energy (energy =Tops and branches) from the forests will also contribute to the acidification of the ground. The forests can so far stand the acidification but the water streams and lakes are sensitive to it due to low buffering capacity. Models show that when timber, branches and treetops are harvested not even mineralogical soils can balance the outtake of cationic nutrients.

2.2. Recycling of ashes

Recycling of ashes gives a reduction of the acidification of the water systems, a long-term balance of the nutrients in the forests and for organic forest soils a profitable increase in the growth of the trees. But ashes influence the complex balance of nitrogen in the soils. Heavy metals are allowed in the ashes but not more than has been taken out during one harvest period.

There have been a lot of research on this topic in Sweden and the ash program has contributed with some projects regarding:

2.2.1 Long-term growth rate and health of forests with ashes on mineralogical soil. This long-term project seems, unlike other more short-term projects, show some better health and growth rate with than without ashes on mineralogical soils [2].

2.2.2 The difficulty to achieve a desirable low leaching rate for potassium chloride. It is difficult [3, 4].

2.2.3 Evaluation of land suitable for forest fertilization with bio fuel ashes on organic soil in Sweden [5]. There are about 200 000 ha of land in Sweden suitable for an economical fertilizing of forests with ashes. Ashes are often essential to get any growth rate on organic forest soils.

2.2.4 The release of climate gases when fertilizing organic forest soils with ashes. The release of climate gases looks to be lower than expected. It too early to make conclusions [6].

3. GEOTECHNICAL USES.

Handbooks for use of alternative materials in roads are made outside the program e.g. for different types of ashes. The handbook "fly ashes in roads" is produced within the program [7].

3.1. Bottom ashes in roads

Earlier results show that MSWI bottom ashes give better stiffness than natural gravel and less stiffness than crushed rock in the sub-base in for newly build roads. Now some years later two test roads show an equal or a little bigger difference to the reference roads with crushed stone [8].

Dynamic cyclic triaxial tests and other tests have been made on rooster boiler wood based and coal based ashes and MSWI bottom ashes. With material parameters such as low density and good bearing capacity they are particularly adaptable in some construction applications in the sub-base. MSWI-ashes are somewhat better in bearing capacity. Coal-bottom ashes give a very light construction. Wood bottom ashes can have nearly the same bearing capacity, as the MSWI-ashes if the amount of unburnt is moderate low and the particle size distribution is not too fine [9].

3.2. Fluid bed bottom ashes in trenches

Bottom ashes from fluid bed boilers have been proven to meet the demands as for filling materials in district heating pipe trenches. But if the fuels contain flam-retarded plastics, the leaching of antimony is a problem [10].

3.3. Bio fly ashes in concrete and as replacement for portland cement

All bio fly ashes give a tribute to the strength in concrete but are more seen as a replacement of fillers than of Portland cement. The bio fly ashes are selfhardening i.e. there are enough of free CaO and SiO_2 to get puzzolanic reactions in moist ashes. Especially when you take out samples for testing you must consider that moist fly ashes exposed to a lot of air reacts rather rapidly with CO_2 and are then no good for puzzolanic reactions. Unburnt and e.g. Pb and Zn retard the puzzolanic reactions. Unburnt acts otherwise more like ballast in the concrete. Chlorides limits the possibilities for many bio fly ashes, too much chlorides corrode the reinforcing bars [4].

Fly ashes from a peat/wood powder-boiler have been proven to have good reological properties in concrete. The program has identified an interesting possibility for powder fly ashes as hardening filler to replace limestone fillers and some portland cement in concrete with crushed stone as ballast. If the amount of water is increased good reological results can also be achieved by fly ashes from fluid bed boilers [11].

Fly ashes from paper industry both from a rooster and a CFBC has been proven to be able to replace 50% of Portland cement in stoop mining. A full scale test is planned to the autumn 2005 [12].

3.4. Fly ashes in roads

The thesis from Pentti Lahtinen about frost heave resistant low volume roads with fly ash from bio fuels in the reinforcing layer has been tested in practice with good results. All tested variants with and without mixes of gravel, crushed stone and cement give stiff and frost heave resistant roads [13, 14]. The roads can be soft and have low bearing capacity if it rains a lot or if it is freezing when the roads are built. But they all have been OK after they have dried up. The more gravel or cement the lesser or no problems. The impact on the environment from the test roads have been very low.

It takes a very long time to get the first drops of water passing trough a gravel road with fly ashes. That makes us to suggest when making environmental leaching tests in the laboratories you shall let the fly ashes have hardened for at least 28 days before the test.

The compressive strength of the tested ashes follows well Kihlsteds formula $T = k/e^2$ where k is the specific strength coefficient for the material, e is the pore number = volume of pores divided by the volume of solids [6]. k indicates to have about the same value for different ashes specially after a long time of hardening. But the compaction characteristics are very different for different ashes. The differences in compaction explain most of the differences in compression strength for fly ashes [13, 15].

3.5. Surfaces

Both fly ashes and bottom ashes are used to make surfaces. Mostly it is for parking places, areas for storing bio fuels or for drying sludge from the paper industry. The ashes are mostly covered by asphalt.

4. USE IN LANDFILLING

4.1. Bottom ashes.

In Sweden many landfills will close during the following 10 to 15 years. That will require at least 100 mtons of material. That will be a good market for waste materials. A lot of MSWI slags are used for this under the dense layers. Some bottom ashes are tested as drainage layers above the dense layers.

4.2. Fly ashes and sludges as dense layers on landfills

There are full-scale uses of blends of sludge from the paper industries and fly ashes on mine tailings and on one landfill as dense layers.

The program has been one part for developing blends of municipal sludges and fly ashes as dense layers on landfills. 50/50 blends on dry weight seem to be optimal. It gives a low percolation, good shear strength, flexibility, can stand subsidences and are easy to repair and none ore very low biodegradation. The durability is long, at least as long as for most of the alternative methods [16, 17].

4.3. Covering mine tailings

When covering tailings from a sulphuric mine, the main aim is to prevent oxygen to react with the remaining sulphides. Trials with about a 40 cm bottom layer of fly ashes and 40 cm of municipal sludge look very promising. Both layers hold water to prevent oxygen to penetrate to the tailings. The content of salts and the high pH of the ash layer prevents the roots to destroy that layer and the sludge layer shall be an eternal layer for plants to grew in. The project examines which plants are suitable for this [18].

5. ENVIRONMET AND CHEMISTRY

5.1. Environmental guidelines for use of ashes for construction purposes.

The aim with this project it is to get a general environmental recommendation how to use ashes for road building. It takes in account the total impact of MSWI bottom ashes and bio fuel boiler fly ashes in roads, including the building and destruction of the roads.

It indicates so far that if MSWI slags are covered by asphalt the impact of the leaching of heavy metals to the surroundings is low. One background information comes from project that has excavated and analyzed an 18-year-old badly maintained MSWI-slag-road on heavy metal release [19].

It also indicates that bio-fuel fly ashes can be used in gravel roads, maybe with the limit that too much of it shall not be in the surface even after many years. The heavy metals in the ash-dust from the road might then be a problem [20].

5.2. Hazardous wastes

One project has given: Guidance for classification of residues from combustion and incineration in accordance with the Swedish ordinance for waste. We have found that one important question is about the limits for ecological toxicity. Too narrow limits can give that even pure wood ashes can be regarded as hazardous wastes [21]. Especially when EU classifies ZnO as ecotoxical substance from November 1st 2005.

The book: The environmental history of the Falun Mine shows that heavy metals don't add to each other's toxicity but they counterbalance each other [22].

There is a risk that good wastes containing free CaO and $Ca(OH)_2$ are classified as hazardous even if these chemicals are wanted in many applications. We think that you can classify ashes with high amount of these chemicals as not hazardous as (if) wastes from fuel-gas cleaning from co-firing per definition are not hazardous.

5.3. Mobility of heavy metals

In the project SMAK, the selective mobilization of critical elements in ashes was studied. A non-hazardous MSWI slag and a hazardous fly ash from a CFBC incinerator were investigated. Factors in the experiments were ultrasonic pre-treatment, pre-treatment with carbonation, L/S-ratio, pH, time and temperature [24].

The treatment with optimal factor settings did not change the classification according to the Council decision on acceptance criteria at landfills of neither ash. For the bottom ash, Sb, Mo and Cr exceeded the limit values for landfilling as inert waste according to the Council decision on acceptance criteria at landfills. Only Cr exceeded the limit value for landfilling the fly ash as non-hazardous waste**.**

5.4. Hydrogen

Last year there was an explosion in Swedish rock cavity when filling it with hazardous fly ashes. The explosion could occur due too little knowledge about abundance of metallic alumina in fly ashes. The hydrogen are produced when the ashes are wet by water. The ashes are alkaline enough to dissolve the protecting layer of alumina oxide. A project have so far found that the following ashes gives a lot of hydrogen in contact with water:

- MSWI bottom slags;
- rooster fly ashes when the fuel contains a lot of alumina foils;
- fluid bed ashes, but not bottom ashes, with household wastes and or building material wastes as fuel. Interesting is that about the same industrial waste gave no metallic alumina in a rooster fly ash but a lot in the fly ash from a circulating fluid bed incinerator;
- there are also some hydrogen produced by MSWI-fly ashes [24].

6. 2006-2008

Today about 50% of the ashes in Sweden are used for different purposes. But we need to do lot more work to keep and increase that level.

The ash program will continue for three more years with the aim: at the end of 2008 there shall be knowledge enough to get 90 % of the Swedish ashes to environmental friendly uses.

REFERENSES

Most of the references are in Swedish. It stands (eng,) if they are in English. Värmeforsk Reports have always a summary in English and all diagrams, charts and figures have an English explanation. All projects will be reported before April 2006. Värmeforsk reports can be loaded down or ordered through the web site www.varmeforsk.se.

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