



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

WRT 177 / WR0115

Case Study:

Quarry Fines & Paper Sludge in Manufactured Aggregate

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Introduction

Quarry Fines

Quarry fines are a category of material vary depending on the operations and type of primary resource being quarried. They can be classified into two main groups:

- Crushed rock fines
- Sand and gravel washings

Crushed rock fines are the material that cannot find a use in the local market. It is usually the fraction of material under 4mm. This upper limit varies depending on location. Traditionally this fraction would accompany coarser material in the provision of well graded fill material for civil engineering works. However changes in the market including greater use of recycled and secondary aggregate and changes in the coarser size requirements especially in road construction have led to such fines not being economic given the £1.90 per tonne Aggregates Levy. These materials can be screened and washed to provide some sand however this again depends on local markets. The composition will be the same as the rock that is being crushed. In the case of limestone it will therefore be calcium carbonate (CaCO_3), in the case sandstone I will be predominantly silica (SiO_2) and for igneous rock it will be silica and feldspars and smaller amounts of mica and hornblende.

Sand and gravel washings are silt and clay material that occur in the same deposit as the sand and gravel required for aggregates. The aggregate is screened and often washed to separate the finer silt and sand fraction. Usually this material is the fractions passing $150\mu\text{m}$ with the majority passing $75\mu\text{m}$. The composition of the washings will vary depending on the locality but will be composed of Ca, Mg, Al silicates.

Paper Sludge

Paper mill sludge is a major economic and environmental problem for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper. The total quantity of paper mill sludge produced in the UK annually is approximately 1 million tonnes (1). The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertiliser, incineration in CHP plants at the paper mill, producing paper sludge ash, or disposal to landfill. The scope for landfill spreading is limited and is covered by an industry code of practice (2,3).

In functional terms, paper sludge consists of cellulose fibres, fillers such as calcium carbonate and china clay and residual chemicals bound up with water. The moisture content is typically up to 40%. The material is viscous, sticky and hard to dry and can vary in viscosity and lumpiness (1). It has an energy content that makes it a useful candidate as an alternative fuel for the manufacture of

Portland cement. Paper sludge is currently in use as an alternative fuel. It is classified as Class 2 (liquid alternative fuels) in the Cembureau classification of alternative fuels (4).

Potential applications for quarry fines

Quarry fines have the potential to be used for a number of applications other than as fine aggregate. They may have compositions suitable for incorporation into brick manufacture or for cement production. Finer materials may also be suitable for the production of manufactured aggregates.

Potential applications for Paper Sludge

Potential uses of paper sludge in construction products include use in board products such as plasterboard, alternative fuels for cement manufacture and brick manufacture. The main limiting factor is the difficult nature of the material's physical properties and its high moisture content.

Paper sludge can be processed to separate the fibre and mineral fractions and to dry the material using a technique developed in Canada (1). Potential end uses for the derived materials include bricks and plasterboard.

Manufactured Aggregate

Manufactured aggregates are almost lightweight aggregates (less than 1000kg/m³) and are predominantly an expanded (or bloated) clay aggregate, aggregate made from pulverised fuel ash (PFA) from coal fired power stations. Their primary use is in lightweight construction blocks but they can also be used for lightweight fill, ground insulation layers in buildings and, where they have sufficient strength, in structural concrete.

The production of manufactured aggregate involves agglomeration usually on an inclined rotating pan in the presence of a small amount of moisture. The agglomerated pellets may then be dried prior to thermal processing. The pellets are then fed directly into a rotary kiln or onto a travelling grate furnace and fired at a temperature between 1100 -1200 °C. The rotary kilns are usually fired by fossil fuel burners. On discharging the aggregate will be cooled prior to stockpiling.

In addition a number of other materials have been researched to assess their possibility of being suitable for manufactured aggregate production. Such materials include River and harbour dredgings, combustion ashes from power stations and waste incinerators and quarrying fines including both silt and clay washing and crushed rock fines. Quarry fines that have been successfully tried include: Granite Washings, Sand & Gravel Lagoon silt, Microgranite Washings, Greywacke Washings, Marine Dredged Aggregate washings, Sandstone quarry fines (5, 6)

Barriers and Benefits (extracted from waste product pairing database)

A commentary on generic barriers and benefits of the production of manufactured aggregate from quarry fines are as follows:

Material related

1. Limited need for dense aggregate as it would be a replacement for relatively cheap natural aggregate.
2. As quarries are very common the potential is high logistically. This is especially so for large site where silt or washing filter cakes are concerned.
3. The material is of a particle size distribution that is well suited to the processing of materials especially in 'wet' or 'semi-dry' processing is used to shape the aggregate prior to thermal processing.
4. Aggregate produced has the potential to produce a strong material once incorporated into concrete.
5. The potential to compete with natural aggregate for certain concrete grades.

Economic

1. Energy needed to produce is a large financial hurdle as is the cost of processing plant which is measured in 10s of millions of pounds.

Environmental

1. The amount of needed to produce the aggregate will mean that there is a large burden on fossil fuels and associated emissions unless alternative fuels can be used.

Specific materials characterisation results

This case study looks at manufactured aggregate production from granite washing filter cake incorporating paper sludge as a binder and to provide some of the energy requirement of the processing.

The granite washings are produced from the cleaning of the *scalpings* produced after crushing of the rock. At present the material is stored in settling lagoons on site. The washings are fine in nature with 99.5 % of the material passing 300 μm and 80 % passing 75 μm . Figure 1 shows this grading in more detail.

The mineralogy is mainly feldspars (plagioclase and K-feldspars) and quartz with some mica and kaolin. The fine fraction (<10 μm – 6.5 %) is mica/illite and kaolin. An elemental analysis by oxide weight is given in Table 1.

Element	% as oxide
Si	66
Al	17
Fe	3
Mg	1
Ca	2
Na	3
K	5

Table 1: Oxide analysis of granite filter cake

The washings are received as filter cake with dry solids of 75 %. It is very homogenous in nature and forms large agglomerated pieces that have good cohesion, but do not behave in a plastic manner. Other trials have incorporated up to 40% of the same material with a size range 300-600µm.

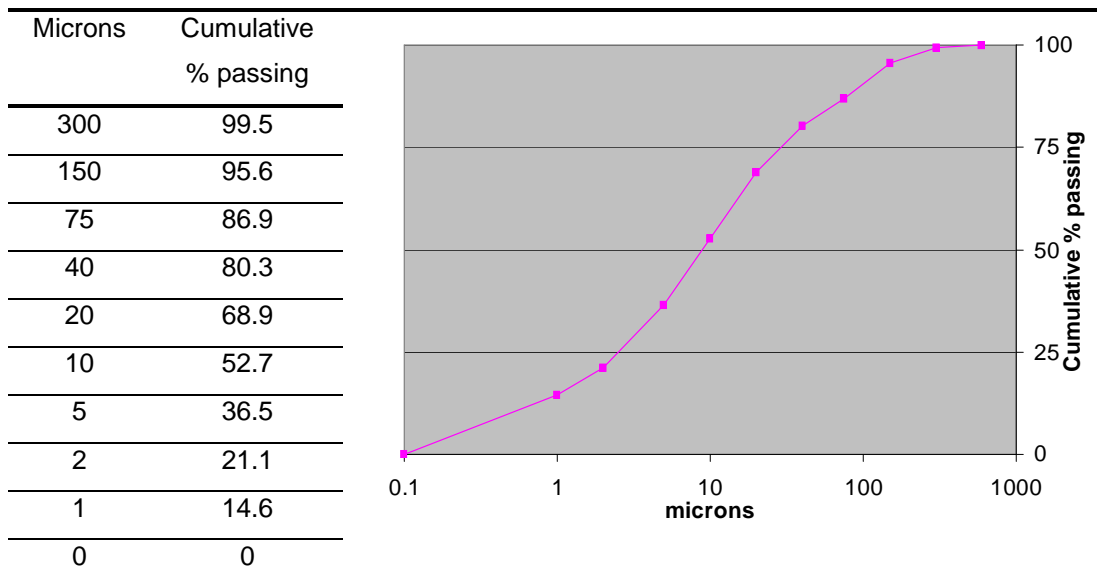


Figure 1 - Granite filter cake particle size distribution.

The paper pulp was a de-inking sludge with contaminants such as As, Cd, Cr, Cu, Mo, V, and Zn. As well as the 40% paper fibres there is also 58 % carbonate (used as brighteners and fillers). The remainder are trace materials such as starch, latex, clays, dyes, Brightening agents, resins, biocides, flocculants, and dispersants.

Results of Laboratory / Pilot product demonstration test-work

Laboratory scale work has been undertaken to assess the material properties of manufactured aggregate made from granite filter cake and clay, Table 2 shows the mixes used. The filter cake and paper sludge were mixed in a planetary mixer and then extruded & kibbled into a rotating drum to produce spherical pellets of 10 - 14 mm in diameter. Once dried these pellets were fired in a rotary kiln at ~1200 °C. The aggregate produced was tested for water absorption and density - two key properties of manufactured aggregates. The sample with 10% clay was produced in larger quantities and then incorporated into concrete to with a water cement ration of 0.42. A control concrete was also produced using Lytag. The compressive strength of this concrete and the lytag control is shown in Figure 2.

Sample	Mix by dry weight	Relative density	Water absorption (% dry mass)	Loose bulk density (Kg/m ³)
01	95 % granite 5% paper	2.23	1.95	1208
02	90 % granite 10 % paper	2.21	2.90	1180
03	85 % granite 15 % Paper	2.1	6.19	1129

Table 2: Mixes of granite filter cake and clay used to produce manufactured aggregate.

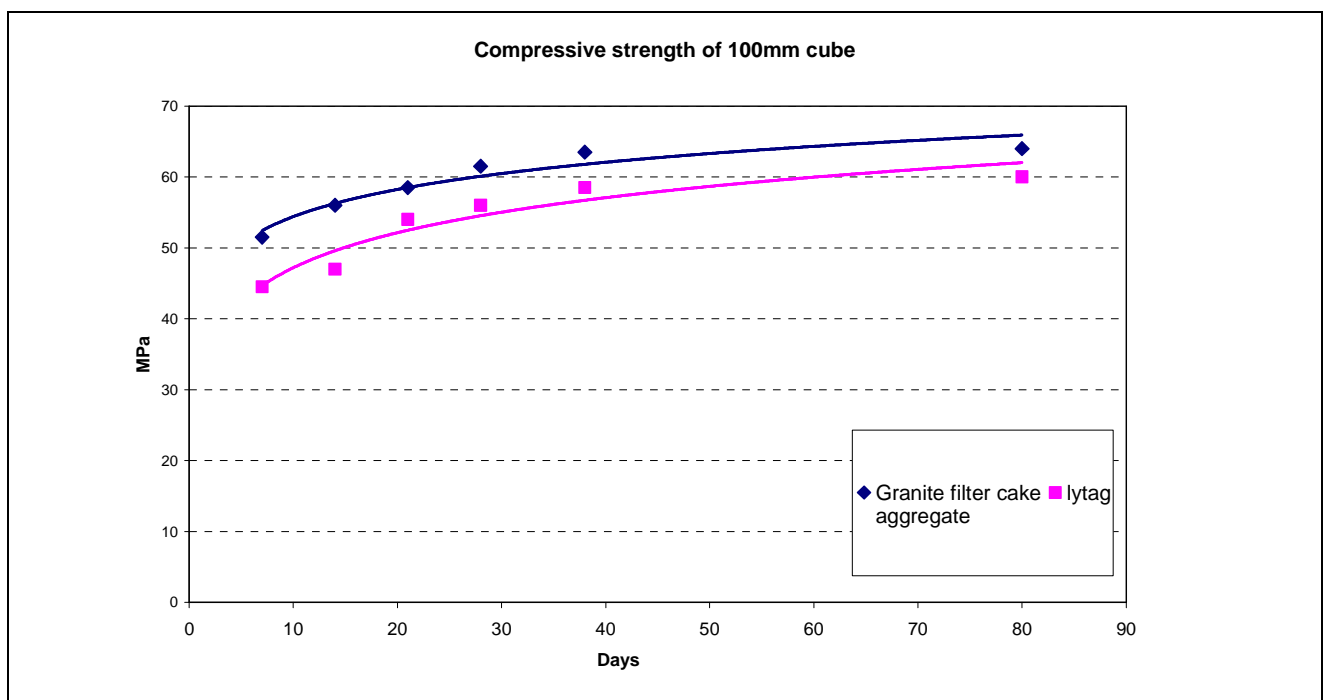


Figure 2: Compressive strength of concrete produced using manufactured aggregate made from granite filter cake and paper sludge



Figure 4: Photograph of aggregate made from granite filter cake washings (bottom) lytag (left) and natural gravel (right)

Conclusions and further work required

In localities where there are large volumes of fine grained quarry fines especially of material under $150\ \mu\text{m}$ the production of manufactured aggregate is a possibility. The aggregate produced is strong has desirable properties. Further applied research would be needed to reduce the primary fossil fuel consumption - lessons could be learnt from the cement industry. If potential sites are found further material based research will enable local materials to be considered that may reduce firing temperature or mineral additions that produce a lighter weight aggregate by bloating during the firing process (7).

References

1. WRAP final report: A new approach to paper mill sludge, March 2007
http://www.wrap.org.uk/downloads/MSP002_Final_Report_April_2007.94f50424.pdf
[access date 23.10.07].
2. Code of practice for landspreading paper mill sludge, the Paper Federation of Great Britain, September 1998 <http://www.paper.org.uk/info/pdfs/landspreadcode.pdf> [access date 23.10.07].
3. Usherton, J. Recycled paper and sludge. *Resource recycling*, 95-100 March 1992.
4. CEMBUREAU "Best Available Techniques" for the cement industry. Brussels, CEMBUREAU, 1999.
5. Wainwright, Barton, Cresswell, Schneider, van der Sloot, Hayes and McKeever 2001. *Final Report Brite Euram project BRST CT98 5234: Utilising Innovative Rotary Kiln Technology to Recycle Waste into Synthetic Aggregate*.
6. Wainwright, P.J., Cresswell, D.J.F, & van der Sloot, H.A. 2002 The Production of Synthetic Aggregate from an Innovative Style Rotary Kiln. *Waste Management & Research* v.20 pp279-
7. Riley, C.M. 1951. Relation of Chemical Properties to the Bloating of Clays. *Journal of American Ceramic Society* v.34/4 p121.