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CHARACTERISATION OF MSWI BOTTOM ASH FOR POTENTIAL USE AS SUBBASE IN GREENLANDIC ROAD CONSTRUCTION

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Abstract

The waste management situation in Greenland needs to be improved. Most waste in towns is incinerated with only limited separation prior to incineration and the bottom ash residue is disposed of at uncontrolled disposal sites. The bottom ash could be a valuable resource within the expansion of infrastructure due to increased oil and mineral exploitation. Thus, in this study MSWI bottom ash from a Greenlandic incinerator was tested for possible reuse as subbase in road construction. The mechanical properties (grain size distribution, wear resistance and bearing capacity) showed that the bottom ash was acceptable for reuse after some small adjustments in the grain size distribution to prevent frost sensitivity. Results obtained from heavy metal content and heavy metal leaching complied with the Danish guideline values for reuse of waste materials in construction. Leaching of Cu and Cr was high from small grain sizes and could be reduced by removing some of these smaller grain sizes to obtain the stability requirement of the bottom ash. All in all, this study showed that the Greenlandic bottom ash has potential for being reused in road construction.

1- INTRODUCTION

In Greenland waste has traditionally been dumped at open disposal sites combined with uncontrolled incineration. In the mid 1990'ties the first waste strategy was implemented in Greenland. As a result simple and small municipal solid waste incineration (MSWI) plants were implemented in towns and settlements primarily to minimize the amount of waste at the disposal sites. In Greenland the household waste is generally sorted into four fractions [1]: combustible, metal, hazardous waste and mixed waste. However, there are problems of sorting the metal and hazardous waste properly from the combustible waste, which can influence the quality of MWSI residues and glass is not separated from household waste. About 6,000 tons MSWI bottom ash is produced annually in Greenland and is disposed of at the open disposal sites without leachate collection or encapsulation [1]. The bottom ash could have value as a secondary resource in construction work in Greenland. This would contribute to solving the problem of disposal and possible related environmental problems in the vulnerable Greenlandic environment.

Natural Greenlandic construction materials are typically expensive and the quality is also variable [2]. Greenland is undergoing a boom in the oil and mineral exploitation which results in an increased demand on the infrastructure, including construction of new roads in remote areas and in connection to existing towns, as well as improving the existing roads [3]. Thus, more aggregates are needed, where bottom ash could be an interesting alternative. Bottom ash can typically replace subbase materials in roads [4-6].

In this study, Greenlandic MSWI bottom ash was characterized and tested for mechanical and environmental requirements for reuse as fill material in road construction.

2- MATERIALS AND METHODS

2.1 Materials

MSWI bottom ash from the incinerator in Sisimiut, Western Greenland was used in the study. The produced bottom ash is disposed of untreated at the uncontrolled disposal site next to the incinerator. The bottom ash was collected from 6 different locations on the disposal site and sampled in the depth 30 – 150 cm below the surface. The disposal age of the bottom ash was more than 3 months. Totally 500 kg bottom ash was sampled and larger debris was removed from the bottom ash before homogenisation and further tests and analysis.

2.2 Methods

The grain size distribution of the bottom ash was determined after DS/EN 933-2/A1:2006 to determine the frost resistance and stability. The wear resistance was determined by use of the Los Angeles Abrasion Test (LA Test) according to EN 1097-2:1998. Visual fraction analysis was made to determine the different fractions (after the grain size distribution) to evaluate the content and purity of each fraction. The bearing capacity and E-module were tested by CBR (California Bearing Ratio) according to EN-13286-47:2004. Total heavy metal concentrations (Cd, Cr, Cu, Ni, Mn, Pb, Zn) in the bottom ash were measured by inductively coupled plasma optical emission spectrometry (ICP-OES) after pretreatment according to Danish Standard DS259 and heavy metal leaching by leaching tests according to EN12457-3. Heavy metal leaching was also made on different grain sizes between 63 μm and 16 mm.

3- RESULTS AND DISCUSSION

3.1 Mechanical properties

Grain size distribution of the bottom ash (figure 1) showed a distribution which does not make the bottom ash sensitive to frost. The bottom ash is not sorted or treated before the current disposal and this reflects the content in the different grain sizes which was visually inspected in grain sizes above 10 mm. The fractions between 10-22.5 mm were dominated by glass pieces, often melted together or with melted debris on them. Small metal pieces, ceramics, small stones and a few pieces of unburned charcoal were also found. In the larger fractions above 22.5 mm metal either in pieces or crushed cans dominated with glass and also stones, concrete pieces and plastic was found. The unburned amount was less than 1.5 %, which indicates that the incineration process is sufficient and complies with the Danish requirement [7]. The large amounts of glass and metal in the bottom ash furthermore imply that the bottom ash could be improved removing these fractions prior to incineration.

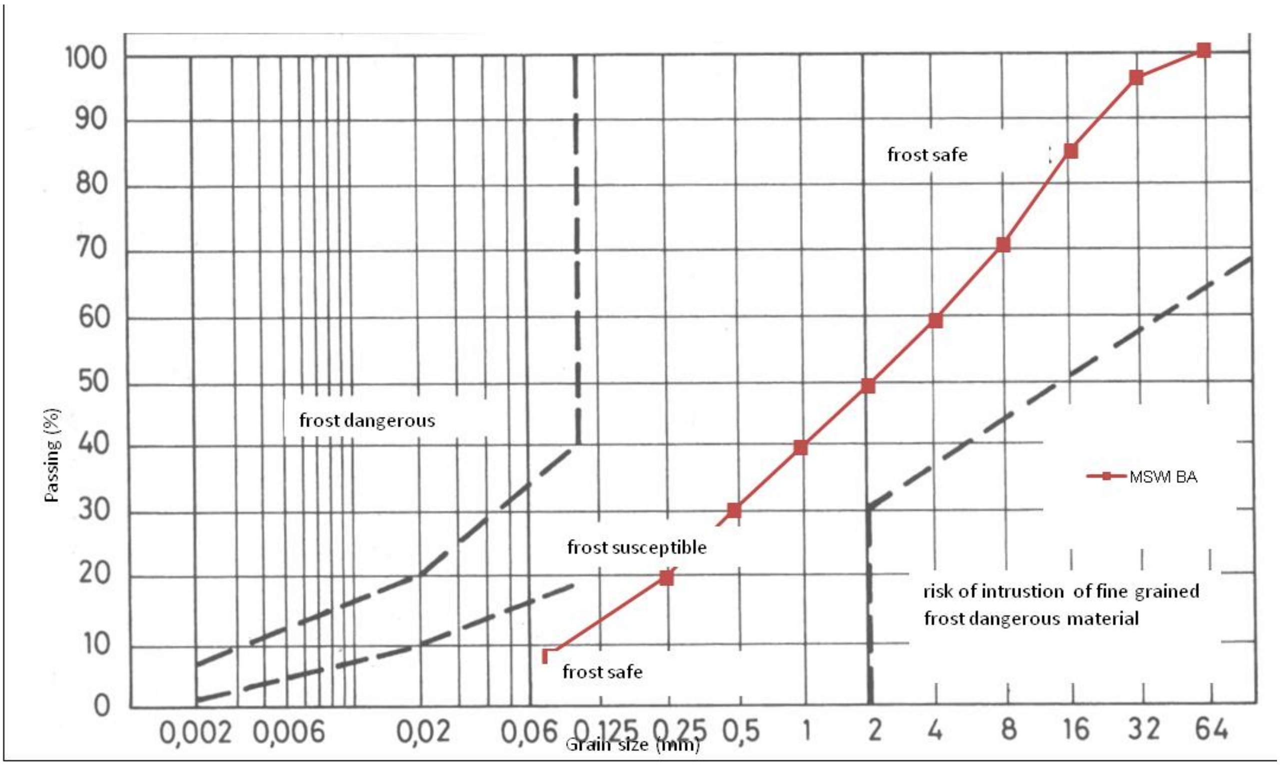

Figure 1:Grain size distribution in relation to frost sensitivity [8]

Furthermore there are several requirements for the grain size distribution of the material to have the correct stability for reuse in roads [7]:

- No grains larger than 45 mm, almost fulfilled with 0.1 % above 63 mm.
- Max 15% larger than 31.5 mm, fulfilled with 4 %.
- Max 9 % less than 0.063 mm, fulfilled as 6 % was below 0.075 mm.

The hardness of unbound materials and their resistance of mineral particles to fragmentation can be evaluated by the Los Angeles abrasion test, which quantifies the fraction of the material under test, which breaks down to pass through a no. 12 (1.70 mm) sieve. The wear resistance of the Greenlandic bottom ash, as determined by the LA test, was 47±4 %, similar to the value for several tested Danish bottom ashes 45-55 %, which is accepted in Denmark when reusing as subbase [7]. LA values observed from other countries have been seen in the range 33-45 % [6, 9-11] and in Spain the LA values should be lower than 50 % to enable reuse as subbase [9]. As a comparison, the natural materials the bottom ashes are replacing often have a wear resistance of about 25 % [7,9]. This suggests that the bottom ash has a certain weakness; however it is still within the normal, but high range for bottom ash.

The bearing capacity showed a CBR-value of 21±5 %, which is acceptable for the intended use. The CBR-values were low compared to results from other studies where CBR-values were found in the range from 21 – 103 [6,9,10]. The CBR – values indicate the resistance of the material towards deformation under moving loads. The E-module (CBR-value^0.64 * 17.6 MPa) should be above 70 MPa according to EN-13286-47:2004 and the found values complied with this requirement. For comparison, according to the Spanish specifications [10] the CBR - values should be above 20 % for materials to be reused as subbase at a sufficient level.

3.2. Environmental properties

The total metal concentrations and leaching results from the bottom ash are shown in table 1. Danish guideline levels for reuse of contaminated waste for geotechnical purposes (Category 2 and 3) [12], which are regulated by the leached concentrations, as well as results from an earlier study of the bottom ash from the same incinerator [2] are shown in the table. The guideline levels regulate the utilization of the bottom ash and each Category represents maximum allowed values. There are no specific regulations for Greenlandic materials and often the Danish regulations are used where there does not exit Greenlandic regulations and therefore the comparison is viable. The investigated bottom ash complied with the values in Category 3 for the leaching and the high Cr, Cu and Pb leaching resulted in the Category 3 classification instead of Category 2.

	Cd	**Cr**	**Cu**	**Ni**	**Mn**	**Pb**	**Zn**
Total concentration (mg/kg)	7	154	1108	80	1056	2865	3521
Ref [2] (mg/kg)	5	405	4110	105	1036	1860	3610
Leaching (µg/l)	n.d	311	252	8	60	18	30
Category 2 (µg/l)	2	10	45	10	150	10	100
Category 3 (µg/l)	40	500	2000	70	1000	100	1500
Ref [2] (µg/l)	1	650	190	<2	-	4	10

Table 1: Heavy metal content and leaching results. N.d. not detected, Category 2 and 3 values are maximum values.

Studying the leaching of Cu, Cr and Pb more closely in their distribution in different grain sizes shows two different patterns (figure 2). Cu and Cr leached mostly from the small grain sizes whereas Pb leaching did not show a clear trend.

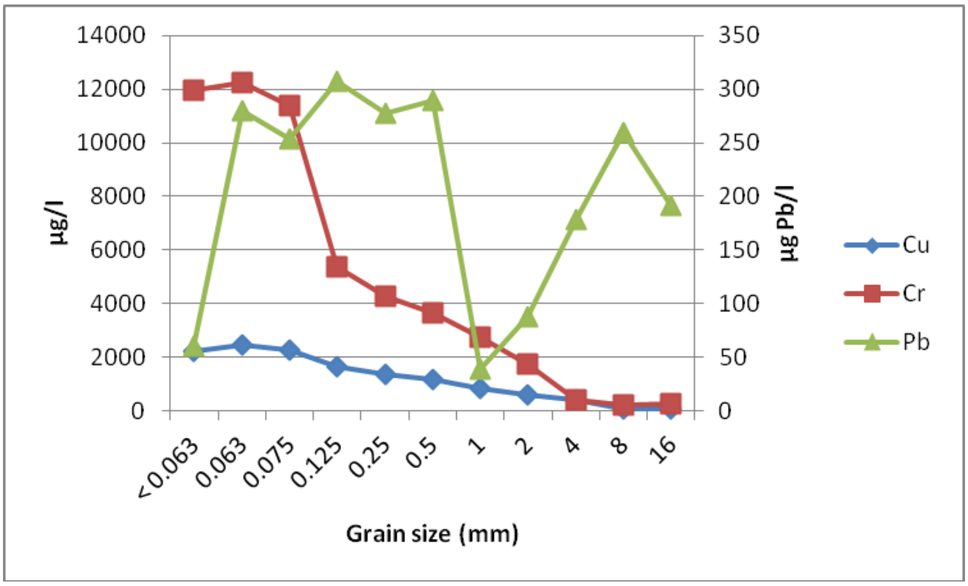

Figure 2: Heavy metal distribution in different grain size

Information about metal distribution in grain size can be used to evaluate if the bottom ash could be separated into a finer fraction which is contaminated and a larger fraction which is uncontaminated. This could be essential for reducing the overall hazardousness of the bottom ash before reusing it in the vulnerable Greenlandic environment. Especially Cu, Zn and Pb have a high leaching impact in the first few years after construction of a road with bottom ash as subbase [4], whereas over a modelled period of up to 100 years, Cu is expected to give the strongest contribution to ecotoxisity [5]. The contaminated finer fractions could be treated by for instance an electrokinetic process to either stabilise [13] or remove [14] the contaminants before end use. At present the knowledge of bottom ash behaviour during long frost and thaw cycles is limited and requires more research.

4- CONCLUSIONS

Mechanically, the bottom ash needs some improvement in grain size composition before the reuse can be possible. Large fractions should be removed or natural aggregates have to be mixed with the bottom ash to gain the desired grain size distribution. The other tested mechanical properties of wear resistance and bearing capacity showed acceptable results however in the lower range of similar studies and could be improved by removing some fractions, especially metal and concrete pieces. Another approach to improve the quality of the bottom ash could be to sort the waste prior to incineration to remove primarily glass and metal which will result in a completely different residue. In either case, the Greenlandic bottom ash has the potential both mechanically and environmentally of being used as a secondary resource in road construction.

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