The British In-situ Concrete Paving Association

Sustainability Benefits of Concrete Step Barrier

delivering a safe, reliable future

Britpave

This report has been prepared by the Britpave Sustainable Construction Working Group comprising of

Mike Connell - Civil and Marine
David Jones - Britpave
Alex Lake - Faber Maunsell
Dr. Bryan Magee - The Concrete Centre
Dr. Tony Parry - University of Nottingham

Britpave, the British In-situ Concrete Paving Association, was formed in 1991. It is active in all areas of transport infrastructure including roads, airfields, light and heavy rail, guided bus, safety barriers and drainage channels, soil stabilisation and recycling.

The Association has a broad corporate membership base that includes contractors, consulting engineers and designers, suppliers of plant, equipment and materials, academics and clients, both in the UK and internationally.

Britpave provides members and clients alike with networking opportunities and aims to develop technical excellence and best practice in key cement and concrete markets through its publications, seminars and website.

The British In-situ Concrete Paving Association

Published by Britpave
Riverside House, 4 Meadows Business Park, Station Approach,
Blackwater, Camberley, Surrey GU17 9AB
Tel +44 (0) 1276 33160
Fax +44 (0) 1276 33170
www.britpave.org.uk

Ref: BP/42 Price code: D
First published September 2008
ISBN 978-0-9556962-75 © Britpave

The Concrete Centre

Britpave acknowledges financial support from The Concrete Centre in the production of this publication.
www.concretecentre.com

Contents

1. Executive Summary

Structured under the four, UK-established, priority areas for immediate action in relation to sustainable development, this document provides a detailed report on Concrete Step Barrier's (CSB) positive contribution to delivering an economic, environmentally sensitive and socially responsible infrastructure solution.

Concrete Step Barrier delivers the following key sustainability benefits:

- **80% less embodied Co_2 than competing systems**
- **Minimum material usage and waste**
- **Non-polluting in service**
- **Fully recyclable**
- **Virtually maintenance- free over its 50 year design life**
- **Reduces traffic congestion and associated emissions**
- **Enhances road user and worker safety**

Sustainable consumption & production

CSB production involves a fully-automated, accurate process that ensures a high quality product in terms of functionality and appearance, using the minimum amount of material and producing the minimum amount of waste. Both recycled aggregates and cement replacement materials can be used in its construction, and the barriers provide a maintenance-free service life of at least 50 years.

Climate change & energy

CSB out-performs competing solutions in terms of both embodied levels of CO_2 in the materials used and holistic impacts over the solution's whole life cycle. The average embodied quantity of CO_2 in a metre of surface-mounted CSB can be as low as 19% of a similarly performing (H2) containment) steel solution over a 50-year period. Further long-term benefits are due to CSB's long maintenance-free service life that reduces CO_2 emissions and energy impacts related with routine repairs and traffic management, and the virtual elimination of potential delays and traffic congestion associated with these operations.

Natural resources & enhancing the environment

CSB can be constructed using a wide range of secondary and recycled materials, is non-polluting in service and, at the end of its 50 year design life, is fully recyclable. CSB requires minimum maintenance so reducing potential sediment loadings to drainage systems, and takes up less space than its competitor barriers.

Creating sustainable communities

By restraining traffic effectively and withstanding impact damage, CSB provides for the safety and well-being of road users and construction workers alike, helps to keep traffic moving and has a neutral impact on vehicle noise. To date there have been no cross-over accidents when using CSB in the central reserve.

2. Purpose of this report

In keeping with 2008 Government construction targets, Concrete Step Barrier (CSB) provides an innovative, buildable, fit–for-purpose, resource- and carbon-efficient, resilient and adaptable road safety solution that impacts positively on the whole-life cycle sustainability of the infrastructure assets that it serves.

This document provides an overview of CSB's positive sustainability credentials by assessing its impact against established sustainability indicators identified by both industry and key construction clients.

Aimed at designers, engineers, clients, contractors and manufacturers – all of whom play an integral role in creating a more sustainable built environment – the remit of this document is to provide an overview of the positive sustainability credentials of Concrete Step Barrier (CSB). In doing so, the objective is to assist key decision makers meet the principles of sustainable development outlined by Government and the construction industry.

3. What is sustainable development?

Sustainable development is defined by the World Commission on Environment and Development **[1]** as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*. The UK Government (www.sustainable-development.gov.uk) has identified the following principles to assist in its delivery:

- Living within environmental limits
- Ensuring a strong, healthy and just society
- Achieving a sustainable economy
- Promoting good governance
- Using sound science responsibly

Effectively, sustainable development involves successful integration across the 'triple bottom line' of environmental, economic, and social issues.

80% less embodied CO_2 than competing systems...

4. Key sustainability initiatives

The past 20 years have seen a growing realisation that previous models of economic development have been unsustainable. In response there have been a number of initiatives at international, European and UK Government level to drive forward more sustainable models of development.

Climate change and the perceived need to reduce CO_2 emissions, in order to mitigate the effects of global warming, have driven much international and UK activity in recent years. There has been a series of international protocols, most recently the Kyoto agreement, to reduce overall CO_2 emissions by 60% by the year 2050. The UN Climate talks held in Bali in 2007 signalled the likelihood that international CO_2 emission targets will be tightened still further, with increasing pressure on the non-signatory states to adopt emissions targets as well. However, the drive towards increased sustainability has also focussed on the need to preserve natural resources such as gas, oil and water for future generations and this is particularly relevant to the construction sector.

The UK Government's current overall Strategy document, *Securing the Future – the UK Strategy for Sustainable Development* **[2]**, published in 2005, set out a framework of guiding principles for securing sustainable development in the future. In 2007, BERR published a draft Strategy for Sustainable Construction which was the subject of consultation; a full analysis of which was published on 29 February 2008. On 11 June 2008, HMG/Strategic Forum for Construction published the final version of the Strategy **[3]**, which is a joint Government/industry initiative. The Strategic Forum has made a number of targets for 2012, of which the following five fall under the heading of sustainability:

- A 50% reduction in CDE waste to landfill compared with 2008;
- A 15% reduction in carbon emissions from construction processes and associated transport compared with 2008 levels;
- 25% of products used in construction projects to be from schemes recognised for responsible sourcing;
- Water usage in the manufacturing and construction phase reduced by 20% compared with 2008 usage;
- All construction projects in excess of £1 million to have biodiversity surveys carried out and necessary actions instigated.

The concrete industry's sustainable construction strategy has taken these targets into account when setting its own targets. The Strategic Forum for Construction (www.strategicforum.org.uk) will be monitoring the industry's progress against these targets and will report bi-annually, starting in 2010.

In addition, the construction industry has been independently working to make its operations and outputs more sustainable. In 1998, the Construction Task Force, chaired by Sir John Egan, produced a report *Rethinking Construction* **[4]**, which set out the construction industry's own change agenda. The principal intention behind the report, which was prepared for the then Deputy Prime Minister, John Prescott, was to establish a joint Government and industry strategy. It was responsible for a step change in construction industry perceptions and activity in key areas such as procurement and skills development.

At an industry level, in 2003 the Civil Engineering Environmental Quality Assessment and Award Scheme (CEEQUAL) (www.ceequal.com) was launched after a four-year development period led by the Institution of Civil Engineers with input from a broad spectrum of consultants and contractors, professional and industry associations, and government agencies. Against 12 identified key themes, CEEQUAL assesses the environmental quality of projects with an objective to encourage the attainment of environmental excellence.

Key civil engineering clients are equally aware of their role in delivering sustainable development. For instance, the Highways Agency in their *Sustainable Development Action Plan 2007–08* **[5]**, acknowledges that the strategic road network significantly delivers both a contribution and a threat to ensuring sustainability. To ensure that Government sustainability principles of sustainability are fully embedded into their business – and building on the principles outlined in *Building better roads: Towards sustainable construction (2003)* **[6]** – a range of key areas for improvement have been identified.

Table 1 provides an overview of CSB's impacts against the key sustainability and environmental indicators identified by government, the construction industry and a key client; namely the Highways Agency. These are grouped under the following UK-established (www.sustainable-development.gov.uk) priority areas for immediate action:

- Sustainable consumption and production;
- Climate change and energy;
- Natural resources and enhancing the environment;
- Creating sustainable communities

Table 1

Summary of CSB's impact (**positive**, **neutral**, **negative**) against key construction-related sustainability indicators identified by Government and industry

Relevent organisations / clients	Key sustainability and environmental indicators grouped by industry-established themes			
	Sustainable Consumption and Production	Climate Change and Energy	Natural Resoucres and Enhancing the Environment	Creating Sustainable Communities
DETR [1]	Re-use existing built assets	Minimise energy in construction	Do not pollute	Respect people and their local environment
	Aim for lean construction	Minimise energy in use	Design for minimum waste	
			Preserve the enhanced bio-diversity	
			Conserve water resources	
ICE / BRE / CIRIA / industry [2]	Land use	Energy	Environmental management	Landscape issues
	Water issues	Transport	Ecology and biodiversity	Archaeology and cultural heritage
			Material use	Nuisance to neighbours
			Waste management	Community relations
BERR / DCLG / DCMS / Defra [3]	Design of better products and services	Use of energy, resources and hazardous substances	Reducing environmental impacts	Creating sustainable communities
	Re-use of existing built assets	Long lasting, energy conscious and future-proof structures	Waste in construction	Committed, skilled and adaptable workforce
	Easily maintained / operated / deconstructed structures	Carbon emissions during construction	Re-use and recycling	Environment of zero accidents and incidents
		Lower carbon footprint in use	Conservation of water	Education and training for workforce
		Innovative solutions to climate change	Wildlife habitats and natural landscapes	
Highways Agency [4]			Air quality	Disruption due to construction
			Ecology and nature conservation	Landscape effects
			Land use	Pedestrians, cyclists, equestrians and community effects
			Traffic noise and vibration	Vehicle travellers
			Road drainage and water environment	Impact of road schemes on policies and plans
			Geology and soils	
Highways Agency [5]		Reducing energy consumption	Management of natural resources	Landscape, townscape and heritage
			Reducing emissions	Respect for people
			Biodiversity	Partnerships to better business
Highways Agency [6]	Processes and materials for construction and maintenance	Electricity and gas used on the network	Emissions to air and water	Customers travelling on the network
	Procurement processes		Noise and light pollution	Staff and contractors commuting and travelling
	Product lifecycles		Biodiversity and habitats	Congestion, severance, accessibility
			Use of natural resources	Regeneration, local economies, cultural heritage
				Safety on the network and for contractors
				Employees, contractors, suppliers and their employees

N.B All references [ ] to be found at end of the brochure.

5. Sustainability benefits of concrete

Concrete is one of the most versatile and durable construction materials known to man, making it the most widely used construction material in the world. Concrete is also one of the more sustainable building materials when energy consumed during its manufacture and inherent performance properties are taken into account. The positive sustainability contribution of concrete encompasses environmental, economic and social issues.

Environment

The cement and concrete sector is committed to an on-going, concerted and co-ordinated effort to reduce its impact on the environment. Key issues include:

- Reductions in polluting and greenhouse gases during production;
- Efficient use of resources such as re-used materials and byproducts from other industrial processes, such as water, aggregate, fuel or alternative cementitious materials;
- Recycling and reduced reliance on quarried material;
- Environmental restoration after industrial activity has ceased;
- Development of low-energy, durable and maintenance-free buildings and structures.

Economy

The concrete sector is a vital component of the UK economy, generating around £5 billion in sales annually, directly employing over 40,000 people and supporting the construction industry which employs approximately 7% of the UK population. With manufacturing plants and quarries distributed across the UK, the associated economic benefits affect many local communities. Concrete and many of its component materials are also exported each year, contributing to national wealth.

Society

UK Government defines 'sustainable communities' as areas "…sensitive to their environment and contributing to a high quality of life" as well as being "… safe and inclusive, well planned, built and run and offer equality of opportunity and good services for all". In addition to concrete's production supporting local communities, concrete structures offer a range of inherent societal benefits such as:

- Versatility of form and shape;
- Strength and durability;
- Impact, flood and fire resistance;
- Excellent acoustics and air tightness;
- Being inert, mould, rot and infestation resistant.

With an average travel distance to construction site of less than 15 miles, ready-mixed concrete is consumed close to source – a key sustainability principle.

For related documents and more detailed information on concrete's positive contribution to sustainable development, please refer to The Concrete Centre's microsite www.sustainableconcrete.org.uk.

with an average travel distance to construction site of less than 15 miles, ready-mixed concrete is consumed close to source…

6. Role of concrete step barrier

Concrete step barrier is the road restraint system of choice by the Highways Agency, which since January 2005 has mandated its use for motorway central reserves.

CSB saves lives and is likely to significantly reduce congestion, as it is maintenance-free for at least 50 years. It is safer than steel barrier for both motorists and maintenance teams and the most recent 'surface mounted' design option reduces both installation costs and delivery times.

Detailed design, installation, performance, cost and maintenance information pertaining to CSB is available from the Britpave website (www.concretebarrier.org.uk).

The positive impact of CSB in terms of sustainable development is discussed in the following sections of this document under the broad sustainability themes listed above and highlighted in Table 1. In this way, the positive role of CSB in relation to established industry and client sustainability drivers is clearly apparent.

7. Role of concrete step barrier installers

Installers of CSB on the highway network are fully committed to quality, reducing the environmental impacts of their actions and the health and well-being of their workforce. All CSB on the motorway network is constructed by Britpave-licensed installers to ensure full compliance with BS EN 1317 **[7-9]**. License holders agree to a set of rigorous conditions, including:

- Payment of appropriate fees to support ongoing product conformity, testing and development;
- Third-party auditing (undertaken at least annually) of quality procedures and systems;
- Third-party certification to BS EN ISO 9001: 2000 **[10]** and 14001: 2004 **[11]** from a UKAS accredited certification body;
- Accreditation by Highways Agency Sector Scheme (www.highways.gov.uk/business/10386.aspx) when available;
- Compliance with agreed specification and construction details;
- Maintenance of employer and public liability insurance;
- Maintenance of equipment to the highest standards;
- Provision of employee training on competency and health and safety matters.

Details of current holders of the Britpave CSB Installation License are available from Britpave's website (www.concretebarrier.org.uk).

8. Role of Britpave

In 2007, the latest *Sustainability Development Strategy and Action Plan for Civil Engineering* **[12]** was published by the Institution of Civil Engineers, Association for Consulting and Engineering, Civil Engineering Contractors Association, CIRIA and Construction Products Association.

Setting standards for best practice, the following actions are proposed in this document for all organisations in the civil engineering supply chain:

- Improve management of impacts and resource productivity, including whole life-cycle assessment;
- Engage the supply chain at the earliest possible stage to ensure sustainable development principles are embedded;
- Promote the business case for sustainable development to clients and financial institutions;
- Be accountable for performance with respect to sustainability.

In response – and building on the work undertaken by Britpave's long-established Environmental Task Group – Britpave has recently formed a Sustainable Construction Working Group to develop and progress the organisation's sustainable construction agenda. The broad objective of the working group is to:

- Promote sustainability amongst Britpave members,
- Identify areas of improvement and set targets accordingly,
- Highlight and disseminate the inherent sustainability credentials of core products and services.

As the Highways Agency's nominated promoter of CSB, Britpave additionally has a technical obligation to its members, funders and clients to ensure that compliant product is installed, existing products are fully supported, revisions to Standards reflected, and future development undertaken.

9. Sustainable consumption and production

CSB production

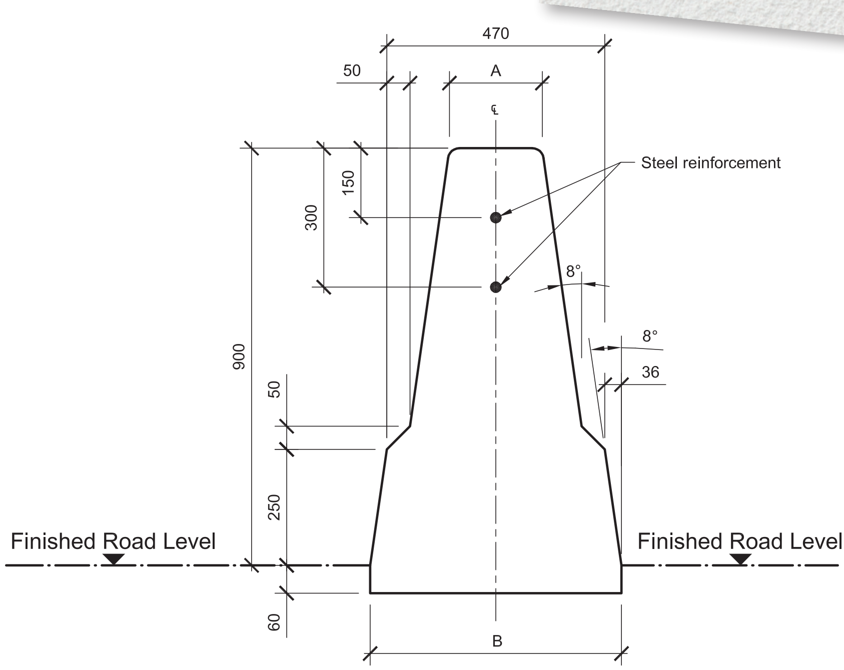
Britpave, in conjunction with the Highways Agency, Arup, Lantra Awards and British Standards Institution (on behalf of certification bodies), has instigated a sector scheme for the installation of concrete step barriers. The sector scheme has been listed in Appendix A of the HA's specification for highways works (May 2007) and will be a mandatory requirement for suppliers. It relates to the quality system requirements for design and installation of CSB and ensures a high quality standard of finished product in terms of functionality and appearance.

The minimum quality standard for design organizations and installers of CSB is third-party certification to BS EN ISO 9001:2000 **[10]** by a UKAS-accredited certification body. Installers are approved by Britpave and hold a Britpave licence. Design and construction outside the specification and design provided in the current Britpave drawings will result in a system which does not conform to BS EN 1317.

Material consumption

CSB is typically constructed using air-entrained concrete with a strength class of C28/35 in accordance with BS 8500-1: 2006 **[13]**. Cement types permitted include CEM I, IIA, IIB-S, IIB-V and IIIA, which allows the minimum binder content of 300kg/m^3 to consist of up to 35% fly ash or 65% ground granulated blast furnace slag by mass. As illustrated in section 8.2, this versatility permits significant reductions in the amount of embodied CO_2 per km of CSB.

Furthermore, and in compliance with BS 8500, the use of recycled aggregates such as recycled concrete aggregate (RCA) is permissible and technically feasible in CSB. This is also in compliance with the Highways Agency's Specification for Highway Works **[14]**, which was amended in May 2007 to permit the use of secondary and recycled aggregates for most applications.



Typical Section

Symmetrical about centre line

Construction cost

Independent studies comparing the construction costs of various barrier systems confirm that CSB is an exceptionally competitive product.

In 2007, Britpave commissioned Arup to undertake cost comparison studies **[15-17]** of various steel and concrete central reserve systems. Assuming typical road layouts, this work looked at both basic barrier construction costs and the influence of different central reserve layouts and lighting column options. In terms of barrier costs alone, this work confirms that surface-mounted CSB (H2, W2) compares favourably with steel systems providing inferior containment (N2) and working width (W3 or W4). For equivalent containment levels (H2), continuous deformable steel systems are considered by Arup to be prohibitively expensive.

Investigating central reserve layouts and lighting provision costs, Arup also reported that CSB on fully hardened central reserve is less expensive than an un-tensioned, corrugated steel beam solution with equivalent containment (H2), sited on a soft central reserve. Similarly, wide profile CSB with integral cable troughs and mounted lighting columns, constructed on fully hardened central reserve provides a more economic solution than un-tensioned, corrugated beam barriers constructed on a soft central reserve with socketed lighting columns.

In addition, with the cost of land being high and space limited, the maximum number of traffic lanes can be obtained by the low working widths provided by CSB. Current steel barrier systems on the UK network do not offer similar reductions to working width.

Maintenance and service-life cost

With a service life of at least 50 years, compared with around 20 for steel solutions, CSB offers significant comparative cost savings in terms of end-of-service barrier replacement alone.

Virtually maintenance-free, even after severe impacts, further potential savings to the tax-payer run to tens of millions of pounds every year. In addition, CSB's inherently high containment level effectively eliminates crossover incidents, which improves safety and avoids accident recovery costs as well as insurance claims. There are over 400 crossover incidents every year in England alone, causing around 40 deaths at a cost of around £1.6 million each. Congestion, resulting from accidents and routine road maintenance, costs the UK economy an estimated £20 billion per year. By increasing levels of motorist safety and reducing maintenance requirements, CSB helps to reduce this cost considerably.

In 2004, the HA commissioned TRL Ltd. to examine the relative performance and whole-life cost effectiveness of median barriers installed on major roads. Costs associated with barrier installation, general maintenance, repair, removal, accidents, and traffic management / delays linked to repair or maintenance were considered. This study **[18]** led to the HA issuing Interim Advice Note 60/05 (www.standardsforhighways.co.uk/ians/index.htm), and subsequently TD 19/06 **[19]**, which mandates the use of concrete barriers in the central reserve on all motorways.

10. Climate change & energy

Embodied CO_2

Comparisons undertaken using industry agreed values for construction materials indicate that CSB out-performs competing steel solutions in terms of levels of embodied CO_2 (see Table 2).

Table 2, which compares material impacts only (including material production, manufacture and delivery to site), clearly shows that the average embodied quantity of CO_2 in a surface-mounted CSB (105kg per m) is lower than competing N2 (156kg/m) and, more applicably, H2 (549kg per m) steel alternatives over a 50 year period. Indeed, even average values for dual, surface-mounted CSB (247kg/m) and wide, surface-mounted CSB (205kg/m) solutions out-perform comparable H2 steel solutions.

Concrete's low environmental impact is attributable, in part, to its major constituent, aggregate, which is often a locally won, low-impact material in terms of energy consumption and CO_2 emission. With respect to cement's CO_2 contribution, highlighted in Table 2 is concrete's environmental versatility. Using GGBS or fly ash in concrete – which is permitted in CSB specification documentation (www.concretebarrier.org.uk/construction/drawings.html) through the use of CEM IIB-V and CEMIII cements – offers designers the ability to further reduce the overall greenhouse gas emissions associated with the production of CSB.

It should be noted that excluded from the figures presented in Table 2 are relative CO_2 impacts associated with barrier construction, deconstruction and maintenance activities, as well as related in-service congestion. As CSB is practically maintenance free over a design life of 50 years (compared to around 20 for steel solutions), as discussed in the following section, these impacts are also predicted to be lower for concrete barrier solutions.

Whole-life environmental impact

While calculations of embodied CO_2 and other greenhouse gases are important, whole life performance should always be considered, given that it is the in-service impacts of buildings and civil engineering structures that typically dominate.

With a maintenance-free service life of at least 50 years, CSB requires minimal levels of service-life maintenance activity and related traffic management. As a result, low levels of road-user disruption and congestion are predicted. As the effectiveness of catalytic converters for vehicles idling or traveling at low speed is dramatically reduced, the net result is an overall positive impact on service-life greenhouse gas emissions.

Steel barrier has a design life of around 20 years and requires maintenance after vehicle impact, an activity often requiring traffic management and lane closures which contribute to congestion. As such, over the 50-year lifecycle of CSB, the comparable amount of work, vehicles and energy required to install and maintain steel barrier is likely to be much higher.

CO_2 recapture

Over their life time, concrete step barrier can absorb around 20% of the CO_2 emitted from the manufacture of its cement content through a process of re-carbonation [20]. This assumes barriers with a service life of 60 years and a secondary life of 100 years. Secondary life describes the process of concrete structures being crushed and recycled into buried applications such as ground works and land reclamation projects. The long time span over which re-carbonation occurs reinforces the whole-life performance approach that should be adopted when considering sustainability issues.

For building structures, re-carbonation is currently accounted for in the BRE environmental profiling methodology used in the *Green Guide to Specification* [21], BREEAM assessment schemes (www.breeam.org) and the *Code for Sustainable Homes* [22], so is clearly an important criterion that should not be overlooked for highway structures.

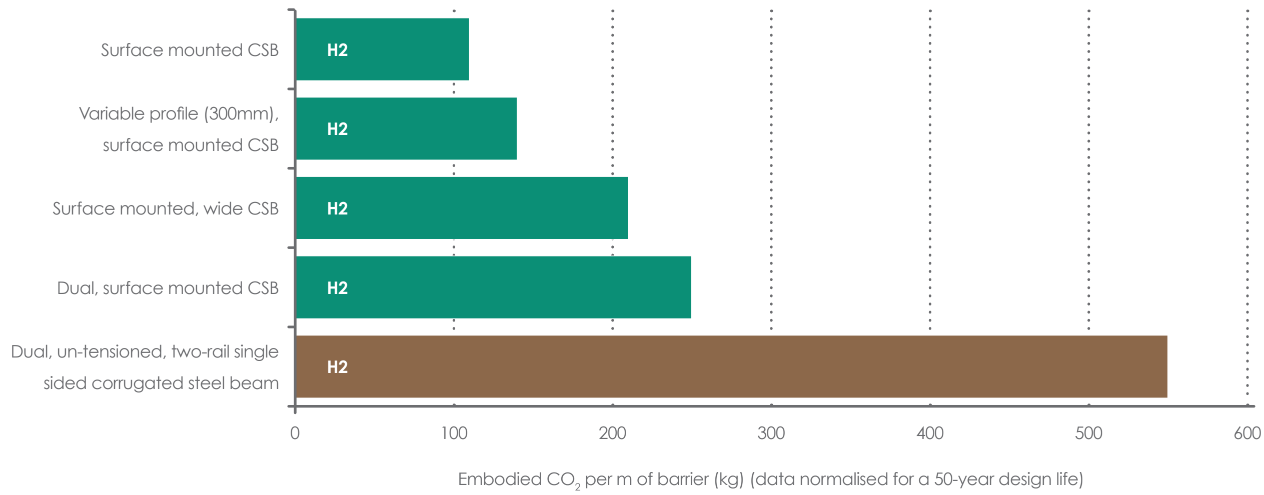


Table 2

Embodied CO_2 comparisons for material use only (excluding construction, deconstruction, maintenance activities, etc.)

Barrier type			Barrier details	Barrier concrete details	Material mass per m of barrier (kg)						Embodied CO_2 per m of barrier (kg)	Average embodied CO_2 per m of barrier, normalised for 50 year design life (kg)[2]
					Aggregate	Foundation Concrete	Barrier Concrete	Rebar	Steel strand	Steel		
CONCRETE [1]	A.	Surface mounted CSB	H2, W2	Grade C28/35; CEM I							125	
				Grade C28/35; CEM IIB-V (30% fly ash)	175	178	764	0	1.56	0	107	105
				Grade C28/35; CEM IIIA (50% ggbs)							83	
	B.	Embedded (60mm) CSB	H2, W2	Grade C28/35; CEM I							135	
				Grade C28/35; CEM IIB-V (30% fly ash)	175	178	842	0	1.56	0	115	113
				Grade C28/35; CEM IIIA (50% ggbs)							89	
	C.	Variable profile (300mm), surface mounted CSB	H2, W2	Grade C28/35; CEM I							173	
				Grade C28/35; CEM IIB-V (30% fly ash)	175	178	1,138	0	1.56	0	147	143
				Grade C28/35; CEM IIIA (50% ggbs)							111	
	D.	Surface mounted, wide CSB	H2, W2	Grade C28/35; CEM I							248	
				Grade C28/35; CEM IIB-V (30% fly ash)	212	274	1,630	0	1.56	0	210	205
				Grade C28/35; CEM IIIA (50% ggbs)							159	
	E.	Embedded, wide CSB	H2, W2	Grade C28/35; CEM I							265	
				Grade C28/35; CEM IIB-V (30% fly ash)	212	274	1,764	0	1.56	0	224	219
				Grade C28/35; CEM IIIA (50% ggbs)							169	
	F.	Dual, surface mounted CSB	H2, W2	Grade C28/35; CEM I							295	
				Grade C28/35; CEM IIB-V (30% fly ash)	349	356	1,885	0	3.12	0	252	247
				Grade C28/35; CEM IIIA (50% ggbs)							192	
STEEL [1]	G.	Un-tensioned, double-sided corrugated beam	N2, W3 (driven post)	Designation - ST5	0	0	0	0	0	31.18	57	156
			N2, W3 (socketed)	Designation - ST5		96	0	0	0	31.16	68	
	H.	Dual, un-tensioned, two-rail single-sided corrugated beam	N2, W4 (driven post)	Designation - ST5	0	0	0	0	0	100.91	184	549
			H2, W4 (socketed)	Designation - ST5		600	0	0	0	100.91	256	

Inputs - Embodied CO_2 per kg of material (kg) [2]

Grade C28/35; CEM I:	0.128
Grade C28/35; CEM IIB-V (30% fly ash):	0.105
Grade C28/35; CEM IIIA (50% ggbs):	0.074
Designation PAV2:	0.120
Designation ST5:	0.120
Asphalt, SHW Series 900:	0.140
Type 1 aggregate, SHW series 800:	0.005
Rebar:	0.460
Steel strand:	2.820
General steel:	1.820

1. Assuming concrete and steel barrier systems to have minimum design lives of 50 and 20 years respectively
2. Values for concrete were derived using industry agreed representative figures for cementitious materials, aggregates, reinforcement, admixtures and an appropriate figure for water. Steel values were obtained from: Amato, A and Eaton, KJ, A comparative environmental life cycle assessment of modern office buildings, Steel Construction Institute, 1998.

11. Natural resources and enhancing the environment

Recycling

CSB can be constructed using a wide range of secondary and recycled materials and, at the end of its design life, is fully recyclable.

CSB and reinforced concrete in general, is 100% recyclable – a practice now commonplace – providing good quality secondary aggregates, which are useable in a wide range of applications, and recyclable steel. CSB recycling is a particularly straightforward process due to the low proportion of steel reinforcement used. In addition to promoting CO_2 recapture (see section 8.2), the crushed material won from such operations provides a valuable, consistent aggregate source that can be re-used in structural applications, including CSB. Excellent guidance and case studies of recycled concrete use are available from the WRAP website (www.wrap.org.uk/construction/materials_recycling).

While steel barrier systems are recyclable, the fact that they are typically hot dip galvanized to prolong their service life introduces economic and environmental constraints. As galvanized steel is recycled with other steel scrap, the zinc used for galvanizing volatilizes early in the process and must be collected for reprocessing. Zinc is a chemical waste subject to pollution control legislation and requires appropriate collection, treatment and disposal (or recycling) processes.

In-service pollution

Research undertaken by the HA since 1997 **[23]** confirms that highway runoff from rural trunk roads and motorways contains pollutants such as metals, hydrocarbons, salts and nutrients as well as microbial waste. Sources of pollution are reported to include construction, operation and road maintenance operations **[24]**. Steel safety fences and street furniture are known to be a significant source of heavy metals in run-off, particularly in winter months **[25]**.

Concrete – a material commonly used for storing, conveying, treating and protecting potable water supplies – does not contain or leach contaminants and presents no risk to environmental pollution when used in highway applications. This is confirmed to be true even when crushed, recycled concrete is used in unbound secondary applications **[26]**. Furthermore, concrete does not burn or support combustion, or degrade under exposure to ultraviolet light or extreme temperatures.

Highway maintenance programmes – which are more common for steel systems due to their deformability on impact and relatively short design life – are also known to significantly affect sediment loadings deposited in drainage systems **[23]**. This impact is clearly minimized as CSB requires minimal maintenance throughout its 50 year design life and is typically situated on hardened medians.

Rebar impact

While CSB construction in the UK typically employs steel strand to optimise construction efficiency, CSB often incorporates rebar, which if sourced in the UK is manufactured from 100% recycled scrap using an electric arc furnace process. While steel manufacture is generally energy-intensive, it should be recognized that the energy needed to produce one tonne of reinforcing steel is as low as half of that required to produce the same mass of structural grade steel (www.sustainableconcrete.org.uk). Furthermore, the UK is a net exporter of scrap steel with a plentiful local supply.

Waste in construction

According to WRAP, adopting principles of effective waste minimisation on projects will help to reduce the significant quantities of construction waste sent to landfill and make a substantial contribution to sustainable development (www.wrap.org.uk/construction). Identified routes to major improvements include efficient design and specification, material procurement and construction logistics.

Construction of CSB is a fully computer automated process using state-of-the-art slip-forming plant operated by licensed installers fully committed to quality and reducing the environmental impacts of their actions. Quantities of concrete and reinforcement can be accurately calculated from the suite of detailed specification documents and construction drawings produced by Britpave (www.concretebarrier.org.uk/construction/index.html). As such, CSB construction produces minimal levels of waste (typically less than 2% by volume). This waste is generally used elsewhere within the construction works. Where this is not possible, all waste is sent to appropriate licensed facilities for off-site recycling.

Land uptake

CSB requires less land than all competing barrier solutions. CSB with N2 and H2 has a respective working width of W1 (0.6 metres) and W2 (0.8 metres), which is lower than for all other competing solutions with similar containment levels. The working width of a barrier system defines the distance from the traffic face to the extreme point to which the barrier deflects, or in the case of a rigid barrier, to the extreme point of a leaning vehicle.

As no vehicles are allowed to travel within the zone defined by the working width, clearly low working width equates to narrower central reserves and less land take.

For new-build infrastructure this benefit represents a significant reduction in land take, and for retrofit schemes, an opportunity for road widening by utilising some of the existing central reservation.

Ecology

Animals travel within and between feeding areas, territories and even countries. Such journeys are essential for the everyday survival of individuals as well as for the maintenance of viable populations **[27]**. With over 380,000 km of roads in the UK, **[28]**, it is not surprising that every year an estimated one million wild animals, including deer, foxes, badgers, otters and squirrels, are killed on UK roads whilst making such movements **[29]**. In addition to the impact of mortality, there is the imposition of reduced or prevented wildlife dispersal and the associated severance of wildlife territories and habitats.

Whilst there are no known data available to compare the impacts of roads with or without concrete barriers on wildlife, it would be easy to jump to the conclusion that the installation of a solid central barrier could serve to increase wildlife mortality and habitat fragmentation. It is acknowledged that, by the very nature of its design, a steel barrier is less likely to block animal dispersal, compared with the solid face of the concrete step barrier. However, in order to minimise wildlife casualties, animal population fragmentation and risk to road users from vehicle collisions with wildlife, it is not the type of safety barrier used that is important. Rather, it is the provision of effective and targeted mitigation measures that holds the key to reducing the environmental impact of road safety barriers.

With approximately 49% of the UK badger fatalities **[30]** and 58% of the UK fox fatalities **[31]** caused by road traffic accidents and with road mortality identified as the major cause of death of otters **[32]**, Britpave's view is that rather than working to increase the chance of animal survival once on the road, proactive intervention should be adopted to minimise animals straying onto the busiest of our roads by providing accessible alternative crossing sites elsewhere. The innovative design of 'eco-passages', such as culverts, bridges, viaducts and overpasses across roads teamed with effective and well maintained wildlife fencing for larger species, is considered to present the greatest opportunities for reducing the impacts of roads and road safety barriers on wildlife.


Mammals on Roads survey
part of the Tracking Mammals Partnership
people's trust for endangered species mammals
Tracking Mammals Partnership
People's Trust for Endangered Species
15 Cloisters House, 8 Battersea Park Road
London, SW8 4BG enquiries@ptes.org 020 7498 4533
registered charity no. 274206
YOUR DETAILS:
Name:
Address:
E-mail:
Postcode:
Please circle the type of vehicle that you are driving: Car Van Lorry Other (specify)
We will send you a free copy of the survey results once they are available. Survey information will be shared in summary form with other environmental organisations, such as Local Record Centres, but will not be passed on to commercial organisations. This information may include your contact details to allow LRCs (in rare instances) to collect further information about a mammal sighting. If you are not happy for your contact details to be passed on, please tick this box. ☐

For animals too small to be stopped by fencing, such as shrews, rodents, reptiles, weasels and amphibians, access through CSB can be provided via a drainage system located at the base of the barrier approximately every 3m. To provide any larger or more frequent holes could compromise the performance of the barrier as a safety restraint system. However, with up to 98% chance of an amphibian being killed as it attempts to cross motorway traffic **[33]**, the drainage system plays a vital role in providing a good opportunity for safe dispersal.

Britpave is committed to improving knowledge on the effects of roads and road barriers on wildlife and actively supports the People's Trust for Endangered Species (PTES) 'Mammals on Roads Survey' (www.ptes.org). This is a nationwide survey of mammal sightings along single-carriageways which has run each year since 2001. To date, over half a million kilometres of road have been surveyed, and changes in counts of species such as hedgehogs, foxes and badgers have been tracked over time.

people's trust for
endangered species
mammals

Water

The UK concrete sector is very aware of the importance of water, especially when considered alongside impacts of global warming and climate change. Water is a finite resource with less than one percent of the world's supply existing as easily accessible freshwater for human consumption. If present levels of consumption continue, two-thirds of the global population will live in areas of water stress by 2025. Each person in the UK currently uses about 150 litres of water every day; a quantity that has been rising by 1% each year since 1930.

Embodied water refers to the amount of water required to produce a product from start to finish. A 2004 Australian study **[34]** estimated that a kilogram of concrete has about two litres of embodied water. This compared favorably to around 20, 40, 88 and 155 litres of water per kilogram of timber, steel, aluminum and plastic, respectively. The UK concrete sector is committed to minimizing its impact at all stages of the production and delivery cycle. Reductions in use are being delivered through the effective use of chemical admixtures and water recovery and recycling facilities as well as the implementation of supporting guidance documents **[35]**.

12. Creating sustainable communities

Construction worker health and safety

In 2005, the Highways Agency experienced five road worker fatalities on their network caused by operatives being struck by third-party vehicles, 12 major injuries and 29 injuries causing absence from work for over three days (www.highways.gov.uk/knowledge/10323.aspx). In 2007, the HA reported a worrying up-turn in the number of people killed while working on HA roads.

Not surprisingly, therefore, clients such as the Highways Agency are committed to road worker health and safety by reducing exposure to live traffic and lessening risks when on the network, as well as improving driver awareness and education. In its Road Worker Safety Action Plan (www.highways.gov.uk/knowledge/11357.aspx) for instance, the HA has committed itself to seven key areas of improvement. These include an urgent review of operations that require road workers to be exposed to live traffic, with a view to reducing risks, and a revision of maintenance priorities to reduce the number of visits and ad-hoc repairs and maintenance to cut the need for road workers to be on the network.

CSB requires no maintenance after impact by a vehicle, with the resultant avoidance of the repair and associated traffic management activities typically undertaken for competing steel systems in live traffic, high-risk situations. Comparing concrete and steel barriers on the M25 for instance, whereas maintenance-free concrete solutions have been in service for around 10 years, around 1200 repairs are required to steel barrier every year at a cost of around £3million.

In addition, while concrete step barrier is specifically designed to last for a minimum of 50 years, steel restraint systems need to be replaced completely every 20 years – an enormous operation, creating traffic congestion and an increase in road worker exposure to dangerous conditions.

Motorist safety

CSB provides excellent levels of motorist safety – a key consideration for clients such as the HA, which ranks road-user safety as one of its top priorities. Arup's Vehicle Design Group, one of the world's leading consultants, has undertaken BS EN 1317-compliant crash tests and related computer simulations to investigate the potential for injury from collisions with CSB and alternative safety barriers.

Crash testing has proven CSB to pass all BS EN 1317 impact severity requirements, including values for Acceleration Severity Index (ASI Class B), Theoretical Head Impact Velocity (THIV) and Post-impact Head Deceleration (PHD). While ASI values recorded for CSB tend to be higher than those for deformable steel barriers, studies prove ASI values at the measured magnitude not to correlate directly to level of injury except that it is generally agreed that a higher ASI value will always increase the risk of injury. In terms of computer simulated predictions of lateral collision protection, CSB values for Head Injury Criterion (HIC), Viscous Criterion and Rib Deflection (both chest injury predictors) and Pubic Symphysis Force (pelvis injury predictor), are much lower than the limits set in ECE Regulation 95 **[36]**. This helps to confirm that injuries resulting from collisions with CSB are very unlikely to be serious.

In reality, CSB also helps to eliminate injury and deaths associated with cross-over accidents, barrier intrusions and deflections, and loss of vehicular control on soft verges, all of which are typical of steel barrier systems. In England alone there are over 400 crossover incidents every year resulting in around 40 deaths. For these reasons CSB is the barrier of choice for The British Motorcyclists Federation. Requiring almost no maintenance or repair after a collision, CSB will also help to avoid motorway accidents in coned areas, such as those required for maintenance activities, which accounts for a high number of incidents each year.

In practice, TRL Ltd. research of the M25 sphere (www.highways.gov.uk/business/14109.aspx) confirmed concrete barrier to be exceptionally safe. Examining accident rates for cars, HGVs and other vehicles for the years 1990 to 2002 inclusive, TRL Ltd. reported no fatal casualties due to impact with concrete barrier and 70% fewer accidents per kilometre of road in comparison with steel alternatives.

Congestion reduction

CSB is simple to install, long-lasting and requires minimal maintenance; all factors which will drastically reduce the need for lane closures and associated levels of congestion.

Installation of CSB – an efficient operation requiring a single paving machine served by concrete truck mixers – can be undertaken during routine road surface repairs or within a low-impact single lane closure in live traffic. Once installed, clients and motorists can expect a maintenance-free barrier for at least 50 years. In comparison, competing steel systems will require complete replacement at least once, and possibly twice, in this period, leading to congestion and traffic delay.

When impacted, CSB is designed to allow vehicles to continue travelling in the direction of traffic without the need for barrier maintenance. Often, incidents occur without even being reported to the overseeing authority. Frequent paint and tyre marks on CSB in the network prove this to be the case. Indeed, TRL Ltd.'s findings, based on the M25 sphere, that significantly fewer accidents were reported alongside concrete barrier compared with steel, indicates that concrete systems are not likely to negatively affect traffic flow to the same extent. Soft ground typically surrounding steel barriers means that any collision has repercussions way beyond the accident itself. Any damage to the steel barrier has to be reported and subsequently repaired. This often means lane closures and severe speed restrictions in both directions.

Accidents in which vehicles cross from one carriageway to the other can all too often result in complete road closure in both directions. Subsequent traffic diversions can quickly bring trunk roads and local feeder roads in the area to a standstill. CSB virtually eliminates cross-overs and the resultant congestion they can cause around the local road network.

In summary, CSB's robustness means less maintenance, resulting in fewer lane closures and delays. So, in addition to contributing to one of the Highways Agency's core targets – more reliable journeys – CSB also delivers a cost saving of millions of pounds to British business, not to mention reduced stress and irritation levels for motorists.

Visual impacts

Visually, CSB provides a smooth, continuous structure that is relatively consistent in terms of texture and colour. Although colour is likely to change with time, due to the natural degradation of water-based curing compounds and weathering, it should remain consistent. From the motorist's visual perspective, CSB's solidity presents a low level screen that will help to reduce glare at night from oncoming traffic and potentially reduce drivers' ability to 'rubberneck' incidents in the opposite carriageway.

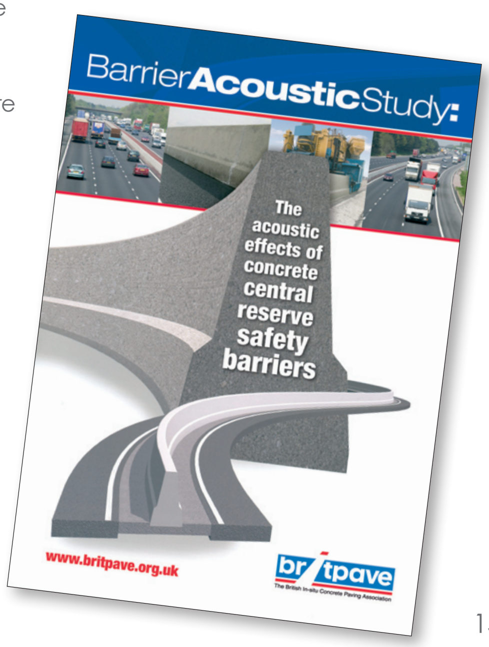
From a motorists' safety point of view, CSB's visual impact has been reported to potentially reduce average traffic speeds, which may be a contributing factor to the excellent accident statistics reported by TRL Ltd. for concrete barrier systems on the M25 sphere.

Potentially of relevance to urban, rather than motorway, CSB applications, the colour and surface texture of CSB could easily be varied to suit local conditions if deemed appropriate and economically viable.

Noise impacts

In 2005, Britpave commissioned a study to investigate the impact on roadside noise arising from installation of concrete barriers in the central reserve. Arup Acoustics conducted a field study and theoretical analysis to establish any differences in roadside noise levels, comparing concrete and steel central reserve barriers.

The results from the empirical and theoretical studies [37] show that there is a negligible difference in roadside noise levels comparing concrete and teel central reserve barriers.



13. References

1. Brundtland, G. (ed.), *Our common future:* The World Commission on Environment and Development, Oxford University Press, Oxford, 1987.
2. *The UK Government sustainable development strategy.* Great Britain Department for Environment, Food and Rural Affairs. The Stationery Office, 186 pp. 7 March 2005. (www.sustainable-development.gov.uk/publications/uk-strategy/index.htm).
3. *Strategy for sustainable construction.* HM Government, June 2008 (www.berr.gov.uk/files/file46535.pdf).
4. *Rethinking construction:* The Report of the Construction Task Force (Egan Report). Department for Transport Local Government and the Regions DTLR (formerly Department of the Environment, Transport and the Regions), January 1998.
5. *Achieving sustainability.* The Highways Agency's Sustainable Development Action Plan 2007–08. Highways Agency, June 2007. (www.highways.gov.uk/aboutus/15577.aspx)
6. *Building better roads: Towards sustainable construction.* Highways Agency, December 2003. (www.highways.gov.uk/aboutus/726.aspx)
7. BS EN 1317–1 *Road Restraint Systems – Part 1: Terminology and general criteria for test methods.* British Standards Institution, 1998.
8. BS EN 1317–2: *Road restraint systems – Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers.* British Standards Institution, 1998.
9. BS EN 1317–3: *Road restraint systems – Part 3: Crash cushions - performance classes, impact test acceptance criteria and test methods.* British Standards Institution, 2000.
10. BS EN ISO 9001: *Quality management systems – requirements.* British Standards Institution, 2000.
11. BS EN ISO 14001: *Environmental management systems - Requirements with guidance for use.* British Standards Institution, 2004.
12. *Sustainability development strategy and action plan for civil engineering.* Institution of Civil Engineers, July 2007. (www.ice.org.uk/downloads/Sustainable%20development%20strategy%20July%2007(1).pdf).
13. BS EN 8500–1: *Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier.* British Standards Institution, 2006.
14. *Design manual for roads and bridges: Volume 2, Highway structures: Design (Substructures and special structures) materials. Section 3, Materials and components, Part 9 - BA 92/07: The use of recycled concrete aggregate in structural concrete.* Highways Agency, May 2007.
15. *Barrier cost comparison* – Study 1 of 3 (ref. BP37). ISBN: 978-0-9556962-2-0. Britpave, 2008.
16. *Barrier cost comparison* – Study 2 of 3 (ref. BP38). ISBN: 978-0-9556962-3-7. Britpave, 2008.
17. *Barrier cost comparison* – Study 3 of 3 (ref. BP39). ISBN: 978-0-9556962-4-4. Britpave, 2008.
18. *Whole life cost-benefit analysis for median safety barriers,* PR/SE/903/04 HA Task Ref No. 3/372/R22, (www.highways.gov.uk/business/14109.aspx).
19. *Design manual for roads and bridges: Volume 2, Highway structures: Design (substructures and special structures) materials. Section 2, Special structures, Part 8— TD 19/06: Requirement for road restraint systems.* Highways Agency, 2006.
20. *BCA Recarbonation scoping study* (internal report). British Cement Association, November 2007.
21. *The Green Guide to specification* (Reprinted 3rd ed). Jane Anderson, Building Research Establishment, David E Shiers, Oxford Brookes University, Mike Sinclair. ISBN: 0-632-05961-3. January 2002.
22. *The Code for sustainable homes, Setting the standard in sustainability for new homes.* Department for Communities and Local Government. February 2008. (www.communities.gov.uk/documents/planningandbuilding/pdf/codesustainhomesstandard.pdf).
23. *Pollutant removal ability of grassed surface water channels and swales: Literature review and identification of potential monitoring sites* TRL, 2006.
24. *Design manual for roads and bridges: Volume 11, Environmental assessment, Section 3, Environmental assessment techniques, Part 10 - HA 216/06: Road drainage and the water environment.* Highways Agency, 2006.
25. Highways Agency Framework No.3/323. *Collection and analysis of sediments from high speed roads for trace element fingerprinting*. 2005.
26. *Characterization of the leaching behaviour of cement mortars to assess long term environmental behaviour during their service life and their recycling stage*, ECN-RX--98-026. Sloot, H.A. van der, Energy Research Centre of the Netherlands, 1998.
27. Seiler, A. & Folkeson, L. Eds (2006) *Habitat fragmentation due to transport infrastructure.* COST 341 national state-of-the-art report Sweden.VTI rapport 530A.
28. Department of Transport (2007) TSGB 2007 Chapter 7: *Road lengths – Data tables.* Available on Department of Transport website: www.dft.gov.uk/pgr/statistics/datatablespublications/roadstraffic/roadlengths.
29. Slater, F. (1994) Wildlife Road Casualties. *British Wildlife*. 5, (4), pp. 214–221.
30. Clarke, P.G., White, P.C.L. & Harris, S. (1998) Effects of roads on badger *Meles meles* populations in South-West England. *Biological Conservation* 86, pp. 117–124.
31. Baker, P.J., Harris, S., Robertson, C.P.J., Saunders, G. & White, P.C.L. (2004) Is it possible to monitor mammal population changes from counts of road traffic casualties? An analysis using Bristol's red foxes *Vulpes vulpes* as an example. *Mammal Review*, 34, pp. 115–130.
32. Jefferies, D. J. & Woodroffe, G. L. (2008) Otter. In: *Mammals of the British Isles: Handbook,* 4th Edition. Eds Harris, S. & Yalden, D.W. The Mammal Society, Southampton.
33. Hels, T. & Buchwald, E. (2001) The effect of road kills on amphibian populations. In: *Proceedings of the 2001 International Conference on Ecology and Transportation,* Ed. Irwin CL, Garrett, McDermott K. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. pp. 25–42.
34. Treloar, G., M McCormack, M., Palmowski, L. & Fay,R. *Embodied water of construction. Environment design guide,* The Royal Australian Institute of Architects, 2004.
35. BS EN 1008: 2002. *Mixing water for concrete— Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.* British Standards Institution, 2002.
36. Regulation No. 95, *Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants in the event of a lateral collision.* United Nations, July 1995 (www.crash-network.com/Regulations/ECE_Regulations/ece_regulations.html).
37. *Concrete barriers and roadside noise,* DS/CSB/515, Britpave, November 2006.

References for Table 1

1. Building a Better Quality of Life - A Strategy for more Sustainable Construction (2000) (www.berr.gov.uk/files/file13547.pdf)
2. The Civil Engineering Environmental Quality Assessment and Award Scheme (2003) (www.ceequal.com)
3. Draft Strategy for Sustainable Construction: A consultation paper (2007) (www.berr.gov.uk/files/file40641.pdf)
   (Note - aimed at buildings but included for completeness).
4. Design Manual for Roads and Bridges: Volume 11 Environmental Assessment (www.standardsforhighways.co.uk/dmrb/index.htm)
5. Building better roads: Towards sustainable construction (2003) (www.highways.gov.uk/aboutus/documents/better_roads.pdf)
6. Achieving Sustainability - The Highways Agency's Sustainable Development Action Plan 2007-08 (2007)
   (www.highways.gov.uk/aboutus/documents/SDAP_Jun_07.pdf)

Other documents referred to:

Rethinking Construction, The Construction Task Force
(www.constructingexcellence.org.uk/pdf/rethinking%20construction/rethinking_construction_report.pdf)

Securing the future - The UK Government Sustainable Development Strategy, HM Government (2005)
(www.sustainable-development.gov.uk/publications/pdf/strategy/SecFut_complete.pdf)

Interim Advice Note 76 / 06 (May 2006) Aims and Objectives of Environmental Assessment
(www.standardsforhighways.co.uk/ians/pdfs/ian76.pdf)

Britpave

Riverside House, 4 Meadows Business Park, Station Approach
Blackwater, Camberley GU17 9AB, United Kingdom.
Tel: +44 (0)1276 33160 E-mail: info@britpave.org.uk

www.britpave.org.uk

Printed on Take 2 Silk. Incorporating 75% recycled paper content and 25% virgin pulp sourced from managed forests.
Forestry Stewardship Council and ISO14001 accredited.