Production & Process Technology

Products
Quarries generally sell a range of products which differ according to the local rock type and the location of the quarry. The products are defined by their particle size grading, based on the lower and upper screen sizes, which represent the smallest and largest particle sizes.

<table>
<thead>
<tr>
<th>Product</th>
<th>Grading (minimum-maximum) mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonstones</td>
<td>45-125 53-180 100-250 45-180 90-180</td>
</tr>
<tr>
<td>Graded</td>
<td>5-40 5-20 5-14</td>
</tr>
<tr>
<td>Railway ballast</td>
<td>29-50</td>
</tr>
<tr>
<td>Single sized</td>
<td>45 28 20 14 10 6 3</td>
</tr>
</tbody>
</table>

Future Technology
Future developments in quarrying technology are discussed in the goodquarry.com Production and Process Technology section. They are likely to be dominated by energy and water use due to the increasing importance of climate change and the increasing cost of energy. Energy efficiency and reduction can be effected through more detailed analysis of energy usage, replacement of high energy consuming plant by newer, more efficient equipment and changes to the material handling and processing routes. Carbon offsetting of industry energy use may become more common with an increase in current tree planting schemes and calculation of carbon equivalent for each product.

Water use will involve more recycling and reuse of process water, increased capture of rainfall and investigation of additional ‘dry’ (or water efficient) processes to replace current ‘wet’ processes.

Recycling of concrete to reuse its contained aggregates is increasing. However, the product generally has a lower compressive strength and bulk density and higher water absorption than primary aggregate due to the cement content. Separation of the cement would enable the production of something closer to natural aggregate.

Summary
There are many ways by which the operation of a quarry can be made more efficient, more productive and less intrusive on the local environment. All stages of the quarrying process should be carefully examined, from initial overburden stripping to final restoration and aftercare. The choice of equipment and operation of crushing equipment can minimise the production of fines, whilst maintaining the required throughput of particular sized products. All energy-intensive processes, such as hauling, crushing and especially drying, should be carefully and regularly examined to eliminate bad practice and encourage savings where possible. Water consumption should be monitored and, if possible, reduced by recycling, reusing and adoption of waterless fines processing. Monitoring of all stages of the process should enable bottlenecks to be identified and the comparative performance of all the separate components to be measured.

The goodquarry.com section on Production and Process Technology has a large amount of information, key findings and summaries to assist operators in improving their quarry’s performance.

Introduction
Virtually everyone connected with quarrying will know of the goodquarry.com website. It has become a well used source of information on a wide range of topical issues ranging from biodiversity to water, air pollution to planning and much more. Now there is a brand new section on Production and Process Technology, written by the British Geological Survey. It contains all kinds of useful information on crushing, screening, washing, etc. including industry case studies. It also has numerous ‘Key Findings’ which give useful information on the process under discussion. The section concludes with a summary of good practice in each of the technologies mentioned below.

Overview
The aggregates industry produces about 214 Mt per year of crushed rock and sand and gravel from over 1500 quarries throughout the UK, plus offshore dredging. Production and processing technology is a key factor in the overall operation. The four main stages in quarrying are preparation by removal of overburden, extraction, processing and finally restoration or reuse.

The methods and equipment used depend primarily on the type of deposit and the source rock being worked. The key factor is whether the material requires crushing before further processing, or just washing and separation. In all cases the overall aim is to use the minimum input (energy, water, manpower, equipment, capital etc) to produce the maximum output of saleable product with the minimum waste and environmental effect.

Extraction
Following removal of overburden by dragline or hydraulic excavator, hard rock aggregates generally require careful blasting to break the rock into small fragments (usually less than 1m across). Excavators load haulage trucks to carry the blasted rock to the primary crusher; alternatively conveyors may be used. Sand and gravel is either worked in wet or dry conditions. Dry working is the most efficient in terms of maximising extraction and it also enables more selective extraction. Where deposits exceed 5 m, dragline excavators are extensively employed; these are robust and efficient at feeding conveyor systems. Where deposits are thinner or more consolidated, hydraulic backhoes are used. Some very unconsolidated deposits, such as dune sands or some glacial deposits may be excavated directly from the face by wheeled front-end loaders. Marine sand and gravel is worked by trail dredging where a suction pipe is pulled across the seabed at slow speed using a specialised dredger. The product, which generally has a very low fines content, is then offloaded at wharves for additional treatment before dispatch.

Crushed rock aggregate quarries tend to be larger, deeper and longer lasting than sand and gravel pits and involve large investments and outputs typically in the range 100,000 to 5 million tonnes per annum (tpa). Sand and gravel pits are usually shallower, sometimes only five or six metres deep. Operations are likely to be shorter term and typically produce 10,000 to 1 million tonnes per annum (tpa), with most in the range 100,000 – 300,000 tpa.
Crushing

Crushing in hard rock quarries is generally carried out in stages (primary, secondary, tertiary etc) using a variety of types of crusher, including jaw, cone and gyratory crushers. The key factors of crusher performance include the throughput per hour, product sizes and shapes, capital cost, amount of fines produced, power consumption, rate of wear of parts and environmental issues (noise and vibration). These govern the choice of crushers for any operation.

The goodquarry.com website now has concise and current information on crushing technology and operation such as that summarised in the table below. Case studies from industry on the effects of changes in crushing equipment or practice can be found in the Quarry Fines and Waste section of the website.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Crusher type</th>
<th>Maximum size mm</th>
<th>Fines %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Gyratory</td>
<td>1000</td>
<td>10-20</td>
</tr>
<tr>
<td></td>
<td>Cone</td>
<td>250</td>
<td>4-5</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Jaw</td>
<td>100</td>
<td>5-30</td>
</tr>
<tr>
<td></td>
<td>Impact</td>
<td></td>
<td>20-40</td>
</tr>
</tbody>
</table>

Type: Gyratory, Cone, Jaw, Impact

Classifying and screening

Classifying and screening is used to separate particles into different size fractions. Screening uses a mesh with holes of set size for the required product. Static and dynamic classifiers can also be used to separate material by air currents or by centrifugal force in a cyclone. There is information on all these processes on the goodquarry.com website. Key findings relating to classifying and screening include:

- The most likely use of air classification in the UK quarrying industry will be for the removal of material finer than 63 microns from fine aggregate of quarry fines to produce manufactured sand. This is already the case in some quarrying operations in the USA.

Drying

Drying is sometimes carried out to facilitate further processing of feed material, to improve the handling of products and reduce the transportation costs. However, it is an energy-intensive, expensive, operation due to the high latent heat of vaporisation of water and the inherent inefficiency of using hot air as a drying medium.

The goodquarry.com website discusses the use of the most commonly used types (rotary dryers and fluidised bed dryers). These are primarily used to dry asphalt plant raw material.

Key findings include:

- Systems for recovery of heat are used in kilns but not with dryers; this leads to poor thermal efficiency and a perception that drying is a prohibitively expensive option.

Washing

Washing is used to remove unwanted silt, clay and dust adhering to the rock fragments and sand particles. It is also used to classify or separate materials by variations in their size, shape or density. A variety of equipment is used, including hydrocyclones, scrubber barrels, log washers and sand screws, depending on the material and the intensity of washing required. The water content of the product is then reduced or removed by settling, filter presses or drying.

The goodquarry.com website describes the different types of washing equipment and has a series of ‘Key Findings’ relating to their use. For example the section for thickener and belt presses has the Key Finding of installing a thickener generally reduces the need for four or five silt lagoons down to one lagoon. Installing a filter press may eliminate the need for a lagoon at all.

There is also a comparison of belt and press filter systems.
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Key findings listed on the website include:
- **Cone crushers** rely on a full chamber (‘choke’ feed) to give the best results. Failure to ‘choke feed’ results in lower quarry fines production but also reduced capacity, poor product shape and uneven crusher liner wear.
- **Jaw crushers** are mainly used in primary crushing where the amount of fines produced is typically less than 5%.
- **Cone** crushers are mainly used in secondary and tertiary roles.
- **Impact** crushers tend to be used where shape is a critical requirement and the feed material is not very abrasive. The quality of these products makes them ideal for use in some highly specified roadstone and concrete aggregate applications.

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<tr>
<td>Primary</td>
<td>Gyration 1000</td>
<td>10-20 1-7</td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td>Cone 250</td>
<td>4-5 30</td>
<td></td>
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Introduction

The goodquarry.com website section on Quarry Fines and Waste has been extensively revised and updated. Quarry fines and wastes are a largely unavoidable by-product of the extraction and processing of aggregates. They form a significant proportion of current quarry output. (see table below). They are defined as wastes because no market currently exists for them, but unlike many other wastes they are generally inert and non-hazardous. Materials that may be classified as quarry wastes include overburden (although this is frequently used in restoration) and interburden (material of limited value that occurs above or between layers of economic aggregate material) and processing wastes (non-marketable, mostly fine-grained material from crushing and other processing activities.)

Good practice calls for the minimisation of waste and fines production, although recent legislation has conflicted with this aim. Operators should also develop methods for the mitigation of any adverse effects on the environment and local communities by screening and careful management of waste production, movement and final use.

Mineral Planning Authorities

Good practice means that MPAs should consider the need to agree or specify planning conditions relating to:
- The location of waste heaps
- Controlling of leachate and run-off
- The height and shape of waste heaps
- Surface treatment, e.g. vegetation
- Progressive restoration
- The duration of temporary heaps.

Operators

Good practice means that operators should try to:
- Minimise the production of waste
- Find a use for waste, e.g. landscaping
- Site waste heaps within workings
- Use waste for progressive restoration
- Site waste heaps having regard to potential effects upon:
  - The landscape
  - Groundwater
  - Surface watercourses
  - The flood regime.

- Encase contaminated waste so that it cannot escape. Store top- and sub-soil and overburden with a view to ultimate restoration.
- Use wastes positively. If they cannot be hidden then they should be landscaped and vegetated as soon as possible.

Estimated production of aggregate, quarry waste and quarry fines in the UK

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Saleable aggregate</th>
<th>Quarry waste</th>
<th>Quarry fines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone</td>
<td>10.0</td>
<td>1.1</td>
<td>3.3</td>
</tr>
<tr>
<td>Limestone</td>
<td>67.3</td>
<td>7.5</td>
<td>18.8</td>
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Summary

goodquarry.com contains much useful information for both operators and mineral planning authorities on the subject of quarry fines and waste which is summarised below.

Contacts

Clive Mitchell
Industrial Minerals Specialist
British Geological Survey
Keyworth, Nottingham, NG12 5G
United Kingdom
Tel. +44 (0) 115 936 3257
Fax. +44(0)115 936 3520
Email: cjni@bgs.ac.uk

Further Information

www.goodquarry.com
www.mineralsuk.com
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