ZeroWaste

Turning waste into a new, sustainable resource for concrete

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ZeroWaste: Turning waste into a new, sustainable resource for concrete

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ABSTRACT
The ZeroWaste research group at the Department of Civil Engineering at the Technical University of Denmark (DTU Byg) was established two years ago and covers the broad range of expertise, required for turning waste materials into attractive, new materials. Members of the group have, prior to that, developed methods for removal of heavy metals and phosphorous from waste incineration, sewage sludge and other bio ashes, providing the basis of to make these ash types an attractive, new material for the building sector. Initial results for upgrading and using different types of ashes are presented in the paper, including an approach for involving large number of project students in the work.

Key words: Waste, environment, new concrete types, puzzolans, design, testing.

1. INTRODUCTION

The production of waste in Denmark is fairly large and corresponds to1.45 tons/person/year. A substantial part of the waste is already recycled or incinerated, and only a small part is deposited. Incinerating waste is beneficial as it will 1) generate energy and heating for the large cities, 2) reduce volume and weight and 3) in the case of e.g. sewage sludge also remove health hazards from pathogens and organic contaminants.

Table 1 - Main waste productions in Denmark with 5.6 mio inhabitants /Miljøstyrelsen 2011/.
[1]The material is normally incinerated.

Origin	Mio ton/year	Solid material	Recycling
Building industry	5.0	5.0	90%
(Concrete)	(1.2)	(1.2)	
Coal fired power plants	1.2	1.2	90%
Household waste	3.4[1]	0.7[1]	85%
Sewage plants	0.8[1]	0.009[1]	

In comparison to this, the use of concrete in the industrialized world is app. 1 m^3/person/year each requiring 1.5-2.0 tons aggregates and 3-400 kg cement and puzzolans (flyash). In addition to this, large amounts of materials are required for road construction, landfills, expansion of harbor areas etc. The large amounts of waste materials and required resources show that both waste handling and construction can benefit from mutual involvement from both sectors. The waste must, however, be turned into environmentally safe, attractive and renewable resources and preferably be used to reduce the cement consumption and improve the concretes. DTU Byg decided therefore to establish a strong and multidisciplinary research group ZeroWaste Byg (www.zerowaste.byg.dtu.dk), to deal with these problems and possibilities.

2. THE ZEROWASTE GROUP

The group consists of 11 faculty members plus 3 PhD students and covers the fields of building materials, structures, deterioration, indoor and outdoor environments, codes and standards, testing, product optimization and other civil engineering fields and has established an efficient code of cooperation (e.g. all questions are welcome and will be answered and all members must both contribute and benefit). The ZeroWaste group follows a number of basic dogmas for the research and development:

- The build environment is placed centrally in a sustainable material cycle of the society Research and innovation is focused on replacement of natural raw materials with secondary resources
- Building technology is rethought and materials are redesigned for todays as well as tomorrows demands

- There is no compromise on the quality of the construction materials
- There is no compromise on environmental impact

Team members have already developed electrodialytic to upgrade the incinerated materials to higher environmental safety by removing heavy metals and salts processes /Ottosen et al. 2006/, /Kirkelund et al. 2013/. A recent innovation has also made it possible to remove the phosphorous from the sewage ash /Ottosen et al. 2013/, which can fulfill the future Danish requirements of recycling the phosphorous /Danish Government 2013/. These new methods provide a potentially cost efficient way of cleaning and upgrading the ashes and their economy will be influenced by a) avoiding deposit taxes (often saving 80€/ton or more), b) capturing heavy metals (price unknown), c) capturing phosphorous from sewage ash to use as fertilizer (value above 100€/t sewage ash) and d) costs of establishing and running the plant. These methods also results in a number of new and interesting materials to use in concrete or other applications.

3. INITIAL RESULTS

The research in the ZeroWaste group initially focused on reuse of sewage sludge ash and later on other ash types. The relevant topics to investigate are many, as e.g. 1) replacement of cement or sand by fly ash, 2) water requirement for the mix, 3) effects on mix stability, 4) coloring of mix, 5) to wash or not to wash ash prior to use, 6) difference between stored ashes from the deposit and fresh ashes, 7) effect of grinding of the ashes, 8) setting time, 9) development of strength, 10) corrosion protection, 11) chloride binding, 12) indoor climate effects and 13) aesthetic impression. In order to work efficiently with this, a semester based R&D plan has been set up.

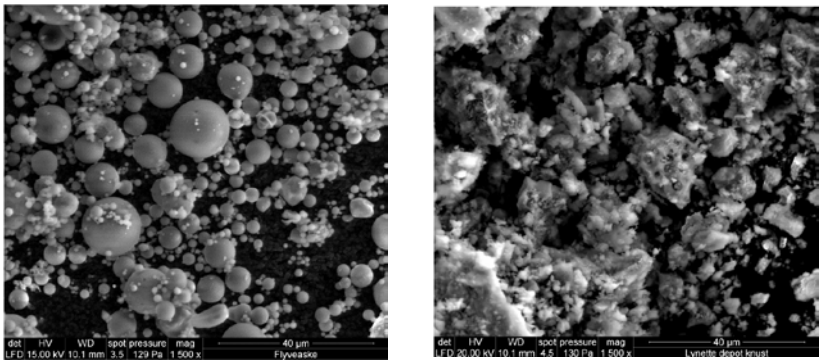

Figure 2 – SEM pictures of coal flyash (left) and milled sewage sludge ash from Lynetten (right). The scale of the two pictures are the same / Carlsen and Petersen 2013/.

The group has supervised app. 30 project students in the past two years, organized in project families (independent projects sharing a common semester focus based on the R&D-plans). The students have so far put 15-20.000 hours of work dealing with different aspects of the use of the ashes, both from incinerations plants and from sewage treatment plants and produced many valuable results. This enables not only efficient supervision, but leads also to many useful results, as the group of students work together with the R&D group and produces app. 5000 hours of work per semester. The results of each semester's student projects have had an impact on the R&D and use of project families facilitates cooperation with the industry significantly.

One important result was that the ash should be ground in a mill in order to improve its structure and to reduce the required amount of water and improve the strength of the mix, probably due to the changes in the ash structures, although the ground ash will still not have the same structures

as coal fly ash, as seen on Figure 2. Tests have indicated that up to 20% of the cement may be replaced while the strength is maintained at reference level with up to 10 % and a structurally acceptable level up to 20 % (Figure 3). Other tests have shown that replacing sand with ash may increase the strength.

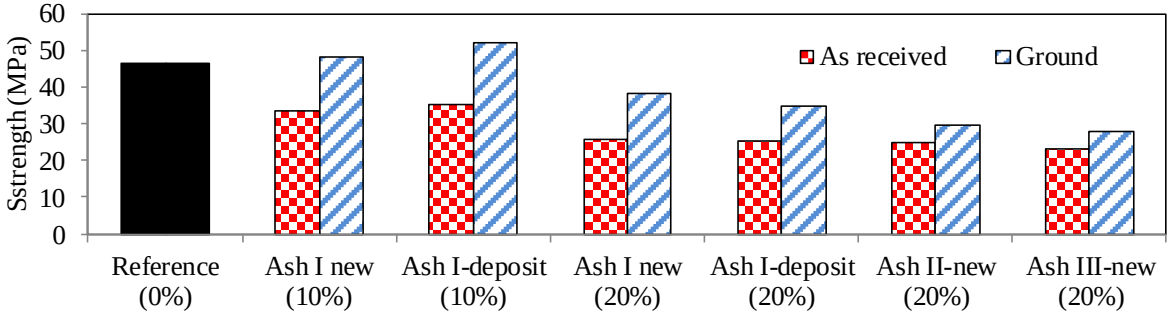

Figure 3 – Compressive 7 days strength in different mixes with constant water content and three different sewage ash types (results from student projects 2012-13).

The tests show sewage sludge ash has no puzzolanic effect, but additional tests show that other ashes can have a puzzolanic effect.

4. CONCLUSIONS

The techniques to extract the heavy metals from the ashes make these environmentally safe to use. The extraction of phosphorous from sewage ash provides a good and renewable source of phosphorous. This transforms ashes from environmentally dangerous waste materials to safe and renewable resources for the concrete mix and for construction activities. A methodology for testing new ashes in concrete is being developed, based on an interdisciplinary approach on the issue.

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