Portland cement: 200 years of building for the future

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Contents

Introduction

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Diana is MPA's Executive Director for Energy and Climate Change, Cement and Lime. She leads MPA's work on the transition to net zero which includes innovation projects to improve products and processes for the net zero transition. She is a key influencer on policy and regulations relating to cement and lime production and use, chairs a working group of the Emissions Trading Group (ETG) and sits on the ETG Board.

She also represents cement and lime in Government-led and other expert groups considering carbon capture, usage and storage and UK carbon budgets.

2024 marks the bicentenary of the invention of Portland cement by Joseph Aspdin, an English bricklayer, businessman, inventor, and stonemason. The patent granted on 21 October 1824 set not just the UK, but the world, on a new construction journey.

The importance of Portland cement to the economy, society and our way of life cannot, and should not, be underestimated. The ability of cement to bind together the ingredients of concrete has quite literally shaped our world. Today concrete is the most consumed man-made substance on earth. There is no other construction material as versatile as concrete, liquid rock that can be poured and moulded into any shape, to produce the safe, durable buildings and structures we all rely on every day. New homes, schools, hospitals, workplaces, roads and railways, as well as the infrastructure that provides us with clean water, sanitation and low-carbon energy, all depend on the industry's products and create the demand for them.

As a consequence, the production of cement has grown from a single factory in Wakefield 200 years ago, to a peak UK output of 20 million tonnes of cement in 1973, to today's production at over 3500 plants across the world, including 10 in the UK that produce a total of 8.4 million tonnes each year.

Delivering such vast quantities of material is not without its challenges. Cement production relies on extracting calcium carbonate (limestone or chalk) and clay minerals from the ground and heating them to volcanic temperatures (1450°C). As a consequence of the basic chemistry, production is highly carbon and energy intensive, which brings challenges that the sector has worked hard to overcome. Significant action has been taken to switch away from coal to waste derived fuels and to utilise alternative raw materials. The industry has made commitments to invest in carbon capture to eliminate carbon dioxide emissions, starting this decade.

Maintaining competitiveness is a key overarching theme to decarbonisation. The future of cement production in the UK relies on the transition to net zero, and that transition relies on domestic producers being able to compete with global production where decarbonisation ambition and associated costs are lower. Today, cement imports are increasingly arriving from outside the EU, from countries not subject to a carbon price. Imports have accelerated in recent years so that in 2022, they made up 30% of the UK cement market.

With the right policy support the UK is ideally placed to deliver a net zero cement sector, particularly given the abundant carbon dioxide storage capacity in depleted oil and gas fields. Key policies to enable this transition are already in motion. A carbon border adjustment mechanism (CBAM) will help level carbon costs between domestic producers and importers to maintain competitiveness, the UK has a clear vision for deployment of carbon capture, usage and storage, and electricity generation is well on the way to decarbonisation.

This brochure, made up of articles from those working in the sector, aims to commemorate the deep history of cement in the UK in this bicentenary year. It examines how the sector has innovated and evolved in the face of new challenges and looks to the future and what is required to deliver net zero domestically produced cement for centuries to come.

This is an exciting time to be part of a sector that has a rich heritage here in the UK and plays such a vital role in the construction of our world.

Key contextual information about the cement sector today:

Cement is made by crushing and heating limestone or chalk with small amounts of other natural materials, such as clay or shale, in a rotating kiln to a temperature of 1450ºC.

This chemically combines the raw materials into a hard substance called clinker, essentially changing calcium carbonate ($CaCO_3$) to calcium oxide (CaO) which then reacts with silica (SiO_2) to form calcium silicates. This is ground to a powder with about five per cent gypsum, added to control the setting time of the cement end-product.

There are six companies manufacturing cement in the UK: two are UK-owned and four are UK subsidiaries of multinational companies. Many of these companies are vertically and horizontally integrated, and therefore engage in downstream activities like concrete production.

The ten cement manufacturing sites owned by the six companies can be seen in the map in Figure 1.

- Demand for cement over the last two decades has averaged around 11.3 million tonnes per annum.
- In 2022, the UK produced 8.4 million tonnes of cement using 7.2 million tonnes of clinker.
- Imports of cement have increased from around 1.5 million tonnes in 2001 to 3.6 million tonnes in 2022, while domestic production of cement has decreased from 11.1 million tonnes in 2001 to 8.4 million tonnes in 2022.
- Imports as a proportion of UK sales have grown from 12% in 2001 to 30% in 2022.
- The cement sector contributes approximately £171m in GVA and employs over 2,300 people (directly) in the UK .

Figure 1: UK Portland cement manufacturing kiln sites.

BREEDON
1. Hope

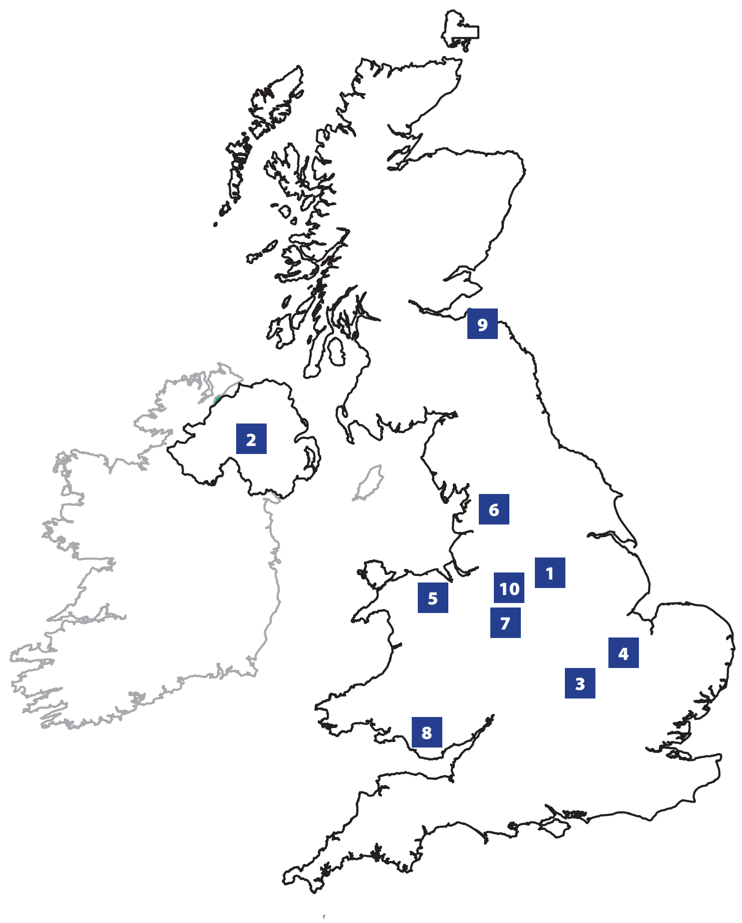
Heidelberg Materials
4. Ketton
5. Padeswood
6. Ribblesdale

CEMCOR Setting the Standard
2. Cookstown

LAFARGE CEMENT
7. Cauldon

CEMEX
3. Rugby

TARMAC
8. Aberthaw
9. Dunbar
10. Tunstead



1824 **1843** **1844** **1851** **1863** **1864** **1867** **1867**

1824 Patent No. 5022 granted to Joseph Aspdin of Leeds on 21 October 1824

1843 William Aspin's Portland cement, improved through discovery of clinkering at a higher temperature than previously, is independently tested by Grissell & Peto

1844 Isaac Johnson independently discovers the importance of clinkering (heating limestone and small amounts of clay to temperatures of 1450ºC)

1851 Cement demonstration at the Great Exhibition

1863 16,000 tonnes of Portland cement produced

1864 Dry grinding of limestone introduced after this date

1867 Portland cement demonstrated at the Paris Exhibition

1867 Contract for Chatham Dockyard extension signals government switch from hydraulic lime to Portland cement

Joseph Aspdin and the Portland Cement Patent of 1824

Author: Edwin A. R. Trout, Manager, Information Services, The Concrete Society

Edwin read history at university and trained as a librarian. He was employed as Information Manager at the British Cement Association from 1995, then in the same capacity for the Concrete Society from 2006.

He has acted as Secretary of the Cement Industry Suppliers' Forum for many years and is now Executive Officer of the Institute of Concrete Technology.

He has written extensively on historical and bibliographical aspects of cement manufacture and concrete construction, with books on nineteenth century cement milling and the literature of reinforced concrete, and chapters in several others on the broader history of cement and concrete. He contributes annual reviews of the British cement industry to Global Cement Magazine.

"We hear that Joseph Aspdin, bricklayer of this town has obtained a patent for a superior cement resembling Portland stone".

Leeds Mercury

Figure 2: Gravestone of Joseph Aspdin

So the Leeds Mercury announced in its edition of 6 November 1824. This patent, No.5022, for 'An Improvement in the Modes of Producing an Artificial Stone', had been granted just days before, on 21 October, and was destined to become the foundation document of an entire industry. The Portland cement-making industry in Britain and throughout the world, can trace a continuous thread of production and technical development from the pioneering activities of Joseph Aspdin: the self-styled "Inventor of the Patent Portland Cement" (Figure 2)[1].

Joseph Aspdin was born in 1778, to a family long settled in Leeds. Joseph was the eldest of six children of Thomas Aspdin (d.1800), bricklayer of Hunslet, Leeds. In adult life, Joseph and his brothers were to follow their father's occupation.

Married to Mary Fotherby on 21 May 1811, the couple were to have two sons – James (b.1813) and William (b.1815) – and four daughters: Caroline, Mary, Charlotte and Louise (1812, 1817, 1818 and 1820 respectively), though the middle two died in infancy. During these years, the family's address was Ship Inn Yard, Back of Shambles, Leeds, marked today by a commemorative plaque.

The 1810s were a time of considerable experimentation in the development of the hydraulic binders that preceded Portland cement, both in Britain and Europe. In England, a natural cement made from fired septaria (cement stones found first in the Thames estuary) and marketed as 'Roman cement' had been patented in 1796 by James Parker, used increasingly in architectural stucco or as mortar in hydraulic engineering works. In France too, sources of natural hydraulic lime had been investigated in the early 1800s, and artificially replicated by Louis Joseph Vicat by 1818.

With the expiry of Parker's patent in 1810, other entrepreneurs entered the British market. There were also several early attempts to artificially replicate the naturally cementitious qualities of septaria. Edgar Dobbs of Southwark was among the first in England, filing a patent granted in 1811 for a mixture of three parts of chalk, one part of clay and one of ash "such as is sold by the dealers in breeze", but his business was short-lived. James Frost, having commenced in Roman cement, also turned to the manufactured product. Travelling to France he sought Vicat's advice before bringing his experiments to a commercial conclusion in 1822, with a patent for a material he named 'British Cement'. Aspdin would be aware of at least some of these developments and it might well be no coincidence that his own patent appeared a mere three months after Dobbs' lapsed in 1824.

Underpinning much of this development was the publication of a book by a fellow Leeds man, the civil engineer John Smeaton, who in 1756-57 had discovered the source of the hydraulic properties found in lime from different formations of limestone. Aspdin is believed to have been aware of Smeaton, as a copy of the book has been passed down to his descendants. It is perhaps significant that Aspdin chose to name his product after the qualities of Portland stone, a term found previously in Smeaton's description – "I did not doubt but to make a cement that would equal the best merchantable Portland stone in solidity and durability"[2] – and used by others such as Bryan Higgins – "almost as hard as Portland Stone at the surface" (1780)[3].

1868 **1870** **1872** **1873**

1868 Henry Reid's monograph 'A Practical Treatise on The Manufacture of Cement' – the first British book on Portland cement – is published

1870s Improved wash mills for the wet process developed this decade

1872 Johnson invents the chamber kiln, which incorporates the drying of slurry by recycling waste gases, before addition to the kiln

1873 56,000 tonnes of Portland cement produced by six firms

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Patent No.5022

Joseph Aspdin's patent for Portland cement – granted on 21 October 1824 and formally 'inrolled' on 18 December – is the most famous of its kind by far, and the direct progenitor of the present Portland cement industry. However, it is obscurely worded, and omits key details. No useful information is supplied regarding the relative proportions of limestone and clay, the kiln temperature, the duration of firing, or the fineness of grinding, making it difficult to assess his intentions and to measure his achievement against them:

> I take a specific quantity of limestone such as that generally used for making and repairing roads, after it is reduced to a puddle or powder; but if I cannot procure a sufficient quantity of the above from the roads, I obtain the limestone itself and I cause the puddle or powder, or the limestone as the case may be, to be calcined. I then take a specific quantity of argillaceous earth or clay and mix them in water to a state approaching impalpability, either by manual labour or machinery. After this proceeding I put the above mixture into a slip pan for evaporation, either by the heat of the sun or by submitting it to the action of fire or steam conveyed in flues or pipes under or near the pan, until the water is entirely evaporated. Then I break the said mixture into suitable lumps and calcine them in a furnace similar to a limekiln till the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beat or rolled to a fine powder and is then in a fit state for making cement or artificial stone. This powder is to be mixed with a sufficient quantity of water to bring it to the consistency of mortar and thus applied to the purposes wanted.

The wording suggests Aspdin's ideas were on similar lines to those of James Frost and others of that period and although the name 'Portland cement' is introduced, it is certain that the material specified was somewhat removed from the cements of today. "Nothing more than a hydraulic lime", Blezard has argued: "its mineralogy was completely different, as was its hydraulic activity"[4]. It offered "little evidence of CaO-SiO_2 interaction", he adds, as the firing temperature was "too low for compound synthesis". Nonetheless, these were to increase over time as the experience of production influenced practice, and Professor Ian Richardson's recent research has found that Aspdin's output of c.1840 is demonstrably a form of Portland cement[5].

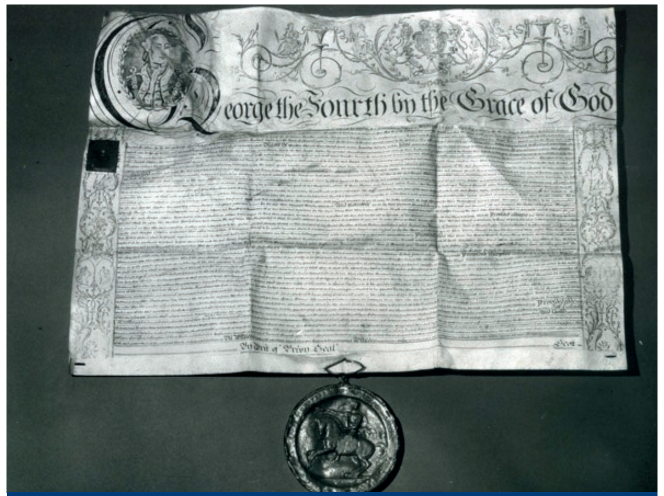


Figure 3: Patent 5022

Production in Wakefield, 1825-37

Aspdin soon established a works at Wakefield, described by his granddaughter Mary Caroline Johnstone, as "under the arches at the bottom of Kirkgate"[6]. In 1828/29, this enterprise was cited as "Aspdin & Co, Cement Manufacturers, Kirkgate"[7]. In the meantime he took into partnership William Beverley of the firm John Beverley & Son, brassfounders and tinplate workers of 68 Briggate, Leeds, whose home address in the 1810s had been – like Aspdin's – Ship Inn Yard. While Aspdin was responsible for the manufacturing workers in Wakefield, Beverley maintained the partnership's presence in Leeds, as indicated by Pigot's National Commercial Directory for 1828/29: "Aspdin & Beverley. Portland cement manufacturers, 68 Briggate."

In 1834, the trading address had changed: "Aspdin & Beverley. Portland & Ornamental cement, manufacturers of chimney pots, 35½ Upperhead Row & Mark Lane, and Wakefield"[8]. Beverley was also carrying out his own business from the same premises as "Iron Merchant & Spade and Shovel Manufacturer", suggesting the cement trade's limited extent. What expansion there was, was to the west, with an agency established in Liverpool during the 1830s, perhaps encouraged by the construction of the Liverpool & Manchester Railway.

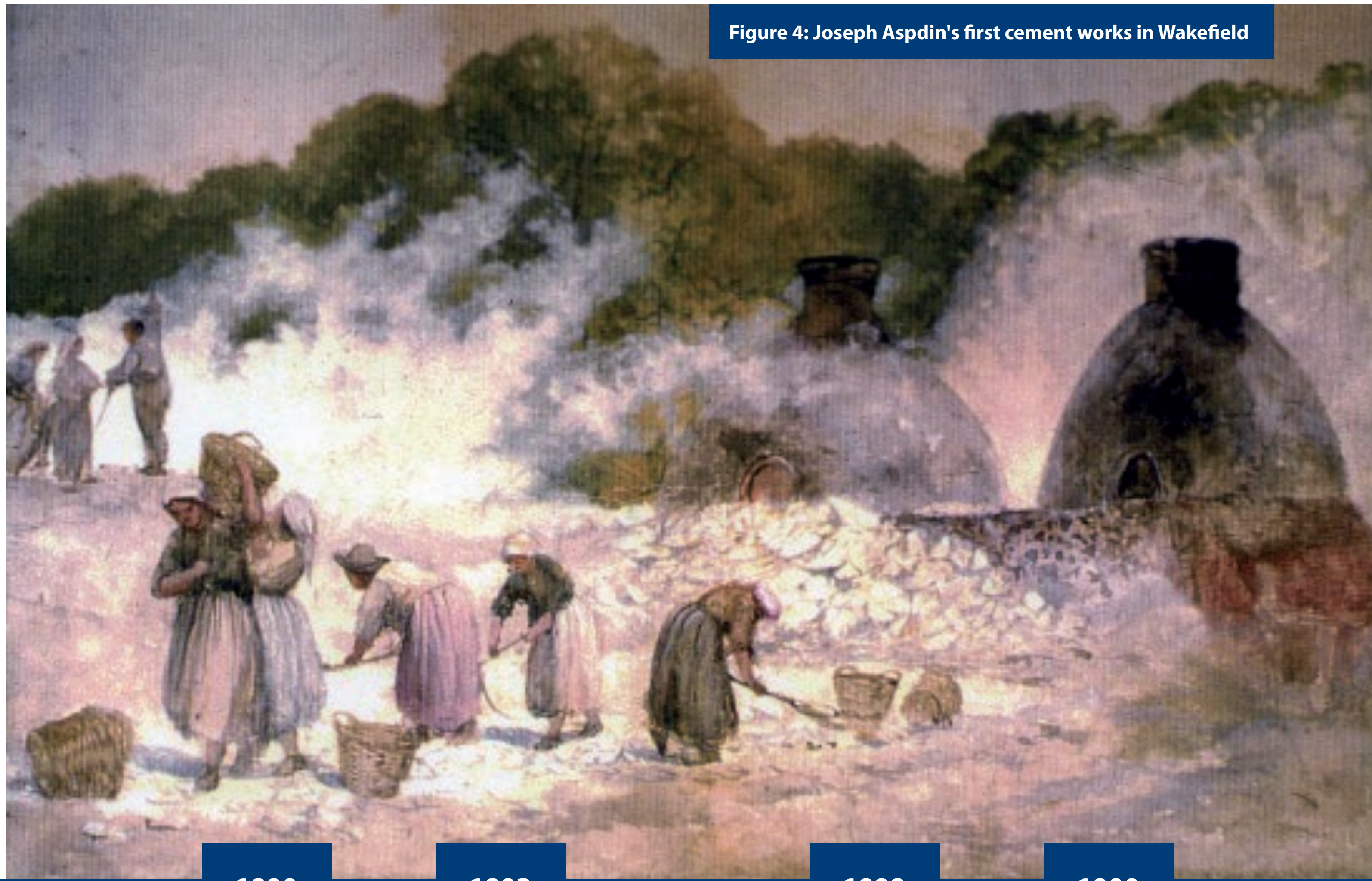
Plans for the Manchester & Leeds Railway included a proposed line eastward through the cement works in Kirkgate, Wakefield. Maps of the route in 1835 shows 'cement pits' on land owned by Aspdin & Beverley and by 1837 notice to quit would have been served. In the spring of 1837, the partnership of Aspdin & Beverley was dissolved:

> Notice is hereby given that the partnership heretofore subsisting between us the undersigned Joseph Aspdin of Wakefield and William Beverley of Leeds, both in the West Riding of the County of York, as manufacturers of Portland cement, and also lately carrying on business at Liverpool in the County of Lancaster, as dealers in cement, is this day dissolved by mutual consent. As witness our hands this first day of March, 1837[9].

In April 1838 the railway company took 'forcible possession'[6,7] of Aspdin's land and took steps to have the works pulled down. In response, Aspdin made arrangements to rent space in an adjoining market garden on which to store his property for a sum of £4.10, paying a further £5 to the incumbent tenant, Mrs Mercy Jacques, as compensation for the loss of crops. Aspdin started to build on the land soon after, and then bought it from the owner, Mrs Elizabeth Horsfall. The land extended to 1,050 sq yd and was described in the deed as being:

> … on the west side of the footpath leading from a certain Occupation Road near the bottom of Kirkgate to Primrose Hill which said plot of land is part of Pear Tree Close and is bounded on the north west by property belonging to the Manchester & Leeds Railway, on the south by the said Occupation Road and on the northeast by the said footpath[7].

Figure 4: Joseph Aspdin's first cement works in Wakefield



1877 | 1880 | 1880 | 1887 | 1890 | 1893 | 1898 | 1900

1877 Thomas Crampton patents the rotary kiln

1880s Alternatives like blast furnace slag and alkali waste are tried but fail to achieve commercial success this decade

1880s Introduction of Hoffmann and Schneider kilns

1887 Prototype rotary kilns trialled at various British cement works

1890s Introduction of powdered coal-fired rotary kilns (c1898/99) and electrically driven ball mills for grinding (c1894/95)

1893 Fragmented British cement industry begins to consolidate

1898 180,000 tonnes of Portland cement produced by 13 firms

1900 Formation of Associated Portland Cement Manufacturers (APCM) combined 34 cement works of 24 firms

The second cement works, 1839-48

Contemporary illustrations indicate the increased height of Aspdin's kilns, suggesting the attainment of higher firing temperatures[10].

Production at the new site commenced in 1839, though the agency in Liverpool was not continued, nor steps taken to replace Beverley with a new partner. Aspdin's sons, however, were now of an age to take greater responsibility: James, a bookkeeper by profession, was 27 and William, long engaged in the cement business, 24.

On 2 Aug 1841, Aspdin transferred a half-share of the business to James by deed and sent an announcement – the wording of which suggesting a family rift – to the Wakefield Journal & West Riding Herald[11]:

> TO BUILDERS AND OTHERS
>
> *I, Joseph Aspdin of Wakefield, cement maker, take this opportunity of returning my best thanks to my friends and the public, for the numerous favour I have received at their hands for many years past; and beg to inform them that I have just taken my son, James Aspdin into Partnership with me, and that we shall hereafter carry on business under the firm of 'JOSEPH ASPDIN & SON'. I think it right at the same time to give notice that my late agent, William Aspdin is not now in my employment, and that he is not authorised to receive any money, nor contract any debts on my behalf or on behalf of the new firm.*
>
> Cement Works, Wakefield. JOSEPH ASPDIN
>
> 2nd August, 1841

In July 1841 Joseph's son William left the family firm and made his way to London and, with a succession of partners, entered into business as a cement manufacturer.

Three years later, Joseph retired and in August 1844, the remainder of the business was transferred to James and the partnership dissolved in November. John Beverley & Son were again appointed as agents for the firm, operating in 1845 from the same premises as before, 68 Briggate, as 'dealers in Patent Portland & Roman Cement'[12].

The third works, 1848-

In 1848, James Aspdin moved the works to a new site in Ings Road, just a short distance from the previous one, and thereafter conducted a business that appears to have continued as a purely local one.

Aspdin senior died on 20th March 1855 and was buried in the churchyard of St John's, Wakefield. His memorial reads:

Sacred

To the Memory of the late
Joseph Aspdin of this town
(Inventor of Portland cement)
who departed this life on the
20th day of March 1855
Aged 76 Years

The early author on cement technology, Henry Reid, commented that while paying a visit to Wakefield in the 1870s, he experienced the "still existing tendency to enshroud the process of manufacture with an air of ignorant exclusiveness". Nonetheless, he did note the improvement in the production plant (even if he misattributed it to an earlier date than 1848):

> The chimney or dome of that kiln is of unusual height and much resembles a glass furnace in appearance. This extreme height while affording excellent facilities for calcination meets also the difficulty in reference to the nuisance created by discharge of gases during calcinations[13].

James died on 21 December 1873, "after a short illness"[14]; he was 60 years old. A year later the works were purchased by a consortium of 12 Wakefield businessmen and the firm converted into a limited company with a share capital of £24,000. Thirty years later, in 1904, a meeting of the shareholders of Aspdin & Co., Ltd, at 30 Ings Road, agreed to wind up the company, production having ceased several years earlier in 1892[6].

Portland cement: 200 years of building for the future

Despite doubts as to the quality of Joseph Aspdin's early binders, often expressed by historians of the industry, double-burning the limestone and the fine subdivision achieved by slaking during the intermediate stage would have represented an advance on the light burning of wet-mixed chalk and clay such as Frost and others relied on. Aspdin is known to have used a kiln of glass-furnace design rather than the traditional lime kiln. The importance of a thorough amalgamation of materials is recognised in the specification of "a state approaching impalpability". Aspdin's patent marks an essential step in the developments that led directly to the Portland cements of today, and Aspdin himself is clearly described on his gravestone as the "Inventor of the Patent Portland Cement".

Figure 5: Joseph Aspdin's 2nd cement works (left of illustration) depicted in 1843.

1902 | 1903 | 1904 | 1907 | 1911 | 1915 | 1918 | 1918

1902 Associated Portland Cement Manufacturers (APCM) request standard specification for cement be considered by the newly formed Engineering Standards Committee

1903 Chemist Bertram Blount draws up standard specification for cement

1904 The first British Standard Specification for cement (BS 12) is published

1907 2.89 Mt of Portland cement produced by 79 firms

1911 The British Portland Cement Manufacturers is formed from 33 companies as a majority owned subsidiary of APCM. It controlled 75% of the 3 Mt national capacity

1915 4th Edition of BS 12 standard specification is published, bringing a step change in improved cement quality

1918 Majority of manufacturers combine to form the Cement Makers' Federation (CMF), representing 90% of the industry. Membership conditional on respecting an agreed minimum price

1918 British Portland Cement Research Association established

Cement Kiln Development

Authors: Dylan Moore, retired, formerly of Blue Circle Industries

Roger Griffiths, Manager, Innovation Projects, Mineral Products Association

Dylan graduated in Organic Chemistry at the University College of Wales, Aberystwyth, specialising in Nuclear Magnetic Resonance (NMR) spectroscopy. He worked for Blue Circle Industries 1973-2002, specialising in sulfoaluminate cement manufacture, X-Ray Spectrometry and X-Ray Diffraction. Now Dylan runs the website www.cementkilns.co.uk on the Industrial Archaeology of the Cement Industry.

Roger has a degree in Chemical Engineering and over 20 years experience in cement manufacturing globally, having worked in 5 continents. Previous roles include process engineer, senior process consultant, and project manager. Roger currently leads MPA's innovation projects, including fuel switching, and investigating the use of reclaimed calcined clays for cement.

Portland cement: 200 years of building for the future

Static Kilns

The role of the cement kiln is to transform a blend of calcium carbonate (limestone) and clay raw materials ('rawmix') into clinker by raising its temperature to 1300°C or more. The equipment needed for this depends on the nature of the rawmix.

When Joseph Aspdin started making cement in Leeds and Wakefield, he combined his raw materials in the form of a fine slurry. This involved burning limestone to produce lime, which was then slaked with water and combined with clay in a washmill to produce the slurry.

The slurry was a thin liquid containing 70% or more of water. This was allowed to settle, leaving a muddy mixture which was dried on heated iron plates ('flats') until it had turned into hard lumps. These lumps were loaded into a kiln with alternate layers of coke (charge). The kiln was a modified lime kiln about 3m in diameter, with a conical extension to increase the draught (a bottle kiln). A fire lit at the bottom of the kiln spread upwards through the charge over the course of a few days, leaving a mass of hard but porous clinker in the kiln.

When cool enough, the clinker was dug out through the bottom, and ground to make cement. Being a batch kiln, it had to be heated up and cooled down again during each cycle. The process of 'double burning' – first to lime, then to clinker – was intensive both in energy and labour.

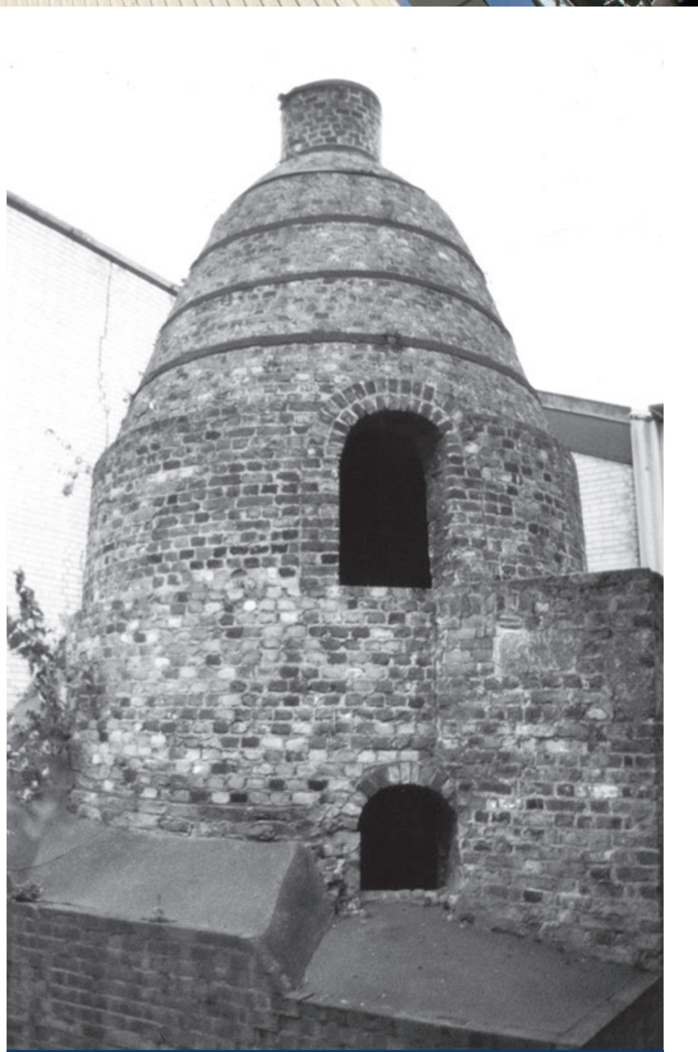


Figure 6: Preserved early cement kiln at Northfleet

1919 1919 1920 1920

1919 National Joint Industrial Council for the Cement Manufacturing Industry formed as a forum for dialogue between cement makers and trade unions

1919 Concrete Utilities Bureau formed as marketing body

1920 5th Edition of BS 12 cement specification standard is published, excluding the incorporation of ground granulated blast furnace slag

1920 Cement Marketing Company (CMC) established

Joseph Aspdin's son William set up a business in London in 1841. Here he had access to soft chalk in place of hard limestone, so he could avoid the first burning stage, and make a slurry by mixing chalk and clay in a washmill. From that point on the process was the same – settling and drying, then burning. Very quickly, his process was copied by numerous Roman cement manufacturers in the Thames/Medway area.

An economic disadvantage of this system was that, because the settlement stage took several months, a cement plant would cover vast areas with settlement tanks, and locked up stocks for a long time. A process with a more rapid turnover was required. The thick slurry process invented by William Goreham involved making a slurry with only around 40% water, which was immediately dried on the drying flats. This increased the amount of heat energy required, but reduced processing time to less than a week, and allowed a more compact plant.

The bottle kiln was very wasteful of energy, with most of the fuel energy escaping as hot exhaust gas. Attempts soon began to duct this exhaust gas under and over the drying flats so that drying fuel could be saved. In 1871 this led to the invention of the chamber kiln, which became standard equipment in British cement plants in the late 19th century. Kiln exhaust gas was ducted over a long shallow reservoir of slurry. During a 3-4 day kiln burn the slurry was dried out, and when the kiln had cooled, the dried material was cut out and loaded into the kiln ready for the next burn.

Throughout the 19th century, it was appreciated that batch kilns wasted a lot of energy in heating up and cooling down during each cycle. Clearly it would be more efficient to continuously load rawmix in the top and continuously withdraw clinker at the bottom. Such continuous kilns were frequently used in the lime industry. The problem in application to cement manufacture was that the clinker at its peak temperature was very sticky and tended to plug up the kiln shaft, so early attempts failed. From 1885 onwards, this problem began to be solved, and various designs of continuous shaft kiln were used. These had the advantage that they could halve the energy used in clinker production. However, with very cheap fuel and the great simplicity of the chamber kiln plant, shaft kilns were not much used in Britain.

Figure 7: Southam Kiln 5 (1938). Typical pre-war riveted construction

Rotary Kilns

A revolutionary change took place at the turn of the century, with the introduction of rotary kilns.

A rotary kiln is a steel cylinder lined with firebrick. It is arranged at a slight slope and slowly rotates. Rawmix, either as a slurry (wet process) or powder (dry process) is introduced into the upper end. Fuel is projected into the lower end through a concentric pipe, producing a long flame. The rawmix moves down the kiln due to its rotating action, getting hotter as it goes, and reaching its peak clinkering temperature under the flame. The resulting clinker took on a new form. Instead of the pumice-like lumps produced by a static kiln, it took the form of hard, uniform pea-sized nodules.

The rotary kiln greatly improved the controllability of the burning process. The forming clinker was visible to the operator, and minute adjustments to fuel, draught and rawmix feed-rate could be made to obtain clinker of the desired quality. A much greater output rate was also attainable. A static kiln would produce 10-40 tonnes of clinker per weekly burn, whereas even the smallest rotary kiln would produce 20-30 tonnes per day, and with less labour.

Another revolutionary change was in the financing of kiln plants. Static kiln plants were easily and cheaply constructed using on-site labour. Rotary kilns, on the other hand, were a significant capital expense, and for their design, the cement maker had to rely on the expertise of a specialised plant manufacturer.

From this point on, the kiln became the economic heart of the plant and had to be kept running all the time in order to justify its capital cost. It also meant that small cement businesses were unable to raise sufficient capital, and rapidly closed.

Britain's first successful rotary kilns were installed around late 1900 to early 1901. A hectic period of experimentation took place in the first decade, in which the earliest kilns were greatly modified, and much larger kilns were installed as new. Despite major losses incurred by the early adopters, the superiority of the new process was so obvious that the rotary process was completely dominant by 1910.

Part of the impetus for the change to rotary production was a change in the fuel market. The coke that was used to fire static kilns had increased dramatically in price. The first rotary kilns had disappointingly high fuel consumptions – in some cases as much as a chamber kiln – but they could use the cheapest grades of coal. The re-design of the rotary kiln to reduce its energy consumption then became the major thrust of its development.

The question of whether a wet process or dry process should be used was an early point of contention. In theory, a dry process should use less energy because there is no slurry water to evaporate. A number of dry process kilns were installed before the First World War, but most of these later reverted to wet process, mainly defeated by the difficulty of properly blending a powder rawmix. From 1930 to 1957, the only dry process rotary kilns were a few burning a slag rawmix, and a few more using the Anhydrite Process.

Wet process rotary kilns having become dominant, they advanced rapidly in size, making over 200 tonnes of clinker per day in the 1920s, and 500 tonnes per day in the 1930s. A major advance came in 1928 with the introduction of chain heat exchangers in the cold end of the kiln, which increased kiln output by 10-50% wherever implemented, while somewhat reducing energy consumption. From 1930 on, the basic design of wet process kilns was set, with increase in size the only innovation, until the last installations in the 1970s.

Figure 8: The rear of Southam Kiln 7, commissioned in 1961. Typical post-war welded construction

1920 **1921** **1923** **1924** **1924** **1925** **1925** **1926**

1920s Rail increases in use for cement deliveries in this decade

1921 A temporary industry-wide surcharge is agreed to cover the cost of importing coal during the miners' strike

1923 Standard BS 146 published for Portland blast furnace slag

1924 Centenary of Portland cement. A tablet to the memory of Joseph Aspdin is unveiled in Leeds Town Hall

1924 Concrete used as an architectural medium in buildings for the British Empire Exhibition, opening up a new market for cement

1925 British Portland Cement Association formed as a national marketing body, in place of the previous Concrete Utilities Bureau

1925 Coloured cement promoted

1926 Water transport updated from sailing barges to tugs and lighters

Efficient Kilns

After the Second World War, the industry came under pressure from Government to reduce energy consumption. Efficient blending of powders in air-fluidised silos had been developed in the USA in the early 1950s, so dry process plant could be considered.

Lepol Preheater

In Germany, from 1927, dry process kilns with Lepol preheaters were developed. The Lepol preheater is a moving grate on which rawmix nodules are placed. The spherical nodules are produced by adding a small amount of water (10-15%) to the dry powder rawmix in a nodulising pan. Kiln exhaust gas passes downwards through the bed of nodules on the moving grate, and by the time the grate discharges them into the back of the rotary kiln, they have reached the high temperatures required.

The first efficient kiln to be installed in the UK was a Lepol kiln at Cauldon in 1957. This had roughly half the energy consumption of a typical wet process kiln. A further ten Lepol kilns were subsequently installed in the UK, the last being at South Ferriby in 1978.

Suspension Preheater

Another approach to preheating rawmix prior to entering the rotary kiln – the one that ultimately became dominant – was the cyclone suspension preheater. This works on the principle that heat is most rapidly exchanged between a powder and a hot gas if the powder is suspended in the turbulent gas. A cyclone separator then separates the heated powder from the gas. If this process is repeated several times, rawmix powder can be raised close to the kiln exhaust gas temperature before it is deposited in the rotary kiln for final clinkering. Furthermore, the residual heat in the exhaust gas could be used to heat the rawmill.

Seven suspension preheater kilns were installed in the UK, the first being at Plymstock in 1961. All proved to be capable of unprecedented low operating costs and low energy consumption.

The perfection of the suspension preheater kiln demonstrated the efficiency of the gas suspension principle, and so it became clear that for ultimate efficiency, the rotary kiln should be used only for that part of the process that needs its action – the sintering process in the burning zone. The most energy-intensive part of the process – removal of carbon dioxide – can be done in gas suspension provided that enough energy is available at that point.

Precalciner

The work on the development of the suspension preheater led to precalciners, which began to be developed in Japan in the late 1960s. Many different designs of precalciner have been produced. All inject a certain amount of the kiln fuel into a combustion chamber forming part of the preheater, typically 50-70% of the total fuel used. Most designs supply combustion air to this chamber from the clinker cooler, through a tertiary air duct.

Increasingly complex gas flow control in precalciner preheaters allows minimisation of energy consumption and nitrogen oxide emissions.

In the UK, eight precalciner kilns have been installed, the first at Ribblesdale in 1983 and the most recent at Padeswood in 2005.

Figure 9: Modern plant cyclone suspension preheater tower at Tunstead.

1927 **1927** **1928** **1930**

1927 Last horse-drawn deliveries of cement by the Cement Marketing Company

1927 5 Mt of cement produced, 75% by 18 CMF members and 25% by 11 members of a non-Federation Association, plus 6 independents

1928 White cement promoted. Trade magazine Cement & Cement Manufacture (now World Cement) first published

1930s Reliance on road transport by diesel lorry grew dramatically throughout this decade

The Future of Portland Cement Manufacture

The development of cement kilns to date has been with the aim of increasing throughput and reducing fuel consumption.

Over the last few decades, this has also included the reduction of fuel costs through the use of alternative fuels. This trend in optimisation will continue, however the most important developments are likely to relate to reducing the amount of pollutants, specifically carbon dioxide (CO_2), emitted to the atmosphere per tonne of material produced. The direct CO_2 emissions from cement manufacture are from both the combustion of fuels to produce the high temperatures needed, and process emissions from the chemical reaction that occurs when the limestone/chalk raw materials (calcium carbonate, $CaCO_3$) are disassociated at high temperatures.

To reduce combustion CO_2, the heat requirement either needs to come from zero carbon fuel (i.e. hydrogen), or carbon neutral waste biomass fuel or from renewable electricity. Hydrogen in conjunction with waste biofuels have been successfully trialled. Electrification, including generating the heat via plasma torches and microwave energy, has yet to be developed beyond the laboratory but may have a place in future kiln technology.

Based on the current materials used for cement manufacture, process emissions cannot be eliminated, and therefore must be captured. To allow cement manufacture to become net zero, CO_2 from the kiln exhaust gases will need to be collected and then either used (Carbon Capture and Usage, CCU) or stored (Carbon Capture and Storage, CCS). Such systems will take one of two forms:

1. A system which 'plugs-on' to the flue gas of current cement manufacturing plants. Such a system requires separation of the CO_2 from the exhaust gas. Amine absorption is the current technology forerunner for this, but there are also a number of other systems including calcium looping that may yet become more economically viable with further development.
2. An oxyfuel process system where all combustion taking place in a cement rotary kiln is performed with oxygen instead of air. This produces a flue gas that is very concentrated in CO_2 instead of being diluted with large amounts of nitrogen from the air. After water has been extracted from the flue gas by condensation, and other minor components have been removed, we are left with CO_2 that is ready for transportation to usage or storage.

An Introduction to Cement Formulations

Author: Dr Diana Casey, Executive Director, MPA

Portland cement is the original general-purpose cement and is a highly trusted material that has been used in construction for two hundred years. It is formed of clinker which has been milled and blended with gypsum.

Other cements, known as composite cements, can be produced by combining clinker with 'supplementary cementitious materials' (SCMs) which include ground granulated blast furnace slag (GGBS), a by-product of steel production, fly ash, a waste from coal fired power generation, and limestone powder. Other SCMs are being researched and these will help reduce the quantity of clinker, which reduces the embodied carbon of cement.

Although some SCM markets are already mature, these are dependent on fossil fuel-based processes like steel production and coal fired power generation, or the use of historical landfilled supplies. Other substitute materials, that are not derived from fossil fuel-based processes, may have greater potential in terms of resource availability, such as calcined clays, and the sector is always looking out for new SCM opportunities.

BS EN 197-1 is the standard that specifies the wide range of cements that can be produced and sold in the UK. In total there are 27 different cements listed in the standard which are produced with a range of different SCMs.

There is substantial research going into potential alternatives to Portland cement for low carbon applications. However, the potential for these to be produced at scale and used in load bearing structural applications is uncertain. They often still require some clinker to activate them, or they rely on traditional SCMs such as GGBS, and their carbon savings can often be matched by composite cements containing SCM's.

The UK has made significant progress in substituting clinker in cement with SCMs. However, this achievement often goes unrecognised because the UK cement and concrete market operates in a different way to other countries. In the UK, SCMs are added at the concrete works to produce equivalent combinations to cement. These combinations never exist as a product in their own right but are produced as the concrete is mixed. In other countries, SCMs tend to be included by the cement manufacturer as part of the cement. There are advantages to the UK approach, it reduces the transportation of SCMs between cement and concrete works and also allows the flexibility to produce a range of cements from more than one silo of cement constituent materials.

More detail on the development of cement formulations, including future innovation, is provided in the next article.

History of Composite Cements in the UK

Author: Dr Colum McCague, Technical Manager, Mineral Products Association

Colum brings a wealth of expertise to his role, particularly in the areas of product development and standards. He prioritises innovation to swiftly implement updates to standards.

Colum earned both his MEng degree in structural engineering and his Ph.D. in civil engineering from Queen's University Belfast in 2009 and 2015 respectively.

Prior to his tenure at MPA, he served as a postdoctoral researcher at City, University of London, where he collaborated with industry partners to pioneer a novel low-energy heat curing process for precast concrete products.

Long before the invention of Portland cement, ancient builders were using volcanic ash as the binding material in concrete. These early practices laid the foundation for the UK's long-standing tradition of incorporating supplementary cementitious materials (SCMs) into cement formulations.

The adoption of ground granulated blast furnace slag (GGBS) began in the early 1900s, while fly ash became more widely accepted in the 1980s. For much of the 20th century, the UK cement market was dominated by formulations containing a single SCM, typically GGBS, fly ash, or limestone powder. However, the closure of coal-fired power stations in the UK led to a significant decline in domestic fly ash production, forcing the industry to seek imported materials and explore local alternatives. In 2018 this shift spurred the industry into investigating multi-component cements, particularly those combining limestone powder with GGBS or fly ash. Consequently, a major revision to the UK concrete standard (BS 8500:2023)[1] now allows for a more optimized use of SCMs in cements. This article traces the historical evolution of non-clinker materials in UK cements, beginning with GGBS and fly ash, and provides an overview of the current low-carbon cements, along with insights into future developments in the industry.

Early adoption of GGBS

GGBS has a long history in the UK. It was first produced in Scotland in 1914 and became standardised in 1923 with the introduction of the British Standard BS 146[2]. Initially, GGBS was developed merely as an extender for Portland cement. However, by the 1980s, the focus began to shift towards its performance benefits, such as reducing the heat of hydration in large concrete pours and improving durability in chloride and sulphate environments. These qualities made GGBS a preferred choice in infrastructure projects requiring enhanced longevity, particularly in marine conditions.

The rise of fly ash

Fly ash emerged as the next significant SCM, gaining broader acceptance in the UK during the 1980s. Like GGBS, fly ash was valued for lowering the heat of hydration, which helped prevent cracking in mass concrete structures. Its combination with Portland cement was particularly recommended for concrete exposed to sulphate-bearing soils and groundwater, making it a popular choice in large-scale construction projects, such as dams and bridges. The material's proven benefits in reducing the risk of alkali-silica reaction (ASR) and enhancing the durability of concrete further bolstered its adoption.

The introduction of limestone powder

Limestone powder has long been recognized for its ability to improve the stability of fresh concrete, especially flowing and self-compacting concretes, as well as improving the appearance and surface finish of the hardened concrete. This makes it particularly valuable in architectural concrete applications, where a high-quality finish is essential. The change in standards now allows for a proportion of the limestone powder to be considered as part of the cement, although typically lower than GGBS and fly ash, and not just as an inert filler where any cementitious benefit was disregarded. In recent years, cements containing clinker and around 15% limestone have been established as having equivalent performance to Portland cement.

Figure 18: Cement and SCM powders

Uptake and the role of standards

Despite evidence from the late 1970s and early 1980s that combining Portland cement with SCMs was beneficial, their use was initially slow to catch on for everyday building projects. Standards like BS 146 for Portland blast furnace cement had existed for decades, yet widespread adoption of SCMs was relatively low. This hesitation was partly due to concerns about the consistency and performance of these materials. However, by the mid-1980s, industry associations introduced certification procedures to verify the performance of cements containing

1934 **1934** **1934** **1938**

1934 Cement Maker's Federation (CMF) extended to all cement makers (three companies remain outside, ICI, Gillingham CO and Batchelor's)

1934 Common Price Agreement (CPA) instituted. Common pricing lasted until 1987

1934 BRE starts consistent testing of water-cured concrete at 28 days which continues until the 1980s, helping to improve quality

1938 8 Mt of cement produced

Figure 11: Precast concrete units produced using reclaimed calcined clay cement.

SCMs, which in turn increased confidence in their use. The formalisation of these processes marked a turning point in the broader acceptance of composite cements in the UK.

In the early 1980s, growing concerns about sulphate-bearing soils and the potential for ASR – a chemical reaction that could weaken concrete – prompted the Building Research Establishment to recommend using combinations of Portland cement with GGBS and fly ash. These SCMs were found to be effective at minimizing the risk of ASR and enhancing concrete durability. As a result, their adoption in construction increased significantly. The continuous updating of UK standards, including the British Standard for concrete (BS 8500), reflected these developments and facilitated the broader integration of SCMs into UK concrete formulations.

The shift towards multi-component cements

The closure of coal-fired power stations in the UK, which led to a sharp decline in domestic fly ash production, prompted the cement and concrete industry to seek alternatives to traditional cements that relied heavily on a single non-clinker constituent like fly ash. This shift accelerated the development of multi-component cements, particularly those combining limestone powder alongside GGBS or fly ash. The revision of the British Standard for concrete BS 8500:2023 was a key development in this process, allowing for a more optimised use of SCMs. This revision not only accommodated the evolving supply of cement constituents but also aligned with the industry's increasing focus on sustainability and carbon reduction.

Future developments

Looking to the future, the UK cement industry is exploring new materials to further reduce the carbon footprint of concrete. Calcined clay, fly ash recovered from stockpiles and recycled concrete fines are among the most promising SCMs in development. Calcined clay and recovered fly ash have the potential to substitute significant proportions of clinker, with chemical properties which are similar to fresh fly ash. Recycled concrete fines may offer a means of utilising old concrete but at lower levels of clinker substitution. These innovations are expected to play a crucial role in the ongoing evolution of low-carbon cements, contributing to the UK's efforts to meet stringent environmental targets and advance sustainable construction practices.

Conclusion

The evolution of composite cements in the UK has been shaped by a combination of historical practices, material availability, and a growing commitment to sustainability. From the early use of GGBS and fly ash to the recent shift towards multi-component cements, the UK cement industry has continuously adapted to meet the demands of modern construction while minimizing environmental impact. As the industry looks ahead to new developments like calcined clay and recycled concrete fines, the future of UK cements promises to be both innovative and aligned with global sustainability goals.

Figure 12: Hinkley Point C construction hit the record books in 2019 with the longest continuous pour of concrete (9,000 cubic metres over five days).

1938 **1941** **1945** **1947**

1938 Cement and Concrete Association (C&CA) established (expansion of the former British Portland Cement Association)

1941 'Balfour Committee' on Cement Production appointed to review capacity to meet wartime requirements

1945 Cement production declines to 4 Mt

1947 Large-scale production of low-heat Portland cement commenced

Recent Developments in Low Carbon Cements

Today, innovation in cement formulations is ongoing, and MPA have led two projects in this area, as detailed in the case studies below.

CASE STUDY

Development of low carbon multi-component cements[1]

Cements for UK concrete applications generally consist of two main components, which are usually Portland cement (CEM I) combined with limited quantities of either fly ash, GGBS, or limestone powder.

The scientific literature has shown that cements can work more efficiently if formulated with more than two main components. In this project, cements with three main components were developed: CEM I-fly ash-limestone powder, and CEM I-GGBS-limestone powder. As well as enhanced performance in concrete, there is also the opportunity to improve energy efficiency and to reduce embodied carbon vs. single component (CEM I) and two component cements (CEM II and CEM III).

Currently 79% of UK cement market sales is CEM I.

Of the new cements trialled in the project, one has a CO_2 profile 60% lower than CEM I. If fully deployed this would result in a reduction in direct emissions from cement production of over 4 million tonnes of CO_2 every year.

Outcome: These cements are now included in the UK concrete standard (BS 8500) to facilitate their use and help designers, specifiers, contractors and the wider construction sector reduce emissions related to the use of concrete.

CASE STUDY

Production and testing of reclaimed calcined clays[2]

An MPA-led consortium has completed a project to assess the feasibility of producing calcined clays from reclaimed clays, specifically those obtained from extraction or other manufacturing processes.

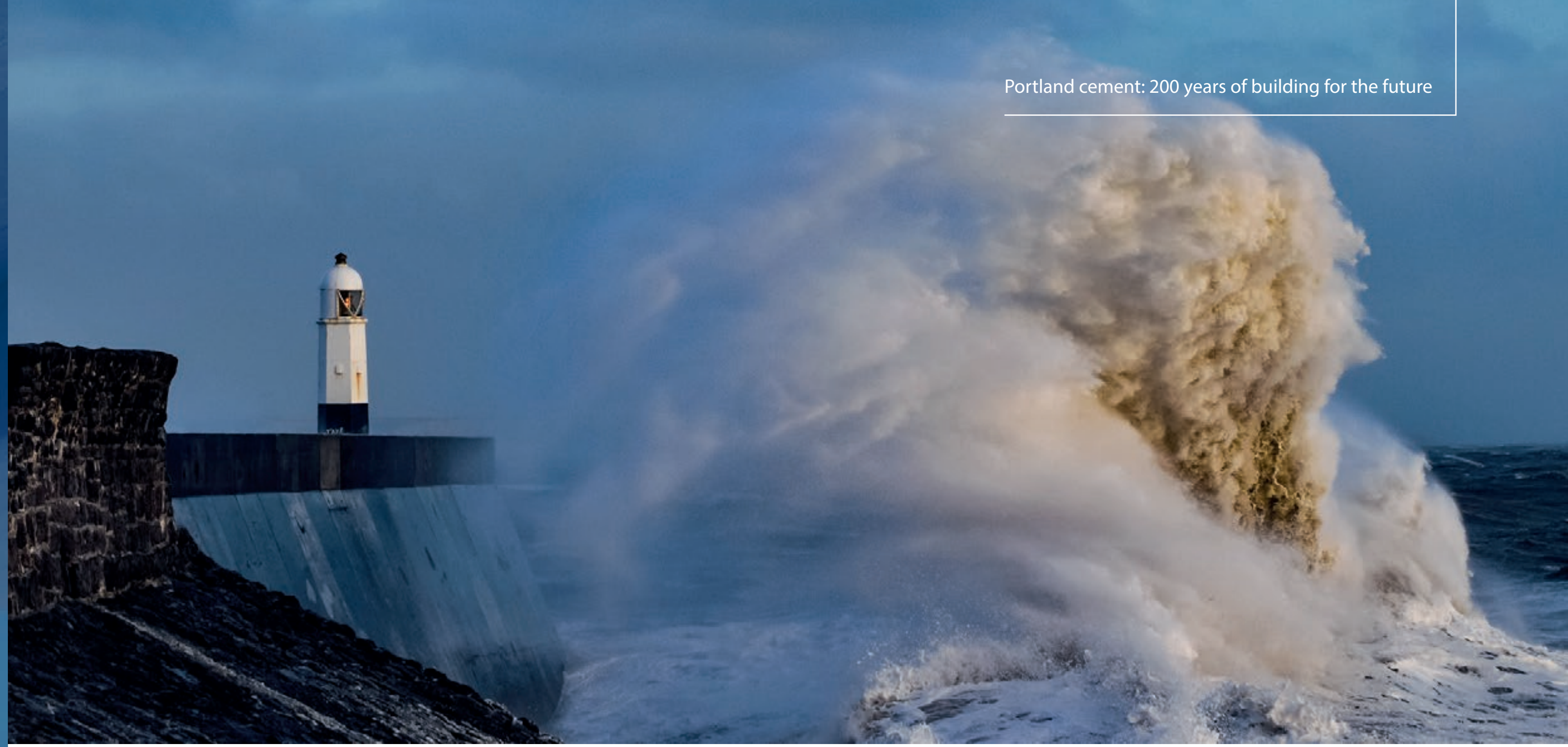
For the experimental programme, a total of 10 clays were sampled (from Heidelberg Materials, Imerys and Tarmac quarries), with parameters such as kiln temperature and particle size optimised to allow the highest-possible clinker substitution in low carbon cement formulations. The project also investigated a brick powder sample – an already calcined material – as a clinker substitution material.

The calcination of clay is achieved at a lower temperature (around 800°C) than the calcination of limestone to produce clinker, and far less CO_2 is released as process emissions. Therefore, using it as a replacement for clinker results in emissions reduction. Of the 10 clays investigated in the project, four clays were selected for pilot scale production using two heating processes: (1) rotary and (2) flash. Following this, low-carbon cements were formulated and tested for conformity against current standards. The cements were tested in concretes as part of a programme designed to inform a future revision of BS 8500. Some of the cements contained as little as 45% Portland cement, which was achieved by using a combination of calcined clay and ground limestone as the SCM component. The results demonstrated that these calcined clays, even those with low kaolinite content, performed exceptionally well in both standard and self-compacting concretes. All cements achieved a strength class of 42.5N and showed continued strength gain beyond 28 days. Durability testing on concrete mixes demonstrated excellent resistance to chloride migration, and the early results from longer term chloride diffusion, natural carbonation, freeze–thaw, alkali–silica reaction and sulfate resistance tests show that all concrete mixes are on track to satisfy BS 8500 requirements. This provides the industry with the necessary confidence that calcined clays perform similarly to mainstream SCMs and, in some cases, better.

Decarbonising Cement

Author: Jon Flitney, Energy and Climate Change Manager, Mineral Products Association

Jon is the Energy and Climate Change Manager at the MPA. He inputs to Government policy development on behalf of the sector, advises members on energy and climate change policy, and develops roadmaps and tools to support cement producers as they transition to net zero.



The cement-making process, is an energy (thermal and electrical) and carbon intensive process, with up to 45% of production costs being related to energy and carbon.

Unlike many other industries, around 70% of CO_2 emissions are process emissions that arise when the raw materials break down at high temperatures. The remaining 30% of emissions are from the combustion of fuels used to reach those high temperatures.

In 2008 the UK Government set a target to reduce greenhouse gas emissions by 80% and a net zero target followed in 2019[1]. The production of cement emits about 6.0 million tonnes of CO_2 per year, which is about 1.2% of total UK emissions[2].

The cement industry has long been at the forefront of carbon emission reductions. Since the early 1990s, the sector has been utilising waste derived materials and fuels to minimise its dependence on primary raw materials and fossil fuels. By doing so, materials are moved up the waste hierarchy to energy recovery and simultaneous recycling of mineral/metal content known as co-processing. In 2023 thermal input to kilns reached 54% waste derived fuels, with 25% classified as waste biomass.

The British Cement Association (BCA) launched its first carbon strategy in 2005, with short-term actions through to 2010, which was followed by the MPA Cement GHG Reduction Strategy in 2013. With the announcement of the government's net zero target, the MPA published the UK Concrete and Cement Industry Roadmap to Beyond Net Zero in October 2020[3].

The latest roadmap has five key levers to decarbonise the sector (see Figure 13): i. Indirect emissions from decarbonised electricity, ii. Transport, iii. Low carbon cement and concretes, iv. Fuel switching and v. Carbon Capture Usage and Storage (CCUS). Once at net zero there are two further levers related to concrete in use, which enable the sector to reduce emissions beyond net zero: carbonation of concrete, and use of concrete's high thermal mass to reduce the energy required to heat and cool buildings. It is CCUS, which will need to provide the majority (61%) of the emissions reduction for the UK cement industry, due to the need to abate unavoidable process emissions.

1949 | 1949 | 1950 | 1950

1949 UK is the world's largest exporter of cement, exporting 1.9 Mt

1949 Masonry cement and sulphate-resisting Portland cement introduced

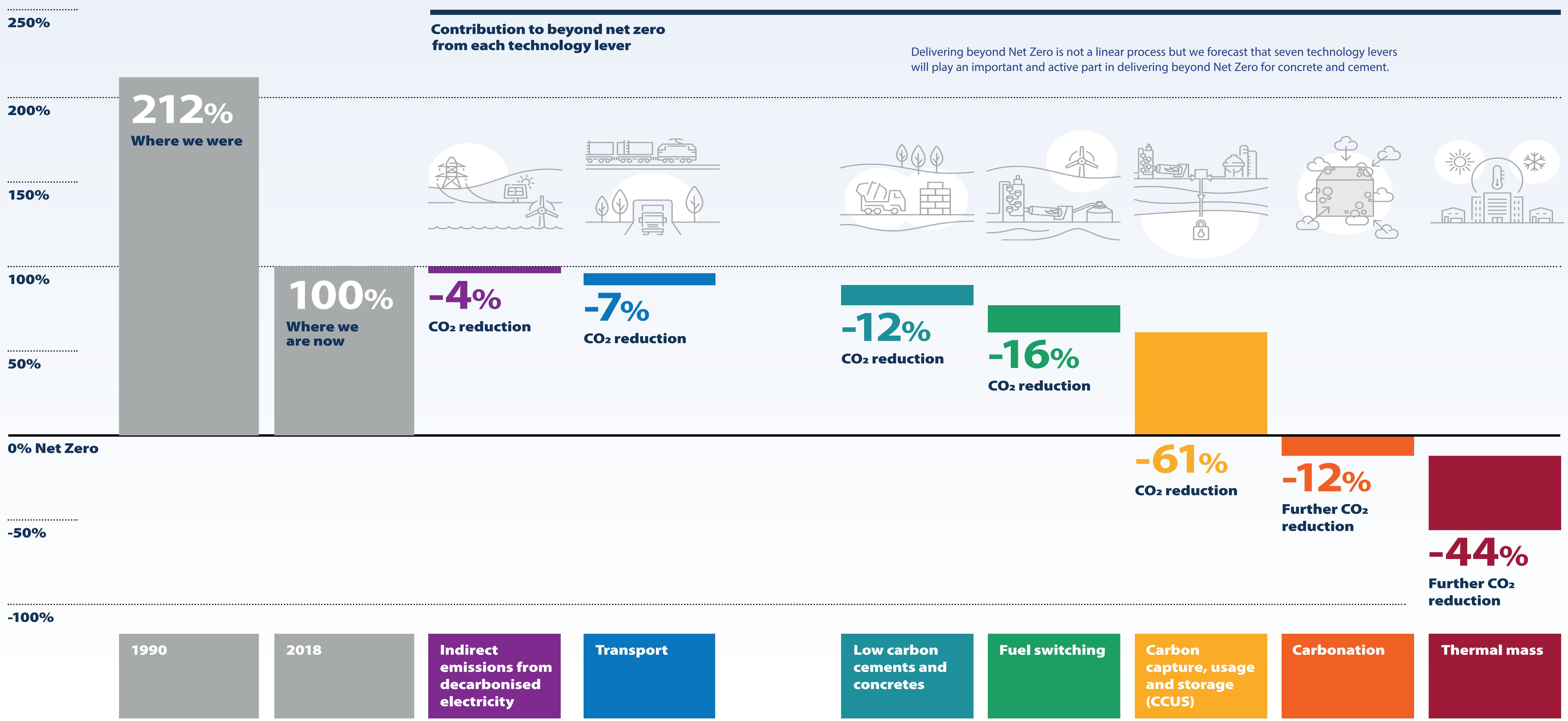
1950 Cement production rises to nearly 10 Mt

1950 Associated Portland Cement Manufacturers invest in large Central Testing Laboratory at Greenhithe

Figure 13: Levers required to reach net zero and beyond

The chart shows absolute 2050 CO_2 emissions reductions compared to a 2018 baseline. Seven technology levers are forecast to play an important and active part in delivering beyond Net Zero for concrete and cement.

Absolute 2050 CO_2 emissions reductions compared to 2018



Source: UK Concrete and Cement Industry Roadmap to Beyond Net Zero 2020

1952 | 1956 | 1957 | 1960 | 1961 | 1961 | 1967 | 1969

1952 London hosts the third Congress on the Chemistry of Cement

1956 Associated Portland Cement Manufacturers, British Portland Cement Manufacturers and Cement Marketing Company combine to adopt Blue Circle brand as Blue Circle Group (later becomes Blue Circle Industries)

1957 Lepol Grate preheater, a new generation of production plant, introduced at Cauldon

1960 13.5 Mt cement produced

1961 First suspension pre-heater kiln installed at Plymstock

1961 Hearing on the Common Price Agreement decides pricing arrangements benefited the customer (a verdict that is repeated again in 1974)

1967 Third suspension pre-heater kiln installed at Aberthaw

1969 17.6 Mt of cement produced

Examples of decarbonisation in action

There are many examples of decarbonisation in action for the cement industry.

- ### Solar farm

Heidelberg Materials have installed a 13 MW solar farm with 58,000 panels, which provides 13% of the electricity used by the Ketton cement plant[4].

Figure 14: Solar farm installed at Ketton

- ### Replacement of horizontal cement mills with more efficient vertical mills

Tarmac have installed a vertical cement mill at Dunbar, which can produce up to 60 tonnes per hour. The new 'vertical roller' mill reduces the use of two of the older mills and uses 50% less electricity.

In addition, further loading capacity was installed to distribute cement across the rail network and remove HGVs from roads.

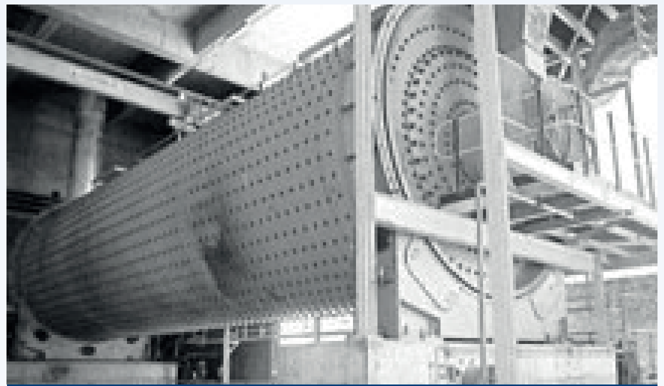


Figure 15: Original ball mill at Dunbar cement works

Figure 16: Vertical roller mill installed to replace the ball mill at Dunbar

CASE STUDY

MPA fuel switching project

The MPA successfully applied for Government funding through the Fuel Switching Competition to undertake a feasibility study and subsequent demonstration of a net zero fuel mix for cement manufacture[5].

A feasibility study demonstrated that a theoretical combination of 70% biomass, 20% hydrogen, and 10% plasma energy could be used to switch cement manufacture to 0% fossil fuel CO_2 emissions, in keeping with the industry's decarbonisation goals and the UK's decarbonisation legislation. The study also identified some uncertainties that required a physical trial before these technologies could be commercially scaled and deployed. The demonstration phase involved trials at two different cement sites. This allowed demonstration of fuel switching of the main kiln burner and calciner to be investigated separately, which reduced the interruption to daily operations for each site. The UK cement manufacturing sites used for the trials were:

- **Heidelberg Materials, Ribblesdale: trialling hydrogen and biomass in the main kiln burner.**
- **Tarmac, Tunstead: trialling plasma and biomass in the calciner.**

The hydrogen trial demonstrated that use of biomass and hydrogen was possible with no detrimental impact on clinker quality. The plasma/biomass trial was more challenging and further work is required to fully understand if plasma has a role in the future fuel mix of the sector.

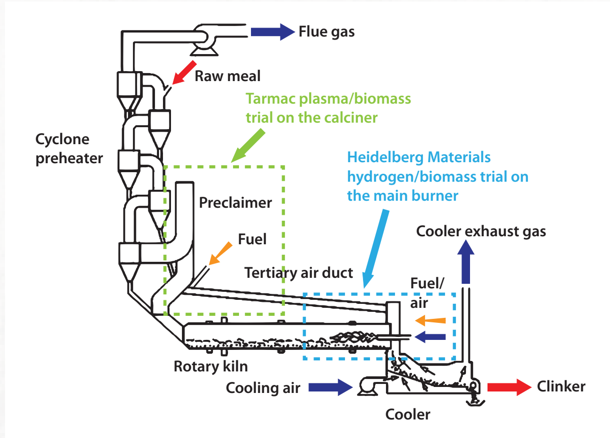


Figure 17: A diagram showing the location of the two fuel switching trials in the cement manufacturing process.

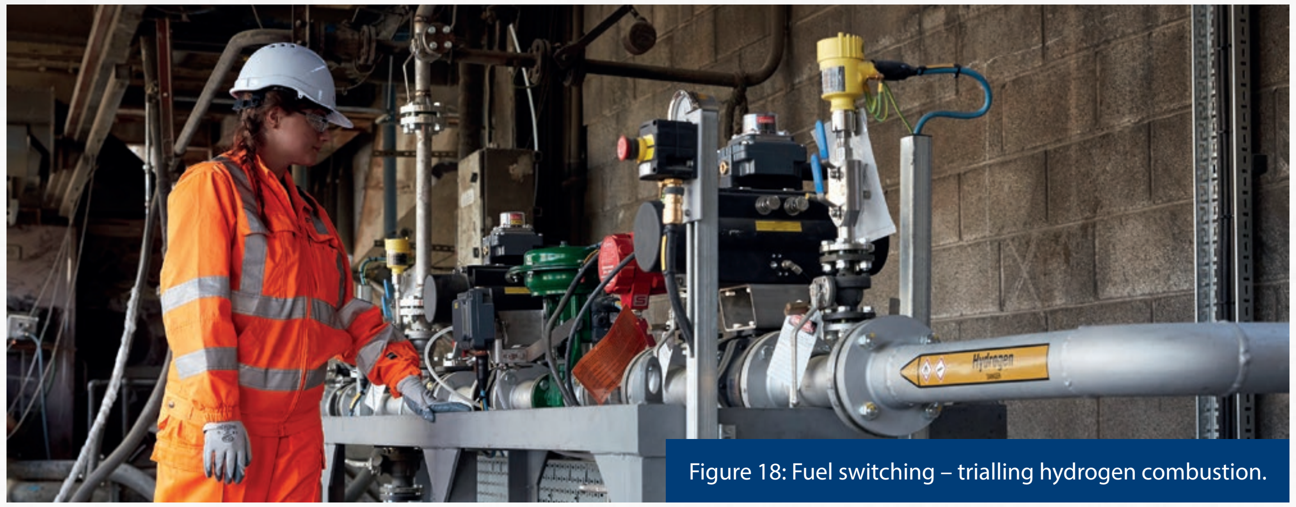


Figure 18: Fuel switching – trialling hydrogen combustion.

1970 | 1973 | 1977 | 1978 | 1980 | 1981 | 1982 | 1986

1970 Work starts on world's largest cement works at Northfleet

1973 20 Mt of cement produced, national maximum output

1977 Full scale use of refuse derived fuel starts at Westbury

1978 Lepol Grate kiln installed at South Ferriby

1980s GGBS and Fly Ash use increases this decade

1981 Cement and Concrete Association sells off commercial publishing arm

1982 UK's first pre-calciner introduced at Ribblesdale

1986 Imports of cement start to increase

Portland cement: 200 years of building for the future

Trajectory to 2050

Following on from the roadmap published in 2020, a net zero pathway has been developed to demonstrate one possible trajectory between now and 2050 to achieve the net zero ambition.

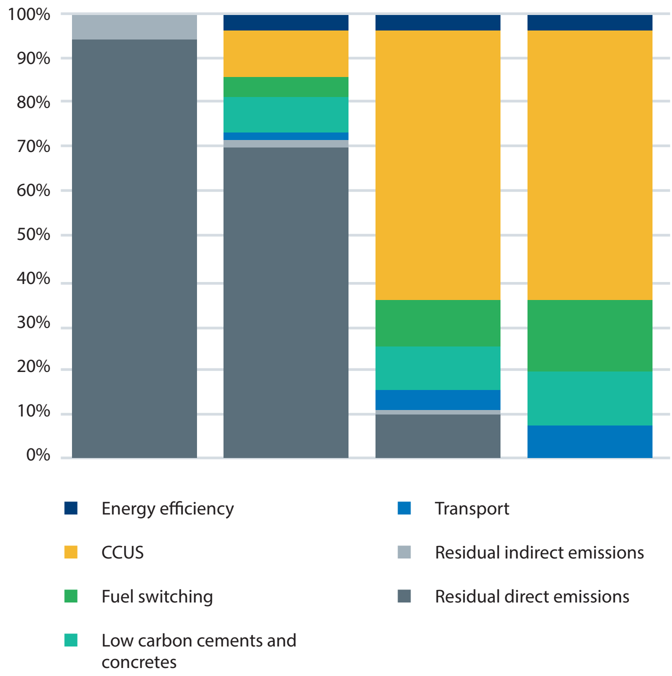
The trajectory shows one possible pathway to net zero for the sector as a whole, and does not reflect the opinion of individual member companies of the MPA or the ability of individual sites to decarbonise. The trajectory is an estimate based on published information and our knowledge of current government policies. It is subject to change and relies heavily on government implementation of enabling policy and regulation, and access to the required infrastructure and decarbonisation technologies.

The baseline is 2018 and the projected reduction is 28% by 2030, a further 61% reduction by 2040 (total of 89% compared to 2018), and achieving net zero by 2050 (see Figure 19).

The trajectory highlights how important Carbon Capture Usage and Storage (CCUS) is to the decarbonisation of cement and concrete. The pathway assumes the Padeswood cement CCS project, which is currently shortlisted under the Track 1, Phase 2 cluster sequencing for Government support, is operational by 2029, and that the Peak Cluster, which includes the Cauldon, Hope and Tunstead works, is fully operational between 2030 and 2040. The remaining CCUS required to meet the roadmap ambition is assumed to be deployed by 2040, but this requires enabling policy.

The other levers in the roadmap such as fuel switching, low carbon cements and concretes, and energy efficiency are forecast to make gradual improvements through to 2050, with the majority of advancements in low carbon cements and concretes being made between now and 2030.

Figure 19: Trajectory to net zero for the UK cement and concrete sector.



Challenges facing the sector

The cement sector operates in an internationally competitive environment, with the UK sites competing in regions for investment within their globally owned groups. In addition, cement (and clinker) is transported and traded internationally, so a level playing field with competitors on energy and carbon costs is vital to avoid carbon leakage (the offshoring of emissions and industry due to differences in carbon pricing and policies).

Cumulative costs on the cement sector

In the UK, industrial electricity, and historically carbon prices, are much higher than many competitor countries, where either the costs do not exist (as they are UK only schemes and charges) or energy intensive industries, such as cement, receive exemptions from the costs[1]. The UK costs arise from policies such as the UK Emissions Trading Scheme (UK ETS), Climate Change Levy (CCL), electricity network costs and policy costs (e.g. renewables obligations aimed at increasing renewable power generation), and the removal of the red diesel exemption. They are categorised as direct costs (e.g. UK ETS), indirect costs (electricity cost obligations), network costs (electricity) and other costs (e.g. plastic packaging tax).

The cement sector qualifies for some, but not all, reliefs available to energy intensive industries in the UK. Crucially, it does not qualify for relief from pass through costs on electricity bills of UK ETS and the Carbon Price Support (CPS) mechanism.

MPA calculates the cumulative burden of energy and climate change related policy costs on the cement sector and forecast future costs (Figure 20). In 2015 the cumulative costs were just under £50 million per year, but by 2035 will be in the order of over £300 million, even after support in the form of exemptions and compensations are applied. Many of these exemptions are reviewed every few years. If they were lost, then the sector would be facing costs of over £430 million. The majority of costs arise from the carbon cost in the UK ETS, along with the indirect costs the sector faces from electricity generators passing through costs of UK ETS and CPS.

Imports

The erosion of competitiveness resulting from high energy and carbon costs faced by domestic producers has contributed to imports of cement steadily increasing their market share over the last two decades. However, in recent years a sharp acceleration has been observed and in 2022, this resulted in imports making up 30% of the UK cement market[2].

The difference in climate ambition globally has resulted in a significant carbon cost differential across countries. Cement producers in the UK are paying a premium in direct and indirect carbon costs, such as those resulting from climate change related policy costs passed on in energy bills, compared to those of competitors overseas, where there is less ambition to reduce emissions.

As a result, a different operating model is emerging, with importers building either silos to directly import cement, or grinding plants to import clinker from outside the EU and grind it into cement for supply to the UK market[3]. This model avoids the high carbon costs of clinker production in the UK, but merely outsources the emissions.

Opportunities for the sector

Despite the challenges outlined here, there is deep commitment to innovation and decarbonisation across the sector. With some changes to government policy to support the transition rather than adding more and more cost, UK cement producers could be a world leader in the production of low carbon Portland cement.

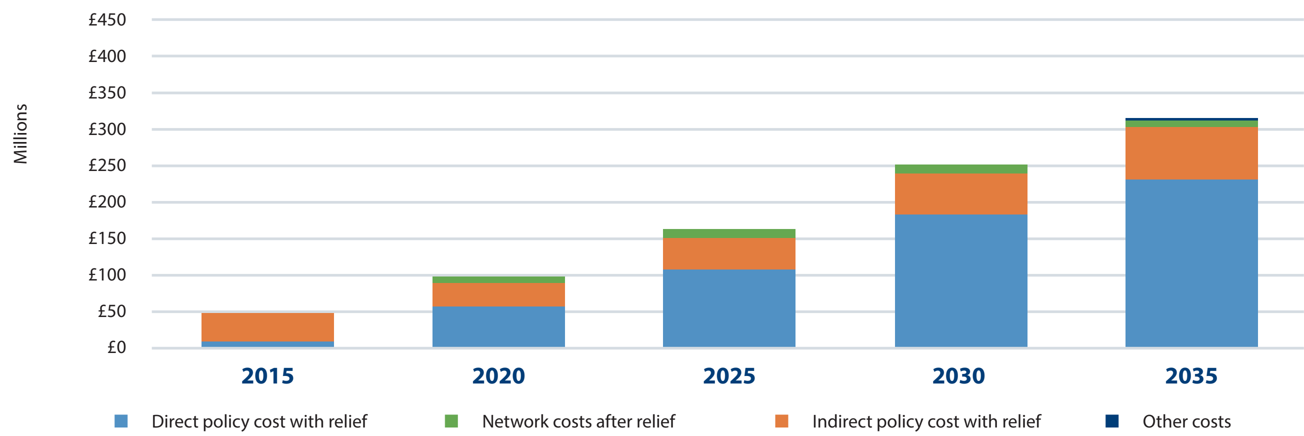


Figure 20: Cumulative burden of energy and climate change policies after support measures have been taken into account.

1987 1987 1988 1989 1990 1990 1990 1991

1987 Castle Cement established after RTZ Cement acquired by Aker & Euroc

1987 Announcement to discontinue the Common Price Agreement

1988 Cement and Concrete Association and Cement Maker's Federation combined to form the British Cement Association

1989 Recession hits

1990 World's oldest works at Swanscombe closes

1990 Many older wet and semi-process plants closed in favour of fewer large and energy-efficient works

1990 Alternative waste derived fuels start to be widely adopted along with rigorous environmental regulation

1991 Ground granulated blast furnace slag included in BS 12 cement specification standard for the first time

Portland cement: 200 years of building for the future

Delivering Net Zero UK Portland Cement

Decarbonisation of the cement sector requires enabling government policies to mitigate carbon leakage while the sector transitions to net zero and to accelerate the deployment of Carbon Capture Usage and Storage (CCUS), fuel switching and resource and energy efficiency measures.

This will help to deliver access to the required infrastructure and decarbonisation technologies, for example; cost competitive renewable electricity, waste biomass fuels and carbon dioxide (CO_2) transport and storage infrastructure.

The top 3 priorities for enabling policy are:

1. Government to implement a watertight UK Carbon Border Adjustment Mechanism (CBAM) for cement, drawing on international best practice, for implementation by 2026, to ensure levelised carbon costs with imports.

Historically the EU and UK Emissions Trading Schemes have mitigated carbon leakage through free allocation of allowances based on a benchmark set by the most carbon efficient plants in the scheme. However, this method is no longer adequate to mitigate carbon leakage, and in October 2023 the EU introduced the first phase of a new policy, the EU CBAM[1]. A CBAM requires importers to declare the embodied carbon in their imported products and then pay the difference in carbon costs between the importing country and the country of origin for each tonne of embodied carbon. If implemented in a watertight manner, this type of policy has the potential to level the playing field on carbon costs and support investment in decarbonisation. A UK CBAM[2] is required to level carbon costs between domestic producers and imports and to reduce the risk of EU bound imports being diverted to the UK to avoid paying the EU CBAM.

2. An Industrial Carbon Capture business model[3] framework, beyond that for Track 1[4] & 2[5] cluster sites (capex and opex) that is visible and remains stable for the next 15 years to enable investment planning at dispersed sites.

Carbon capture, and the infrastructure required to transport the captured CO_2, is currently a long term and expensive, but necessary, technology for the cement sector to decarbonise. It will therefore require Government support if the net zero cement produced is to remain competitive. The UK Government has proposed a business model to support both capex and opex costs, but it currently only covers the eight shortlisted projects (one of which is a cement project) in the Track 1 Phase 2 cluster sequencing process. The investment in a CCUS project is a long-term investment: sites beyond the Track 1 process need visibility of the funding available to start planning investments and the business model has to continue to reflect the need for stability over a long period.

3. Funding, at a suitable scale, to support upfront development costs, such as Front End Engineering Design study, for CCUS projects.

There are large upfront costs to develop a CCUS project, ahead of a Final Investment Decision, which are not currently supported by existing funding schemes in the UK. Companies must take on all the risk before knowing if the project will receive business model support and be viable. The UK has to attract new project investment by international businesses who will be comparing the support available in the UK to that available elsewhere. Currently the EU Innovation fund provides 50% funding for upfront costs with no requirement to repay this if the project is not found to be viable.

Looking forward there are extensive projects being progressed by UK cement producers which will contribute to the UK cement sector achieving net zero by 2050:

i. Heidelberg Materials Padeswood site is developing a project to deploy CCUS and is part of the track 1 phase 2 process in the HyNet cluster, with an aim to start operation by 2029[6].

ii. Three cement companies (Aggregate Industries, Breedon and Tarmac) are part of the Peak Cluster with the aim of deploying CCUS to capture over 3 million tonnes CO_2 a year by 2030[7].

iii. Cemex have installed hydrogen technology to help fire high proportions of waste derived fuels at Rugby cement works with the aim of reducing combustion emissions[8].

Figure 21: Map of Peak Cluster

1991 | 1994 | 1997 | 2000

1991 Tunstead works sold by ICI to Minorco

1994 Cement production falls to 12.2 Mt

1997 First gas scrubber installed at Ribblesdale

2000 Major new plant commissioned at Rugby replacing production at 7 other kilns located at Southam, Chinnor and Rochester

Environmental Performance of Cement Production

Author: Michael Conroy, Environment and Regulatory Affairs Manager, Mineral Products Association

Michael joined MPA in June 2022 and works closely with the UK cement manufacturers on environment management and regulatory matters.

He also engages with environmental regulators and Government departments to ensure the manufacturers have a supportive regulatory landscape to enable the journey to beyond net zero.

Portland cement: 200 years of building for the future

Figure 22: Flue gas pollution control.

Several decades ago cement was viewed as a dirty, polluting sector. However, cement producers have invested heavily to improve environmental performance and ensure sites are good neighbours that mitigate impacts on the environment to protect employees and local communities.

Emissions to air and improvement in performance

Producing 8.4 million tonnes of cement per annum, the UK cement sector is a key component of the UK construction industry. However, cement production also emits pollutants such as nitrogen oxide (NOx), sulphur dioxide (SO_2) and particulate matter (PM) which must be controlled to limit impacts on the environment and human health. Each pollutant has a different effect, such as smog due to emissions of NOx, acid rain due to SO_2 and impacts on people with breathing difficulties from emissions of particulate matter[1].

Each cement manufacturing plant in the UK is subject to the obligations set out in Part A environmental permits issued by the relevant environmental regulator[2]. Emissions limits based on the current Industrial Emissions Directive (IED)[3] and Best Available Techniques (BAT)[4] for several pollutants are set within the conditions and tables of each permit and each site must ensure they do not breach the limits[5]. Monitoring of various types is undertaken by each site based on site specific requirements to assist with tracking emissions.

Significant progress has been made in reducing emissions from the cement sector in recent decades through fuel switching away from coal, energy efficiency improvements and clinker substitution. Combined, these have resulted in an overall reduction in NOx of 87%, SO_2 by 95% and PM emissions by 92% (Figure 23) since 2005, and such emissions remain at a very low level.

Some of the main measures that have contributed towards the reduction in emissions to air are:

- Enclosure of dusty operations and collection of particulate matter in fabric filters (also known as a bag house) – collected particulate matter is often recycled back into the process.
- Installation of 'scrubber' systems.
- Installation of Selective Non-Catalytic Reduction (SNCR) technology.
- Use of alternative and waste derived fuel (WDF)[6].

2000 **2001** **2002** **2004**

2000 Rugby acquired by RMC

2001 Blue Circle acquired by Lafarge

2002 The Concrete Centre established

2004 New kiln installed at Padeswood

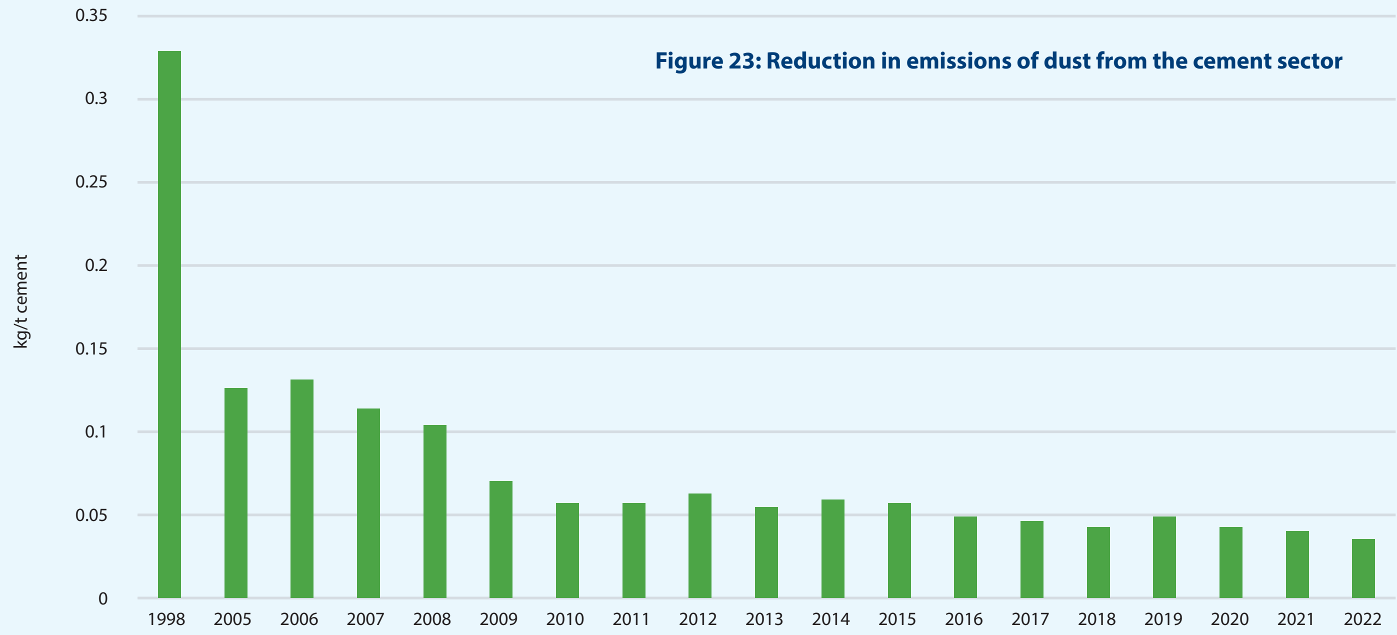


Figure 23: Reduction in emissions of dust from the cement sector

In order to maintain or further improve the reduction in emissions to air, there are several technical and regulatory barriers that need addressing, including:

- Ensuring there is a ready and consistent supply of alternative fuels and raw materials, especially biomass and waste derived fuels which are in high demand from other sectors such as Energy from Waste.
- The scalability and cost effectiveness of innovative or novel technologies that will enable the sector to further reduce its emissions.
- The current regulatory framework for reducing emissions to air from the cement sector results in lengthy permitting processes which delay, and sometimes prevent, quick deployment of innovative technologies. Such frameworks must be able to balance competitiveness, innovation and environmental objectives.

The cement sector is committed to being a good neighbour and reducing emissions to air ,to ensure no detrimental impact on air quality or the local environment. However, collaboration between the sector, regulators and relevant Government departments is required to develop a suitable regulatory regime that enables the sector to exploit novel technologies to continue reducing emissions to air.

Changes in fuels

Prior to the 1990s the primary source of fuel for the cement sector was fossil fuels such as coal, and the use of alternative fuels derived from wastes was only at 1%. In 2023 alternative fuels derived from wastes made up 54% of thermal input and consumed around 680 kt of waste. This contributed to a significant overall reduction in the emissions to air from the UK cement sector.

To enable the sector to more quickly deploy alternative waste fuels and switch away from coal, MPA and the Environment Agency developed a Waste Code of Practice (WCoP), which was first published in 2015. The objective of the WCoP is to recognise that once an alternative fuel is permitted at one site then it can be used at all UK sites. This allows new fuels to be quickly adopted across the sector whilst still ensuring no detrimental impact on the environment.

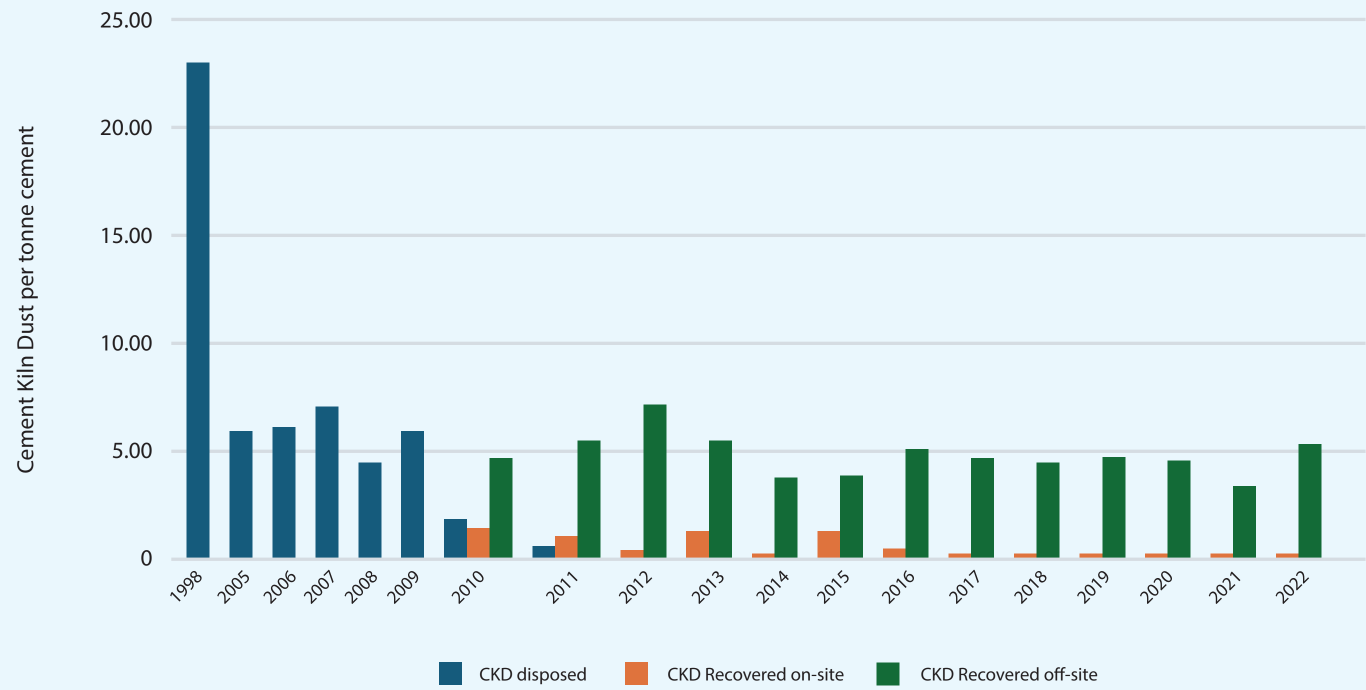
The WCoP sets out the procedure to introduce a new waste stream at a site. Wastes contained in an annexed list are enshrined in all cement plant permits in the UK as they have been trialled to determine the risk to the environment and human health from their use. They can be used after discussions with the relevant regulator. If a site wishes to introduce a new waste stream not included in the annexed list there is a clear flow chart that determines the type of notification or permit variation required. The WCoP is designed to reduce permitting delays and allow cement producers to use more waste derived fuels, therefore reducing the demands on non-renewable materials and reducing the impact on the environment.

One of the advantages of cement manufacture is that 'co-processing' means it utilises waste as a resource and not just for energy. Co-processing refers to simultaneous material recycling and energy recovery, and it means that waste fuels not only provide energy, but the combustion ash is also recycled into the cement clinker, replacing primary raw materials and resulting in a zero waste production process (Figure 24).

Unfortunately current UK policy incentivises waste, particularly waste biomass, towards electricity generation and anaerobic digestion. This means there is an ever decreasing volume of suitable waste available for the cement sector to increase its use and further switch away from traditional fossil fuels like coal. The lack of recognition for co-processing in waste management policy prevents the benefits of simultaneous recovery of energy and material recycling being maximised. Co-processing needs better recognition of the benefits it brings to the use of wastes, particularly those that may be deemed hard to recover or recycle, in a circular economic manner.

New waste streams are continually being explored by the cement sector. Some of the most recent waste streams to be considered are composite materials such as end-of-use wind turbine blades and orphaned boats, contaminated waste wood, and carpets and textiles. There are also encouraging trials looking at the co-processing of waste materials containing forever chemicals such as PFAS and POPs[7]. Increasingly, other sectors are looking at co-processing in cement plants as a more sustainable option for the use of their waste material.

Figure 24: The amount of cement kiln dust (CKD) recovered annually (note that no CKD is sent to landfill).



2005 **2005** **2006** **2007** **2008** **2008** **2008** **2009**

2005 Emissions trading adopted across Europe

2005 RMC acquired by Cemex

2006 Tarmac acquired by Anglo-American; rebrands as Tarmac Buxton Lime and Cement

2007 Heidelberg Cement acquires Hanson

2008 Financial crisis

2008 Mothballing of kilns at Ketton, Ribblesdale and South Ferriby and the closure of works at Barrington and Westbury

2008 Fewer works mean investment in distribution network with significant investment in specialist rolling stock, new terminals and handling facilities

2009 British Cement Association, The Concrete Centre and Quarry Products Association form the Mineral Products Association

Portland cement: 200 years of building for the future

Ref	Activity	Permit application	Minor variation	Normal variation	Substantial variation	Transfer application	Surrender application
1.13.1	Section 3.1 – production of cement using waste derived fuel	£17,707	£5,312	£8,854	£15,936	£2,459	£10,824
1.13.2	Section 3.1 – production of cement without using waste derived fuel	£13,903	£4,171	£6,952	£12,513	£2,459	£8,342

Figure 25: Permitting charges for the production of cement with and without waste derived fuels (Environment Agency, 2022)

Future environmental regulation

Much of the regulation that pertains to the UK cement sector has been developed over the last 30 years. However, it has a heavy focus on fossil fuel based technologies[8], does not consider business competitiveness, does not provide the best environmental option and does not support innovation or the move towards a more circular economy. The current permitting charges for a cement manufacturing plant that uses waste are more than the charges if a plant were to use 100% fossil fuels (Figure 25).

To support the decarbonisation of the cement sector through innovation, the environmental regulatory regime needs to:

- Be flexible and responsive
- Deliver the best environmental outcomes
- Deliver in a timely manner
- Encourage investment
- Keep UK businesses competitive

All UK cement plants are obligated to comply with the conditions laid out in their environmental permits issued by the relevant environmental regulator. Currently the majority of changes that need to be made to a cement plant to achieve the beyond net zero target require a permit variation to be undertaken. 89% of the decarbonisation technologies detailed in the MPA Roadmap to Beyond Net Zero[9] – low carbon cement and concretes, fuel switching and Carbon Capture Usage and Storage (CCUS) – are reliant on permitting in some form.

The current environmental regulatory regime is bureaucratic, time consuming, costly and can deliver perverse environmental outcomes. Although permitting timescales are improving, the length of time it takes to obtain a permit variation to trial a new technology remains a determining factor in whether an international business chooses the UK for such a trial. If the trial is undertaken in the UK, continuing to use the technology beyond the trial requires an amended permit. This can result in further scrutiny from the regulator which takes more time and incurs higher fees. This regime could be considered a barrier to innovation. The permits cement sites must comply with are ultimately based on single point emissions from the site, either to the air, land or water. This can have the effect of forcing investment in those point source emissions without accounting for any environmental gain or consideration of whether investment would be better spent elsewhere, such as on the transport infrastructure from the site to aid in reducing transport emissions.

The European Commission is currently establishing the Net-Zero Industry Act (NZIA)[10] with an aim of making the EU the home for clean manufacturing and green jobs. The regulatory controls on new and novel technologies will be simplified and the permitting process will be accelerated. To promote innovative net-zero technologies the NZIA establishes the use of regulatory sandboxes.

Many of the UK cement manufacturers are headquartered outside the UK and the concern with the development of the NZIA in Europe is that this has the potential to lead to a leak of innovation investment out of the UK. In turn, this has the potential to lead to a de-industrialisation of the UK cement sector in favour of the import of low carbon cements from other countries where the process of innovation and permitting is simpler, quicker and more cost effective.

However, the UK has the opportunity to create an environmental regulatory regime that instead invites innovation investment. To this end MPA and its members are actively promoting a different approach to regulation that ensures the UK cement sector is at the forefront of the development and deployment of net zero technologies. This includes the use of regulatory sandboxes, which has been discussed with, and well received by, the UK Government.

Summary

The UK cement sector has made significant progress in addressing and reducing emissions of pollutants to the atmosphere from the production of cement. Measures to reduce emissions further are constantly being explored by the sector and this will build on the positive progress made to date.

One of the contributing factors in the reduction of emissions has been the switch away from fossil fuels towards alternatives derived from waste, which currently meet over 50% of the sector's fuel needs.

The sector will continue to proactively work with relevant Government departments, the regulators and other key stakeholders to ensure the continued reduction in emissions of pollutants, use of more fuels derived from waste, and to develop an environmental regulatory regime that supports innovation, encourages investment and keeps UK businesses competitive.

2009 **2012** **2013** **2013**

2009 New grinding plant commissioned by Cemex at Tilbury

2012 Lafarge Cement UK and Tarmac propose merger to LafargeTarmac

2013 Mineral Products Association publishes Greenhouse Gas Reduction Strategy

2013 Hope Construction Materials established out of newly merged LafargeTarmac

CASE STUDY

Tarmac Community Liaison Committee meeting and site visit

To ensure the needs and expectations of the local community are fully understood an assessment is made.

A stakeholder heat map is produced to allow the whole site to focus on the stakeholders requiring regular engagement and others that require regular communication.

A plan for each site is produced which covers the following:

- **Community meetings, visits and events.**
- **Donations and volunteering hours made to local communities.**
- **STEM engagements and school events.**
- **Any communications in the press and social media.**

The aim at Tunstead Cement Works is to have at least one Community Liaison Committee meeting per year and at least one community event per year.

The Community Liaison Committee is made up of local parish councillors, district councillors, mineral planners, and invitations are extended to other local interested parties when applicable.

The meetings are held in various locations around the plant to showcase each operation or to discuss topics of interest.

The site also invites local schools to visit.

CASE STUDY

Cemex grassland restoration for Lepidoptera, Kensworth Quarry, Bedfordshire

Objective

Creation of grassland to support species of Lepidoptera.

Context

Kensworth Quarry is in Bedfordshire and supplies chalk to Rugby Cement Works. The chalk is quarried before being liquified and pumped, via an underground pipe, to the cement works over 90 km from the quarry. Areas of the site have been restored and are now open to the public and classed as a nature reserve. The habitats created include woodland and scrub, but also chalk grassland which is a much rarer type of habitat. Chalk grassland has been in decline in the UK and, because of its low nutrient but base rich soil, supports many rare wildflowers and invertebrates – including butterflies and moths (Lepidoptera). Working with the support of the local Wildlife Trust and the RSPB, Cemex planted specially selected wildflower seeds to attract butterfly species defined as species of principle importance.

Top left: Conservation Grazing – Herdwick Sheep
Top right: Kidney Vetch, Bottom: Cowslip

Kensworth Quarry and restored areas.

Solutions

Working closely with the three counties Wildlife Trust and the RSPB, areas within the restored area were chosen and sown with wildflower seeds that would attract rare butterflies. This included wildflower species Primula veris (Cowslip) and Anthyllis vulneraria (Kidney Vetch). These species of wildflower form an essential part in the lifecycles for Duke of Burgundy (Hamearis Lucina) and Small Blue (Cupido minimus) Butterfly species. The grassland is also grazed during the late autumn by Herdwick sheep to maintain the quality of the habitat.

Result

Recent surveys have identified a growing variety of wildflower and invertebrate species on site at Kensworth. There are several colonies of Small Blue Butterflies as well as the nationally rare Duke of Burgundy Butterfly. Two other species of principal importance doing well on site include Dingy Skipper and Small Heath. The site also hosts many species of wildflower which are dependent on chalk grassland, including Milkworts and Orchids.

Left: White Helleborine (Orchid Species)
Top right: Duke of Burgundy
Bottom right: Small Blue Butterfly

Sustainable Concrete

Author: Dr Noushin Khosravi, Head of Sustainability, UK Concrete, Mineral Products Association

Noushin is a civil engineer and has an MSc and PhD in concrete technology. Her role as Head of Sustainability involves demonstrating how concrete can be used as part of a net zero and circular economy.

She is responsible for providing technical and sustainability advice and support to designers, constructors, and clients of concrete construction.

She has successfully led the update of the UK Concrete Sustainable Construction Strategy and manages delivery of its commitments on behalf of the UK concrete sector.

Concrete and cement applications

Concrete is a versatile construction material with a wide range of applications due to its strength, durability, adaptability, and local availability. There is a diverse application of concrete from buildings to a wide range of infrastructures. Examples include residential and commercial buildings as well as factories and warehouses, transport infrastructure, bridges, water infrastructure, energy infrastructure, and architectural or even decorative uses. The applications of concrete continue to evolve as technology and construction methods advance, making it a fundamental material in the field of civil engineering and construction.

Cement is a key component in concrete, playing a crucial role in its properties and performance. Cement acts as a binding agent that holds the various components of concrete together. The type and composition of cement influences the final strength and durability of the concrete. The cement content of concrete is normally in the range of 10-15% by volume, but it is the main source of embodied carbon in concrete. UK concrete and cement currently account for around 1.5% of UK carbon dioxide emissions, five times lower than the global average where cement accounts for around 7% of emissions. Early action by the UK concrete and cement industry has resulted in emissions already being 53% lower than 1990. However, there is an urgent need for further action to address the climate emergency, which requires a comprehensive approach that includes both technological innovation and changes in industry practices.

Demand for sustainable construction materials

The demand for lower carbon and sustainable concrete has been growing steadily in recent years, driven by increased awareness of the environmental impact of concrete production and a combination of regulatory, market, and societal pressures for more responsible construction practices. By launching the Concrete Industry Sustainable Construction Strategy in 2008, the concrete industry demonstrated its leadership position by setting clear targets and ambitions for the delivery of a sustainable, low-carbon built environment in a socially, environmentally, and economically responsible manner. The first milestone of the new strategy was the launch of a framework of performance indicators that have been reported by the industry annually since 2008. The strategy and framework were informed by sector and stakeholder collaboration to agree best practice sustainable outcomes. Some of the industry's notable highlights and achievements were published in the MPA's Ten Years, Ten Insights publication[1].

The UK concrete industry has recently updated its sustainability strategy[2] which sets a new vision for the sector aligned with new targets, priorities and sustainability considerations that have emerged and evolved since the development of the original strategy some 15 years ago, including the publication of the UK Concrete and Cement Industry Roadmap to Beyond Net Zero[3].

The Low Carbon Concrete Group (LCCG)

Achieving a net zero carbon target for concrete involves a combination of technological advancements, regulatory support, industry collaboration, and a commitment from stakeholders across the value chain. That is why the Low Carbon Concrete Group (LCCG), which is a cross industry group of stakeholders, was formed in the UK in 2020. The LCCG was formed by the Green Construction Board and is the author of the Low Carbon Concrete Routemap[4] published in 2022 by the Institution of Civil Engineers (ICE).

The LCCG Routemap to net zero sets out recommendations and guidance for clients, designers, researchers, suppliers and policy makers to enable production and use of lower carbon concrete. The Routemap sets out its proposals across seven strands, followed by a section identifying the 'next steps' with a timeline for improvements. Every strand will require continued research and development to meet the target of net zero by 2050, with the next 10-15 years being critical to scale up new technology and approaches. The first strand covers the continuous process of accurately benchmarking concrete. Strands 2, 3 and 4 are related to the use of concrete. Strands 5, 6 and 7 are related to the production of concrete. The document proposes several key actions, including:

- Creating a standardised carbon rating system that would make it easier for clients and designers to choose lower carbon options.
- Maximising opportunities for reducing the clinker content, especially by using limestone and other additions/ supplementary cementitious materials.
- Using design approaches that require less concrete or lower-carbon concrete, such as using voids, coffers, non-structural fill and smaller spans between columns.

2015 **2017** **2020** **2020**

2015 Global companies Holcim and Lafarge announce merger to form LafargeHolcim. In the UK Cauldon and Cookstown assigned to Aggregate Industries (LafargeHolcim subsidiary in the UK). The other cement works sold to CRH and trade as Tarmac Ltd

2017 Breedon Group acquire Hope Construction Materials

2020 Mineral Products Association publishes UK Concrete and Cement Industry Roadmap to Beyond Net Zero

2020 Cemex mothball South Ferriby plant

- Early engagement with concrete suppliers to discuss and choose a mix that meets the requirements with the minimum carbon.
- Updating technical standards to reflect the priority of reducing carbon and the latest materials and techniques.

The Routemap will remain a live document that is subject to updates as many workstreams emerge from the recommendations it makes. The LCCG stays active and engaged to support the decarbonisation of the construction industry.

Development of embodied carbon classification schemes

The first step in the Low Carbon Concrete Routemap is to measure carbon and to create a baseline or benchmark. The Embodied Carbon of Concrete – Market Benchmark[5] (Figure 26) was created to provide a mechanism for rating the embodied carbon of concrete within the range of concretes in use across the market based on strength. It is important to note that $kgCO_2/m^3$ connected to strength is not applicable for all concrete, nor for one concrete application at all times in all regions. However, the current benchmarking exercise can be a starting point with the intention to evolve in the future. The LCCG Market Benchmark is a tool to assess the embodied carbon of concrete. The tool must be used in the context of reducing overall project and global greenhouse gas (GHG) emissions. Sometimes a concrete with higher embodied carbon used more efficiently may result in lower project and/or global GHG emissions.

The LCCG Market Benchmark summarises the distribution of cradle-to-gate carbon emissions of normal weight concrete recently produced in the UK. The Benchmark covers Life Cycle Analysis (LCA) stages A1 to A3 ('cradle to batching plant gate', or 'cradle to precasting mould'). The benchmarking is updated annually with the data provided by MPA member companies to reflect what has been specified and supplied in the market.

Other classification schemes like the Embodied Carbon Classification Scheme for Concrete – Arup/UKRI[6] and the Industrial Deep Decarbonisation Initiative (IDDI)[7]/ Global Cement and Concrete Association (GCCA)[8] global scheme have also been recently developed. These schemes are going to be static tools and complimentary to the LCCG dynamic market benchmarking. Together they will provide a powerful tool for planning, specifying, and reporting the embodied carbon of concrete in the short and long term. They will facilitate defining lower carbon concrete. LCCG encourages reporting of carbon for all concrete against the frameworks and further guidance is under development with regards to how the tools work together, and which tool should be used when. The rating systems aim to provide a comprehensive framework for evaluating and comparing concrete products, promoting optimisation and conservation for achieving lower carbon solutions.

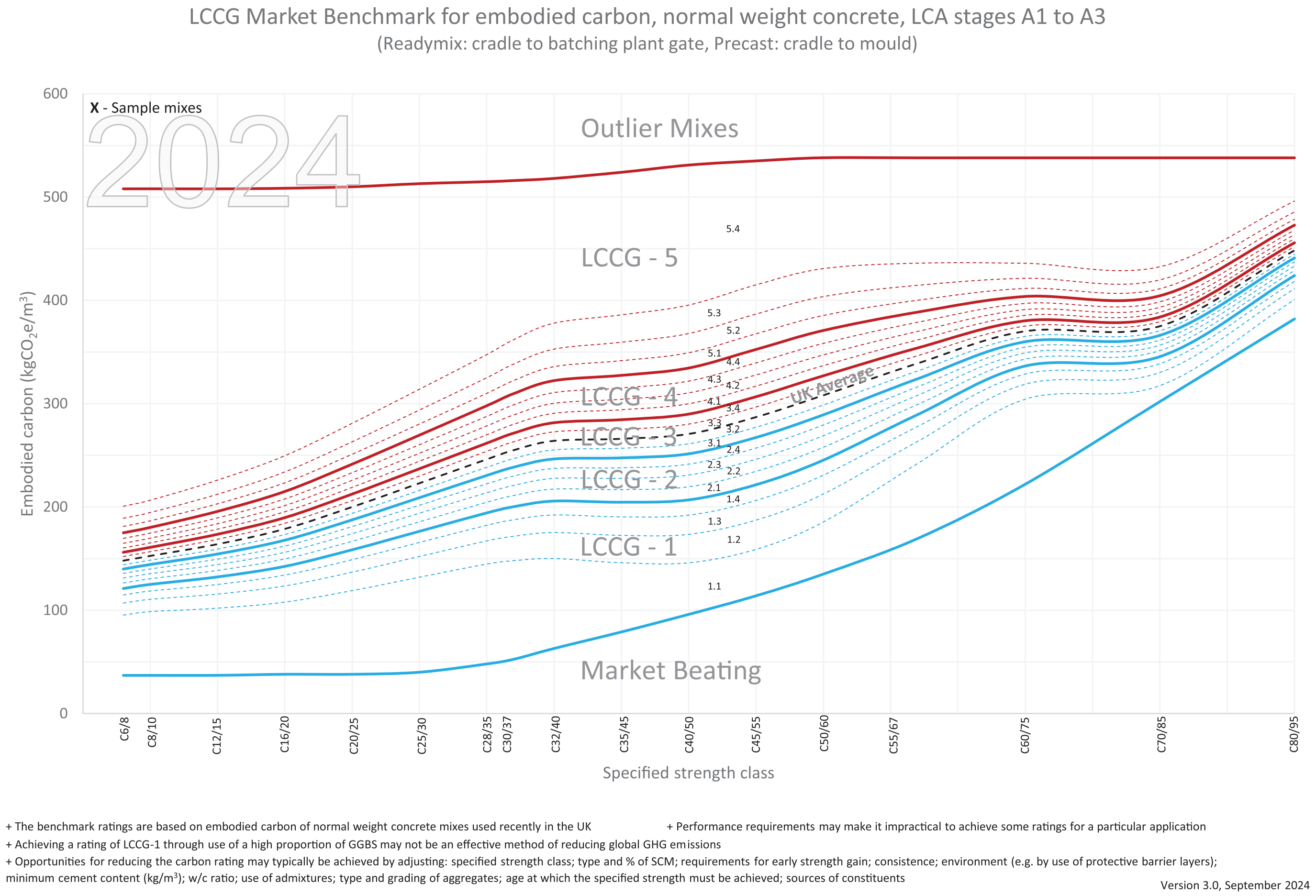
Concrete is essential

The need for infrastructure development, including transportation, water supply, and low carbon energy projects, will contribute to a sustained demand for concrete in the coming years. As the global population continues to grow, especially in urban areas, there will also be an increased demand for buildings and infrastructure, leading to a higher demand for concrete globally. Concrete's remarkable properties, including its inherent stability, robustness and resilience, make it an indispensable material for current and future generations. From the significant progress the industry is making to lower its carbon footprint through to the outstanding sustainable buildings and green infrastructure being constructed, concrete is part of the solution towards creating a net zero carbon society.

Achieving net zero carbon concrete is necessary for climate change mitigation and adaptation, and it can only happen through collaboration across the value chain which promotes a holistic and integrated approach for decarbonisation. By working together, stakeholders can address challenges, share knowledge, and collectively contribute to the development of more sustainable concrete solutions.

Portland cement: 200 years of building for the future

Figure 26. LCCG Market Benchmark for embodied carbon, normal weight concrete, LCA stages A1 to A3, with rating subdivisions included (Ready-mixed: cradle to batching plant gate, Precast: cradle to mould)



2020 2021 2021 2022 2023 2023 2024

2020 UK exits the European Union

2021 UK Emissions Trading Scheme established

2021 Cookstown sold and rebranded to Cemcor

2022 Mineral Products Association completes demonstration of net zero fuelled cement production

2023 Hanson Cement rebranded to Heidelberg Materials

2023 BS 8500 updated to include ternary cements

Portland cement: 200 years of building for the future

Portland cement: 200 years of building for the future

Celebrating 200 years

Author: Dr Pal Chana, Special Advisor to the Mineral Products Association

Pal is a Special Advisor to the Mineral Products Association. Previously he was an Executive Director with responsibility for several mineral products including cement. He has 45 years' experience in the cement and concrete industry, and has led several joint venture projects with industry, Government and academia. He is the author of numerous publications and the recipient of several honours and prizes for his work on advancing knowledge and developing best practice in cement and concrete construction.

A chartered civil engineer by training, he held senior positions at Imperial College London and BRE Ltd before joining the Mineral Products Association. He is an Honorary Professor in the School of Science and Engineering at Dundee University.

This celebratory brochure has been produced to mark the invention of cement 200 years ago in the UK by Joseph Aspdin. Its continuous use since 1824 makes Portland cement one of the most important, and often overlooked, British inventions.

The story of Portland cement is simply amazing. As the 'glue' that makes concrete, it has made an essential contribution to the UK's economy and our way of life for the past 200 years and continues to do so today.

Yet, the story of cement is far from over. In the future, low or zero carbon cements will form the essential building material for our new homes, schools, hospitals, workplaces, roads and railways, as well as the infrastructure that provides us with clean water, sanitation and low carbon energy.

The sector will continue to work towards meeting low carbon demand through ongoing production of UK Portland cement.

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The Mineral Products Association is the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and industrial sand industries.

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