

# Cement, Concrete & Sustainability

A report on the Progress of the UK  
Cement and Concrete Industry  
Towards Sustainability

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## ABSTRACT

Recent developments in sustainability, as outlined in Government and other publications, are introduced. They relate to indicators of sustainable development and data for energy use, resource use, emissions and waste. These, plus social behaviour, are key factors for understanding and controlling impacts such as consumption of scarce resources, polluting emissions, climate change and waste. The major role that construction can play in increasing sustainability is highlighted with a broad perspective on the impacts associated with concrete, construction materials, buildings and transport.

An initial framework for assessing and improving the sustainability of cement and concrete, that reflects the views of UK and European cement industries, concrete industries, Government departments and users of concrete buildings and structures, is outlined. The long-term aim is to provide convincing information on the roles cement and concrete can play in improving sustainability at local, national and world levels. The following coordinated actions are suggested:

- Maintain the database on resource use, energy use and environmental impacts for UK cement industry to provide credible whole-industry data for analyses at subsequent life cycle stages.
- Illustrate, with case studies the environmental advances afforded by using cementitious materials.
- Regularly update the environmental report on the UK concrete industry to review performance and provide a perspective relative to other sectors.
- Undertake benchmarking to highlight areas of potential improvement.
- Monitor UK and European sustainability developments, particularly with regard to indicators that are pertinent to construction.
- Provide support for minimising environmental impacts from the operational lifecycle stage of buildings and structures, particularly those associated with fossil energy use and from the disposal/recycling lifecycle stage of buildings and structures.

- Expand contacts with owners and users of buildings and address any reservations about the sustainability of concrete.
- Provide support for renewable energy projects that utilise concrete.

## INTRODUCTION

Sustainable development involves meeting present needs without compromising the ability of future generations to meet their needs. The UK cement and concrete industries will be expected by its stakeholders to develop progressive policies on environmental performance improves in unison with social and economic performance. The industries are strategically important for the bulk of construction, i.e. housing, schools, hospitals, commercial buildings, industrial buildings, water supplies, railways, roads and bridges. The commercial activity and employment associated with construction and the use of concrete have significant social and economic benefits; concrete sector sales amount to about £4 billion and the direct employment figure is about 27000.

The UK has a mature infrastructure and the per capita cement consumption of around 210Kg/year is about half of the typical European figure. Similarly, ready-mixed concrete usage per capita in the UK is around 60% of that of its continental neighbours. It is a major challenge for the UK concrete industry to find ways that are acceptable to all stakeholders to improve environmental performance without social and economic penalties.

The UK Department of the Environment, Transport and the Regions, DETR has published several reports that illustrate how sustainability might be monitored and improved both nationally and within the construction sector. In 1994 DETR published *Sustainable Development – the UK strategy* and followed this in 1996 with *Indicators of sustainable development for the UK* <sup>(1)</sup> to provide relevant statistical data. The 120 indicators were arranged into 21 families to provide a preliminary framework for assessing various aspects sustainable development. Many of the indicator families were relevant to cement, concrete, construction materials and other construction sectors: the economy, waste, mineral extraction, land use, air quality, acid deposition, climate change, forestry, energy and transport. The publication in 1999 of *Quality of life counts* <sup>(2)</sup> refined and updated the 1996 publication and provided a baseline assessment for a

broad range of sustainability indicators. At the end of 2000 the UK Environment Agency released a report *Environment 2000 and beyond* <sup>(3)</sup> that identified energy use, resource use, agriculture and social behaviour as key factors for climate change, loss and damage to habitats and pollution of air, water and soil.

The DETR report *Building a better quality of life* <sup>(4)</sup> confirmed earlier views <sup>(5,6)</sup> about the critical role construction could play with regard to UK environmental impacts. It highlighted five ways that the construction industry could contribute to sustainable development:

1. being more profitable and more competitive
2. delivering buildings and structures that provide greater satisfaction, well-being and value to customers and users
3. respecting and treating its stakeholders more fairly
4. enhancing and better protecting the natural environment
5. minimising its impact on the consumption of carbon-based energy and natural resources

More specifically the construction industry was encouraged to reuse built assets, minimise waste, recycle materials, minimise energy in the construction and use of buildings, use environmental management systems to reduce pollution, enhance bio-diversity, conserve water, respect people and their local environment, measure performance and set targets for improvement. The cement and concrete sectors routinely provide comment on DETR consultation papers relating to the environment and sustainability.

In December 2000 the European Commission's Directorate General for Energy and Transport organised a meeting of experts to review energy usage and carbon dioxide emissions associated with housing, buildings, industry and transport <sup>(7)</sup>. In order to meet climate change commitments there could well be pressure to develop and adopt harmonised energy efficiency standards for new and existing buildings. Furthermore climate change commitments could become more stringent in the light of recent warnings from the Intergovernmental Panel

on Climate Change that the effects of global warming will be greater than previously forecast <sup>(8)</sup>.

This paper presents preliminary information for assessing and improving sustainability to stimulate greater concrete industry participation in the reporting of performance. The long-term aim is to provide convincing information on the role concrete can play in improving sustainability at local, national and international levels. It attempts to reflect the views and interests of:

1. The cement and concrete industries
2. Relevant UK Government departments including regulators
3. Architects, designers and contractors
4. Owners and users of concrete buildings and structures

The approach spans commercial, engineering, environmental and health and safety aspects of cement and concrete.

## **THE UK CEMENT INDUSTRY**

The British Cement Association regularly collects environmental data from UK cement manufacturers, much of which is reported to the Environment Agency, on resource use, energy use and environmental impacts of cement industry (by company and works) to provide credible whole-industry information. For example the BCA liaises with the National Atmospheric Emissions Inventory staff to ensure that UK cement industry data are realistic. The environmental data are also core items for life cycle analyses of concrete, concrete products and structures. In the pursuit of continuous improvement all UK cement works operate environmental management systems and all are certified to ISO 14001 or EMAS standards.

The recent introduction of a climate change levy has involved the BCA in the compilation of energy use, energy efficiency performance and targets for the UK

cement industry. In return for a reduced levy rate the cement industry has agreed with Government to achieve a specific energy consumption of 1.25 kWh/kg of cement by the year 2010, a 25% improvement over 1990. Also the UK cement industry liaises with the Environment Agency on the recovery of more energy from waste, thereby reducing fossil fuel use, manufacturing costs and UK greenhouse gas emissions. The above interactions with other organisations have helped to improve the quality and credibility of environmental data for the UK cement industry.

The UK cement industry is participating in a World Business Council for Sustainable Development (WBCSD) project *Towards a sustainable cement industry*. The broad-ranging project has addressed thirteen sub-studies as follows:

1. Stakeholder communications approaches
2. Communications strategies for external stakeholders
3. Business case for SD
4. Company alignment on SD
5. Performance indicators
6. Life cycle analysis
7. Innovation
8. Climate Change
9. Industrial Ecology.
10. Improving Environmental Performance along the Value Chain
11. Impact minimization (land, biodiversity)
12. Socio-economic developments
13. Public policy instruments

The first stage of the project was completed this year and in July the participating companies announced their commitments on reporting progress, health, safety, alternative raw materials and fuels, emissions and climate change impacts. The current position can be monitored on the WBCSD website <sup>(9)</sup>. The UK cement industry also collaborates with its European neighbours via

Cembureau to produce international information on cement plant, cement production, fuels, energy and emissions. The BCA has provided environmental inventory data on UK cement manufacture, to be aggregated with data from other countries, for use in a European concrete industry joint project on the life cycle analysis of concrete that is coordinated by Cembureau.

The need to reuse existing urban sites, some of which are contaminated, for housing and business premises has stimulated remedial ground engineering using cement for chemical and physical stabilisation. A research centre has been established at the University of Greenwich <sup>(10)</sup> and UK cement manufacturers have developed tailored products and processes.

## **CONCRETE INDUSTRY**

A recent Concrete Industry Alliance project produced an environmental report on the UK concrete industry that reviewed recent performance, provided a perspective relative to other UK sectors and outlined future prospects <sup>(6)</sup>. The project also produced eight environmental case studies that addressed issues of particular significance to partners <sup>(11)</sup>. The data in the environmental report have been updated to include those for 2001 and a review is given below. The cradle to construction site environmental effects of concrete are aggregated from cement, pulverised fuel ash, ground granulated blastfurnace slag, reinforcement, aggregate and concrete production, electricity use and generation and all transport contributions. The concrete production data include contributions of pre-cast, ready-mixed and site-mixed plain and reinforced concrete. Data reliability has improved over the period 1994 to 2002 but it should be noted that numerous assumptions are required to produce the following charts and figures.

There are variations of production from year to year that reflect market activity and, for clarity, information in Table 1 is presented per kilo-tonne of concrete.

The reductions in employment reflect commercial pressures to improve efficiency. The extraction of minerals for the production of concrete diminishes slightly from 1994 to 2001 due to an increase in the use of wastes. The landfilled waste figures of about 60 t/Kt of concrete are dominated by the nominal returns of extracted material during aggregate production; such material is environmentally inert. There should be reductions of landfilled waste and extracted minerals where concrete waste is an economically viable concrete or construction aggregate. The water usage figure of around 1400 m<sup>3</sup>/Kt of concrete is also largely associated with aggregate production but much of the water is non-potable and is reused.

**Table 1:** Parameters per kilo-tonne of concrete

<b>Parameter</b>	<b>1994</b>	<b>1996</b>	<b>1998</b>	<b>2001</b>
Direct employment - staff	0.278	0.278	0.207	0.209
Extracted minerals - Kt	1.021	1.009	0.995	0.914
Land in active use - ha	0.200	0.200	0.196	0.182
Waste to landfill - t	66.7	67.9	68.5	62.8
Water consumption - m3	1450	1436	1418	1297
Fossil fuel energy - GJ	483	501	485	426
Electrical energy - GJ	91.7	93.7	91.2	87.5
Transport - KtKm	47.3	47.5	48.7	49.2
Carbon dioxide to air - t	126	131	124	114
Sulphur dioxide to air - t	0.640	0.350	0.328	0.273
Nitrogen oxides to air - t	0.795	0.680	0.681	0.606
Carbon monoxide. to air - t	0.419	0.363	0.312	0.284
Particulates to air - Kg	77.9	64.6	59.4	53.0
Heavy metal to air - Kg	0.592	0.567	0.539	0.477

There was a reduction of fossil fuel energy used in 2001 primarily due to improvements in the plant for cement manufacture. Electrical energy usage decreased slightly from 1994 to 2001; it accounts for 17% of primary energy. About 60% of the electricity usage is for cement manufacture and 20% for the manufacture of steel reinforcement. The average fossil and electrical energy usage in 2001 for plain concrete were 412 and 73 MJ/t and for reinforced concrete they were 451 and 116 MJ/t, respectively. The higher figures for reinforced concrete reflect the electrical energy usage in steel reinforcement manufacture. The small transport figures reflect the fact that concrete largely

employs local materials but there are signs that the transport impact is starting to increase, possibly as a result of closures at less efficient sites.

About 85% of the emissions of carbon dioxide derive from cement manufacture. The reduction from 1994 to 2001 reflects closure of less efficient cement kilns, an increase the average size of kilns and an increase in thermal efficiency. Furthermore current usage of ground granulated blastfurnace slag and pulverised fuel ash at about 14% of the cementitious material significantly reduces the environmental impact of concrete. Without this replacement level the average specific carbon dioxide emission would have been about 10 kg/t greater. Table 1 shows that emissions to air of sulphur dioxide, nitrogen oxides, carbon monoxide, particulates and heavy metals have reduced from 1994 to 2001: the reductions derive largely from improvements in cement manufacture. Road transport is a significant contributor to emissions of nitrogen oxides and carbon monoxide.

The lower thirteen rows of Table 1 show key indicators of the environmental impact of concrete. There has been an average improvement, over this basket of indicators, of 17% from 1994 to 2001; the main improvement has been in emissions to air. Using the same set of indicators 40% and 8% of the environmental effects of concrete in 2001 were attributable to Portland cement and reinforcing steel manufacture, respectively.

A Concrete Society Environmental working Group has published a review of the role of concrete in the built environment in the journal *Concrete* <sup>(12)</sup>. It presents an overview on the way concrete affects our environment in terms of its production and use in construction. Another review, entitled *ECOconcrete*, published by The Reinforced Concrete Council <sup>(13)</sup>; addresses sustainable design of a range of reinforced concrete buildings and structures.

In order to foster the development of Life Cycle thinking at the operational level, the British Precast Concrete Federation has developed and implemented a

'Waste minimisation Award Scheme'. The purpose of this is to encourage pre-cast concrete manufacturers of all scales, to discuss, refine and carry out waste minimisation activities at their operations and to enter these initiatives into a national award. Each year, a winner is selected by a panel of judges and the five best entries become the contents of a 'best practice' paper, which is then distributed to all within the industry. Although the scheme is not prescriptive to a particular method of waste minimisation, it operates on the principles of eco-efficiency and thus will improve a process's and associated products' score in most LCA models. Areas that are commonly tackled by the scheme include water use, material density, energy consumption and reducing wastage.

At an international level the European concrete sector is engaged in an environmental life cycle analysis project that is examining ten ready mixed and precast concrete units including pavements, piles, walls, floors, columns, beams and slabs. The project partners from the relevant European associations are Cembureau (cement), BIBM (pre-cast concrete), ERMCO (ready-mixed concrete), EISA (independent steelworks), UEPG (aggregates) and EFCA (admixtures). The life cycle analysis software will improve sector understanding of environmental issues and assist in defining and improving environmental performance.

## **CONCRETE IN PERSPECTIVE**

The concrete industry directly employs around 27000 people and is an essential element of a construction sector that employs about 7% of the UK workforce. Table 2 provides a broad, UK perspective on the environmental effects of concrete: the data are based upon recently published statistics but estimation of construction components required numerous assumptions so the figures in columns 3 and 4 should be regarded as approximate. The table gives the percentages of the UK totals that can be attributed to the supply of concrete and

to other sectors directly and indirectly (e.g. transport) connected with construction design and planning.

**Table 2:** Concrete, construction materials, construction, transport and UK totals: estimated 2001 environmental data and percentages of UK totals

Parameter	Plain & reinforced concrete	Construct. Materials [a]	Construction & buildings [b]	Transport	UK total
Extracted minerals - Kt (% of UK)	116897	201715	201715	62087	293000
	39.9	68.8	68.8	21.2	100.0
Land in active use excl timber - ha (% of UK)	23224	2215781	3812981	1573000	24200000
	0.1	9.2	15.8	6.5	100.0
Water consumption - m3 (% of UK)	1.659E+08	6.000E+08	6.847E+09	0.000E+00	1.170E+10
	1.4	5.1	58.5	0.0	100.0
Energy [c] - TJ Primary (% of UK)	65708	347056	4480504	2370870	9433646
	0.7	3.7	47.5	25.1	100.0
Carbon dioxide emission to air - Kt (% of UK)	14587	39829	262700	134271	557700
	2.6	7.1	47.1	24.1	100.0
Sulphur dioxide emission to air - Kt (% of UK)	34.9	161.9	820.8	62.0	1258.0
	2.8	12.9	65.2	4.9	100.0
Nitrogen oxides emission to air - Kt (% of UK)	77.5	247.2	854.8	1011.1	1806.6
	4.3	13.7	47.3	56.0	100.0
Carbon monoxide emission to air - Kt (% of UK)	36.3	104.4	606.8	3458.6	4311.3
	0.8	2.4	14.1	80.2	100.0
Particulate, pm10 emission to air - t (% of UK)	6778	20956	84004	44757	196927
	3.4	10.6	42.7	22.7	100.0
Heavy metal emissions to air - t (% of UK)	61	619	902	477	1780
	3.4	34.8	50.7	26.8	100.0
Waste to land - Kt (% of UK)	8027	12000	154000	7000	424000
	1.9	2.8	36.3	1.7	100.0

[a] includes concrete

[b] includes construction materials, construction process, maintenance and in service operation of dwellings and buildings

[c] UK total includes primary energy for electricity

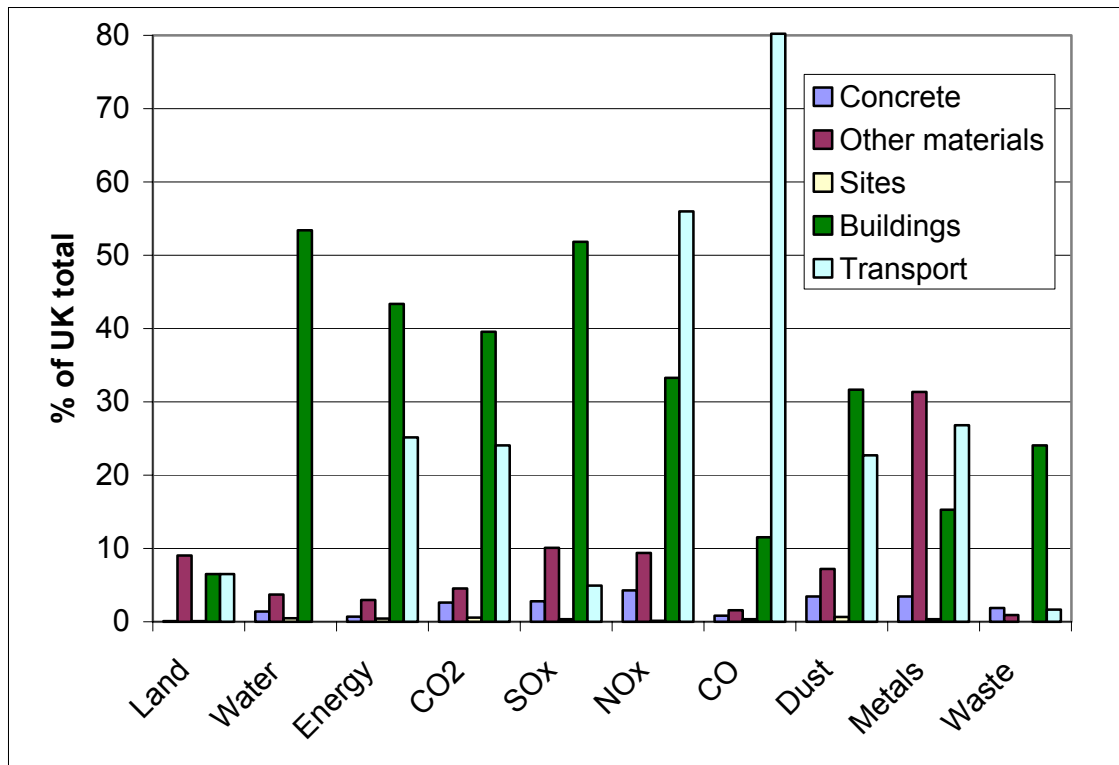


Figure 2. Environmental indicators, as percentages of UK totals., for concrete, other construction materials, construction sites, operation of buildings and transport.

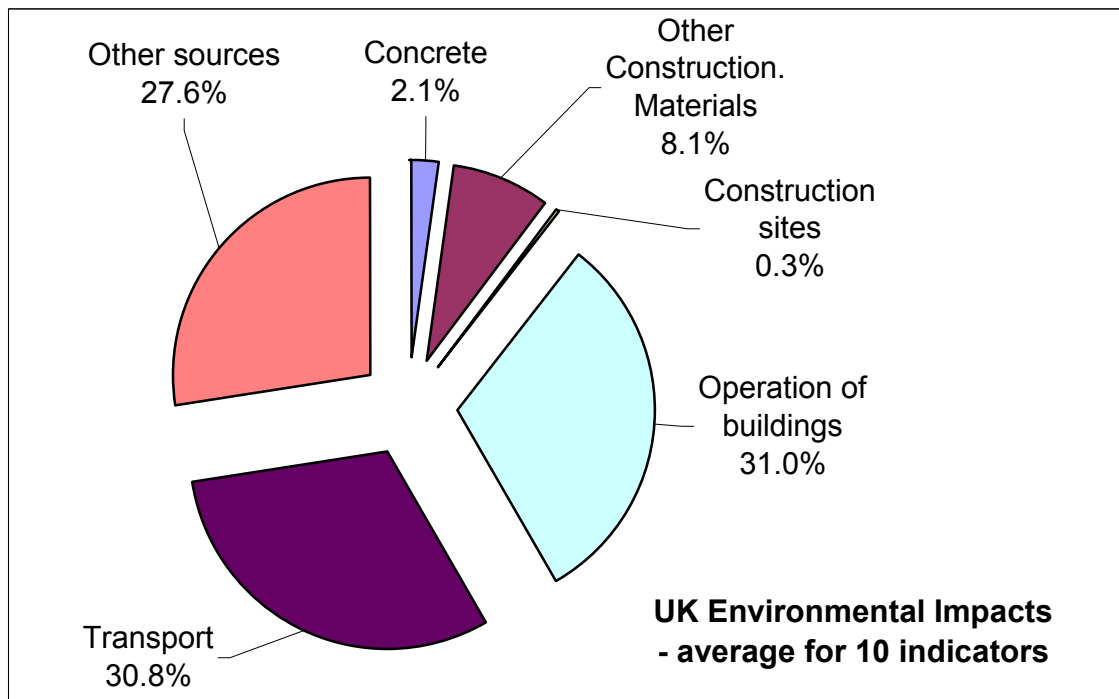


Figure 3. Sources of UK impacts, - percentages of UK totals averaged over the ten indicators in Figure 2.

Plain and reinforced concrete are responsible for almost 40% of UK mineral extraction but the subsequent environmental impacts in Table 2 are in the range 0.1 to 4.3% of UK totals. Construction materials account for almost 70% of UK mineral extraction and the subsequent impacts range from 2.4 to 34.8%. The subsequent range for construction, including the provision and operation of its products, is 14.1 to 65.2% and that for transport is 0 to 80.2%.

The bar chart in Figure 2 shows ten environmental indicators, as percentages of UK totals, for concrete, other construction materials, construction sites, operation of buildings and transport. It can be observed that:

- The relative importance of the impact source depends upon the indicator selected. It would not be appropriate to use one indicator, such as energy or carbon dioxide emission, as a proxy for the others.
- The operation of buildings and transport account for a large part of UK impacts.

Figure 3 consolidates the results in Figure 2 and suggests that improvements in the design of buildings and in the planning of the transport infrastructure should be priorities for more sustainable construction. Concrete is responsible for a significant part of UK impacts but it is clear that we should consider how concrete can be employed to reduce the operational impacts of buildings and the associated transport infrastructure. Furthermore renewable energy schemes should be integrated with construction projects where feasible and cost-effective in order to reduce fossil fuel use and associated environmental impacts. Addressing these issues would lead to significant environmental improvement for a given expenditure and widen market opportunities, including those for concrete. This approach broadly aligns with the thinking of the UK Government and environmentalists. The concrete industry has corresponding support, research and implementation roles to play that are consistent with its market aspirations.

## CONCLUDING REMARKS

Sustainable development is at a formative stage and construction materials, design and planning are clearly key elements for improving national performance. Environmental indicators are reasonably well defined but economic and social indicators require extensive development to achieve consensus on assessing overall performance. Convincing information is needed on the roles cement and concrete play in improving sustainability at local, national and world levels. This requires coordinated actions such as:

- Maintain the database on resource use, energy use and environmental impacts for UK cement industry to provide credible whole-industry data for analyses at subsequent life cycle stages.
- Illustrate, with case studies where possible, the environmental advances afforded by using cementitious materials.
- Regularly update the environmental report on the UK concrete industry to review performance and provide a perspective relative to other sectors.
- Undertake benchmarking to highlight areas of potential improvement.
- Monitor UK and European sustainability developments, particularly with regard to indicators that are pertinent to construction.
- Participate in consultations relating to sustainable construction and construction materials.
- Provide support for minimising environmental impacts from the operational lifecycle stage of buildings and structures, particularly those associated with fossil energy use.
- Provide support for minimising environmental impacts from the disposal/recycling lifecycle stage of buildings and structures.
- Expand contacts with owners and users of buildings and address any reservations about the sustainability of concrete.
- Provide support for renewable energy projects that utilise concrete.

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