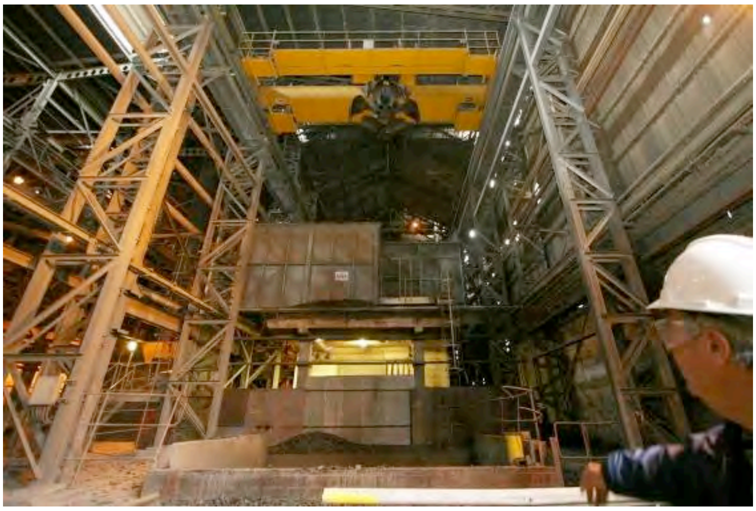
# Inside Manufacturing Enterprise (IME)

# Case Study



- The aim of this case study is to give teachers a resource to use when preparing for or following up a visit to **Lafarge Cement UK-Cauldon Works** a company involved in the IME regional visit programme. This programme was developed to give schools access to some of the best manufacturing and engineering companies in the West Midlands.
- It can also be used as a stand-alone teaching aid.
- The case study supports the teaching of **Manufacturing & Product Design, Systems and Control, Land Based & Environmental Diploma courses.**

Case study prepared January 2009 by Staffordshire STEM Centre with the help and support of Lafarge Cement UK- Cauldon Works, Staffordshire

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**Teachers notes:**



**Section 1. Cement- an overview**

Cement is used to make concrete and mortar, which is like a sort of 'glue' which holds blocks and other building materials together. Man's first building glue was wet clay which sets hard as it dries and holds the stone in place. The Egyptians and Romans discovered how to make a stronger building glue than clay by using limestone, which they burnt and mixed with gypsum.

The pyramids are one of the oldest examples of blocks held together by a cement-like material. Many new buildings were built in Britain in the 19th Century and there was strong demand for an improved building glue, or cement. In 1824, the first 'Portland cement' was made. It is called this because, once set, it looks similar to Portland Stone. Cement is used to make concrete and mortar.

Cement is the most versatile building material in the world. It is the main material on the construction of buildings and structures, from homes to hospitals, transport links to patios.

Materials used in building a house which are made with cement include: Roof tiles; Screed; Render; Concrete blocks; Mortar; Concrete; Foundations and Paving. The average house requires six tonnes of cement for its construction.

Over 80% of cement is used in making concrete. Concrete gives buildings thermal mass and insulation which leads to significant savings on heating and cooling equipment and cuts energy costs. Concrete is one of the most environmentally friendly and cost effective construction materials. It takes less energy to produce a tonne of concrete than many other building materials.

Major projects completed with cement made at Cauldon include: Toyota car factory, Burnaston; Michelin Head office, Stoke; The Potteries shopping Centre; Derby County, Stoke

City and Manchester United football stadiums and an aircraft apron at East Midlands Airport for DHL's sorting facility.

The Government regulators – The Environment Agency in England and Wales; Scottish Environment Protection Agency in Scotland; and the Industrial Pollution and Radiochemical Inspectorate in Northern Ireland set high environmental standards for manufacturers to meet. They use Environmental Management Systems to identify and set out procedures to manage any possible or actual impacts their operation has on the local environment. These include:

- Gaseous emissions to air
- Discharges to water
- Waste management
- Noise and vibration
- Land management/visual impact
- Energy consumption
- Water use
- Transport and distribution

In the case of emissions to air, these are checked using continuous monitoring equipment.

Lafarge UK- Cauldon Works uses alternative fuels to help maintain their environmental performance which also in some cases helps to reduce emissions. For example, using tyre chips to replace some of the coal and coke has reduced emissions of oxides of nitrogen by around 20 per cent.

Making cement requires a great deal of expensive energy, particularly for heating the raw materials. Traditionally this has been achieved using coal. As energy represents about 30 percent of the costs at most of Lafarge UK works, reducing these bills by using cheaper alternative fuels will help to improve their competitive position. This is particularly important as cement makers in other European countries use alternative fuels. Zero fuel costs have been achieved at some of the plants in these countries.

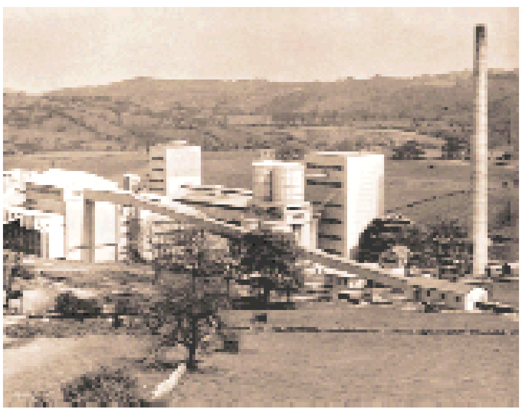
Cement has an important role in the increasing recycling of demolition debris. Some demolished materials that would have been dumped are now crushed on site using a mobile crusher ready to be recycled as aggregate. This recycled rubble is combined with cement to make new concrete. This helps the environment by reducing the need to extract fresh aggregates; reduces transport costs if the rubble is used on site and reduces the need to send demolition debris to landfill.

Cement manufacturers are part of the chemical industry manufacturing sub sector.

## Section 2. Overview of Lafarge Cement UK

### a) History

From this



**The company**

to this

The Blue Circle brand was introduced in 1928. In 2001, Blue Circle Industries was taken over by the Lafarge Group to become part of the world's leading producer of cement and building materials. The name was changed to Lafarge Cement in early 2002, but kept the famous Blue Circle cement brand. When the Cauldon Works began operating in 1957 it was the first of a new generation of semi-dry ‘Lepol’ or wet process works in the UK capable of making 200,000 tonnes of cement a year which expanded to 600,000 tonnes in the 1960’s.

Lafarge was started in France and is the number one manufacturer of cement in the world. Sales of cement and cement based products makes up 57% of all sales. Lafarge now operates in 46 different countries and has 45,481 employees working within the cement divisions. It is one of the top 100 most sustainable companies in independent rankings.

**b) Site details and developments**
An investment of over £20 million in the last 5 years at the Cauldon Works has improved environmental performance and increased efficiency. The annual cement production capacity has risen to around one million tonnes of cements each year.

In 1963 550 people were employed. Increased automation has reduced this number to just over 150 people at the Cauldon Works.
For the last 13 years over 2,000,000 scrapped tyres are used a year as fuel, reducing emissions and saving fossil fuels. The rubber from the tyres is made into chips or shreds to make them easier to handle and burn. Old tyres are very hard to dispose of in an environmentally friendly way. A second alternative-carbon neutral fuel, Processed Sewage Pellets (PSP) has been used since 2004 and permission has now been gained to trial use of other sustainable fuels- waste-derived Recovered Fuel Oil and also Solid Recovered Fuel (SRF). By using Solid Recovered Fuel (SRF) Lafarge can offer a local solution to a local waste problem. See Figure 1.

Environmental effect is a major focus and the Works operates an environmental management system registered under the European Union’s Eco-Management and Audit Scheme to track and ensure continued improvement in environmental performance. Raw material reserves of limestone based on the current rates of production will last for another 90 years and shale 20 years.

**'Bio-mass'** is a term for vegetable matter used as a source of energy. It has been used for hundreds of years for instance in wood fires.
**'Carbon Neutral'** -biomass energy sources are described as 'carbon neutral' because the carbon dioxide released during the use of the biomass as a fuel is cancelled out by the carbon dioxide used by the plants when they grow.
Fuels which have a high biomass carbon neutral content and therefore help to limit climate change include:

- Processed Sewage Pellets (PSP) as used at the Cauldon Works. (Processed sewage pellets are made from sludge that remains after sewage treatment and can offer an alternative fuel which has a similar energy value to coal)
- Meat and Bone Meal (MBM) (permitted at their Aberthaw plant in South Wales, permitted and being used at Hope Works in Derbyshire)
- Coffee husks and palm kernel shells
- **Recovered Fuel Oil** is made up of waste oils which come from everyday activities such as car servicing and maintaining lift systems. These oils are collected and filtered for use as a fuel. The UK generates more than 400,000 tonnes of waste oils a year. That is equivalent to seven litres for every man, woman and child in the country. RFO is already used extensively around the world.
- **Solid recovered fuel** - a processed form of domestic waste. SRF is made from the biodegradable elements of household waste, once all other recyclable constituents such as paper and plastics have been removed.

**Figure 1**

### c) Product and Markets served

Cement produced at Cauldon Works is for distribution to UK customers mainly in the Midlands and northern Home Counties. Recently some of the Mastercrete cement has been sent to Ireland and some of their cements are blended at their Barnstone works and then sent to places such as Hong Kong and USA. A range of Blue Circle Portland cements are produced which can be used for civil engineering, building applications, ready-mixed concrete and concrete products. The level of production of cement throughout the year varies due to market influences and seasonal variations in demand - for example, people use less cement in the winter when ground conditions are likely to be poor.


Distribution area showing the paper and waterproof recyclable plastic bags with the Blue Circle brand

### d) The Processes

The kiln runs continually unless there is a major breakdown or shutdown situation.  The raw meal grinding depends on the stock levels of raw meal that are needed to be fed into the kiln so there may be some downtime from this piece of plant, but generally the grinding mill will run continuously to provide feed for the kiln.  There is approximately 3500 tonnes of raw meal storage.

Cement Grinding is run in what are called ‘campaigns of product’ to ensure orders for the next three days can be met.  Each grinding campaign has to be longer than two hours to ensure a consistent quality of product but can last for 5 days if the demand for the product is there and there is enough silo storage space.  Cement mills operate more on a batch process than a continuous process.

### Quarrying and Raw Material Preparation

Limestone and shale are the main raw materials used to make cement at Cauldon Works, these are dug from separate quarries close by. The rock is blasted two to three times a week. Each blast will loosen around 20,000 tonnes of stone which supplies the works for up to four days. The blasted limestone can vary in size. It is loaded into dump trucks and taken to the rock crushing system.

Stone on the conveyors

stockpiles

Primary crushing reduces the stone to 300 millimetres in size. The second stage reduces it to less than 100 millimetres. The crushed rock is then transported by conveyor belt to a stockpile.

The second material, shale which is much softer than the limestone does not need to be blasted. Large motor scrapers or excavator and dump trucks collect shale during the dry summer months. A stockpile is built up of up to 100,000 tonnes which will supply the Works for up to six months. This is also crushed and taken by conveyor to the works as it is needed.

The chemicals in the raw materials can vary from one quarry to another so they are analysed regularly. This helps to ensure the raw materials are used in the right mix or ratio to give the chemical balance needed to make a consistent, high quality cement. The chemicals in cement consist mainly of calcium oxide, silicon oxide, aluminium oxide, ferric oxide and sulphate. The raw materials are ground together in the raw mill, a four metre revolving table with steel rollers pressing down on it. The fine powder this produces is called Raw Meal. The raw meal is then pumped into blending silos where it is mixed and analysed before being stored.

Raw material milling

To help reduce waste and dust, a wet process or ‘Lepol’ process has been developed that mixes the crushed materials with approx 10-14 % water to make slurry. The slurry is then formed into pellets of 2.5mm to 5cms in size. The pellets are then dried and fired in the kiln to make clinker.

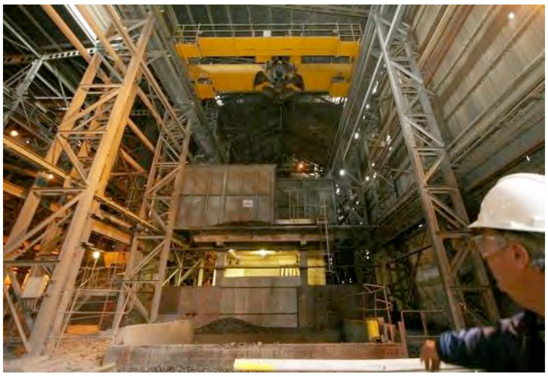
**Pre heaters and kilns**

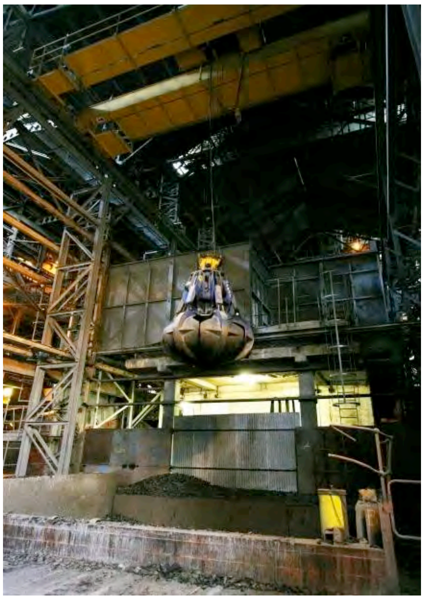
To get to the kiln, the raw meal must first pass down the pre-heating tower. As it descends, the powder is heated by hot exhaust gases, which rise up through a series of cyclones helping to heat the meal evenly.

Pre heating tower

The final stage of the tower is the 'precalciner', where powdered coal and 50mm rubber tyre chips are added to keep temperatures in excess of 850° Celsius.


Coal supply


Tyre chip store


Tyre chip store

From the precalciner, the raw meal enters the kiln. This is a single 58 metre long, four meter diameter rotating kiln which is heated by a flame of around 2,000$^0$C. Steel melts at around 1,370$^0$C so the flame temperature is very high. The fuels used are coal and processed sewage pellets (PSP). As the kiln slowly rotates, the raw meal moves down the kiln to reach the burning zone where its temperature rises to 1,450$^0$C. This is hotter than molten lava. The meal is converted into nodules (lumps that are roughly round in shape) of hydraulic calcium silicates, called clinker. The heat is vital as at this temperature the raw material reacts chemically to form the cement clinker. When the clinker leaves the kiln it passes over cooling grates to reduce the temperature to 100°C. This is then stored.

**Grinding process**

A small amount of gypsum (calcium sulphate or plaster) is added to the clinker in the cement mill and then ground up. Some of the gypsum comes from electricity power stations as a bi-product of removing sulphur from the flue gases. A fine grey powder is produced which is the cement. The gypsum helps to control the setting time of the cement. This is then stored in the cement silos.

**Controlling the process**

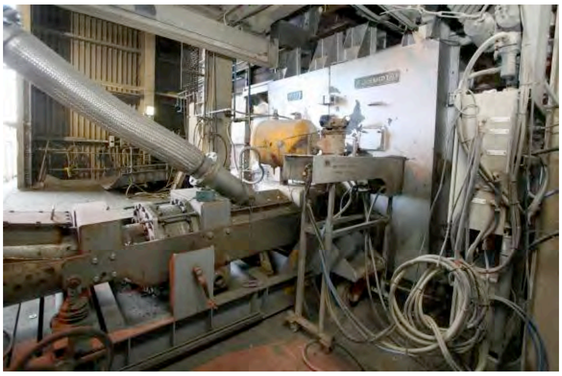
**Process Team**

The Process department measures how the process performs. This is to ensure the site is getting the maximum efficiency from the plant, meeting the required quality requirement with the lowest power usage. Oxygen, temperature and airflow measurements are the typical measurements taken all through the process. The results from these measurements allow the Company to compare the results against Company Best Practice procedures or new targets that may be set. The department will discuss any improvements with the production and maintenance teams to put forward corrective actions if required to reach the set target.

Oxygen measurements check to see if there any leaks within the process which is allowing false air or unwanted air into the process. This extra air requires more fan power to pull the air through the system and decreases the power efficiency.

Samples are also taken from each grinding process. The raw meal, coal and cement and size analysis is carried out to check the grinding efficiency and grinding size. From these results decisions can be taken relating to how well the classifier (size regulator) is working and if it requires speeding up or if the vanes require resetting.

Silos



Sensors and controls

Thousands of sensors around the plant send information to the computer systems in the central control room helping the operators to constantly monitor and adjust every stage of the process. The sensors around the plant measure temperature, weight (as in tonnes per hour) on conveyor belts, pressure and suctions all around the plant and flow measurements of the gases in the process.

These measurements show up on the control panel so the control room operator is aware of the conditions in the process at any time and can alter them accordingly.

The environmental impact on air, water, land and transport is closely monitored. All operations are regulated by the Governments Environment Agency and the systems and operators also monitor emissions from the process. A bag filter and heat exchanger has been installed on the clinker cooler exhaust. The bag filter contains over 1,000 fabric bags which makes a physical barrier between the gases from the process and the atmosphere. The dust in the exhaust gases is trapped by the filter bags This cuts dust emissions from that part of the process by over 95%, cutting emissions by more than 100 tonnes of particulates (dust) a year.

Water samples are also taken at certain times so the site can monitor that the PH quality of the water is acceptable for water leaving the site via drainage systems that discharge into the river. Oil and water separators are also in use to aid this control of water quality.

**Maintenance**

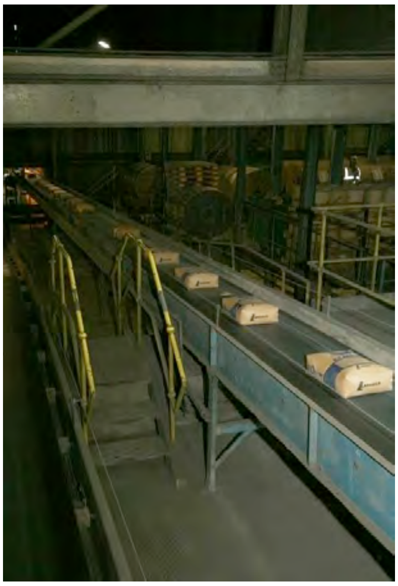
Over a long period of time the site has built up a preventative maintenance programme.  This involves Inspectors going around the plant carrying out inspections.  Any corrective work observed during this inspection is then logged onto a computer driven maintenance system as an urgent requirement. This information is called a works order and is then looked at by the planners.

A maintenance plan is then scheduled for the following week or the next planned ‘stop’ for a given piece of equipment. At the same time the planners check that they have the spare parts in stock or order them if necessary, so that they can complete the works order. Records have been kept over the years so the department knows when they need to change certain pieces of equipment. For example, bearings, due to wear rates. These work orders are issued by the maintenance system at a given time and then given to the mechanical or electrical engineers to carry out the work required.

Each week there is a ‘scheduling’ meeting where the proposed pieces of plant required are agreed by all departments. Then any works orders outstanding will be completed during the agreed ‘stop’.

**Packaging and distribution**

Paper has always been the traditional packaging material (recently with a waterproof membrane) but the company now also packs cements in waterproof recyclable plastic bags. Most of the cement produced is distributed in bulk using 30 tonnes cement road tankers based at the works. These deliver cement to ready mix concrete companies and concrete products’ manufacturers. Pallets carrying more than five million bags every year go to builder’s merchants and DIY stores. To meet demand these operations run 24 hours a day 7 days a week.  Cement bags are restricted to 25Kgs in size to help reduce back injuries.



Packaging

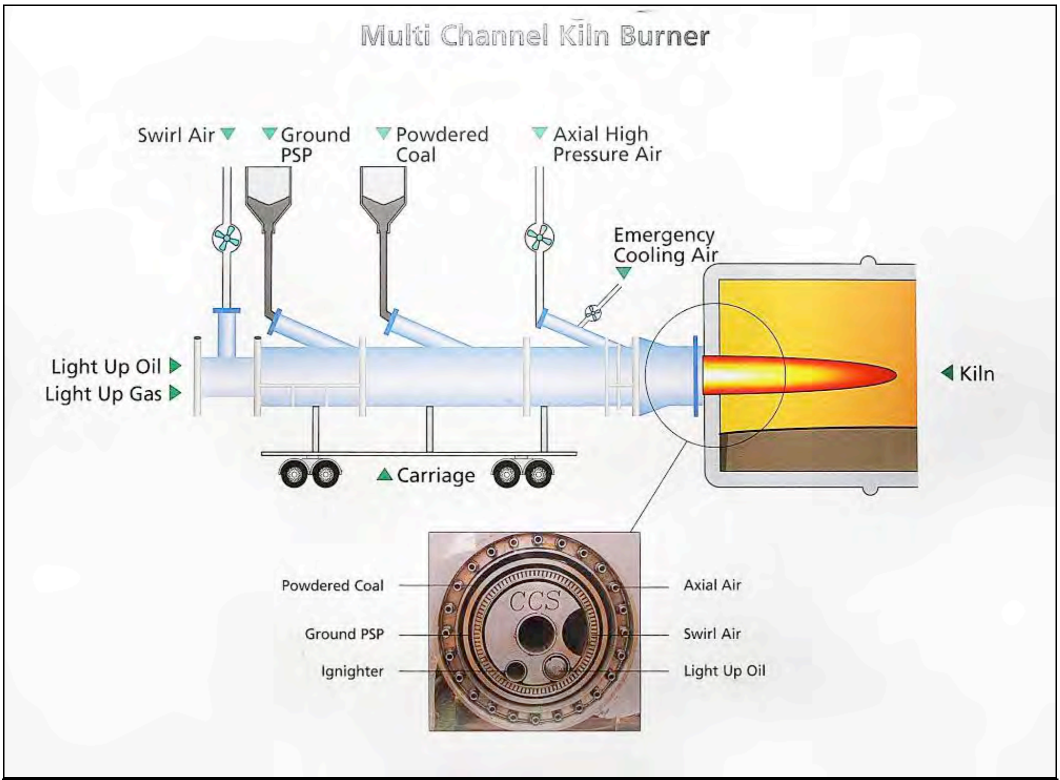
Packaging and Distribution

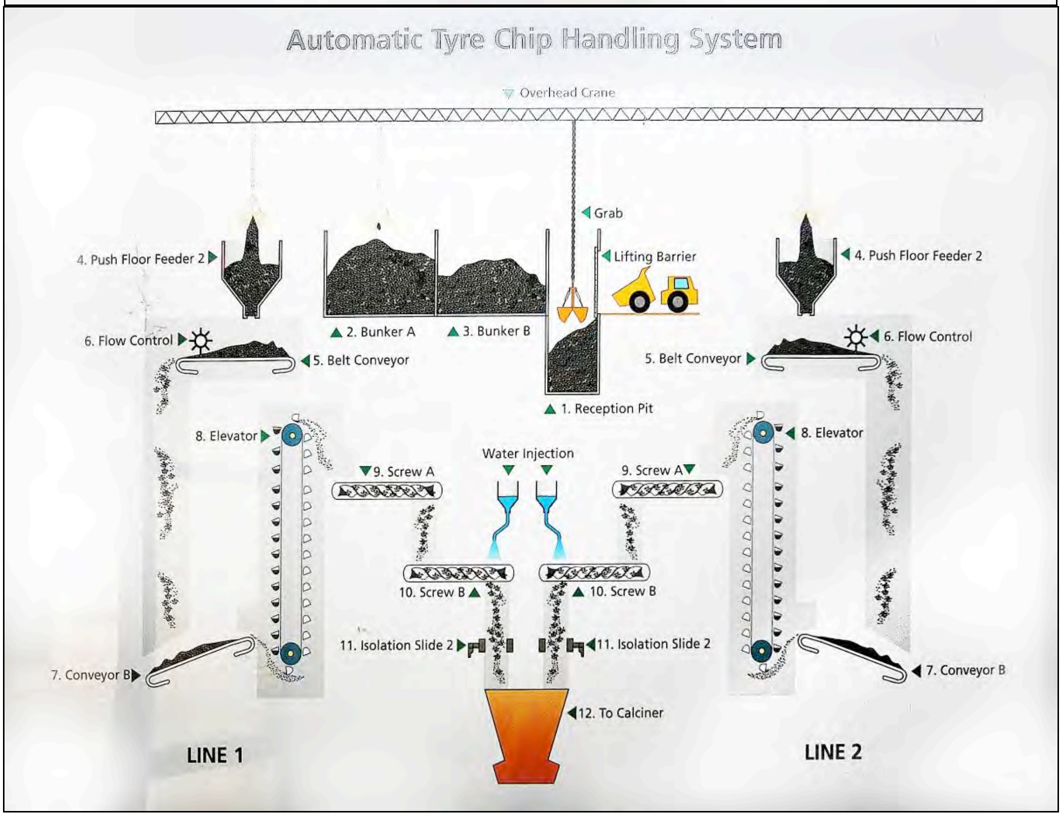
**Hazards**

Cement products are strongly alkaline and need to be handled carefully. When cement comes into contact with moisture a chemical reaction begins that can cause burns to the skin. If cement powder got into the eyes these burns would be very painful and severe. Cement products can also cause the skin sensitisation known as dermatitis.

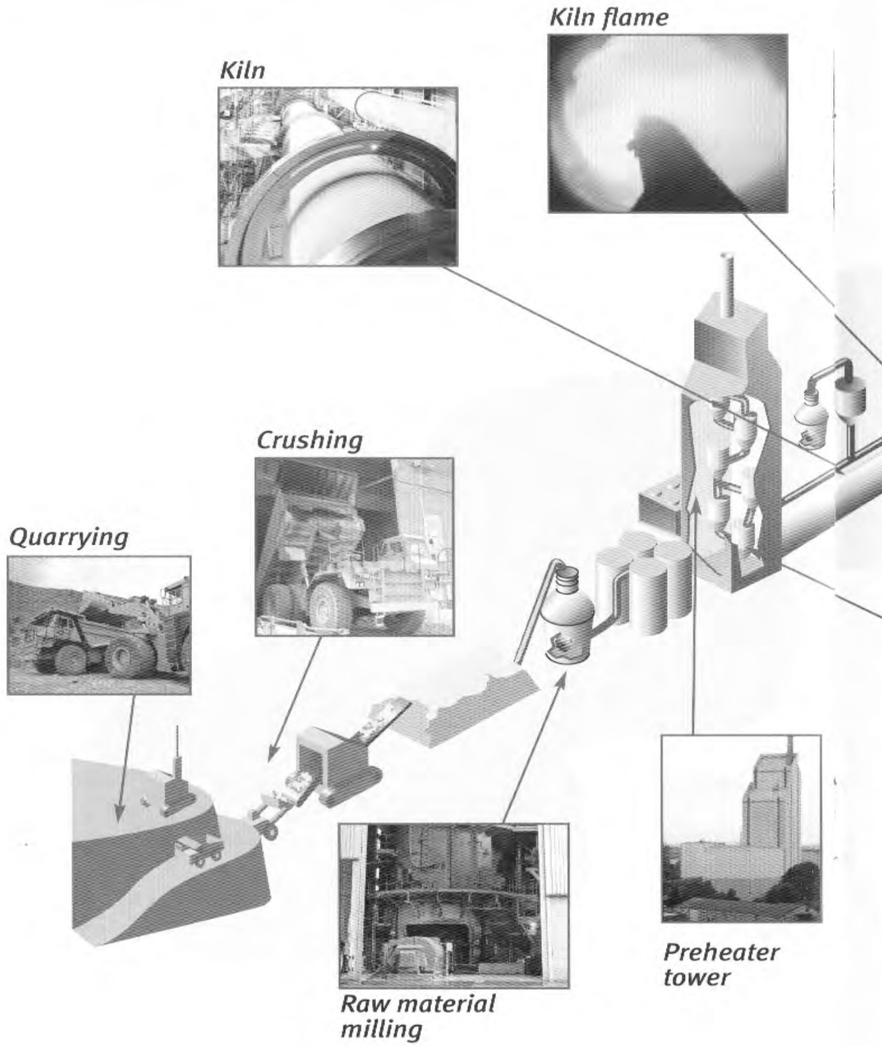
**e) Diagrams showing the cement making process at the Cauldon Works site**

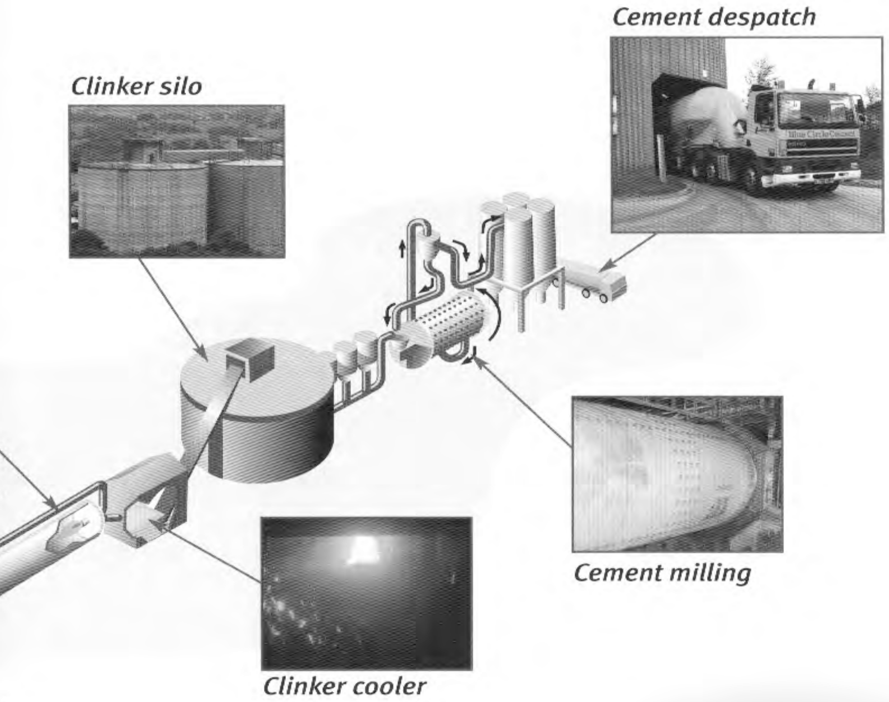
The diagrams below show the Multi Channel Kiln Burner and the Automatic Tyre Chip Handling systems. The diagrams on pages 11 and 12 provide a clear overview of the cement making process.


Multi Channel Kiln Burner
Swirl Air
Ground PSP
Powdered Coal
Axial High Pressure Air
Emergency Cooling Air
Light Up Oil
Light Up Gas
Kiln
Carriage
Powdered Coal
Ground PSP
Ignighter
Axial Air
Swirl Air
Light Up Oil
CCS


Automatic Tyre Chip Handling System
Overhead Crane
Grab
Lifting Barrier
4. Push Floor Feeder 2
4. Push Floor Feeder 2
2. Bunker A
3. Bunker B
6. Flow Control
6. Flow Control
5. Belt Conveyor
5. Belt Conveyor
1. Reception Pit
8. Elevator
8. Elevator
Water Injection
9. Screw A
9. Screw A
10. Screw B
10. Screw B
11. Isolation Slide 2
11. Isolation Slide 2
7. Conveyor B
7. Conveyor B
12. To Calciner
LINE 1
LINE 2

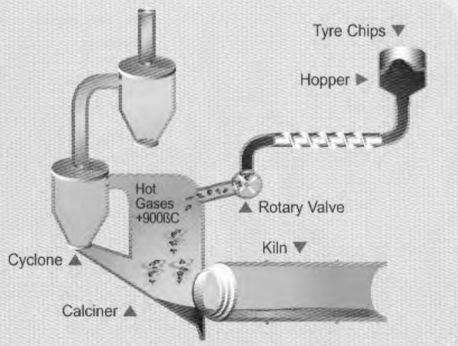
## Diagram showing Cauldon cement making process




### *Tyre chip feed system*

Tyre chips are used as a fuel to heat the raw materials and begin the chemical reaction needed to make cement clinker before they enter the kiln. The tyre chips are fed from a hopper into the precalciner at the foot of the preheater tower, where the raw material enters the kiln. They combust there in temperatures of over 900°C.



## Section 3. Career Paths

Jobs at Lafarge UK Cauldon Works range from process operations and engineering to distribution and chemistry. Most posts are for day time workers. Over 75% of employees have gained skills and qualifications through the company's apprenticeship scheme and NVQ courses.

A 'competency' profile exists for each job with the company. This competency profile has three different levels. In each level it details the skills and academic qualifications that are required to be achieved in a given timescale for the given role.

Employees have a yearly staff appraisal system during which the competency profile can be discussed. This can involve an employee requesting the training required for the next level. Career interviews can also be requested with local and / or head office personnel in order to progress the next career move an individual would like, or to investigate what other potential career paths are available in the business.

Details on careers in quarrying can be found in the Quarry Products Association website.

http://www.qpa.org

## Section 4. Useful website links

http://www.technologystudent.com/ - A design and technology site which contains numerous information sheets and exercises to enhance study, the understanding and teaching of Design and Technology

http://www.bbc.co.uk/schools/gcsebitesize/design/ -revision notes for design and technology, including systems and control

http://www.lafargecement.co.uk/default.asp?skipCheck=true - Lafarge Cement Cauldon website

http://www.lafargecement.co.uk/site_homepage/default.asp - Lafarge Cement website

http://www.lafargecement.co.uk/home_frame/main_content/frameset_pdf_popup.asp?pdf=../../pdfs/works_locations/works_locations_cauldon.pdf Lafarge Website-Company guide

http://www.lafargecement.co.uk/home_frame/main_content/frameset_pdf_popup.asp?pdf=../../pdfs/quality_policy/quality_policy.pdf-Lafarge - Quality Policy

http://www.qpa.org - Quarry Products Association-the trade association for aggregates and quarry products industry. Its Youth Zone and Careers Sections particularly are useful

http://www.cementindustry.co.uk/cement/education.aspx -British Cement Association-excellent education section- **includes a virtual tour of a cement works and quarry**

## Teachers Notes

### Section 5. How to use this case study

This case study is intended to support teachers and students, particularly in Key Stage four when studying **manufacturing, systems and control and product design**.

Ofsted recognises the value of learning outside the classroom as being most successful when it is an integral part of curriculum planning and closely linked to classroom activities. When this case study is used with students to prepare and follow up a visit to Lafarge Cement it can enrich the experience and help embed the learning. It can also help to achieve the goals within the '*Learning outside the classroom'* manifesto.

As a standalone resource it will give a valuable insight for students into the quarrying of raw materials, processing and control, packing and despatch, chemical compounds/constituents and reactions of cement manufacture. It also provides an indication of the relevant student learning outcomes and projects within **manufacturing, systems and control and product design GCSE's** it can help students achieve.

From 2009 some students will be starting the **Manufacturing and Product Design Diploma.** This case study along with the company visit will help to reinforce their skills, knowledge and understanding of Manufacturing and Product Design by giving a real context for the work.

### Section 6. How to arrange a visit to the company

A typical visit to Lafarge Cement, ideal for Year 11 and Year 12 students lasts approximately 1 hr 40 minutes and includes:

- Introduction and Health & Safety talk
- Tour of Quarry and Manufacturing Site
- De briefing

Sensible footwear (no trainers, sandals) is required. Trousers must be worn. 4 weeks notice is required.

To arrange a visit contact Staffordshire STEM Centre;
Staffordshire STEM Centre
Room C146
Faculty of Computing, Engineering & Technology
Staffordshire University
Beaconside
Stafford
ST18 0AD

Tel: 01785 353348
Fax: 01785 353363

Email: stempoint@staffs.ac.uk Website: www.staffsstem.co.uk

**Photographs:** If you would like copies of any of the original photographs which were taken during a school visit to Lafarge Cement UK- Cauldon Works in November 2008 as a classroom resource, please contact the STEM Centre.

## Section 7. Learning Outcomes

This case study can support the following subject criteria:

| Subject | Learning Outcomes | Knowledge & Understanding of |
|---|---|---|
| GCSE Manufacturing | Gain an understanding of the contribution that manufacturing makes to society and the economy<br><br>Develop an awareness and appreciation of commercial and industry issues, and of emerging technologies, in the context of manufacturing | **Production details and constraints:**<br>Materials and components<br>Available technology<br>Health, safety and hygiene<br>Quality standards.<br>**Materials, components and/or ingredients and their constraints:**<br>Their properties, characteristics and performance<br>**New technology used in and by the manufacturing industries:**<br>Systems and control technology, to organise, monitor and control production.<br>**Impact of modern technologies:**<br>When manufacturing a product<br>Stages in manufacturing a product<br>**Manufactured products:**<br>Investigate a variety of manufactured products that use modern technology.<br>**A range of manufacturing industries:**<br>Research and analyse existing products, materials and manufacturing processes and market needs |
| AS/A Level Design & Technology Product Design | The use of technology in designing and manufacturing processes<br>Health & safety issues<br>Quality Assurance<br>Manufacturing Processes<br>Manufacturing Systems & Controls<br>Manufacturing Methods | The protection of the worker/operator<br>The protection of the user/customer<br>Quality control<br>Quality assurance<br>continual flow<br>automated production<br>The implications of these industrial production processes/ procedures<br>Appropriate manufacturing methods that take into account the properties of different materials<br>The effects of the manufacturing process on the properties and structure of materials preparation of materials<br>Processing of materials<br>Sequencing and timings of manufacturing stages<br>Monitoring, testing and tracking during production<br>Processes, materials and components used to manufacture products from differing materials<br>Recycling and green issues in product and systems design<br>Programmable control devices – integrated with electronic or mechanical or pneumatic components to provide efficient control of systems |
| Manufacturing and product Design- High Level Diploma | Science and Design 2.3B | Careers, pre entry and on the job training |
| Manufacturing and product Design- High Level Diploma | Science and Design 2.4A | Good manufacturing design and development<br>The importance of research, design and development<br>Factors affecting the design and manufacture of a product (for example cost, concern for the environment or new developments in materials) |
| Manufacturing and product Design- High Level Diploma | Business and Enterprise 2.4B | Analyse whether the features and benefits of a designed product meet the clients' needs |
| Manufacturing and | Business and Enterprise | Materials, scientific processes and principles used to increase |

| | | |
|---|---|---|
| product Design-<br>High Level Diploma | 2.5A | productivity and sustainability<br>Testing analysis and measurement methods<br>Chemical, biological and physical properties |
| Manufacturing and product Design-<br>High Level Diploma | Business and Enterprise<br>2.5B | Scientific terminology, symbols and units<br>Material preparation in line with health and safety and organisational guidelines |
| Manufacturing and product Design-<br>High Level Diploma | Production systems<br>2.6A | Different processes and systems used<br>Maximising efficiency and effectiveness through use of technology<br>What might happen if health and safety legislation and guidelines are not followed<br>Control procedures used for the safe use of tools, equipment and plant |
| Manufacturing and product Design-<br>High Level Diploma | Production systems<br>2.6B | Critical control points needed to maintain product quality<br>Measuring equipment used to monitor quality of a product<br>Apply control techniques safely in line with relevant legislation and guidelines |
| Manufacturing and product Design-<br>High Level Diploma | Production systems<br>2.7A | Product design specifications, standard operating procedures and integrate operations<br>Health and safety and environmental guidelines<br>Maximising efficiency (for example, lean manufacture and maintenance systems)<br>Environmental impact and cost of remanufacture, recycling materials and safe disposal of waste materials |
| Manufacturing and product Design-<br>High Level Diploma | Production systems<br>2.7B | How products and materials are packaged, transported and stored<br>Standard operating procedure in line with specification and agreed tolerances (for example, setting up or calibrating equipment) |
| Environmental and Land-Based Studies Diploma | Foundation level | Understand how the environment is used in the modern world<br>Discover the value of sustainable use and management of resources |
| Environmental and Land-Based Studies Diploma | Higher Level | Gain a broad understanding and working knowledge of the availability of natural resources |

**We are extremely grateful to Lafarge Cement UK –Cauldon Works for their help and support in the preparation of this case study**