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THE COLOUR POTENTIALS OF SSA-CONTAINING MORTAR

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Abstract

This paper reports an experimental study of aesthetical qualities of mortar containing sewage sludge ash (SSA). SSA is the residue produced at water treatment plants where incineration of the sludge is applied in order to decrease volume and to prevent pathogens from spreading. Today SSA is with a few exceptions landfilled and thus, wasted.

The purpose of the experiments was to examine the influence of SSA and how it affected the colour of mortar samples. SSA was ground in 6 different intervals and added to mortar mixes by replacing 20% of the cement. An additional focus was to examine the possibilities to accentuate the colours of the hardened mortar by using paper cuttings in the production of the samples. The result of the experiments showed that a colour scale can be developed from ground SSA, and that paper may have the potential of providing divers textural qualities when it is used in combination with other form materials.

Keywords: Sewage sludge ash, colour potentials, mortar, textures.

1 Introduction

The cement industry is often singled out to be a considerable contributor to climate changes. Currently, cement production is estimated to be responsible for 5 - 8% of the total global emission of CO_2(Scrivener & Kirkpatrick 2008).

In the fifth assessment report by The Intergovernmental Panel on Climate Change (IPCC, 2014) “resource use efficiency” (Fischedick M., J & al. pp.59, 2014) is identified as essential but also one of several strategies to mitigate climate change. As part of this political agenda “Waste as resource” is also promoted in the waste hierarchy, as in the latest Waste Framework directive (2008/98/EC) of the European Union. The waste hierarchy, ranks waste handling options from most to less favoured in the order: prevention > minimization > reuse > energy recovery > disposal. The purpose of such a priority order is to strengthen resource use efficiency by regulating behaviour explicitly through the principle of “polluter pays”. Thus, scientifically and politically it is identified that mitigation of climate change necessitates a transformation of the way the available resources are governed. This also includes the resources that eventually end up on a landfill, such as SSA. To obtain a sustainable cement production in the future there are two main challenges: to reduce the CO_2 emission and increase the resource use efficiency. Thus, the advantage of replacing cement with SSA seems advantageous.

Several studies, (e.g. review by Cyr, Coutand & Clastres 2007; Donatello & Cheeseman 2013), have investigated the possibilities to utilize SSA as a supplementary cementitious material (SCM) with the potential of lowering the environmental impact of the cement production. The focus of the previously conducted research has mainly been on the chemical, mechanical properties and environmental consequences attached to the use of SSA in cement based materials (Cyr, Coutand & Clastres 2007; Chen & al. 2013; Donatello, Tyrer & Cheeseman 2010). One question which has sought to be answered is whether SSA possesses pozzolanic properties. In some studies SSA is compared to other by-products that possess pozzolanic properties but also advantageous characteristics such as spherical particles of coal fly ash . Generally, research has found that the compressive strength decreases when SSA partly replaces cement. The porous and coarse particles of SSA raise the water demand in the mix, and as such, SSA is not comparable to by- products with more obvious properties. SSA also varies in accordance to parameters such as the level of industrial activity in catchment area, seasons and the processes applied at water treatment plant (Donatello & Cheeseman 2013). However, the process of grinding SSA has shown to improve the compressive strength of SSA - containing mortar (Donatello & al. 2010).

Some SSA has a distinct red colour due to chemical precipitation of phosphorus in wastewater treatment plants by iron. If cement is replaced by such SSA it can affect the colour of concrete which may challenge the traditional comprehension of concrete. Thus, to unfold the potential of utilizing SSA as SCM further, this study concentrated on the aesthetical qualities of using ground SSA in mortar. Thus, the aim of this study was to examine the colour development of hardened mortar samples when ground SSA was added to the mix by partly replacing the cement.

2 Experimental framework

This study included hands-on experiments for an investigation of: 1) the effect ground SSA had on the colour of the mortar samples and 2) the possibilities to use simple paper cuttings as a method to provide different textural qualities- rough and smooth surfaces.

Within the entire experimental study 50 samples were produced with varying percentage of cement replacement ranging from 10 to 50 % by weight. The SSA was also ground to obtain increasing fineness and larger specific surfaces areas of the SSA particles. The colour scale which was produced consisted of seven samples altogether; one mortar sample contained no SSA (reference) whereas the other 6 samples had 20 % cement by weight replaced by SSA grinded in the six different time intervals 0-10 min.

The samples originated from several separated experiments in which essential parameters were investigated: cement replacement percentage, time interval of the grinding procedure, and form materials. The focus was to detect the influence each parameter had on the colour of SSA containing mortar.

2.1 Materials

An iron-rich SSA was collected from Avedøre Spildevandscenter (AVE), BIOFOS in Denmark. The SSA was taken directly from the process line and stored in plastic containers at room temperature before use. Due to the high containment of Fe the SSA had a characteristically red oxide colour. A coarsely-grained sand, sea-sand 0-4mm, and a Portland cement labelled CEM II/A-LL 52.5R was used for the mortar production. This particular Portland cement used in the experiment had a content of 20 % of limestone filler.

2.2 Grinding process

The SSA was dried at 50 °C for 24 h before it was dry-milled for 6 different durations: 0 sec, 10 sec, 30 sec, 3min, 6 min, and 10 min. A vibratory cup mill (FRITSCH - pulverisette 9) was used for the milling.

2.3 Mortar and sample preparation

The basic recipe which was used for the mortar samples was 75 % sand, 25 % binder and a water/binder ratio of 0.5. The mortar was prepared in a small mixer with the capacity of 5 liters. Binder; either cement or cement and SSA, was placed in the bowl, and immediately after the water was added, the mixer was switched on for 30 sec at low speed. The sand was added during the next 30 sec, and then the mixer was switched to high speed and the mixing continued for another 30 sec. The mixer was stopped and the paste adhering to the inside of the bowl was within the next 30 sec removed by a scraper. After 60 sec of rest, the stirring process proceeded and the paste was stirred at high speed for another 60 sec.

The compaction procedure was executed by a vibrating table at a frequency of 53 Hz. The mortar was placed in the mould within the first 30 sec and the mortar was vibrated for another 90 sec. The mortar samples were sealed in plastic for 24 hours, unsealed and stored at room temperature.

The paper cuttings used to generate rough and smooth surfaces of the hardened mortar was created by cutting a circular shape out of the lining paper using a circle cutter. The paper was moistened by placing it under running water for a few seconds Fig. 1. Before the frame was mounted, the paper cutting was placed at the base of the mould and evened out with the means of a wall paper brush Fig. 2. The samples were casted in moulds made from film faced ply wood. The dimensions of the moulds were either 100x100x30mm or 200x200x30mm. For the colour scale a steel mould was used. The samples measured 80x40x40mm.

Fig. 1. The paper was moistened before it was placed on the base of the mould.

Fig. 2. The wet paper glued to the base**.**

3 Results and discussion

The experiments of this study revealed that the colour of the SSA-containing mortar intensified as the time interval of the grinding process increased, Fig. 3. Each of the 6 steps within the time interval 0 – 10 min provided an additional colour tone and generated a colour scale consisting of mortar samples ranging from greyish to a more saturated red brown colour.

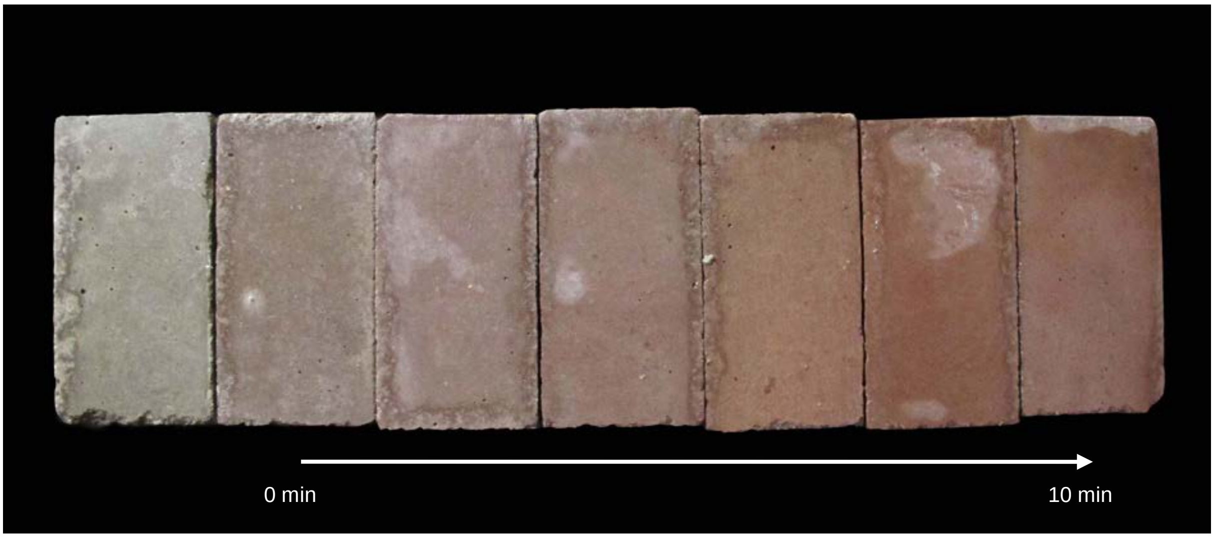

Fig. 3. Colour scale of moisturized mortar samples. The Grey colour of normal mortar gradually changes as the fineness of SSA particles increases. The first mortar sample to the left does not contain any SSA. The second sample contains un-treated SSA. Hereafter, the samples contain ground SSA of increasing fineness.

Additionally, the experiments revealed that the colour of mortar containing untreated SSA did not display a noticeable colour change particular when the samples had less than 20 % cement replacement. Fig.4.

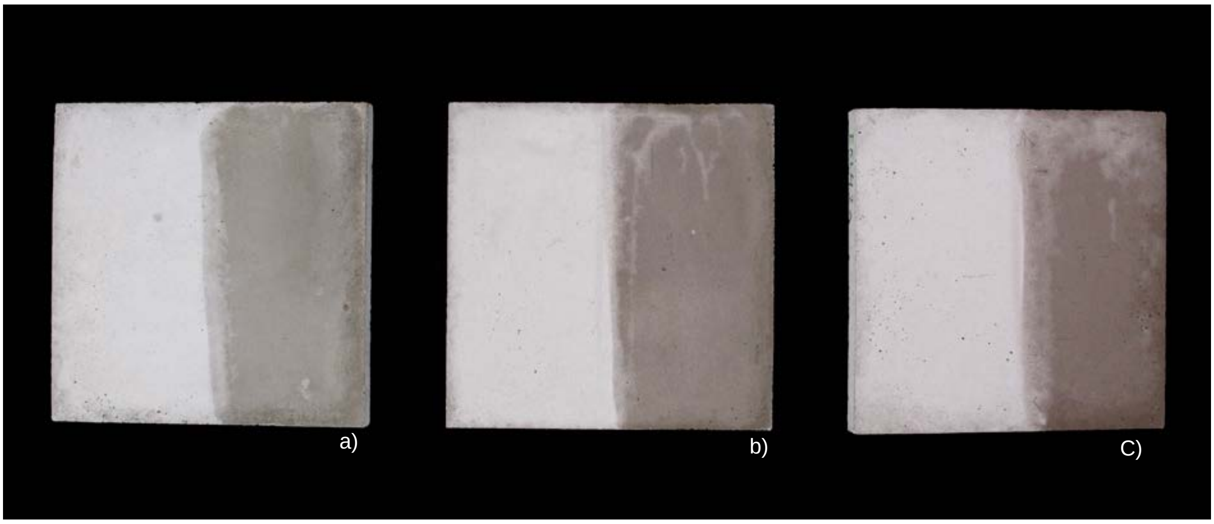

Fig. 4. a) sample –reference b) 10% cement replacement by un-treated SSA. C) 20% cement replacement by un-treated SSA. Half the tile was moistened .The Colour change was easier to see when the samples were wet.

Generally, increasing the SSA amount intensified the colour. Furthermore, it was found that the plain form materials -the film faced plywood and the lining paper generated diverse textural qualities in both rough and smooth surfaces. The rough and smooth surfaces highlighted the tones of the colour differently. Thus, the experiments displayed a possibility to influence the colour and to create circular imprints on the surface of the mortar samples Fig. 5.

However, the experiments also showed that the use of paper as form materials can cause technical challenges. In some cases the paper attached to the surface of the hardened mortar and it was not possible to remove it Fig. 6. Only by using a brush and running water did the paper detach. Consequently, the samples lost some of their vibrancy because the textural differences were blurred by this treatment. The reason why the lining paper sometimes was stuck to the surface was not identified and will need to be investigated further. Despite the fact that these form materials showed constrains in usage, the experiments exhibited a general idea of using absorbent and water repellent form materials combined to accentuate the colours of cement based materials which in this case was SSA-containing mortar.

Fig. 5. Accentuation of colour displayed by the difference of rough and smooth surfaces. The circular parts are smooth and the surrounding areas are rough.

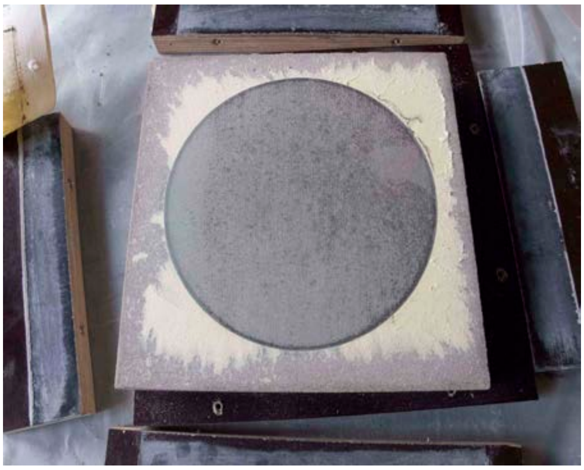

Fig. 6. Paper stuck to the hardened concrete tile.

The variability of SSA challenges it's suitability as SCM in cement based material. Nevertheless, Scrivener & Nonat 2011 advocate for the necessity to adjust future demands for cement by using locally available materials, and to develop on the basis of a scientific approach new SCM and cement types in order to produce sustainable cement based materials.

Empirical, initial testing of new materials such as SSA does not establish profound understandings of reactions on micro level and predictions of long term material performances at macro scale. Such testing will, however, often confront existing theoretical knowledge, pose new questions and unfold material properties, not perceived by a parametric model such as the aesthetical quality of a colour.

Even though the variability of SSA challenges its usage in cement based materials and application in construction, it also confronts the general idea and requirements for uniformity especially when thinking about concrete. For construction materials such as brick and wood, variation in colour and texture is in contrary, often desired and thrived for as aesthetical qualities that add value to the build environment. And although SSA containing concrete could be used at places where the colour is less important e. g in hidden structures there is also a possibility to incorporate variability into a design solution of a facade. As a good example can be mentioned Yardhouse designed by the London based architecture collective ASSEMBLE. The design solution for the facade exhibits how variation intentionally can be included by using coloured concrete tiles in an unusual scale for normal concrete facades Fig. 7. Thus, variation of cement based materials can be aesthetically unfolded trough rethinking scale and component. And as such, SSA shows potential as a secondary resource for colouring concrete, and if the aesthetical aspects such as colour are taken into account at an early stage, it could challenge a general idea that concrete is a grey, and in some views, a drab material.

Fig. 7. Yardhouse, 2014 by Assemble. The facade is made from concrete tiles. The colourful tiles is hand made on site. Photo:ASSEMBLE

4 Conclusions

This study revealed that SSA shows potential as a secondary resource for colouring concrete and a colour scale can be developed when different time intervals are applied to the process of grinding SSA. Additionally, the experiments displayed that the colour can further be accentuated by the use of simple form materials such as lining paper and ply wood. However, the usage of lining paper showed some technical challenges and is at present not applicable in large scale and optimisation needs to be investigated further.

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References

Chen, M. et al. (2013), Environmental and technical assessments of the potential utilization of sewage sludge ashes (SSAs) as secondary raw materials in construction. *Waste Management*, 33(5), pp.1268–1275.

Cyr, M., Coutand, M. & Clastres, P. (2007), Technological and environmental behavior of sewage sludge ash (SSA) in cement-based materials. *Cement and Concrete Research*, 37(8), pp.1278–1289.

Directive 2008/98/EC on waste (Waste Framework Directive) - Environment - European Commission, n.d. URL http://ec.europa.eu/environment/waste/framework/index.htm [Accessed November 27, 2014].

Donatello & al. (2010), Effect of milling and acid washing on the pozzolanic activity of incinerator sewage sludge ash. *Cement and Concrete Composites*, 32(1), pp.54–61.

Donatello, S. & Cheeseman, C.R. (2013), Recycling and recovery routes for incinerated sewage sludge ash (ISSA): A review. *Waste Management*. 33(11), pp.2328–2340

Donatello, S., Tyrer, M. & Cheeseman, C.R. (2010), EU landfill waste acceptance criteria and EU Hazardous Waste Directive compliance testing of incinerated sewage sludge ash. *Waste Management*, 30(1), pp.63–71.

Fischedick M., J. Roy, A. Abdel-Aziz, A. Acquaye, J.M. Allwood, J.-P. Ceron, Y. Geng, H. Kheshgi, A. Lanza, D. Perczyk, L. Price, E. Santalla, C. Sheinbaum, and K. Tanaka, (2014): Industry. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

IPCC (2014): Climate Change 2014: Mitigation of Climate Change. *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Scrivener, K.L. & Kirkpatrick, R.J. (2008) Innovation in use and research on cementitious material. *Cement and Concrete Research*, 38(2), pp.128–136.

Scrivener, K.L. & Nonat, A. (2011), Hydration of cementitious materials, present and future. *Cement and Concrete Research*, 41(7), pp.651–665.