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Afatek is a bottom ash processing company owned by five public waste companies in east Denmark. They operate a total of 6 WtE plants incinerating about 1.2 million tons of waste per year with the production of about 250,000 tons of bottom ash per year corresponding to about 40 percent of the Danish market.

Afatek takes care of the complete handling of the bottom ash with transportation to the sites, recovery of the metals and up-grade of the minerals for use in road constructions.

During the recent 10 years Afatek took part in an innovation process with the purpose to both recover metals at a high recovery rate as well as to refine the minerals to an extent, where the minerals could be acknowledged as a valuable product in road constructions.

In the recent 20 years environmental protection has been regulated based on leaching tests. The introduction of the ecotoxic tests further strengthen environmental protection and thus contribute to refinement of the bottom ash gravel product.

Afatek is on the way with a certification of the bottom ash gravel product for road constructions and in this connection, it is a considerable strength that the product not only...
prove a bearing capacity much higher than expected but also that the protection of the environment is on the highest possible level. Both qualities aim at bringing the bottom ash back into the cycle as a proper end-of-waste product replacing valuable gravel.

1. HP14 classification

Since 2017, when Regulation (EU) 2017/997 introduced the new HP14 rules, Afatek has worked with Danish Waste Solutions (DanWS) to develop and refine an appropriate methodology for classification of incinerator bottom ash based on the content of substances and the summation formulas in the Regulation.

The classification model has been tested on a comprehensive set of data – composition and leaching data from the production of bottom ash from 6 WtE plants over 12 years, a total of more than 500 samples of bottom ash.

1.1. Description of the classification model

The classification model is based on further development of a stepwise approach, which e.g. has been presented in [5]. The first step is a screening for non-relevant HPs and POP substances. In this context only HP14 is considered, and the content of POPs does not render the bottom ash hazardous.

In the second step, an informed worst-case assessment on basis of the content of the HP14 harmonised (or otherwise relevant) substances is performed, assuming that each element to be considered is present entirely in the form of the most critical substance (with the highest molecular weight). This exercise performed on the 95th percentile of the contents of the above mentioned incinerator bottom ash samples shows that only Cu, Pb and Zn can result in the bottom ash being classified as hazardous. Therefore Cu, Pb and Zn have been further examined.

As metals must be dissolved in water to exhibit aquatic toxicity, only leachable amounts of metal substances are relevant for the HP14 classification. The further examination of Cu, Pb and Zn is therefore based on own leaching data as well as leaching data from other sources. L/S = 10 l/kg is chosen, because it is also accepted in the preparation of eluates for the aquatic ecotoxicological tests which are allowed as alternatives to classification based on content. By inserting worst-case leaching data (at the own pH of the bottom ash or the pH range of 7 to 12) into the HP14 classification formulas, it is found that bottom ash is not hazardous. As an alternative to the direct insertion into the formulas, pH static leaching data may in some cases also be used in conjunction with hydrogeochemical modelling to indicate the presence or non-presence of worst-case minerals. A more thorough description is expected to be issued mid-2019 [4].

Due to the lack of guidance on HP14 classification, other initiatives using other or similar approaches to classification based on the formulas in the Regulation are under development in other countries. To the best of our knowledge, they have so far all resulted in classification of the assessed bottom ashes as non-hazardous.
It can be mentioned that a comparison of the composition of 350 Danish bottom ashes from 2001 - 2013 with the composition of 170 bottom ashes from 2014 - 2017 at 90th percentile level, shows decreases of the content of Cu of 21 %, of Pb of 52 % and of Zn of 13 % with time [6].

1.2. HP14 in operation

The classification approach described above will be presented to and discussed with the Danish Environmental Protection Agency (EPA) which hopefully, for the time being, will approve that the methodology can be put into operation – eventually to be further improved and/or to be replaced by other models should they show better performance. In this way a Best Practice is realised which is also sought for by the authorities.

2. Up-grade and certification of bottom ash gravel for road construction

In the following is explained how bottom ash gravel has been used in road construction historically and how we expect it to be used in the future.

2.1. Use of bottom ash gravel in road constructions

For several decades, bottom ash gravel has been used in construction of roads and sites in Denmark where it replaces natural resources such as sand and gravel. The use of bottom ash gravel is governed by national legislation, setting up limits for the content and leaching of certain substances as well as the use is limited to sites and roads where the top layer such as asphalt or concrete keep leaching on a low level.

Present use

At present bottom ash gravel can be used in the sub-base (foundation) of the road at a traffic load of max. 600 trucks per day (Class T4). In the sub-base the bottom ash gravel replaces lower gravel qualities such as sand, where the bearing capacity need not be as high as in the base course (top-layer positioned under the asphalt) of the road.  

Figure 1    Bottom ash gravel in road construction, at present used in the Sub-base with the potential to be used also in the Base
**Future (Potential) use**

Tests have shown much higher bearing capacity of the bottom ash gravel than expected, which suggest that the bottom ash gravel may be used in the base of the road replacing higher gravel qualities.

If bottom ash gravel is used in both the base and sub-base a more efficient construction work can be carried out with lower costs as the result.

As with normal base course gravel the bottom ash gravel can be stabilised with e.g. cement. Binding the bottom ash gravel will increase the bearing capacity of the layer as well as reduce the leaching potential of the material.

No matter present or future use of bottom ash gravel – all material is recovered (also the fine grained) – substituting sand and gravel from Danish gravel pits.

**2.2. High bearing capacity proven in a full-scale test**

A full-scale test in a road in the Copenhagen Harbour was carried out by the Danish Road Directorate. The bottom ash gravel was used in different positions i.e. both in the sub-base and base course of the road. A section with standard sub-base and base course made of natural raw materials was made as reference. A mid-term report [3] and a presentation [1] has been carried out. The results show a bearing capacity in the sections with bottom ash gravel on the same high level as the standard natural materials. The rut depth in the heavy traffic side of the road was low (3 - 4 mm) for all the sections.

The results from this project may lead to acceptance of bottom ash gravel to be used in roads with a higher traffic load and also in the base course of the road. The future more valuable use of bottom ash gravel may lead to a better selling price.

**2.3. Norm for use of bottom ash gravel in roads**

In 2012 The Danish Road Directorate set up a norm for use of bottom ash gravel in the sub-base of roads. The geotechnical criteria that have to be fulfilled by the bottom ash gravel include limits for the grain size distribution including a limit on the amount of fine-grained material, a limit on the amount of total organic carbon (TOC) and a limit on the amount of particles lighter than water [2].

In the recent 6 years, the bottom ash gravel from Afatek has been tested according to these criteria and a quality declaration for each 5,000 tons batch of bottom ash has been issued. A substantial database on the geotechnical qualities of the bottom ash gravel has been established, showing a uniform and consistent quality on all parameters and all on the safe side of the limits.

Since 2012 the contractors and controlling authorities, supervisors and others have been well informed about the bottom ash gravel as a construction product.
3. How to achieve the true value of the recovered gravel

The innovation effort in bringing the minerals back into the cycle as an end-of-waste product is not the only objective, we should also be concerned about the value creation.
3.1. Pricing of the bottom ash gravel

At present we find a price difference of about 20 EUR per ton between bottom ash gravel and virgin materials used in the construction of roads and sites. The price difference is less compared to lower qualities of construction material such as crushed asphalt and concrete, but still those recycled products carry a positive price.

It is very likely that the price gap can be reduced considerably. There is a good possibility that the bottom ash gravel can carry a positive price when the following main activities have been carried through:

- Improvement of the quality of bottom ash gravel – has already been achieved and the bottom ash gravel is on the way to have issued a product certificate.
- A large stock is needed to be able to supply to large projects on the level of 100,000 to 500,000 tons per project. A large stock also provides with negotiation power.
- Environmental safety is proven by the present environmental regulation and now also by means of the ecotoxic tests.
- A long-termed information campaign towards the Municipalities and other large gravel consumers will have a very positive effect

The general development in the market is that gravel pits are closing which is expected to drive prices up on both virgin and recycled materials.

3.2. Improve economy and achieve real end-of-waste status

As a result of the development of the minerals as a proper product, it is likely to expect that the outcome will be sale of the minerals at much higher prices.

As we have kept processing costs at a low level, a net-income for the minerals and the company is expected to be a reality bringing the bottom ash back into the cycle as a valuable product and is expected to achieve status as a real end-of-waste product.

4. Concluding remarks

The HP14 classification is an important element in the pursue of bringing bottom ash into the cycle at the highest value level.

- The ecotoxic test is an extra security on top of the existing leaching test.
- The ecotoxic tests support the general refinement of the bottom ash gravel through certification of the product.
- All bottom ash minerals are recovered – and the mineral continues moving its way up in the value chain.
5. References

[1] Caroline Hejlesen, Danish Road Directorate (2016): Presentation at the meeting Vejforum: Link: https://www.dropbox.com/preview/Kommunikation/berliner%20konference%20maj%202019%20vivis/Pr%C3%A6sentation/Caroline%20Hejlesen%20presentation%20Link%20til%20artikel/Fors%C3%B8gsstr%C3%A6kning%20i%20Nordhavn%2C%20Caroline%20Hejlesen.pdf?role=work


[4] Danish Waste Solutions (2018): Progress reports for Afatek on a project to develop a testing/analytical method which can determine if incinerator bottom ash is hazardous according to HP14. In Danish, not published. A final report is expected mid. 2019


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