



Characterisation of Mineral Wastes, Resources and Processing technologies – Integrated waste management for the production of construction material

WRT 177 / WR0115

Case Study:

Incinerated sewage sludge ash in facing bricks

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Introduction

Incinerated sewage sludge ash (ISSA) is a combustion residue generated from the incineration of sewage sludge arising from municipal wastewater treatment works. Approximately 22% of the sewage sludge is incinerated. The quantity of ISSA produced in the UK is estimated to 100,000 tonnes per annum and is commonly disposed to landfill.



Figure 1: Incinerated sewage sludge ash from Knostrop Incinerator – Yorkshire Water

Potential applications for ISSA

Incinerated sewage sludge ash may be used in ceramic products as a sand or clay substitute, in concrete mixes as a cement substitute (up to 20% replacement), as a secondary fine aggregate in concrete (replacement up to 30%) and in asphalt (replacement up to 10%) (Gunn et al, 2004).

The use of incinerated sewage sludge ash in bricks is not new. Several past trials were undertaken in the UK and overseas, where the incorporation of ISSA into bricks as clay or/and sand substitute was investigated. The production of 100% bricks made from ISSA is common practice in Japan and there are currently eight plants operating (Gunn et al, 2004).

The composition of ISSA varies substantially from different sources and it may not always comprise an appropriate alternative material for brick making. The purpose of this case study therefore is not to prove that ISSA could find application in brick manufacture, but to investigate the properties and performance of ISSA from a specific source. A summary of past research investigations is given in Table 1. Trials in the UK utilised ISSA in substitution rates up to 25% (by weight), but it was thought that a replacement up to 10% would be suitable, because it will not alter the strength and appearance of the end product.

Table 1: Previous research projects on the incorporation of ISSA in brick manufacture

Project title	Location	Reference
Use of sewage sludge in construction	UK & Overseas	(Gunn et al., 2004)
Variability study of incinerated sewage sludge ash in relation to future use in ceramic brick manufacture	UK	(Anderson & Skerratt, 2003)
Use of sewage sludge ash as brick material	Overseas	(Lin & Weng, 2001)
Factory-scale proving trials using combined mixtures of three by-product wastes (including incinerated sewage sludge ash) in clay building bricks	UK	(Anderson et al., 2002)
Evaluation of Color Changes in Sewage Sludge Ash Brick by Using Image Analysis Method	Overseas	(Luo & Lin, 2003)
Case study involving using fluidized bed incinerator sludge ash as a partial clay substitute in brick manufacture	UK	(Anderson, et al., 1996)

Brick manufacture

Brick manufacturing is a historic industry and the production process is well established. Brickworks commonly operate in close proximity to clay quarries, owned by the same company, so as to satisfy their needs for raw materials. The market of bricks presented significant changes with the introduction of concrete blocks as the latter replaced common bricks in construction. This resulted to a shift of the market in producing facing bricks, used for aesthetic purposes.

The use of 'facing bricks', accounts for over 90% of demand and the production of facing bricks appears quite stable for the last seven years (BGS, 2007). Bricks are produced either by extrusion or by the 'soft-mud' process, but extrusion comprises the commonest option (Figure 2). Bricks are dried prior to firing and fired in a linear kiln (tunnel kiln), which commonly operates on natural gas.

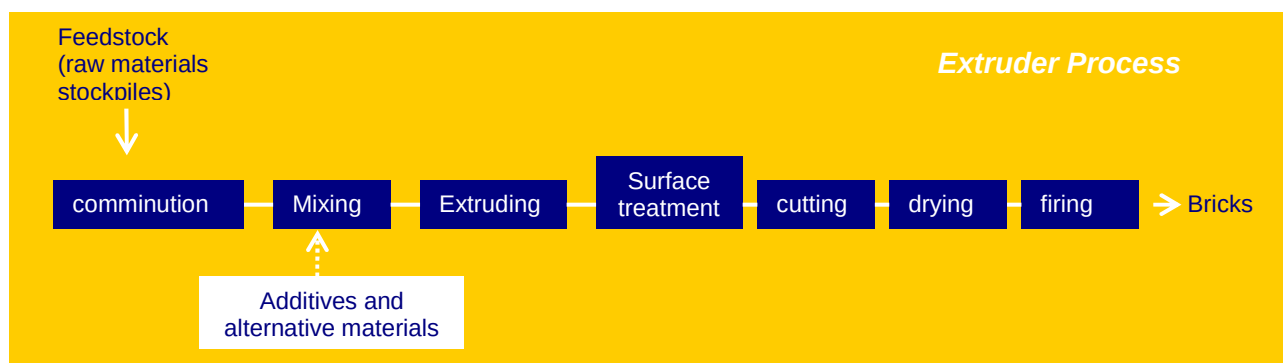


Figure 2: Brick manufacture – The extrusion process

Alternative materials are considered for use by brick manufacture as a potential cost effective solution to access materials with desirable compounds/ properties that will satisfy the demand for large portfolios of products with different aesthetic properties. The sector's view is that customer demand and expectations have changed significantly and a market for 'green products' is currently present.

Barriers and Benefits (extracted from waste product pairing database)

The Waste-Product Pairings (WPP) database includes information relevant to the benefits, obstacles and analysis required for determining the potential for ISSA to be utilised by the brick manufacture. Analytically this information is shown below:

1. Contribution to the end product. ISSA could be used primarily as a filler material (sand substitute), but it may also comprise a clay substitute, a fluxing agent and to lesser extend a colourant.
2. Potential benefits:
 - Material related:
 - i. ISSA often comprises a fluxing agent. In that case improved vitrification results to lower firing temperature without affecting the end product properties.
 - ii. The strength of unfired bricks is improved hence the risk of handling damage is minimised.
 - iii. ISSA may improve thermal insulation and fire protection.
 - Environmental – Organisational - Social:
 - i. Conservation of resources of virgin materials
 - ii. Emission reduction and less energy requirements due to the fluxing properties of ISSA
 - iii. Production of 'green products' with recycled content
 - iv. Achieving brick sector sustainability objectives by minimising the use of primary resources
 - Economic:
 - i. The need to buy primary materials such as sand is reduced
 - ii. Reduced energy cost due to the fluxing properties of bricks.
3. Potential barriers:
 - Material related:
 - i. ISSA may contain soluble salts, which can cause scumming during firing.
 - ii. The composition of ISSA varies substantially for different sources and the use of anti-scumming agents may be essential.
 - Legal
 - i. Brickworks may require a waste management licence in order to use ISSA depending on the chemical analysis and metals content of the ash.
 - Economic
 - i. The use of anti-scumming agents may increase the manufacturing cost
 - ii. Additional storage infrastructure will require company's investment.
 - iii. Marginally increased quantity of tempering water requires more drying energy, which will increase cost manufacture.
 - iv. Low landfill cost discourages exploration for alternatives to disposal.
 - v. Absence of testing facilities for small and large scale trials require from brickworks to stop production in order to perform trials.
 - vi. Transport of material through long distances may increase its cost.
 - Social
 - i. Public perception towards ISSA may comprise a barrier.

4. Analysis requirements:

Testing is carried out to identify the properties and characteristics of alternative materials and end products, as well as to determine that the inclusion of certain alternative materials provide desirable results during lab-based experimentation.

Analysis on alternative materials:

mineralogy; chemical analysis; particle size analysis; bulk density

Analysis during lab-based experimentation:

appearance of test bricks after firing; shrinkage; experimentation with different substitution rates; decision upon the type of clay body suitable for use with ISSA; firing temperature

Analysis on end products:

in accordance with BS EN 771-1 on masonry products; colour; durability; green strength; water absorption; efflorescence; compression strength

ISSA samples

Samples of ISSA were acquired from Knostrop Incinerator of Yorkshire Water Services located in Leeds. The plant consists of the process stages seen in Figure 3.

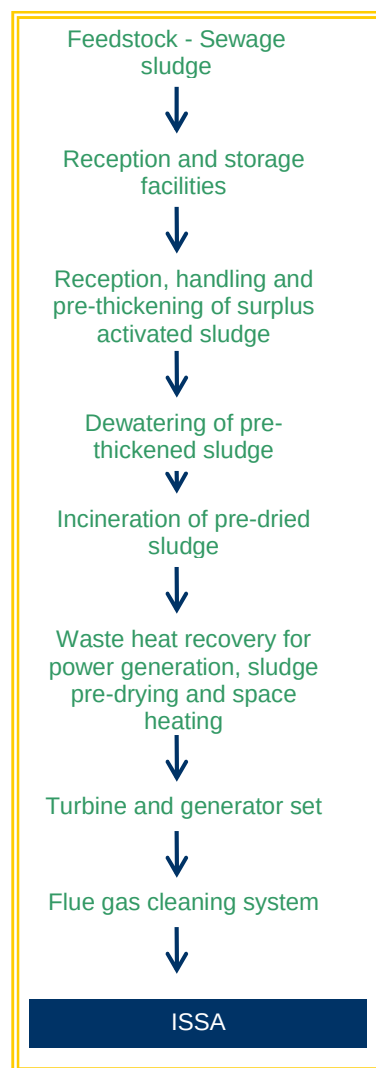


Figure 3: Knostrop Incinerator – process stages

This plant generates approximately 20 tonnes per day of ISSA, which is currently disposed in to the company's own landfill site. The license of this landfill is expected to end during 2007. Therefore alternative utilisation routes are being investigated. Yorkshire Water operates four incineration plants in total. Only half of total sewage sludge is incinerated in these plants, the remainder is used in the production of compost. The other three incinerators produce approximately 50 tonnes per day of ISSA.

ISSA in Knostrop Works is stored in a silo. Samples were provided in 10 kg bags. Yorksire Water state that ISSA produced from Knostrop Incinerator is very consistent with regards to its composition and particle size.

ISSA characterisation results

Characterisation of the ISSA samples was carried out and results are summarised in Table 2. Parameters such as the mineralogy, the particle size distribution, the particle density, the acid soluble chloride, the moisture content and the loss on ignition were determined.

According to the mineralogy results, ISSA appears rich in silica minerals such as quartz. Taking into consideration the particle size analysis results (90% passing 1.00 mm) it could be concluded that ISSA comprises a substitute for sand in bricks. The glass content of ISSA is low, therefore it is expected that this material will not present fluxing properties. The water absorption value is quite high and it may imply that additional water will be required during mixing and preparation of the clay – ISSA body.

Table 2: ISSA characterisation results.

ISSA	
Visual description	Medium grey, free flowing powder
Mineralogy	Quartz, (SiO ₂), Whitlockite (Ca, Mg H phosphate), Tridymite, (SiO ₂), no evidence of significant glassy content.
Particle size distribution	100% passing 2.0 mm; 90% passing 1.0 mm; 62% passing 0.5 mm; 40% passing 0.25 mm; 22% passing 0.125 mm; 18.8% passing 0.063 mm.
Particle density	2.41 Mg/m ³
Water absorption	48 %
Acid soluble chloride (%)	0.008
Total sulphur (%)	0.40
Moisture content (%)	0.36
Loss on ignition (%)	1.43

Results of Laboratory / Pilot product demonstration test-work

The use of ISSA in bricks was investigated by lab –scale trials. The objective of these experiments was to identify whether the specific material could be incorporated into bricks primarily as a sand substitute and to examine if changes in the colour and face appearance of the bricks occur.

A control material of brick shale was used and with additions of ISSA of 2.5 and 5% (by weight). Laboratory characterisation was performed by *Hargreaves Mineral Services*. The appearance after firing, the moisture content, the loss on ignition, the fired temperature and the water absorption were recorded for all different samples.

Results from lab trials demonstrated that ISSA could be used as filler for sand replacement in bricks. No obvious differences in colour between the control sample and ISSA rich bricks were observed, except from some small degree of scumming (white spots on face surface). Scumming is produced due to soluble salts included in ISSA, which during firing, deposit on the surface of the bricks giving a white colour. The degree of scumming observed in bricks with ISSA is not considered unacceptable, as similar levels may be occur with some clay. Although only small amounts of this material were added to the clay body, it was found out that water absorption increased considerably (~2%) in comparison to the control sample, which indicates that higher levels of water will be required to produce a suitable feedstock. Also during the drying process additional energy consumption may occur. This is seen as a substantial economic and environmental barrier. Finally, ISSA from Knostrop Works did not illustrate any fluxing properties. Experimentation with different clay bodies may give different results.

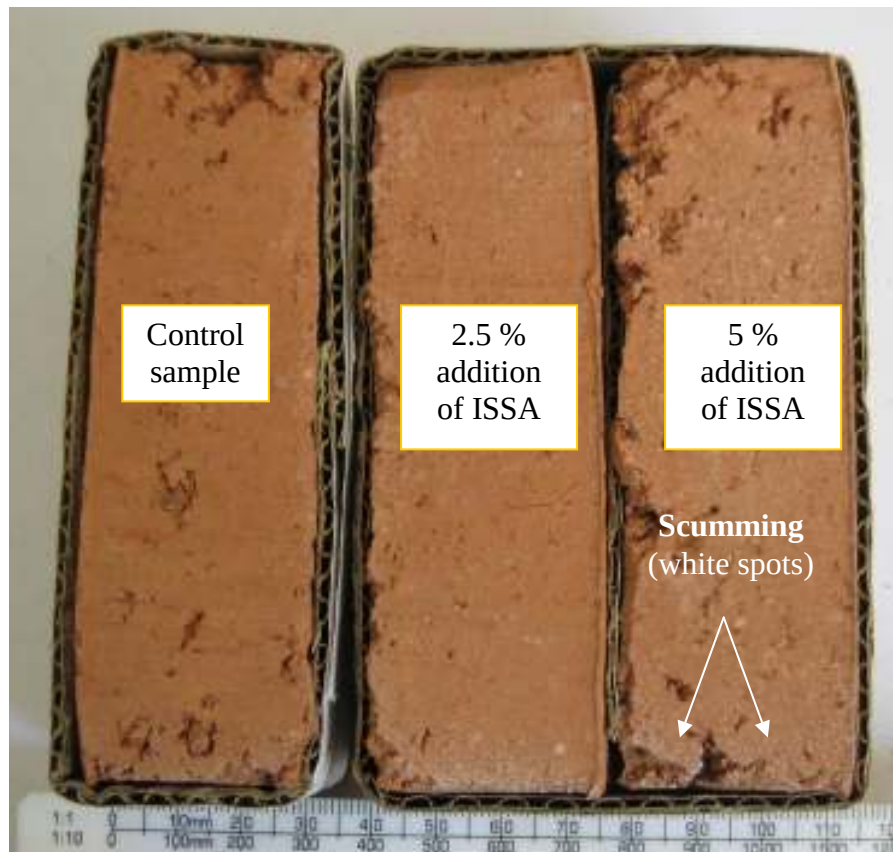


Figure 4: Test bricks with ISSA addition. The first sample on the left of the picture comprises the control sample (100% brickshale)

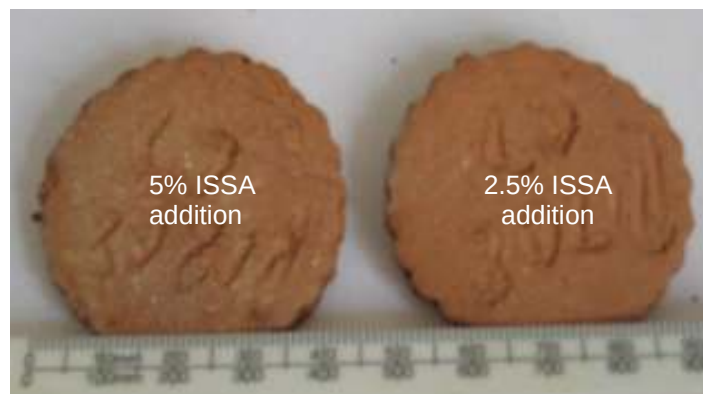


Figure 5: Ceramic test tiles with ISSA additions.

Conclusions and further work required

The use of ISSA from Knostrop Works as a filler substitute for bricks is technically feasible. The high water absorption values recorded during experimentation however may be seen as an obstacle by brick manufacturers, particularly so, as the addition of ISSA does not provide any desirable aesthetic results. The market of bricks is mainly interested about materials that can provide a range of colours, marks and textures hence visual effects. The use of alternative materials as filler substitutes are considered by the brick sector only when suitable primary sources are not found in close proximity or if the cost of secondary materials in combination with their properties is advantageous. The final decision upon the use of ISSA or any other alternative material in bricks is taken after several trial stages including small scale and full scale trials. Often the cost and disturbance from production caused from industrial scale trials is considered a constraint for the brick manufacture. The use of ISSA from Knostrop Works could be applicable to local brickworks, but further experimentation including a feasibility study is required to determine that. It is anticipated that ISSA will be utilised only if profit made by substituting primary sand is enough to cover the additional water and energy consumption.

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References

Anderson, M. & Skerratt, R.G. (2003). Variability study of incinerated sewage sludge ash in relation to future use in ceramic brick manufacture. British Ceramic Transactions, 102(3), 109-113.

Anderson, M., R. G. Skerratt, et al. (1996). Case study involving using fluidized bed incinerator sludge ash as a partial clay substitute in brick manufacture. Water Science and Technology 34(3-4 pt 2): 507.

British Geological Survey (2007). Mineral Planning Factsheet - Brick Clay.:

URL<<http://www.mineralsuk.com/britmin/mpfbrickclay.pdf>>. Access date:[16.10.2007].

Gunn, A., Dewhurst, R., Giorgetti, A., Gillot, N., Wishart, J. & Pedley, S. (2004). Use of sewage sludge in constrction.: CIRIA. C608. London.

Lin, D. & Weng, C. 2001, Use of sewage sludge ash as brick material, Journal of Environmental Engineering, vol. 127, no. 10, pp. 922

Luo, H. & Lin, D. 2003, Evaluation of Color Changes in Sewage Sludge Ash Brick by Using Image Analysis Method, Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management, vol. 7, no. 4, pp. 214-223.

Michael Anderson, M. E. C. H. (2002). Factory-scale proving trials using combined mixtures of three by-product wastes (including incinerated sewage sludge ash) in clay building bricks. Journal of Chemical Technology & Biotechnology 77(3): 345-351.

Petavratzi, E. & Barton, J. (2006). Mineral Wastes, Resources and Processing Technologies - Integrated waste management for the production of construction materials - Case studies on the utilisation of alternative materials in the manufacture of ceramic products.: School of Civil Engineering, University of Leeds.