Sustainable choice of materials for highway works: A guide for Local Authority highway engineers

J M Reid, J W E Chandler, I Schiavi, A Hewitt, R Griffiths and E Bendall
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SUSTAINABLE CHOICE OF MATERIALS FOR HIGHWAY WORKS
A GUIDE FOR LOCAL AUTHORITY HIGHWAY ENGINEERS

Version: Final

by J M Reid, J W E Chandler, I Schiavi, A P Hewitt, R Griffiths and E Bendall (TRL Limited)

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Glossary

**Aalborg commitments**: The 50 Aalborg Commitments were launched in 2004, with the aim of helping all local authorities across Europe measure and improve their sustainability performance. The Commitments are split under the following 10 themes:

1. Governance
2. Local management towards sustainability
3. Natural common goods (including energy, water, soils, air, biodiversity)
4. Responsible consumption and lifestyle choices
5. Planning and design
6. Better mobility, less traffic
7. Local action for health
8. Vibrant and sustainable local economy
9. Social equity and justice
10. Local to global (including climate change)

Further information is available from [http://www.aalborgplus10.dk/](http://www.aalborgplus10.dk/)

*Source: Hampshire County Council and Aalborg + 10*

**AggRegain**: AggRegain is a free Sustainable Aggregates information service provided by the Waste and Resources Action Programme (WRAP) Aggregates Programme with the aim of increasing the use of recycled and secondary aggregates and the sustainable use of all aggregates. The information service consists of a website ([www.aggregain.org.uk](http://www.aggregain.org.uk)) and a supporting free telephone helpline - 0808 100 2040. The website was launched in February 2003 and further expanded in 2005 and 2006. Through eight different modules, a specification guidance service and a case studies database and search engines, it provides producers, specifiers, buyers and suppliers with a reliable, independent 'one-stop' source of information on which to base procurement and production decisions.

*Source: AggRegain*

**Aggregate levy**: the environmental tax on the commercial exploitation of aggregate in the United Kingdom. introduced in April 2002, it addresses the environmental costs associated with quarrying that are not already covered by regulation, including noise, dust, visual intrusion, loss of amenity and damage to biodiversity. The levy aims to bring about environmental benefits by making the price of aggregates better reflect these costs and encouraging the use of alternative materials such as recycled materials and certain waste products. The levy is still set at its original level of £1.60 per tonne.

*Source: HM revenue and Customs*

**Argillaceous rock**: Denoting a clastic sedimentary deposit or rock in which the constituent fragments are of silt or clay grade in size. This includes particles smaller than 1/16 mm in diameter. These consist of finely ground rock as well as the various clay minerals that have been produced in the course of weathering of the parent rock. Siltstones and mudstones are rocks formed of sediment in this size range.


**Carcinogenic**: substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence.

**Duty of care:** Under the Duty of Care the producer of waste has the following responsibilities:

1. To ensure that all waste produced is handled, recovered and disposed of responsibly.
2. To ensure that only authorised businesses and individuals deal with the waste.
3. To keep a record of all waste received or transferred using the system of Waste Transfer Notes.

More information is available from [http://www.netregs.gov.uk/netregs/275207/275430/?version=1&amp;lang=_e](http://www.netregs.gov.uk/netregs/275207/275430/?version=1&amp;lang=_e)

Source: NetRegs

**Egan review:** published in 2004, the Review looked at the skills and training required by professionals, planning authorities and developers and how they can work together in achieving measurable improvements to the communities they serve. It also considered how any skills gap can best be bridged. The review contained a number of recommendations for central and local government to improve planning mechanisms, supply chain relations and delivery of the infrastructure needed for achieving sustainable communities.


Source: DCLG

**Environmental Protection Act (1990 and amendments):** This Act provides the basis for licensing controls and other provisions aimed at ensuring that waste handling, disposal and recovery options do not harm the environment. It also states that responsibility for waste rests on all parties involved in its management; from the original producer to everybody who handles it up until its full recovery or disposal. To this end it introduced the 'Duty of Care'. The Waste Management (England and Wales) Regulations 2006 (SI 2006 No. 937) introduce the latest amendments to the Act, including an extension of the definition of industrial waste to include agricultural and mining and quarrying waste, which therefore become controlled wastes.

Source: AggRegain

**European Waste Catalogue:** Schedule 1 of the List of Wastes (England) Regulations 2005 is the current version of the European Waste Catalogue. Each type of waste is defined by a six digit number, with all wastes grouped into one of 20 broad categories, defined by the first two digits. More detail on the nature and origin of the waste is given by the remaining four digits. All wastes which are hazardous wastes are marked by an asterisk in the List of Wastes.

Source: HA EnvIS Material Resource Management: Inventory

**Exemption from WMLR:** Exemptions from waste management regulations are mainly for small-scale waste storage, recycling and recovery operations. There is an overriding requirement that in order for an activity to be exempt, it must be carried out:

- a) without endangering human health or harming the environment;
- b) without risk to water, air, soil plants or animals;
- c) without causing nuisance through noise or odours, and
- d) without adversely affecting the countryside or places of special interest.

In addition, each exemption specifies the type and quantity of wastes, methods of recovery, time limits for storage and pollution control measures.

To register an exempt activity there is a need to provide the Environmental Regulator with information regarding the activity, who is carrying it out and the site address. For a comprehensive list of conditions which apply consult the Waste Management Licensing Regulations 1994 Schedule 3 as amended.

Source: AggRegain
**Factory Production Control:** A control system to monitor production so that the product characteristics are achieved and maintained consistently - required by the Construction Products Directive as amended. For aggregates, it is prescribed in the relevant BS EN Standards for aggregates.

*Source: AggRegain*

**Hazardous waste:** Article 1(4) of the Hazardous Waste Directive (HWD) defines hazardous waste as wastes featuring on the list of hazardous wastes in the European Waste Catalogue 2002, because they possess one or more of the 14 hazardous properties set out in Annex III of the HWD. The HWD is implemented in the UK through the Hazardous Waste Regulations. The Environment Agency has published Technical Guidance WM2 to clarify how to identify hazardous waste.

*Source: AggRegain*

**Inert waste:** Waste is considered inert if:

1. It does not undergo any significant physical, chemical or biological transformations;
2. It does not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health; and
3. Its total leachability and pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater.

*Source: The Landfill (England and Wales) Regulations 2002*

**Johannesburg World Summit on Sustainable Development:** The World Summit on Sustainable Development (WSSD) took place in Johannesburg from 26 August to 4 September 2002 with 183 countries taking part and committing to implementing sustainable development actions. There were 3 formal outcomes from the Summit: a Political Declaration, a detailed plan of implementation (PDF), and a number of Type 2 Multi-stakeholder partnerships. More information on the UK activities can be found at [http://www.sustainable-development.gov.uk/international/wssd/index.htm](http://www.sustainable-development.gov.uk/international/wssd/index.htm).

*Source: Defra’s Sustainable Development Unit*

**Key Performance Indicators:** (KPIs): Indicators used to define and measure progress toward defined priority and key success factors of a project or system. KPIs can also be used as a performance management and improvement tool by providing focus on project goals. Monitoring KPIs enables management to spot and correct weaknesses.

*Source: AggRegain*

**Landfill tax:** Tax on the disposal of waste at landfills. It has been introduced to encourage waste producers to produce less waste and recover more value from waste. There are two rates of landfill tax depending on the type of waste. The low rate of £2 per tonne applies to those inactive (or inert) wastes listed in Schedule 2 of the Landfill Tax (Qualifying Material) Order 1996. Increases in the low rate have not been considered yet.

A standard rate applies to all other taxable wastes. From April 2006 the standard landfill tax rate is £21 per tonne. The Government has stated that the standard rate would continue to increase by at least £3 per tonne in future years, on the way to a medium to long term rate of £35 per tonne.

*Source: AggRegain*
**Leachates**: liquid, percolating through waste deposits, which can include various minerals, organic matter or other contaminants and can contaminate surface water or ground water.

*Source: Environment Agency*

**Non-hazardous waste**: Waste that is active, meaning that it will decompose or otherwise change. Chemically active, combustible, biodegradable or polluting waste.

*Source: Waste Aware Scotland*

**Open book accounting**: way of providing transparent accounting methods that allows providers to describe their expenditure whilst enabling commissioners to understand all aspects of service delivery and forward investment. At the point of tender, commissioners should establish the principals of Open Book Accounting that they wish to use and these should be communicated to potential providers. Providers would provide detailed costing in line with the agreed model including management, staff and administrative and regulatory costs as well as proposed investment in training, service development and quality promotion etc. They would also demonstrate their assumed margins and show why this was necessary; for instance for longer-term investment or as a hedge against risk.


*Source: DOH’s Health and Social Care Change Agent Team (CAT)*

**PAH**: Acronym for polycyclic aromatic hydrocarbons. PAHs are a group of hydrocarbon compounds with a structure in which 2–6 or more carbon rings are fused together. In practice, these compounds always occur together as a mixture of many components. They occur naturally in some hydrocarbon mixtures deriving from minerals, such as coal or petroleum, and they can also be generated in processes involving the combustion of any organic matter, including fuels. Many are carcinogens.

*Source: HSE*

**Phenols**: Organic aromatic compound which occurs naturally (during the decomposition of organic materials, and as a constituent of coal tar). Its presence in the environment is however primarily the consequence of human activities. The most important source of diffuse phenol emissions results from the use of phenolic resins as binding materials in insulation products, chipboard, paints, and casting sand moulds (used by metal foundries). Phenol is highly mobile in the soil environment, particularly through leaching into ground and surface water. Many phenols are toxic.

*Source: EA*

**Public Procurement Directive**: European Directive that since January 2006 regulates local government public procurement in the EU. This new Directive simplifies and consolidates three former Directives on public works, supplies and services into a single text. It intends to reduce red tape and to set out social and environmental criteria that can be applied in awarding contracts.


*Source: European Commission*

**Quality control**: Quality control is the formal assessment of products or materials for to ensure that they conform to the customer’s or standard requirements.

*Source: AggRegain*
**Quality management**: process of continual improvement to meet both customer needs and the applicable regulatory requirements. More information can be found at [http://www.aggregain.org.uk/quality/introduction_to_the_quality_management_system/index.html](http://www.aggregain.org.uk/quality/introduction_to_the_quality_management_system/index.html)  
*Source: BSI*

**Recycled Roads**: WRAP guidance document and series of workshops on local authority procurement which present a model approach to ensure that recycling and reuse of road materials is embedded in all highways contracts and schemes. The guidance is aimed at senior officers, highways budget-holders, procurement officers and highways engineers – plus their consultants and contractors. The guidance covers the procurement process, key approaches for specifying recycled content, and in-depth case studies. More information at [http://www.aggregain.org.uk/recycled_roads.html](http://www.aggregain.org.uk/recycled_roads.html)  
*Source: AggRegain*

*Source: United Nations*

**SMART waste**: suite of tools and consultancy services for measuring and auditing waste produced during construction and demolition, designed by BRE. More information at [http://www.smartwaste.co.uk/](http://www.smartwaste.co.uk/)  
*Source: BRE*

**SSSIs**: Acronym for Sites of Special Scientific Interest. They are sites protected under national legislation due to flora and fauna of special scientific interest. *Source: AggRegain*

**Sustainability**: Sustainability can be defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their needs. Sustainability is based upon three components: economic growth, social progress and environmental protection. *Source: AggRegain*

**Third party certification**: Where a management system is audited by an organisation independent from the assessed organisation. This can provide additional reassurance to a client where the certification body meets national, European or international standards. *Source: AggRegain*

*Source: AggRegain*

**Whole Life Cost**: The whole-life cost of a facility (often referred to as through-life costs) comprises the costs of acquiring it (including consultancy, design and construction costs, and equipment), the costs of operating it, and the costs of
maintaining it over its whole life through to its disposal - that is, the total ownership costs. These costs include internal resources and departmental overheads, where relevant; that also include risk allowance as required, flexibility (predicted alterations for known change in business requirements, for example), refurbishment costs, and costs relating to sustainability and health and safety aspects.

Source: OGC

WRAP: Acronym for the Waste and Resources Action programme. WRAP is a not for profit company created in 2000 as part of the Government's waste strategies across the United Kingdom. WRAP is aiming to make a major contribution to the achievement of the Landfill Directive targets and to Government's broader environmental objectives, including the reduction of carbon emissions to help tackle climate change. More information at www.wrap.org.uk

Source: WRAP

Waste Management Licensing Regulations 1994: These regulations and amendments set out the procedure for obtaining a waste management licence. They also identify a number of activities which are excluded from requiring a licence or that are exempt from licensing.


Source: AggRegain
Executive Summary

Over the past ten years there has been an increasing appreciation of the importance of sustainability, for instance in government policy documents such as "A better quality of life" (DETR, 1999) and "Securing the future" (DEFRA, 2005). This has required Local Authorities to review their operations and look for ways to make them more sustainable. The maintenance and construction of highways is an area that presents many opportunities for increased sustainability, by the use of materials and methods that minimise the impact of these activities on the environment. Many Local Authorities have been quick to adopt more sustainable practices in this area, and there are many publicly available case studies that illustrate the materials and methods that can be used. However, this information is scattered among a variety of sources, and there is a need for a document that brings all this material together into guidance that is clear and relevant for Local Authority highway engineers.

This document provides a detailed description of how to make sustainable choices in the selection of materials and methods for Local Authority highway works, including maintenance and new construction. It is designed to support “Sustainable Highways” (Reid et al., 2008), the summary guidance that constitutes a daughter document to “Well-maintained Highways” (Department for Transport, 2005a). This reference document offers detailed practical guidance for Local Authority highway engineers, their contractors, designers and suppliers on how to choose materials and methods of work for highways taking into account sustainability and environmental factors. The main focus of this document is on maintenance activities for road pavements and footways. However, the advice is equally applicable to new construction.

The document is intended to be applicable throughout the United Kingdom. Case studies are given throughout the document to illustrate specific materials, methods or issues.

The choice of materials and methods falls under the wider issue of sustainability, and greater progress can be made when it is approached within an overall strategy for sustainability within a Local Authority. Examples of how various Local Authorities have made the link between corporate objectives on sustainability and highway maintenance activities are given. The support of senior officers and elected members, and liaison with other departments within the Local Authority is critical for success, as is involvement of the supply chain.

Local Authorities are responsible for a very wide range of roads, from heavily trafficked principal roads to very lightly trafficked rural lanes and suburban housing estate roads. While the busiest roads and most new roads built in the last thirty years are likely to have been designed and built to high standards, many of the older roads will have evolved over the years through the addition of successive layers of asphalt. These roads pose a challenge to the highway engineer when maintenance works are required.

The various layers that make up a typical pavement are described, together with the recycled and secondary materials that are generally permitted in them under current specifications. The main methods of maintenance are then described, concentrating on techniques for the surface course where most repairs are carried out. Opportunities for recycling are highlighted.
In sustainability terms, the first priority should be to maximise the recycling of the arisings from highway and footway maintenance works. The opportunities for reuse and recycling of these materials are described. Where it is not possible to recycle these materials, they have to be disposed of. The implications of this for various materials are discussed, with particular mention of the occurrence of coal tar, a hazardous waste, in some old pavements.

After the reuse of arisings, the next priority is the use of recycled or secondary aggregates in place of primary aggregates where this is economic and environmentally sustainable. Generally this will be where transport distances are less than for equivalent primary aggregates. A number of recycled and secondary aggregates are potentially available for use in highways and footways. Their properties and availability are described.

The key issue of standards, specifications and design guides is then addressed. The importance of using appropriate specifications is stressed; over-specification by use of the Specification for Highway Works for minor roads can prevent the use of locally available materials that might be perfectly suitable for the application. The Specification for the Reinstatement of Openings in Highways/Roads encourages the use of recycled and secondary materials and innovative techniques, but requires the approval of the Local Authority for their use. Local Authorities thus need to take a positive approach when the use of these materials and techniques is proposed. The importance of quality control for all materials and processes is stressed.

Applying environmental considerations to the choice of materials and methods is described, and a number of models are presented that enable designers and planners to make decisions based on evidence of the environmental impact of various options for highway maintenance and construction. One model that may be particularly useful is the CO₂ emissions estimator that is available on the AggRegain web site. Transport distances are usually critical in the overall CO₂ emissions of construction works. It is not sustainable to transport recycled or secondary aggregates long distances if suitable primary aggregates are available close to the works. A decision support process map is presented to enable relevant factors to be taken into account when deciding on the choice of materials and methods.

A number of possible Key Performance Indicators for recycling in highway maintenance works are presented. Local Authorities should use those which are most relevant to their particular situation and most in line with those already being used by their suppliers and contractors.

Finally, a series of suggestions are made for how to construct a sustainable road, within the overall context of a sustainability policy for a Local Authority. Examples of Local Authorities who have developed links from corporate objectives to highway maintenance are given in Appendices.

The maintenance and construction of highways present many opportunities for increasing sustainability compared to conventional methods of working. The objectives of this document and the associated short guidance (Reid et al., 2008) are to improve understanding among highway engineers of the effects on the environment and implications for sustainability of their choices of carriageway and footway materials and to provide best practice guidance on the application of sustainability to highway construction and maintenance.
1 Introduction

1.1 Scope of guidance and readership
This document provides a detailed description of how to make sustainable choices in the selection of materials and methods for Local Authority highway works, including maintenance and new construction. It is designed to support “Sustainable Highways” (Reid et al., 2008), the summary guidance that constitutes a daughter document to “Well-maintained Highways” (Department for Transport, 2005a). This reference document offers detailed practical guidance for Local Authority highway engineers, their contractors, designers and suppliers on how to choose materials and methods of work for highways taking into account sustainability and environmental factors. The main focus of this document is on maintenance activities for road pavements and footways. However, the advice is equally applicable to new construction.

This document is intended to be applicable throughout the United Kingdom.

Guidance on how to use the document is given on Figure 1.1.

1.2 Sustainability and highway materials
The need and desire for change to the methods and materials used in construction and maintenance has accelerated in the last 20 years. The major instigator was the Rio Earth Summit in 1992 that brought sustainable development to the forefront of government policy in most developed countries. In 2002, the United Nations' World Summit on Sustainable Development was held in Johannesburg with the aim of focussing the world’s attention again and directing action toward meeting difficult challenges, including improving people's lives and conserving our natural resources in a world that is growing in population, with ever-increasing demands for food, water, shelter, sanitation, energy, health services and economic security. Sustainable development was defined as long ago as 1987 as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987).

In the UK, the Government definition of sustainable development was developed as “…a better quality of life for everyone, now and for generations to come” with four key elements [DETR, 1999]:

- Social progress which recognises the needs of everyone;
- Effective protection of the environment;
- Prudent use of natural resources; and
- Maintenance of high and stable levels of growth and employment.

As an industry, Highway Engineers know that the amount of recycling and use of alternative materials in construction must be increased in order to lead to sustainable development. Taking these actions reduces the demand for primary aggregates and the associated transport and environmental disturbances [Reid and Chandler, 2001]. Sustainable construction requires the minimisation of waste, the efficient use of materials and the recycling of waste.
The UK sustainable development strategy is described in Securing the Future (DEFRA, 2005), and includes priority areas for:

- Sustainable consumption and production;
- Climate change and energy;
- Natural resource protection and environmental enhancement;
- Sustainable communities.

Figure 1.1 How to Use the Guidance Document
The choice of materials for highway maintenance clearly falls within these priority areas.

Local Authority Engineers and their partners are crucial to achieving sustainability in highway maintenance and construction by making informed choices about the materials that they use and the techniques that they employ. Sustainability in highway maintenance and construction means living within our environmental limits whilst achieving a sustainable economy.

An example of achieving sustainability in construction and maintenance within a Local Authority could involve linking functions such as minerals and waste, procurement and highways in order to create a market demand for products such as recycled and secondary aggregates (Reid et al, 2006).

The majority of Local Authorities (LAs) now have some reference to sustainability in their corporate strategic objectives. In order for these objectives to be achieved, there needs to be a link between them and what actually happens on the ground. This requires a clear lead from the top and the establishment of policies that translate these objectives into action. It may also require a major change in the culture and attitude of the council staff and those of the organisations that work for them (Reid et al, 2006). It is vital that these objectives are fed down and incorporated into the aims of all departments in order for there to be a common approach across the organisation. Examples are given in several of the boxes in this chapter and in Appendices 2 and 3.

**Box 1.1 Corporate Objectives**

**Cardiff City Council's Local Sustainability Strategy:** states that ways to integrate sustainability into the design of new developments, buildings and the regeneration of existing Council properties should be considered. [http://www.cardiff.gov.uk/content.asp?nav=2870%2C3148&parent_directory_id=2865](http://www.cardiff.gov.uk/content.asp?nav=2870%2C3148&parent_directory_id=2865)

**Glasgow City Council's Draft City Plan:** states that sustainability should be promoted through design and construction and energy efficiency and by helping reduce the need to travel and increase use of sustainable modes for those trips which are undertaken. [www.glasgow.gov.uk](http://www.glasgow.gov.uk)

**Stirling Council's Road Management Plan:** states that one of the key aims is to support and enable future quality sustainable development and transport. To obtain a copy of the Plan please contact the Council directly.

Sustainability is a far-reaching concept that encompasses far more than recycling. It includes the management and conservation of natural resources such as aggregates, water and fossil fuels with a view to preserving what we have so that these assets are available to future generations.

In order to encompass the wider picture of sustainability, taking account of all resources, it is essential that the whole life costs of any maintenance or new construction are assessed. This means evaluating the future costs, such as resurfacing, joint sealing or road user delay, as well as the expected initial construction costs. In addition to this, the use of recycled materials in a scheme should always be costed as an option so that alternative designs can be compared on a like-for-like basis.
Box 1.2 Hampshire County Council. As a community leader, Hampshire County Council has demonstrated its strong commitment by voluntarily signing up to the Aalborg Commitments in June 2004. These commitments provide a framework for the County Council to look at environmental, economic and social issues together. The Aalborg Commitments are designed as a way for local authorities to achieve local action on sustainability through a target-setting process. Hants CC are currently assessing their performance against the 50 commitments, which are split under the following 10 themes

1. Governance
2. Local management towards sustainability
3. Natural common goods (including energy, water, soils, air, biodiversity)
4. Responsible consumption and lifestyle choices
5. Planning and design
6. Better mobility, less traffic
7. Local action for health
8. Vibrant and sustainable local economy
9. Social equity and justice
10. Local to global (including climate change)

“The Waste Strategy 2000” (DEFRA, 2000) establishes the waste hierarchy (Figure 1.2) to promote recycling and reuse at the highest level possible leading to sustainable waste

- Reduce the levels of waste produced;
- Reuse products wherever possible;
- Recycle what cannot be reused;
- Recover energy from waste that cannot be reused or recycled.

Landfill disposal should only be considered as a last resort and then only if it best option for the particular waste material involved. Equally it is important that recycled materials are reused in the highest value situation possible. For example, all too often, recycled aggregates are used in low value applications such as capping or sub base when actually, with a little more effort, they can be used in high value applications such as road base or road surfacing (Carswell et al., 2005).

The highways construction and maintenance section of a Local Authority will, inevitably, include engineers who are members of professional institutions such as the Institution of Civil Engineers (ICE) and the Institution of Highways and Transportation (IHT). These organisations publish sustainability charters which members need to be aware of as part of their professional development and incorporate these principles into their work.
The Egan review (ODPM, 2004) set out to look at the skills that are needed to deliver sustainable communities and the part that the construction industry plays in this task. It proposed that all parts of the supply chain, for example Local Authorities, aggregate suppliers and waste management companies, should work together, or form partnerships, in order to develop or improve products and techniques, minimise waste and innovate and learn from experience. This is very demanding as there has to be recognition of interdependence between clients and contractors, an open relationship and an ongoing commitment to improvement. The opportunities that this route creates for achieving sustainability in construction are many and it is up to Local Authorities to pursue and enhance these relationships with the companies that they currently work with.

**Box 1.3 Surrey County Council (WRAP, 2004a)**

In 2003, Surrey County Council developed a bespoke partnering contract. The contract was awarded on both quality and price (50/50). The contract requires all parties to work towards the delivery of key objectives – including the reduction or elimination of waste and selection of the most cost-effective solutions. The process will be driven by setting targets, which will include recycled content. The partnering approach and open book accounting will enable construction wastes to be stockpiled and redeployed between the partners in the most effective way to achieve mutual benefit.
An example of maximising recycling in highway works is given by this case study, which is available on the AggRegain web site at http://www.aggregain.org.uk/case_studies/sustainable_1.html. The A6116 is a major feeder road into Corby which required full reconstruction after many years of heavy traffic loading. The design was based upon sustainability principles in line with the Northamptonshire County Council Cabinet Plan Priority of “recycle more-waste less”.

The design solution comprised a replacement structure of cold recycled structural course beneath a partly recycled hot-mix asphalt surface course. Over four thousand tonnes of material was removed from the existing road and re-processed in a mobile plant adjacent to the works using cold-mix technology. The re-engineered material was manufactured using processed millings from the existing road blended with pulverised fly ash, cement and foamed bitumen to create a viscoelastic/hydraulic composite material. The remixed material was then re-installed in the works to form a 100% recycled structural course.

The use of cold mix recycling reduced the carbon dioxide emissions by 127 tonnes compared with the use of hot mix asphalt. By carrying out the processing adjacent to the site, over five hundred lorry journeys were saved which would otherwise have been necessary if virgin material was being used in the project. The hot mix surfacing material was also unusual as it included 20% recycled material that was recovered as milled material from elsewhere on the local road network. The project achieved an impressive overall 83% reuse of components from the existing highway asset in the re-engineered road. The recycled project cost was approximately 25% less than a traditional solution to yield the same outcome.

Details of CO₂ savings associated with the project are given in Box 9.3.
1.3 Current practice

In the past, many of the larger Local Authorities had developed their own specifications which had been amended to permit the use of locally available materials, which in some instances were recycled or secondary. The reduction in resources experienced by many Authorities in recent years and the implications of legislation, such as the Public Procurement Directive, has meant that nowadays probably the most commonly used specifications are based on the Specification for Highway Works (SHW), which is maintained jointly by the Highways Agency, Scottish Executive, National Assembly for Wales and the Department for Regional Development for Northern Ireland.

The majority of the advice and guidance for the use of recycled materials in highway construction and maintenance is found in the Specification for Highway Works (SHW) and the Design Manual for Roads and Bridges (DMRB). Both of these documents are regularly updated by the Highways Agency (HA) so are up to date with new developments and materials. Details of useful documents and websites are given below. Current practice within most Local Authorities is to default to the SHW as this is taken to be best practice and there are no other up-to-date comprehensive specifications for highway works. The SHW is primarily aimed at the design, construction and maintenance of trunk roads and motorways so adhering to this regardless of the application means that Local Authorities may be over-specifying materials and not be making the best use of locally available materials. The County Surveyors Society (CSS) is currently developing a Local Authority Roads Guide to avoid potential problems of over-specification using the DMRB and SHW.

**Specification for Highway Works (SHW)**
([www.standardsforhighways.co.uk/mchw/index.htm](http://www.standardsforhighways.co.uk/mchw/index.htm))
This document provides the engineering and technical details related to all aspects of pavement construction and is complemented by the DMRB.

**Design Manual for Roads and Bridges (DMRB)**
([www.standardsforhighways.co.uk/dmrb/index.htm](http://www.standardsforhighways.co.uk/dmrb/index.htm))
This offers extensive guidance on all aspects of pavement construction from earthworks to different surfacing types to different construction techniques such as recycling which are detailed in HD35/04 (Vol. 7 Part1). There is an increasing trend towards performance requirements as seen in recent updates to HD 25 (Foundations) & HD26 (Pavement Design).

Prepared by Highway Authorities and Utilities Committee (HAUC UK) this governs how streetworks and reinstatements shall be carried out. For Scotland there is the equivalent Specification for the Reinstatement of Openings in Roads, 2003. There is also the Roads and Utilities Council (Scotland) (RAUC(S)) which aims to helping various bodies and organisations co-ordinate and communicate activities involving disruption to the road network around Scotland.
WRAP Quality protocol for the production of aggregates from inert wastes (WRAP 2004b).
This can be downloaded from www.aggregain.org.uk and enables a very wide range of waste materials to be assessed for suitability for use in highway construction and offers extensive guidance to Local Authority engineers on the procedure for approving these materials. Similar Quality Protocols are available for Scotland and Northern Ireland as well as England and Wales.

WRAP AggRegain web site (www.aggregain.org.uk): a one-stop shop for information on recycled and secondary aggregates
In order to encourage the increased recycling of materials, the UK government established the Waste and Resources Action Programme (WRAP) in 2001. It aims to help meet recycling and composting targets through identifying market opportunities for various recyclates, and also identifying barriers to recycling, infrastructure requirements and material flows. One of the first actions of the WRAP Aggregates Programme was to set up a dedicated web site, AggRegain (www.aggregain.org.uk) to act as a ‘one-stop shop’ for information on recycled and secondary aggregates. It now contains the following features:

- The Opportunities tool, which helps users identify the opportunities and potential to use recycled and secondary aggregates (RSA). It assists designers, specifiers, contractors and local authorities to identify where RSA can be used in construction projects, it also helps those who have limited knowledge of RSA or have previously been cautious to use RSA due to perceived barriers and limitations.
- The Specifier tool, which allows users to establish how RSA can be used in a range of construction applications under existing specifications.
- A supplier directory.
- A number of case studies demonstrating the use of RSA in a range of construction applications and demonstrating both cost benefits and comparative performance compared to primary aggregates.
- Access to the WRAP quality protocol and a number of other WRAP publications on recycled and secondary aggregates.
- Modules on planning, recycling infrastructure, quality, Waste Management Regulations, demolition, procurement and sustainability related to RSA.

The AggRegain web site is a very valuable resource for Local Authority highway engineers considering recycling. Many of the case studies presented in this report are available on AggRegain, and the opportunities tool can be used to identify applications where recycled and secondary aggregates can be used in highway and footway applications. The various modules contain information on a range of topics that will be important to highway professionals proposing to use recycling techniques or recycled and secondary aggregates. For specific queries, a free phone helpline is available on 0808 100 2040.

The specifications and standards relating to highway maintenance and construction are discussed in more detail in Chapter 8. A survey of the specifications used by Local Authority highway engineers, contractors, suppliers and designers undertaken for the WRAP Recycled Roads workshops in 2006 (Moulinier et al, 2006) is shown on Figure 1.3. Most organisations used more than one method of specification. The Specification for Highway Works was the most widely used specification for highway and street maintenance, used by 76% of those surveyed. Local variations to the SHW, the HAUC Specification and Local Authority Adoption Specifications were also widely used, with over 40% of delegates using each of them. The HAUC
Specification was particularly used by delegates at the London event (69%) and Local Authority Adoption Specifications by delegates at the Glasgow event (67%), but otherwise there was little regional variation.

![Figure 1.3 Specifications used for Highway and Street Maintenance](image)

**Figure 1.3 Specifications used for Highway and Street Maintenance**

Additional information can be found on the internet which provides an extensive database of information on sustainability and recycling in highway construction and maintenance. The AggRegain website operated by the Waste and Resources Action Programme (WRAP) provides many useful case studies highlighting how recycled and secondary materials can be used in various applications including Local Authority highway construction and maintenance applications. The AggRegain website [www.aggregain.org.uk](http://www.aggregain.org.uk) offers technical notes on specification requirements for recycled and secondary aggregates and a number of modules dealing with aspects such as quality and the waste management regulations in relation to recycled aggregates. It also contains a supplier directory so that you can find out what materials are available in a specific area of the UK. In addition to this, copies of The Big Picture (WRAP, 2004a) and Recycled Roads (WRAP, 2005b) can be downloaded from the AggRegain website.

CIRIA maintains an internet based registry of recycling sites [www.ciria.org/recycling](http://www.ciria.org/recycling) which is organised on a regional basis and includes sections for those wishing to buy or sell recycled materials. The website BREMAP [www.bremap.co.uk](http://www.bremap.co.uk) is part of the BRE SMART Waste system and is of interest to anyone wishing to minimise the waste that they produce during construction.

The document “Well Maintained Highways” (Department for Transport, 2005) contains extensive guidance on all the activities and obligations that a Local Authority should be carrying out and fulfilling. It highlights the importance of best value in highway maintenance and aims to encourage coordination, consistency and the sharing of best practice in the delivery of Local Authority highway maintenance. This document is available at [www.roadschemes.org](http://www.roadschemes.org).

As has already been mentioned, recycled materials are currently most often used in relatively low-value applications such as sub base. This is illustrated in Figure 1.4.
which shows the results from a questionnaire of delegates attending the Recycled Roads workshops in highway and street maintenance organised by WRAP (Moulinier et al, 2006). Use as capping and sub-base, in footways and cycleways and the base and binder course of bituminous pavements were the most common applications, used by over 50% of delegates. Over 40% used recycled and secondary aggregates in earthworks, and over 25% in the surface course of bituminous pavements. There was very little use in concrete pavements or structural concrete. The figures cover events throughout England and Scotland and do not show large variations between events in different regions. The report on the Recycled Roads events is available at http://www.wrap.org.uk/downloads/AGG0092_Final_Report_27June1.50d14127.pdf.

![Figure 1.4 Uses of Recycled and Secondary Aggregates in Highway Maintenance Applications as Reported by Delegates to Recycled Roads Workshops in 2006](image)

However, increasing awareness of the waste hierarchy and the importance of sustainability in construction means that many Local Authorities are making much more effort to look for higher value uses of these waste materials.

It is important to use the design and specification that are most appropriate for the job in hand. In order to be sustainable, it is important to design and specify in order to just meet the requirements rather than over-specifying which is wasteful. Local Authorities can make the best use of available technical expertise and local knowledge by asking contractors to put forward their own proposals for using recycled and secondary materials. Outcome- or performance- based specifications encourage this approach and help to avoid over-specifying and make the best use of locally available materials. Equally the move to performance specifications such as that described in TRL Report 611 (Merrill et al, 2004) allows contractors the flexibility to try out different materials as long as they satisfy the end performance criteria.
There is some risk associated with using recycled materials, as there is always the fear that the product may not be “fit for purpose”. Where existing standards do not cover a particular material then certification of its performance can offer assurance that it is suitable for use. In addition to this, recycled aggregate producers who declare that their aggregates are produced to the WRAP Quality Protocol for production of aggregates from inert wastes (2004b) are operating to a quality management plan that enables them to demonstrate that their aggregates are recovered from waste and are not subject to the Waste Management Licensing and can therefore be handled in the same way as primary aggregates (WRAP, 2004b).

Being aware of these risks and taking steps to address them should not be a barrier to using new recycled materials, especially if significant cost savings and other sustainability benefits can be made. Resource management and efficiency requires continuous review and improvement and products and processes will have to be used for the first time in order for them to be assessed (WRAP, 2004a). Local Authorities should share experience with new materials and techniques with each other to avoid carrying out unnecessary trials and to build upon existing expertise rather than reinventing the wheel.

In order to realise the maximum potential from the primary materials that are used in construction, it is vital that wherever possible they are reused and recycled back into as high value an application as possible. This is especially true of high polished stone value (PSV) aggregate that is used in road surfacing generally and in large quantities in porous asphalt and modern thin surfacing. This is a material that is in short supply in the UK and is a valuable natural resource (Thomson et al., 2004).

However, up until now, the surfacing layer has been recycled along with the rest of the pavement material when really it needs to be separated and reused as surfacing material. This issue is being addressed by research at TRL, sponsored by HA, which is assessing the feasibility of recycling thin surfacing back into thin surfacing. See Box 1.9 for further information.

### Box 1.6 Quality Assurance of materials

Devon County Council has established a Technical Appraisal Panel to identify, test and evaluate new products for highway maintenance, including recycled materials. The Panel assess the product quality by on-site visits and demonstrations, controlled trials and a formal review process. It meets once a month to solve problems and share experiences, all serving to reduce risks (WRAP, 2004a).
Box 1.7 Dundee City Council
Dundee City Council encourages the use of recycled material in construction and welcomes approaches from contractors regarding this. The Council already has some experience in the use of recycled materials that can be reviewed during the early stages of consultations. Where a contractor is proposing the use of a recycled material that is unfamiliar to the Council, then a proposer-led certification process can be followed. 
http://www.dundeecity.gov.uk/ptrans/streetsahead.pdf. The Highway Maintenance team recognises the environmental impact of its work and supports the use of recycling techniques and materials where appropriate. 

Box 1.8 Nottinghamshire County Council
The highway network maintenance policy summary states that: “To facilitate re-use of materials, contract specifications will be written to require the incorporation of recycled material where feasible and economic. Wherever possible, traditional materials will be re-used on site or stored for re-use elsewhere”. 

Box 1.9 TRL Research project sponsored by HA looking at the feasibility of recycling thin surfacing back into thin surfacing (Carswell et al., 2005)
Many sites with thin surfacings need resurfacing in the next few years, and the aim of this project is to assess the feasibility of recycling the surfacing back into new surfacing material and make the best use of the high PSV material that is used in this application. Trial sites of recycled surfacings containing between 10 and 30% of Recycled Aggregate (RA) were constructed and so far all are performing satisfactorily. The research is ongoing. The results of the initial trials are reported in TRL 645 (Carswell et al., 2005).
Box 1.10 Hampshire County Council Partners in Innovation (PII) Demonstration Project 3 Recycled surface dressing chippings

Hampshire County Council used a number of small depots across the county to store surplus surface dressing chippings and sweepings. The chippings were screened and lightly coated with bitumen and laid successfully as a surface dressing. In May to August 2004 the recycled coated chippings were used at 33 sites and a total of 4,000 tonnes of chippings were reused. The sites were monitored and are performing well. The case study can be downloaded from http://www.aggregain.org.uk/case_studies/reuse_of_surplus.html.

Box 1.11 Durham City Council

Sustainability in practice means that every action should be carefully examined to look at its overall effect. For instance the council is now incorporating sustainability measures into all minor/major highway schemes and at the same time, undertaking reviews during the development of designs to ensure that all materials possible are recycled or reused and that the need for new imported materials is minimised. http://www.durham.gov.uk/durhamcc/usp.nsf/Lookup/LTP2_Main_Doc/$file/LTP2_Main_Doc.pdf
1.4 How to make it happen

The document “Recycled Roads” (WRAP, 2005b) is a guide that is dedicated to showing interested parties how to increase the amount of recycling through procurement in their LA. It offers a step-by-step approach, making the link from the Local Authority strategic objectives, showing how these can feed in to the bidding process and into the final construction. The guide highlights the key issues and most importantly, the key role of decision makers in reducing waste and maximising waste throughout the authority. Figure 1.5 below illustrates this process.

**Figure 1.5 Framework from Recycled Roads Guide to Local Authority Procurement (Courtesy of WRAP)**

In order to achieve sustainability in construction, it is essential that targets are set for the use of recovered or recycled materials in the specification of highways contracts. This vital step needs to be mandated by elected Members and senior Council officers (WRAP, 2004a). This ensures that all contracts will include a recycling element for consideration and will go some way to helping the Local Authority/Council satisfy its sustainability and waste management policies. Equally, it is essential for all departments within the Local Authority to be striving for sustainability, so that everyone shares the strategic objectives.

The document “Maintaining a vital asset” (DfT, 2005b) sets out the Local Authority’s responsibilities with regard to the highway. In order for it to fulfil its potential, it is essential that the local highway network is adequately maintained. This infrastructure includes carriageways, footways, bridges, street lighting and signing and much more. The Local Authority is the owner of this valuable asset and
therefore responsible for co-ordinating works and for ensuring that the road continues to be safe and available for users. In order to do this, the Local Authority should produce a Highway Asset Management Plan (HAMP) which sets out what they want to achieve with their highway network, the value of this asset and identifying investment needs and priorities based on whole-life cost.

The Egan review (OPDM, 2004) highlighted the need for Local Authorities to take the lead in delivering sustainable communities; however they should not be doing this in isolation and should link up with service providers and key players in the local community. Consequently there are now many different procurement options available to Local Authorities such as partnering, term contracts, and frameworks. They all offer benefits from the point of view of increasing the amount of recycled materials used in construction.

**Box 1.12 Partnering: Staffordshire Highways**

Staffordshire County Council has been a leader in the use of recycled and secondary aggregates in highway works for many years. Until 2004, however, the maintenance and new construction programmes were undertaken via a number of organisations and contracts. This made coordination of different aspects difficult, the procurement processes were expensive, and there was little opportunity for collaboration between design and construction teams. This has changed following a Best Value Review, which led to the setting up of the partnership Staffordshire Highways in April 2004. There are three main organisations involved in the partnership:

- ACCORD Operations Ltd: primarily maintenance works,
- Wrekin Construction Ltd: primarily new construction,
- Staffordshire County Council: design and laboratory testing.

The partnership has resulted in much greater collaboration and flexibility between the various organisations, leading to efficiencies in operations and rapid resolution of problems. The early involvement of the contractors has led to greater innovation and more efficient programming of works. A relatively predictable workload over a period of several years means that it is worth-while developing design methods and specifications to take advantage of locally available materials. Details are available at [http://www.staffordshire.gov.uk/transport/staffshighways/staffordshirehighways/](http://www.staffordshire.gov.uk/transport/staffshighways/staffordshirehighways/).

When evaluating tenders, Local Authorities should ensure that there is a recycling option and that tenders take account of community benefits such as using recycling materials, avoiding having to landfill any material or reduced traffic disruption (WRAP, 2004a).
Box 1.13 Councils Increasing the Recycling of C&D Waste Back into Construction

East Sussex and Brighton and Hove City Council are partnering to provide a “Supplementary Guidance Note for Construction & Demolition (C&D) Waste”. C&D accounts for over half of the waste produced in this area, over half of which goes to landfill. The guidance note will apply to all developments, and the contractor or developer will have to state how a project will comply with it (WRAP, 2004a).

It is vital that reuse and recycling are built in to the initial stages of a project, as this is where they can have the greatest impact and their benefit can then be fed through the whole project. This should include not only the use of recycled materials in the works, but also the maintainability of the product and the ease of recycling it in the future, even if primary materials are used in the construction. The evaluation of recycling and reuse should be undertaken at the project inception, planning, options and procurement phases. In the later stages such as design, works and operation it is much more difficult to make changes to introduce reuse or recycling as this can have a profound effect on other aspects of the project.

In a Local Authority, one of the major challenges of procuring and using greater amounts of recycled material is one of logistics. Local Authority (LA) highway maintenance and construction usually consists of a large number of small projects, which, individually, do not warrant the substantial investment required to process and stockpile the waste material for future recycling and reuse. On LA schemes, materials are often needed in small quantities, at short notice, at erratic times dependent on external constraints with the works being undertaken by a number of differing organisations who are all relatively small themselves. Consequently, it is a logistical challenge to plan how these materials can be accommodated and processed in order for them to be ready to use at short notice within the LA (WRAP, 2005b). These facilities should, ideally, be located where they will minimise the transport distances between where the materials arise and where they are to be used at a later date. These are unlikely to be the same places (Reid et al, 2006). It may be that this is a local opportunity to partner with a neighbouring Local Authority in order to maintain a shared stockpile of processed material that is ready for use in the local area.

Key Performance Indicators (KPIs) need to be monitored to track the use of recycled materials in highways contracts to ensure that contractors are fulfilling their obligations and doing their best to minimise waste and use recycled products (WRAP, 2004a). The role of KPIs and their use in monitoring the level of recycling in construction is discussed in more detail in Chapter 9 and a number of KPIs that could be used to monitor sustainability in highway maintenance works is presented in Appendix 1.

The aim of sustainability in construction is an important topic that needs to be taken seriously by Local Authorities. This document provides guidance, advice and case studies to inspire and guide engineers towards making sustainable choices. It also highlights the importance of sustainability being a corporate and community goal that can be achieved through cooperation, coordination and forward planning.
**Box 1.14 West Lothian Recycling**
This company was set up as a joint venture between West Lothian Council and Tarmac in 1999 and is based at a former spent oil shale bing at Addiewell. It is a civil engineering and green waste recycling facility, accepting demolition waste, road arisings and green waste, processing them and supplying certified Type 1 sub-base, Class 6F5 capping, engineering fills, unbound footway surfacings, wood mulch, peat free compost and soil enhancers. West Lothian Council specify that all material produced on contracts let by the council must be sent to the recycling centre. The centre takes material from, and provides materials to, not only the Council but, contractors operating on behalf of the council, public utilities, local civils and grounds maintenance contractors, and other local authorities. The business plan is based on 100,000 tonnes per year of incoming waste, of which 29,000 tonnes is green waste, and 74,000 tonnes per year of outgoing material.
2. Materials and Applications: Introduction

2.1 General comments
This section deals with the materials and layers that make up roads and footways and the opportunities that exist for adopting a more sustainable approach to maintenance and new construction. As indicated in the previous section, government policy encourages the use of reclaimed and marginal materials wherever possible to obtain environmental benefits and to conserve primary aggregates. The Landfill Tax and Aggregate Levy act as powerful economic drivers towards sustainable construction, encouraging the increased use of secondary and recycled materials in construction, a reduction in construction waste going to landfill and a reduction in the use of primary aggregates.

Suitable materials may be those reclaimed from roads during reconstruction, from residues of industrial processes or from the demolition of other construction projects. These materials may provide good value for money especially where haulage distance are small. HD35 (2004) draws the attention of those responsible for the design, specification, construction and maintenance of roads to conserve and re-use materials arising from roadworks, as well as the potential uses for secondary or recycled materials from other sources that may prove to be cost effective. This document is part of the Design Manual for Roads and Bridges and is owned by the Highways Agency, Transport Scotland, the Welsh Assembly Government and the Department for Regional Development, a department of the Northern Ireland Executive, and hence applies in all parts of the UK.

A Joint Circular from the DoE (20/87), DoT (3/87) and Welsh Office (36/87) entitled ‘Use of Waste Material for Road Fills’ sets out the administrative procedures to ensure that information about future road schemes and their likely fill requirements are passed to local Planning Authorities at the earliest possible stage. In Scotland the National Planning Policy Guideline NPPG4, Land for Mineral Working, issued by the Scottish Office Environment Department (1994), gives guidance to planning authorities on the recycling and re-use of construction waste and materials in waste tips where this is environmentally acceptable.

As recycled and secondary materials may be more variable than primary aggregates, to give confidence in their use, more frequent testing may be required to enable their re-use at high level within the road pavement construction. Quality protocols can be used by suppliers to give clients greater confidence in the consistency and quality of their products. This is discussed in more detail in Chapter 8, along with the relevant standards and specifications.

The layers and materials that make up the highway are described, along with the materials that are generally permitted for use in them. Techniques for repair and maintenance are then described, followed by the possibilities for reuse of the materials arising from these works. The potential use of other recycled and secondary aggregates, and their availability across the UK, are then described. Finally, the standards and specifications that are used for highway works, and the opportunities to use recycled materials in these works, are briefly described.
3. Layers and Materials in a Pavement

3.1 Construction of the pavement
The pavement consists of a number of layers made up from different materials. The naturally occurring ground is the subgrade. If this is unweathered rock it may have adequate strength to be built directly upon, however, most subgrades require construction of some form of foundation to the main structural layers of the pavement. The structural layers of the pavement consist of a base, a binder course and a surface course. In the case of a rigid pavement these three layers are combined into one layer of pavement quality concrete. In a rigid composite construction the base layer is pavement quality concrete and is overlaid with a bituminous surfacing, this may be during the original construction or as maintenance during the life of the pavement. In a flexible composite construction the base course will be constructed with a hydraulic bound material. Figure 3.1 indicates the pavement layers for flexible, flexible composite, rigid composite and rigid construction.

The structural layers are supported by the sub-base, which may be either unbound or hydraulically bound. The bottom of the sub-base is taken as the formation level and the base of the pavement. Beneath the pavement is the existing ground, or subgrade, which may be natural or made ground depending on the situation. A capping layer is often placed on top of the subgrade to create a layer of sufficient strength to allow construction of the pavement layers. The capping is part of the subgrade and may be unbound or hydraulically bound material imported to the site or existing ground strengthened with lime or cement in-situ.

Figure 3.1 Pavement Layers for Various Types of Construction

The layers indicated above are typical for schemes constructed by the Highways Agency using the Specification for Highway Works (SHW) and design standards HD25 for foundations and HD26 for the pavement design. This specification and the design standards may be overly conservative for low traffic roads. The Local Authority road network consists of a wide range of roads categorised as Built-up and Non-built-up which are sub-divided into Principal, Other Classified and Unclassified.
These categories represent roads that have been constructed from the above designs, others that have evolved with successive layers being constructed over a number of years to those that are merely surface dressed. Roads constructed over the last thirty years are likely to be built to standard designs corresponding generally to Figure 3.1 whether these are heavily trafficked major roads connecting to the trunk road and motorway network or lightly trafficked minor roads in housing estates. Older roads, including many heavily trafficked major roads, may have ‘evolved’ by the addition of successive layers of bituminous material over many years (Figure 3.2). Often there may be little or no record of the various phases of construction. These roads pose particular challenges when maintenance is required because of the uncertainty associated with their construction and their potential variability.

![Figure 3.2 A Typical ‘Evolved’ Road: Nine Mile Ride, Crowthorne](image)

### 3.2 Materials used for pavement construction

The materials that may be found or used in the various layers of the pavement and in other aspects of pavement construction are discussed below. The materials that are permitted under the Specification for Highway Works for the various layers are listed. A wider range of recycled and secondary aggregates is permitted in HD 35/04, Conservation and the Use of Secondary and Recycled Materials (Highways Agency et al., 2004). Table 2.1 from HD 35/04 is reproduced as Table 3.1. It may be possible to use other locally available materials for these applications, so long as they meet the requirements of the Specification and do not have any adverse environmental effects. This should be particularly considered for lightly trafficked roads, where the requirements of the Specification for Highway Works may be unduly onerous. It should be noted that where a material is shown as a permitted constituent, this does not mean it will automatically be suitable in any given situation; the particular material, whether primary, recycled or secondary, still has to meet the requirements of the Specification for that application, e.g. in terms of grading, particle strength and other properties as necessary.
<table>
<thead>
<tr>
<th>Application and Series</th>
<th>Pipe Bedding</th>
<th>Embankment and Fill</th>
<th>Capping</th>
<th>Unbound Mixtures for Sub-base</th>
<th>Hydraulically Bound Mixtures for Sub-base and Base</th>
<th>Bitumen Bound Layers</th>
<th>PQ Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>500</td>
<td>600</td>
<td>600</td>
<td>800</td>
<td>800</td>
<td>900</td>
<td>1000</td>
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<tr>
<td>Blast furnace slag</td>
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<tr>
<td>Burnt Colliery Spoil</td>
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<td>✓</td>
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<td>x</td>
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<tr>
<td>Spent Oil Shale</td>
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<td>✓</td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Steel Slag</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Unburnt Colliery Spoil</td>
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<td>✓</td>
<td>X</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

**Key:**

✓ Specific permitted as a constituent if the material complies with the Specification (MCHW 1) or General Provision (permitted as a constituent if the material complies with the Specification (MCHW 1) requirements but not named within the Specification (MCHW 1)).

X Not permitted.

**Important Notes:**

1. Table 1 is for guidance only and reference must be made to the accompanying text (of HD 35/04) and the Specification (MCHW 1). Materials indicated as complying with the Specification (MCHW 1) for a particular application may not necessarily comply with all the requirements of the series listed, only particular clauses. For example in the 600 Series, Unburnt Colliery Spoil can satisfy the Specification as a general fill, but is excluded as a structural fill, and in Series 1000 recycled or secondary materials are not permitted within the running surface of PQ concrete. Reference should also be made to the Specification (MCHW 1) for any maximum constituent percentages of specific recycled or secondary aggregates. For example, in the 1000 Series, the maximum by mass constituent of Recycled Asphalt is given under the limits for ‘other material’ (Table 10/2) within the Specification (MCHW 1).

2. There is no Specific or General Provision for the use of recycled glass as an aggregate in PQ concrete or Hydraulically Bound Mixtures due to the potential for deleterious alkali-silica reaction (ASR). However, its use may be permitted by the Overseeing Organisation if sufficient provisions to minimise the risk of deleterious ASR are included in the mixture design.

3. There is no Specific or general Provision for the use of steel slag as an aggregate in PQ concrete or Hydraulically Bound Mixtures due to the potential for volume instability. However, its use may be permitted by the Overseeing Organisation if sufficient assurance of volume stability is provided.
The surface and binder courses are layers comprised of aggregate held together by a binder. The binder used in these layers may be bitumen or cement based. The cement bound material is pavement quality concrete and the bitumen bound material is asphalt. The surface course is the layer in contact with the vehicles using the pavement and has to provide a safe running surface and often contains high quality aggregate. Skid resistance is particularly important for this layer, generally measured by the Polished Stone Value (PSV) of the aggregate (see Chapter 7.3). The materials permitted for coarse aggregate in bitumen bound layers in the Specification for Highway Works are listed below. The materials also have to comply with the specific requirements for the layer.

- **Permitted materials** for asphalt: crushed rock, gravel, blastfurnace slag, steel slag, recycled coarse aggregate and recycled concrete aggregate; reclaimed asphalt may be used as up to 10% in surface course and up to 50% in binder course; pulverised-fuel ash (PFA) may be used as filler.
- **Permitted materials** for pavement quality concrete: crushed rock, gravel, blastfurnace slag, recycled aggregate or recycled concrete aggregate; PFA may be used as a partial replacement for cement.

The base layer may consist of any of the materials used for the surface and binder courses or hydraulic bound materials. Hydraulic bound materials may be cement bound, slag bound, fly ash bound or bound with hydraulic road binder. Older pavements may also contain layers of wet mix or dry bound macadam which are not in use as a base layer in current construction practice. For lightly trafficked roads, an unbound or stabilised layer may be suitable. The purpose of the base layer is to spread the load from traffic onto the weaker underlying layers.

- **Permitted materials** for asphalt: as for surface and binder course.
- **Permitted materials** for pavement quality concrete: as for surface and binder course.
- **Permitted materials** for hydraulically bound materials: PFA, granulated or ground granulated blast furnace slag, cement and lime may be used as binders; any primary, recycled or secondary aggregate meeting the requirements of the specification may be used as coarse aggregate.

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1 “Permitted materials”, both here and subsequently in this section, refers to the materials generally permitted without specific approval by the client in the current version of the Specification for Highway Works. Furthermore, for certain mixture types or specific uses, there may be further restrictions and/or easing of the restrictions.
Box 3.1 Use of Granular Material Stabilised with Fly Ash (GFA) by Staffordshire County Council

The use of hydraulically bound materials (HBM) has increased considerably in the UK in recent years. An example of this is the development of Granular material treated with Fly Ash (GFA) by Staffordshire County Council.

GFA consists of a coarse aggregate, often asphalt planings, bound with about 12% pulverized-fuel ash (PFA) and 3% lime or cement. PFA is widely available in the Staffordshire area from a number of coal-fired power stations, and planings are available from regular highway maintenance works. Staffordshire Engineering Services and Wrekin Construction have been developing methods of working with GFA over the last five years. Processed Incinerator Bottom Ash (IBA) has also been used as the coarse aggregate, and GFA incorporating aggregates produced from both planings and IBA was used in the Burntwood Bypass in 2001. GFA can be placed with a paver or tracked excavator and compacted like a soil, but it gains strength to be similar to a cement bound material with time. Hence a single layer of GFA can be used to replace separate layers of unbound sub-base and road base in a conventional road construction.

Two GFA applications were carried out in 2005: a 1350 m single carriageway access road to Kingswood Lake Development near Cannock and Phase 1 of the Rugeley Bypass, involving 650 m of single carriageway and a roundabout junction. Both applications were designed using the principles of TRL Report 611 and were carried out very successfully. 9,300 tonnes of GFA were placed at Kingswood Lake, and 6,800 tonnes at Rugeley. The projects have estimated traffic loads of 5 – 7 million standard axles (msa) and 8 – 12 msa respectively. Direct cost savings of about 40% on the base and sub-base layers were achieved by the use of GFA compared to conventional construction, plus environmental benefits. A formal design guide and specification for GFA is now available via TRL Report 611 (Merrill et al., 2004). Staffordshire are now looking to use GFA in other projects. They have also developed an in-situ process using the design guidance in TRL 611.
The sub-base, which may be a bound or unbound layer, gives uniform support to the structural layers and also acts as a working platform when constructing the base layer. The unbound material may consist of graded aggregate (Type 1 or Type 2 mixtures), open graded (Type 3 mixture), close graded (Category B mixture) or asphalt arisings (Type 4) and should have a California Bearing Ratio (CBR) of at least 30% to allow construction of the pavement layers. Frost heave is a particular concern for this layer. Some recycled aggregates with a high proportion of crushed brick may be susceptible to frost heave, so this should always be checked using the test given in Series 800 of the SHW (see Chapter 8). The bound sub-base would be a hydraulically bound material, with cement, slag, fly ash or other hydraulic road binder.

- **Permitted materials for unbound sub-base:** recycled asphalt, recycled coarse aggregate or recycled concrete aggregate, crushed slag and well burnt non-plastic shale, crushed rock and gravel. Various combinations of these materials, such as up to 50% recycled asphalt in Type 1 and Type 2 unbound sub-base. Up to 25% glass is permitted in Types 1, 2 and 4.

The capping is a layer used to improve the bearing capacity of the subgrade, the top of the capping should have a CBR of at least 15%, to allow construction of the sub-base and act as a structural layer in the longer term. Capping may be a bound or unbound layer which utilises locally available material. Typical unbound capping materials are selected granular (fine or coarse grading), or recycled asphalt. Natural soils that are not sufficiently strong to act as capping may be rendered acceptable by the addition of cement or lime. Figure 3.3 shows how selected conditioned pulverised fuel ash, selected granular or selected cohesive materials that fall into the Specification for Highway Works (SHW) Classes 6E, 7E, 7F, 7G or 7I can be stabilised with cement or lime to form acceptable Class 9 materials. Material that is unacceptable Class U1 because of excessive moisture content can be dried out by the use of lime to one of the Class 6 or 7 fills before further treatment to turn it into an acceptable Class 9 fill.

- **Permitted materials for unbound capping:** see Table 3.3 Recycled aggregates are generally acceptable for capping but certain materials are not permitted in some Classes. These are unburnt colliery spoil, argillaceous rock, chalk and materials containing tar or tar/bitumen binders.

The subgrade is the naturally occurring ground and is assessed by means of its CBR value. Subgrades with CBR < 2% make it very difficult to compact upper layers and are usually removed to a substantial depth, overlaid with a thick capping layer or stabilised with cement and/or lime. Subgrades of CBR 2% to 15% require a capping layer, which reduces in thickness as the subgrade gets stronger, beneath the sub-base. For CBR of 2.5% to 15% in flexible construction, the capping may be replaced with additional sub-base. For strong subgrades of greater than 15% only a nominal sub-base is required. Generally clays will have a CBR of 1% to 5%, sands and gravels will have a CBR greater than 5%. However, the CBR of a material is not constant but is very heavily affected by its moisture content, as shown in Box 3.2. It is therefore important that values are measured by laboratory or in-situ tests, and that the design CBR chosen allows for the long term moisture content of the material.
Figure 3.3 The Process of Stabilising Class U1 Material for Capping (from HA74/07)
Box 3.2 California Bearing Ratio (CBR) and Pavement Design
The California Bearing Ratio (CBR) is a test in which a 50mm diameter plunger is forced into a sample of soil at a constant rate of strain. The resistance to penetration is recorded and is reported as the ratio to the value for a standard crushed rock; thus crushed rock would have a CBR of 100%, whereas soft clay would have a CBR of less than 2%. The test can be performed in the laboratory or on site and is widely used in road and airfield pavement design. The CBR of a soil is affected by its density/degree of compaction and by its moisture content, as indicated for silty sand in Figure 3.4. The CBR decreases from over 50% at a moisture content of 5% to about 8% at a moisture content of 10% and less than 2% at a moisture content of 12%.

![Figure 3.4 Variation of CBR of Silty Sand with Moisture Content (from Lamb and Reid, 2006)](image)

Drainage materials consist of the pipes and the bedding, laying, surrounding and backfilling materials. The pipes may be constructed of vitrified clay, concrete, glass reinforced plastic, iron, unplasticised polyvinyl-chloride (PVC-U), polypropylene (PP), polyethylene (PE) or corrugated steel.

- **Permitted materials for pipe bedding and filter drain material:** crushed rock, gravel, aggregate, recycled aggregate or recycled concrete aggregate.

General fills may consist of well graded, uniformly graded, or coarse granular, wet or dry cohesive, stony or silty cohesive materials, reclaimed pulverised fuel ash cohesive material or chalk conforming to SHW Classes 1, 2 or 3. This means that most recycled and secondary aggregates will be acceptable as general fill with the exception of chalk for some Classes and reclaimed pulverised fuel ash containing >20% furnace bottom ash.

- **Permitted materials for general fill:** See Table 3.2.
Table 3.2 Permitted Constituents for General Fill in Series 600 Earthworks

<table>
<thead>
<tr>
<th>Class</th>
<th>Description and use</th>
<th>Permitted Constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Well graded granular material</td>
<td>Any material or combination of materials, other than material designated as Class 3 in the Contract. Recycled Aggregate</td>
</tr>
<tr>
<td>1B</td>
<td>Uniformly graded granular material</td>
<td></td>
</tr>
<tr>
<td>1C</td>
<td>Coarse granular material</td>
<td></td>
</tr>
<tr>
<td>2A</td>
<td>Wet cohesive material</td>
<td>Any material or combination of materials, other than material designated as Class 3 in the Contract.</td>
</tr>
<tr>
<td>2B</td>
<td>Dry cohesive material</td>
<td></td>
</tr>
<tr>
<td>2C</td>
<td>Stony cohesive material</td>
<td></td>
</tr>
<tr>
<td>2D</td>
<td>Silty cohesive material</td>
<td>Reclaimed material from lagoon or stockpile containing not more than 20% furnace bottom ash</td>
</tr>
<tr>
<td>2E</td>
<td>Reclaimed pulverised-fuel ash</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Chalk</td>
<td>Chalk and other materials designated as Class 3 in the Contract.</td>
</tr>
</tbody>
</table>

Selected Fills may be selected well graded granular, selected granular, selected cohesive or selected conditioned pulverised fuel ash cohesive material to SHW Classes 6 or 7. A number of different applications are covered by these classes, including starter layers for embankments, fill for gabions and backfill to a wide range of structures. Excluded are argillaceous rock (shale, mudstone, siltstone, slate and micaceous schist) because it is flaky and tends to delaminate, is soft and difficult to compact. Argillaceous rock includes unburnt colliery spoil.

Slag is excluded from applications which may potentially be below the water table because of concerns about leachate or in direct contact with corrugated steel buried structures. Unweathered slag is likely to swell when exposed to moisture, as well as generating polluting leachate, and this can cause disruption to overlying road pavements. Slag should always be fully weathered before use in construction, to avoid potential problems with swelling and leachate. Even if unweathered slag does not swell when it is first placed, because it is dry, it can be activated by ingress of moisture at a later date, for example when the road is opened for utility works.

Recycled asphalt is excluded from applications where it may be present in layers of significant thickness because of the risk of long term creep settlement due to the bitumen content. Research has shown that up to about 2% bitumen content, a fill material will behave essentially as a granular material. Above this level, it will start to become more compressible. This is particularly important in applications such as backfill to structures, retaining walls and corrugated steel buried structures where settlement of the backfill would have a major impact on the performance of the structure.

- **Permitted materials for selected fill**: See Table 3.3.
<table>
<thead>
<tr>
<th>Class</th>
<th>Description and use</th>
<th>Permitted Constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>6A</td>
<td>Selected well graded granular material: below water</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock other than argillaceous rock, crushed concrete, chalk, well burnt colliery spoil or any combination thereof. Recycled aggregate</td>
</tr>
<tr>
<td>6B</td>
<td>Selected coarse granular material: starter layer</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, chalk, well burnt colliery spoil, slag or any combination thereof. Recycled aggregate</td>
</tr>
<tr>
<td>6C</td>
<td>Selected uniformly graded granular material: starter layer</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock other than argillaceous rock, crushed concrete, chalk, well burnt colliery spoil, slag or any combination thereof. Recycled aggregate</td>
</tr>
<tr>
<td>6D</td>
<td>Selected uniformly graded granular material: starter layer below pulverised-fuel ash</td>
<td>Any material, or combination of materials, other than unburnt colliery spoil and argillaceous rock. Recycled aggregate</td>
</tr>
<tr>
<td>6E</td>
<td>Selected granular material: for stabilisation with cement to form capping</td>
<td>Any material, or combination of materials, other than unburnt colliery spoil and argillaceous rock. Recycled aggregate</td>
</tr>
<tr>
<td>6F1</td>
<td>Selected granular material (fine grading): capping</td>
<td>Any material, or combination of materials, other than unburnt colliery spoil, argillaceous rock and chalk. Recycled aggregate</td>
</tr>
<tr>
<td>6F2</td>
<td>Selected granular material (coarse grading): capping</td>
<td>Any material, or combination of materials, other than unburnt colliery spoil and argillaceous rock. Recycled aggregate</td>
</tr>
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<td>6F3</td>
<td>Selected granular material: capping</td>
<td>Recycled bituminous planings and granulated asphalt, but excluding material containing tar or tar-bitumen binders. Recycled aggregate</td>
</tr>
<tr>
<td>6F4</td>
<td>Selected granular material (fine grading) – capping</td>
<td>Unbound mixtures complying with BS EN 13285.</td>
</tr>
<tr>
<td>6F5</td>
<td>Selected granular material (coarse grading) – capping</td>
<td>Any material, or combination of materials imported on to the Site: – including recycled aggregate, but excluding unburnt colliery spoil, argillaceous rock and chalk. Recycled asphalt up to 50%, provided bitumen content is &lt; 2.0%.</td>
</tr>
<tr>
<td>6G</td>
<td>Selected granular material: gabion filling</td>
<td>Natural gravel, crushed rock, crushed concrete or any combination thereof. None of these constituents shall contain any argillaceous rock</td>
</tr>
<tr>
<td>6H</td>
<td>Selected granular material: drainage layer to reinforced soil and anchored earth structures</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, chalk, well burnt colliery spoil or any combination thereof. None of these constituents shall contain any argillaceous rock. Recycled aggregate except recycled asphalt</td>
</tr>
<tr>
<td>Class</td>
<td>Description and use</td>
<td>Permitted Constituents</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>6I</td>
<td>Selected well graded granular material: fill to reinforced soil and anchored earth structures</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, slag, chalk, well burnt colliery spoil or any combination thereof except that chalk shall not be combined with any other constituent. None of these constituents shall contain any argillaceous rock. Recycled aggregate except recycled asphalt</td>
</tr>
<tr>
<td>6J</td>
<td>Selected uniformly graded granular material: fill to reinforced soil and anchored earth structures</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, well burnt colliery spoil or any combination thereof. None of these constituents shall contain any argillaceous rock. Recycled aggregate except recycled asphalt</td>
</tr>
<tr>
<td>6K</td>
<td>Selected granular material: lower bedding for corrugated steel buried structures</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, well burnt colliery spoil or any combination thereof. None of these constituents shall contain any argillaceous rock. Recycled aggregate except recycled asphalt</td>
</tr>
<tr>
<td>6L</td>
<td>Selected uniformly graded granular material: upper bedding for corrugated steel buried structures</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, well burnt colliery spoil or any combination thereof. None of these constituents shall contain any argillaceous rock. Recycled aggregate except recycled asphalt</td>
</tr>
<tr>
<td>6M</td>
<td>Selected granular material: surround to corrugated steel buried structures</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, well burnt colliery spoil or any combination thereof. None of these constituents shall contain any argillaceous rock. Recycled aggregate except recycled asphalt</td>
</tr>
<tr>
<td>6N</td>
<td>Selected well graded granular material: fill to structures</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, slag, chalk, well burnt colliery spoil or any combination thereof. None of these constituents shall contain any argillaceous rock. Recycled aggregate except recycled asphalt</td>
</tr>
<tr>
<td>6P</td>
<td>Selected granular material: fill to structures</td>
<td>Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, slag, chalk, well burnt colliery spoil or any combination thereof. None of these constituents shall contain any argillaceous rock. Recycled aggregate except recycled asphalt</td>
</tr>
<tr>
<td>6Q</td>
<td>Well graded uniformly graded or coarse granular material: overlying fill for corrugated steel buried structures</td>
<td>As Class 1A, 1B or 1C granular fill materials, but not to include argillaceous rock, slag or PFA in any proportions. Recycled aggregates except recycled asphalt</td>
</tr>
<tr>
<td>6R</td>
<td>Selected granular material: for stabilisation with lime and cement to form stabilised capping</td>
<td>Any material, or combination of materials, other than unburnt colliery spoil and argillaceous rock</td>
</tr>
<tr>
<td>6S</td>
<td>Selected well graded granular material: filter layer below sub-base</td>
<td>Crushed rock or sand</td>
</tr>
<tr>
<td>7B</td>
<td>Selected conditioned pulverised-fuel ash cohesive material: fill to structures and reinforced soil</td>
<td>Conditioned material direct from power station dust collection system and to which a controlled quantity of water has been added</td>
</tr>
<tr>
<td>7G</td>
<td>Selected conditioned pulverised-fuel ash cohesive material: for stabilisation with cement to form capping</td>
<td>Conditioned material direct from power station dust collection system and to which a controlled quantity of water has been added</td>
</tr>
<tr>
<td>8</td>
<td>Class 1, Class 2 or Class 3 material: lower trench fill</td>
<td>Any, except that there shall not be any stones or lumps of clay &gt; 40mm nominal diameter. Recycled aggregate</td>
</tr>
</tbody>
</table>
**Kerbs** may be of concrete, asphalt, plastic or rubber construction. Advantages of kerbs made from recycled plastic or rubber are that they are much lighter than conventional concrete kerbs and hence can be handled manually, whereas machines are now required for handling conventional kerbs. A potential problem with kerbs made from recycled plastic is that they may change colour with time, as variability in the nature of the feedstock can affect the colour fastness of the product. Specialist machines are now available for planing existing concrete kerbs and backing, producing high quality recycled concrete aggregate which can be used as Type 1 unbound sub-base.

**Footways** may be constructed with a surfacing of concrete, natural stone, bituminous bound material, concrete blocks or clay pavers. The surfacing would be laid on a bound or unbound sub-base. The permitted materials for these applications are generally the same as those for in highways listed above. However, footways often provide a good opportunity to trial new materials and techniques in areas of little risk; if successful, they can then be extended to more demanding applications.

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**Box 3.3 Trial using Cold Recycled Bituminous Bound Material in Footways in Hampshire**

Hampshire County Council, their routine highway maintenance term contractor RCS Limited and supplier Foster Yeoman carried out a trial using cold recycled bituminous bound material with foamed bitumen as the binder and recycled asphalt planings from work elsewhere in the county (Foamix) for the repair of 700m of footway in the village of Martyr Worthy. The foamix was used to repair the sub-base and as a combined base and binder course with a surface dressing. Normally, a reconstructed footway would require a full surface course. However, the foamix and surface dressing has performed as well as conventional construction with hot asphalt and a full surface course. The material was easy to place and saved time by using one material for the sub-base, base and binder. Environmental savings were made by the reuse of asphalt planings and by the use of cold mix materials instead of hot asphalt with primary aggregates. Useful experience with foamix was obtained from the trial, and it is now used widely for highway maintenance work in Hampshire.

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Various materials that satisfy the requirements of the SHW Class 4 material are used for **Landscaping** fill. These are often excavated soils that are not strong enough or have too high an organic content to be acceptable as general fills. The materials may also be wood or compost (see [http://www.wrap.org.uk/landscaping/highways_roads.html](http://www.wrap.org.uk/landscaping/highways_roads.html) for more information).
Topsoil is classified in the SHW as Class 5 materials and may be topsoil or turf existing on the site or imported topsoil.

Road marking materials consist of thermoplastics, polymers, resins, silica sand and glass beads.
4 Maintenance Techniques

4.1 Introduction
Roads are designed to have a maintenance strategy, so that interventions are necessary on a planned basis to maintain serviceability as the cumulative traffic load increases with time. Maintenance may also be necessary on occasion in response to unplanned events. Standard maintenance strategies have been developed to deal with this type of deterioration, involving regular surveys, surface dressings and eventually complete reconstruction of the pavement. This mode of deterioration is particularly applicable to the Principal Roads at the top end of range of road types for which Local Authorities are responsible. However, for many Local Authority roads weather and localised overloading or weak spots are the main deterioration models, and treatments are often restricted to small scale patching and repair works spread across the network. Guidance on maintenance techniques for trunk roads and motorways are given in Volume 7 of the DMRB, and the various techniques are described in the SHW and discussed in this chapter. These techniques are also applicable to many Local Authority roads. Maintenance techniques commonly used by Local Authorities are described in the following sections.

There are a number of maintenance techniques which will allow the re-use of existing materials or the use of recycled or secondary aggregates in the pavement. It is essential that the reclaimed materials are consistent, as variability in materials will reduce the efficiency of the operation.

4.2 Surface course
Repairs to the surface course probably constitute the single greatest area of maintenance for Local Authority highway engineers. These can form large single projects, where an extensive length of highway requires surface dressing for example, but often constitute a large number of small projects spread over a wide area. In general they require good quality aggregates such that the texture depth and skid resistance can be maintained for a considerable length of time. This therefore precludes the use of most secondary and recycled materials, which generally have relatively low skid resistance. However, steel slag can be used in this layer and is widely used in the surface course in some parts of the country.

It is possible to recycle the existing surface course for use in new surface course, as indicated by the case studies for TRL 645 (Carswell et al., 2005) (Box 1.9) and Rockingham Road (Box 1.4). This requires the surface course to be separated from the binder course and base layers during the planing and subsequent processing works, but enables higher value applications to be obtained for the recycled material. Care has to be taken in assessing the PSV of the recycled material, which may come from a variety of sources and aggregate sizes (e.g. 6 & 10mm).

Recycling of road surface layers results in the economic use of readily available materials and produces savings from reduced energy requirements for mineral extraction, transport and mixing, and advances environmental conservation by reducing the extraction of new material and the corresponding reduction in the disposal of excavated material. Recycling may be undertaken hot or cold and may be in-situ or in a central plant.

In-situ hot recycling may be by the repave process in which a thin layer of surfacing material is bonded to the pre-heated, scarified and reprofiled surface. This
is not suitable if excessive hardening of the binder has occurred. Another technique is the **remix** process in which the existing surface is pre-heated and scarified. The scarified material is collected into a mixing unit in the paving train and mixed with new material before being re-laid. Pre-coated chippings contained in existing hot rolled asphalt surfacing need not be removed for these processes as they are mixed into the scarified material, increasing the stone content. The remix and repave processes are covered by Clause 926 of the SHW. Remix/repave can be used together but require a paving machine with two augers. These three processes can address the following defects:

- Deteriorating skid resistance;
- Cracking and crazing caused by binder hardening in the surfacing;
- Ravelled or fretted surfaces or chipping loss;
- Ruts, pot-holes and poor ride quality;
- Reflective cracking above cement bound bases;
- Short-term strengthening prior to major strengthening.

The **in-situ cold recycling** process is **retread** in which the existing road surface is scarified, has new binder added, and is reshaped and compacted to form a new surfacing. More recent techniques allow this process to a depth of 350mm using cement or foamed bitumen. TRL 611 (Merrill *et al*., 2004) gives guidance on the use of these techniques which may be used for roads up to 30msa; a departure is required for higher trafficked roads. These techniques can also be undertaken using a mobile plant on the site.

**Central plant hot recycling** is a process where the surfacing material is planed and taken from the road to a mixing plant where a new asphalt mixture is created using the old material. For asphalt binder course and base, up to 30% reclaimed asphalt is considered to be the optimum mixture for ease of quality control. However, even with the surface course, significant proportions of reclaimed asphalt can be incorporated successfully, as demonstrated on the M4 between junctions 32 and 33 in August 2006 when CEMEX used 25% reclaimed porous asphalt planings in their thin surfacing for the Welsh Assembly.

**Central plant cold recycling** is the process of excavating bitumen or cement bound pavements and using the crushed and graded material in the highest value pavement layer as possible. If quantities are sufficient to justify it, a mobile crusher is bought onto the site. Asphalt may require a granulator as opposed to a jaw type crusher to reduce the material to an acceptable and consistent grading.

**Inlay** involves planing the existing surface material, usually to a nominal 15mm, and then utilising the repave or remix process to restore the profile and levels. This process can save up to 45% in new material compared to a conventional 40mm inlay.

For an **overlay**, planing is not normally required unless surface dressing is present. This should be removed before the repave or remix is performed to avoid enrichment of the scarified material, difficulties with plant operation and excessive fume emissions. The thickness of new material in an overlay is 15 – 30mm for repave or 10 – 30mm for remix, offering savings of 30 – 50% in materials compared to a conventional 45 – 50mm overlay. This process only raises the road level by 10 – 30mm obviating the need for raising kerbs etc.

Flow charts are given in HD 31 for determining when to use remix or repave and overlay or inlay processes.
**Haunching** is the maintenance of the outer edges of the carriageway. This involves partial or total reconstruction of a defective edge structure or the construction of a new section to widen the carriageway. In 1991, the County Surveyors Society published a report entitled "A Practical Guide to Haunching" (CSS, 1991). This report gives practical advice for engineers and technicians working in Highway Maintenance and covers the investigation, design, supervision and testing required for the effective repair of haunches. To complement this document, there is the TRL Report “Road Haunches: A Guide to Maintenance Practice” (Luck, 1991) which gives full details of haunch design and materials and introduces the concept of “versatile design” with local materials.

When undertaking haunching there is often the opportunity to recycle material removed from the pavement or adjacent to the pavement. TRL report TRL 216 “Road Haunches: A Guide to Re-usable Materials” (Potter, 1996) is based on the measured performance of re-usable materials in road trials over a period of two years. It incorporates and updates the design guidance given in the CCS publication to make it a "stand alone" document. However, it is recommended that this report is used in conjunction with the CSS and TRL publications because the engineering principles used in design and construction of haunches are equally applicable to virgin and re-usable materials.

**Box 4.1 Use of Recycling Techniques in Haunching Works by Staffordshire Highways**

A common operation for Local Authority highway maintenance works is haunching and overlay works to upgrade narrow rural roads for higher traffic loads. The verges of the existing roads are often damaged by the wheels of heavy vehicles going over the edges of the paved surface. Staffordshire Engineering Services and ACCORD have developed techniques to maximise the use of recycled materials in these operations. These include the use of cement stabilisation to improve the verges, followed by the use of cold lay asphalt (foamix) produced with foamed bitumen and recycled asphalt planings as the coarse aggregate as a 150 mm overlay, with a thin surface dressing layer. These techniques avoid the production of any excavation waste from the site, or the use of any primary aggregate in the overlay. An example is the repair of 1200 m of 3.1 m wide single carriageway Class C rural road at Moat Lane, Newborough in the summer of 2004. The road had been damaged by 20 tonne lorries accessing a depot on Moat Lane. The road was widened by 1.0 m on either side, and the recycling operation was about 20% cheaper than one using primary aggregates and conventional construction methods.

**Surface dressing** is a form of maintenance that is required when a road shows extensive surface deterioration and is applied as part of a planned maintenance operation for a complete stretch of road. However, if the pavement is allowed to deteriorate too far, surface dressing will not be effective.

**High friction surfacing** is increasingly used in specific short stretches of road where there is particular risk of skidding, such as the approaches to roundabouts (Figure 4.1). The aggregate most commonly used for this application is calcined bauxite, a fine-grained material produced by heating bauxite in a rotary kiln to over 1200°C. This provides excellent skid resistance, but unfortunately the material is not very durable and tends to break up after a few years. Attempts have been made to find materials that combine high skid resistance with long term durability, but so far with limited
success. These high cost/short life materials should be used where they are really needed, and where it is affordable to replace them on a regular basis, e.g. at pedestrian crossings.

![Figure 4.1 High Friction Surfacing at Approach to Roundabout](image)

4.3 Deeper pavement repairs

When a highway has deteriorated to such an extent that it is showing major signs of distress, such as deep rutting and cracking and unevenness, it becomes necessary to reconstruct the entire pavement rather than just the surface layer. Traditionally this has been carried out by excavating the existing layers and replacing them with completely new construction. However, in recent years a number of techniques have been developed that enable the existing materials to be recycled into the new construction, thus saving on primary resources, disposal of waste to landfill and transport and related environmental impacts.

A variety of recycling processes are covered by the SHW, as indicated in Table 4.1.

<table>
<thead>
<tr>
<th>SHW Clause</th>
<th>Recycling Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>614, 615, 643</td>
<td>Lime and cement stabilisation for capping</td>
</tr>
<tr>
<td>713 to 716</td>
<td>Saw cut and seal, crack and seat (concrete and HBM)</td>
</tr>
<tr>
<td>902</td>
<td>Reclaimed bituminous materials in hot asphalt</td>
</tr>
<tr>
<td>926</td>
<td><em>In-situ</em> recycling: the remix and repave processes</td>
</tr>
<tr>
<td>948</td>
<td>Cold recycled bitumen bound material</td>
</tr>
<tr>
<td>1046</td>
<td>Cold recycled cement bound material</td>
</tr>
</tbody>
</table>

One of the major developments in the last decade has been **cold recycling** techniques for asphalt and concrete pavements. Initially this was developed as an *in-situ* technique, and guidance was first published in TRL 386 (Milton and Earland, 1999). With more experience, the technique has been extended to a wider range of binders, covering all combinations of hydraulic and visco-elastic binders, and to *ex-situ* applications as well as *in-situ* ones. In *ex-situ* applications, the existing pavement layers are broken out as for the *in-situ* applications, but the materials are removed to a nearby temporary depot where they are screened and mixed with the relevant binders under controlled conditions before being taken back to the site and placed with a conventional paver. With both techniques, pavements can be recycled to a
depth of about 325mm. A conventional surface course is generally required on top of the cold recycled materials.

There are advantages and disadvantages to both techniques. The ex-situ technique allows better control over the materials going back into the road than the in-situ technique, hence there is more certainty that design stiffness values can be achieved and the layers are generally thinner than with in-situ cold recycling. There can also be problems with existing services or obstructions that make the use of in-situ cold recycling difficult, particularly in urban areas. However, in-situ cold recycling avoids the need for temporary sites for storing and processing the materials, which can be difficult to obtain in urban areas. Both in-situ and ex-situ techniques are reported to offer savings of up to 25% in cost and time, as well as the environmental savings of avoiding material going to landfill and emissions of CO₂ due to the reduced transport and hot-mix asphalt emissions compared to conventional repairs. Savings in the time for which roads have to be closed can be particularly important in congested urban areas. The case study of Rockingham Road, Corby in Part 1 is an example of ex-situ cold recycling. In areas where primary aggregates are readily available, cold recycling may not always be the cheapest material cost option, but offers other sustainability benefits such as energy savings and reduced time of road closures.

The experience of the London Borough of Merton with a range of techniques is summarised in the case study below.

Asphalt planings and other arisings can also be recycled back into new hot asphalt as reclaimed asphalt under Clause 902 of the Specification for Highway Works. Up to 50% reclaimed material is permitted in base and binder course, and up to 10% in the surface course.

**Box 4.2 Use of Reclaimed Asphalt in the A34 Chievely/M4 Junction 13 Improvement**

This major project was undertaken by Costain for the Highways Agency and was designed as a sustainable transport solution. Significant quantities of recycled asphalt were obtained at an early stage in the works from planing works on the M4 by surfacing contractor Foster Yeoman. The planings were taken to Foster Yeoman’s plant at Theale, 12 miles east of the site, where the asphalt plant had been set up to incorporate the planings as 10% of the new asphalt base and binder course layers. The planings were screened and processed prior to incorporation in the new asphalt. The bitumen content of the planings was checked and the binder content of the new asphalt adjusted to take this into account. The planings were used in the base and binder course of the new A34; 28mm HMB base (35 pen) and 20mm HMB binder course (35 pen) respectively.
Box 4.3 Recycling and Reclaimed Asphalt use by Tayside Contracts
Tayside Contracts is the commercial arm of Perth & Kinross, Angus and Dundee City Councils. They provide a range of services for the councils, including cleaning, catering, road, vehicle and winter maintenance. They have obtained capital support from WRAP for equipment to enable them to recycle their arisings from road works, including screening facilities at five depots, with the potential to process 72,000 tonnes per year. Some 30,000 to 40,000 tonnes per year is used as unbound granular material for general fill, Type 1 sub-base, pipe bedding and drainage and filter media. This is mainly used by the councils and developers in housing estates.

Tayside has also invested, with the aid of WRAP, in recycling asphalt planings back into new hot asphalt at their asphalt plant at Collace Quarry, between Perth and Coupar Angus. At present all of the asphalt produced from this plant contains 10% reclaimed asphalt. Tayside believe that with extra developments in storage to keep the planings dry, they could increase the reclaimed content to 20%. This high level recycling is in line with the waste hierarchy and represents a more sustainable use of the recycled materials than using them only in relatively low value unbound applications.

Using crack and seat techniques, concrete pavements can be conserved as the lower base in flexible composite construction or as the sub-base for a new pavement. Continuously reinforced concrete pavements (CRCP) can be converted to become the base with a strengthening flexible overlay. Jointed concrete pavements can be converted to function as a lower base with a strengthening flexible overlay of adequate thickness to inhibit the formation of reflection cracks over joints. Further advice is given in HD 30/99.

Box 4.4 Use of Crack and Seat on Local Authority Road
Barnstable District Council in Devon has successfully used the crack and seat technique on the A361. It was used to incorporate the existing concrete pavement as an integral part of the new pavement construction.
Box 4.5 Cold Recycling ex-situ and in-situ in the London Borough of Merton

Experience of highway maintenance in the London Borough of Merton has shown that cold recycled bitumen bound material produced ex situ using the ‘Foamix’ process is effective for general maintenance work. The material uses asphalt planings mixed with foamed bitumen under controlled conditions. The material was initially used for bitumen bound base and binder course layers in carriageways, and was later extended to footways, patching and trench reinstatement.

The largest contract to date using this ex situ technique was the full reconstruction of 3500 m² of carriageway in Somerset Road in Wimbledon, outside the All England Lawn Tennis Club. The road was reconstructed to a depth of 235 mm, comprising 200 mm of Foamix and 35 mm of Stone Mastic Asphalt. In total the works took 8 days to complete. For this scheme, 10% of recycled glass was added to the Foamix and the road has performed well since the works were carried out.

The cost for using cold recycled bitumen bound material was marginally cheaper than full reconstruction using conventional methods. However, the method has a number of other advantages that combine with the cost saving to make it significantly more attractive than conventional repairs.

The London Borough of Merton has carried out one contract using cold in situ recycling, for the reconstruction of Church Road, Mitcham in 1999. The project was successful, with savings of 30% in costs and 50% in time. 2,500 tonnes of aggregate were recycled in situ, saving 250 lorry journeys. However, in situ recycling is often not possible in urban areas because of shallow services or restrictions on space and time available for the works. Ex situ cold recycling has proved more generally applicable for highway maintenance, but in situ recycling will be appropriate in certain circumstances.

The London Borough of Merton has also been using the ‘Rhinopatch’ and ‘Rhinopave’ methods for repairing bituminous materials for three years. These methods involve less disturbance to residents than conventional methods, and hence they can be carried out at night in some areas. This in turn reduces disturbance to busy urban areas during the day. These techniques are now used for the majority of patch repairs in the borough.

Overall, the London Borough of Merton has found that recycling is cheaper than conventional methods, reduces disruption, improves quality, enables the use of other recycled materials such as glass that would otherwise have to be disposed of, and increases the sustainability of their highway operations. The case study can be downloaded from [http://www.aggregain.org.uk/case_studies/2689_in_situ_and.html](http://www.aggregain.org.uk/case_studies/2689_in_situ_and.html).
Box 4.6 Cold Recycled Asphalt in Footway Repairs for Edinburgh City Council

Repairs to Frogston Road, Edinburgh were carried out in October 2001 for Edinburgh City Council by Linear Quarry Products. The work involved footpath resurfacing and edge reconstruction. Some 250 tonnes of asphalt planings were used with a foamed bitumen binder. The planings were obtained from a council roads depot. Cement was added to the mix to enable a rapid development of strength because wet weather was forecast, and this proved very successful as heavy overnight rain had no effect on the surface so long as the material was well compacted. Normally lime rather than cement would have been used for footway applications, giving the material a longer shelf life. Oven cured stiffness values of 2400 to 3000 MPa were obtained, well above the minimum required for a footway.
4.4 Earthworks
Earthworks may be required in Local Authority highway maintenance from time to time, particularly for situations such as repairs to existing cutting or embankment slopes that have failed, or where new construction is required. There are a number of opportunities for sustainable choice of materials in these situations.

Slope failures are particularly likely to occur where steep slopes have been constructed in clay soils. These may be stable in the short term, due to the high undrained strength of the clays, but over time the clays soften and tend towards the drained condition, which has lower strength, and failures may start to occur on slopes of more than 2m or so in height. This type of failure is more common on the trunk road and motorway network (Perry, 1989), where earthwork slopes tend to be much higher than on most Local Authority roads and are often at slopes of 1:2.5 or steeper. The main formations in which these failures occur are overconsolidated clays such as the London Clay, Gault Clay, Oxford Clay and Lower Lias Clays in the South and East of England. Failures can occur, however, in any soils where the slopes are constructed at too steep an angle and where groundwater or other conditions are adverse. In some areas this is compounded by natural instability and land slipping of the entire hillside. In some cases this can lead to closure of the road, e.g. the A625 at Mam Tor (Department of the Environment, 1994).

Where slope failures occur, the usual methods of repair are:
- Replace the failed material with high strength, free-draining granular material;
- Construct a reinforced soil with layers of geotextiles; this allows reuse of the existing soil, if necessary treated with lime to dry it out;
- Regrade the slope to a more stable angle, using either the existing soil or imported material; this may involve additional land take.

Specialist techniques such as soil nailing may be used where it is economically advantageous to do so, i.e. to retain a steep slope. Methods of repair for infrastructure embankments are given in Perry, Pedley and Reid (2003) and for cuttings in Perry, Pedley and Brady (2003).

Where it is decided to replace the failed material with high strength, free-draining granular material it may be appropriate to use recycled aggregates, especially where primary aggregates are not readily available, e.g. in the South and East of England. Recycled aggregate, derived from crushed and screened construction, demolition and excavation waste is particularly suitable, as it is widely available in and around most urban areas and may be cheaper than equivalent primary aggregates. An example from Hampshire is given in Box 4.6.

New construction: where new roads are required, for example in new housing, industrial or mixed use developments, there are opportunities for use of recycled or secondary materials in place of primary materials as indicated in the previous sections of this chapter. There may also be opportunities to retain earthworks materials on site, by treating them with lime or cement, instead of sending them to landfill and importing primary aggregates. This can also reduce the need for imported capping or sub-base materials. As it becomes more expensive to ‘dig and dump’, this option is becoming increasingly attractive. It can also be used to enable earthworks to be carried out beyond the normal earthworks season, thus preventing delays in the programme. An example is given in Box 4.7.
Box 4.7 Stabilisation of a Weak Clay Embankment in Hampshire

Embankment stabilisation was required on the A325 between the junction of the B3006 at Sleaford and north to the Hampshire county boundary at Holt Pond. The work covered a distance of about 1.8km. The embankment was previously made up of poor quality clay. The embankment was dug out in benches and the excavated material was replaced with Class 6F5 selected granular fill. Recycled aggregate obtained from processing inert construction and demolition waste was used as the Class 6F5 material. The embankment ranged from 0.8 m to 5.0 m in height and the works required a total of 29,000 tonnes of imported fill. The new embankment was built at a uniform slope of 1:3.

The recycled aggregates performed as well as primary aggregates and had the added benefits of reduced haulage distances, savings in CO₂ emissions and lower costs. More details are available at http://www.aggregain.org.uk/case_studies/a325_major.html.
Box 4.8 Soil Stabilisation in the North Popley Development, Basingstoke

North Popley is a new, mixed development site near Basingstoke, comprising residential units, a school and sports facilities. The site owners, Hampshire County Council, are carrying out preliminary infrastructure works to provide a spine road and services across the site. Contract 1 of the works entailed constructing 250m of 6.1m wide single carriageway access road and footways for a new secondary school.

The site is underlain by Chalk, and it was decided to stabilise this by the addition of 2% ordinary cement to form cement bound sub-base. The contractor, Envirosoil, treated a 225 mm thickness of Chalk in-situ using rotovating plant. Cement stabilised Chalk was also used as sub-base for 200m of footway and as backfill in trenches for the drains, but in these instances the Chalk was excavated, treated ex-situ and compacted into place. The Chalk above sub-base level was excavated and reused as general fill. In all, over 1,000 m³ of Chalk that would otherwise have been disposed to landfill and replaced with imported aggregates was retained on site.


4.5 Streetworks

In urban areas no road remains undisturbed for long; one statutory undertaker or another is always coming along and digging it up for the purposes of maintaining or repairing existing services or installing new ones. These operations are governed by the Specification for the Reinstatement of Highways (or Roads in Scotland), which is described in more detail in Chapter 8.3.3. Arisings from utility excavations are generally a mixture of natural soils, asphalt and unbound sub-base, often wet and intimately mixed (Figure 4.2). It is not generally possible to reuse these materials in the excavation, but rather than disposing of them to landfill they can be sent to a
recycling centre where they can be sorted, treated as necessary and reused as backfill for future excavations. A ‘closed loop’ system can thus be set up, enabling beneficial reuse of nearly all the excavated materials (Box 4.8).

![Figure 4.2 Typical Arisings from Utility Excavations](image)

In addition to reuse of arisings as unbound backfill, it is possible to use additives such as cement, lime or proprietary compounds to treat silty or cohesive materials to render them suitable for use as backfill. An example of the use of cement and PFA to treat clay arisings from the West Midlands to create a cementitious backfill is given by Ghataora et al. (2006). The material was monitored over a period of one year and settled less than control trenches with granular backfill. The settlements of both sets of trenches were within the permissible limits of the Specification for the Reinstatement of Highways and did not require any subsequent intervention measures.

WRAP has produced a guide to the use of recycled and stabilised materials in trench reinstatement (WRAP, 20070, which is available at [http://www.wrap.org.uk/construction/construction_waste_minimisation_and_management/utilities.html](http://www.wrap.org.uk/construction/construction_waste_minimisation_and_management/utilities.html). This contains exemplar information and case study evidence and is aimed at local authorities, utility companies and their supply chains.

The key to effective recycling of streetworks arisings is segregation of materials; if this can be done on site, it will be much easier to achieve high value reuse of the materials in subsequent backfill applications. As far as possible, asphalt, concrete, unbound aggregates and subsoil should be kept separate; it is very difficult to separate them once they are mixed (Figure 4.2).
Box 4.9 Severn Trent Network’s Closed Loop Recycling Experience in the West Midlands

The Networks repair and maintenance section within Severn Trent Water excavate on average 300 separate holes a day across a wide geographical area. The geographical area that Networks operate in is covered by 9 county based field service depots. The spoil from these excavations used to go to landfill, with primary aggregates used to backfill the excavations. In 1997 Severn Trent reviewed their operations and decided they had to move to a more environmentally friendly and cost efficient way of dealing with their spoil and began developing with its contractors a ‘closed loop’ system of recycling as much as possible of the excavated material.

The Specification for the Reinstatement of Openings in Highways Second Edition 2002 (the HAUC Specification) was used. This allows recycled, secondary or primary materials, or any combination thereof, provided they meet the performance requirements and any compositional requirements detailed in the Specification for the relevant material layer (Clause S1.6.2). The specification was developed with the active support and encouragement from the West Midlands Highway Authority Utilities Committee with support from Staffordshire Laboratories. There were no significant technical barriers to substituting Recycled S5.1.2 Class A – Graded Granular materials for primary Clause 803 Granular Sub base material Type 1. A rigorous monitoring regime by the West Midlands Highway Authority Utilities Committee, and contracted monitoring teams from Staffordshire Labs and Halcrow has ensured that the correct material specification is maintained in practice which ensures that Severn Trent Networks can be confident that the Recycled S5.1.2 Class A – Graded Granular materials will perform properly during and after maintenance or new build operations have taken place.

The ‘closed loop’ system has been operating since 1997 and has led to significant savings in materials and costs, by the avoidance of landfill charges and haulage, as well as environmental benefits. More details are available at http://www.aggregain.org.uk/case_studies/severn_trent.html.
5 Recycled highway materials

5.1 Reuse and recycling

In sustainability terms, reuse of the arisings from highway maintenance works either back into the same works or in other applications in the highway should always be the first option. The previous chapter has indicated the materials generally permitted in the various layers of the pavement and the techniques available for recycling them. This chapter summarises the opportunities for different materials obtained from these maintenance activities. Table 5.1 is a summary table, for using the materials found in the pavement, and indicates the requirements either for recycling and using in the same application or the processing requirements for use in a new application.

<table>
<thead>
<tr>
<th>Material</th>
<th>Recycle in-situ/ex-situ in same application</th>
<th>Excavate, process and use for new application</th>
<th>Method of reprocessing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bituminous bound materials: surface course</td>
<td>Yes</td>
<td>Keep separate from other bituminous layers to enable use as reclaimed asphalt in new hot mix for surface course; otherwise use as for base and binder course materials</td>
<td>Screening</td>
</tr>
<tr>
<td>Bituminous bound materials: base and binder course</td>
<td>Yes</td>
<td>Reclaimed asphalt in new hot mix, coarse aggregate in HBM, unbound sub-base Type 1 or 2, capping Class 6F3, hardstanding for site offices, unsurfaced roads</td>
<td>Crushing and screening</td>
</tr>
<tr>
<td>Tar bound materials</td>
<td>Cold recycling only</td>
<td>If to be disposed of, has to be to hazardous waste landfill</td>
<td>In-situ or ex-situ cold recycling; records must be kept</td>
</tr>
<tr>
<td>Unreinforced and reinforced concrete, concrete blocks and pipes</td>
<td>Re-use as aggregate in concrete.</td>
<td>Re-use as aggregate for pipe bedding, embankment and fill, capping, unbound sub-base, hydraulically bound mixtures and bituminous layers.</td>
<td>Crushing, screening, removal of contaminants and reinforcement</td>
</tr>
<tr>
<td>Hydraulic bound materials</td>
<td>Re-use as aggregate in hydraulic bound mixtures.</td>
<td>Re-use as aggregate for pipe bedding, embankment and fill, capping, unbound sub-base, hydraulically bound mixtures or bituminous layers.</td>
<td>Crushing and screening</td>
</tr>
<tr>
<td>Material</td>
<td>Recycle <em>in-situ</em> / <em>ex-situ</em> in same application</td>
<td>Excavate, process and use for new application</td>
<td>Method of reprocessing</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Wet mix / dry bound macadam</td>
<td>Not now used</td>
<td>Re-use as aggregate for pipe bedding, embankment and fill, capping, unbound sub-base, hydraulically bound mixtures, concrete or bituminous layers.</td>
<td>Screening</td>
</tr>
<tr>
<td>Unbound sub-base materials</td>
<td>Yes</td>
<td>Unbound capping, other Class 6 structural fills, can incorporate with overlying asphalt layers for cold <em>in-situ</em> recycling</td>
<td>Screening</td>
</tr>
<tr>
<td>Capping</td>
<td>Use as fill</td>
<td></td>
<td>Screening</td>
</tr>
<tr>
<td>Subgrade</td>
<td>Yes</td>
<td>May be stabilised with cement and/or lime as capping or sub-base.</td>
<td>Mixing and compaction</td>
</tr>
<tr>
<td>Drainage bedding etc materials</td>
<td>May be re-used if material still meets requirements of the specification</td>
<td>Use for other general or special fill applications if material meets the requirements of the specification</td>
<td>Washing/screening</td>
</tr>
<tr>
<td>General fills</td>
<td></td>
<td></td>
<td>Recompacted</td>
</tr>
<tr>
<td>Landscaping materials</td>
<td></td>
<td>Not generally suitable for other applications</td>
<td>Screening</td>
</tr>
<tr>
<td>Natural stone</td>
<td>May be re-used</td>
<td>Aggregate – various uses</td>
<td>Crushing and screening</td>
</tr>
<tr>
<td>Kerbs</td>
<td>May be re-used if undamaged</td>
<td>Reuse as Recycled Concrete Aggregates (RCA) in a variety of applications, including unbound sub-base</td>
<td>Crushing and screening</td>
</tr>
<tr>
<td>Line marking material</td>
<td>Re-used when water jetted to remove existing material</td>
<td>Removal by flailing or planing with the surfacing results in the line marking material being used with the recycled surfacing.</td>
<td>Drying out and new ingredients added</td>
</tr>
</tbody>
</table>

5.2 Waste Management Regulations and disposal of materials

All material that is excavated during highway works has the potential to be waste, even if it is reused on site or sent for recycling or recovery, and may be classed as a waste and be subject to the Waste Management Regulations. Waste is defined in the European Union Framework Directive on Waste (91/156/EEC) as follows: “Waste means any substance or object ….. which the holder discards or intends or is required to discard”. The term ‘discard’ is interpreted widely and does not just include materials that would ordinarily be thought of as being ‘thrown away’. Waste is thus defined not by its nature or properties but by the intention of the holder. “Holder” is defined as the producer of the waste or the person who is in possession of it; and the “producer” is anyone whose activities produce waste or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste.
The owner, producer and handler of the waste have a Duty of Care under the Environmental Protection Act 1990, reinforced by the Clean Neighbourhoods and Environment Act 2005 to ensure that the waste is handled safely and does not present a threat to human health or the environment. This includes ensuring that the waste has a transfer note identifying what it is under the European Waste Catalogue, ensuring that it is handled by registered waste carriers and that it is delivered to a site that is properly licensed to treat and receive it. Although the actual work will generally be carried out by subcontractors, the Local Authority still has a Duty of Care to ensure that the waste is handled and disposed of responsibly. Guidance is available at [www.netregs.gov.uk](http://www.netregs.gov.uk) and in the Waste Management Regulations module of the AggRegain web site ([www.aggregain.org.uk](http://www.aggregain.org.uk)).

In England and Wales the Environment Agency adopts a regulatory risk based approach, such that activities that pose a high risk are heavily regulated and those that pose a low risk are less heavily regulated. Engineers should liaise with their local Environment Agency area office to seek advice on the need for waste controls, and to ensure the need for licenses, exemptions etc are recognised at the early stages of any project or maintenance programme.

It is also important to note the difference between recycled materials and materials which have been recovered and cease to be waste. The use of recycled or secondary aggregates may still be subject to waste controls unless they have been fully recovered, for example in accordance with the WRAP Quality Protocol for the production of aggregates from inert waste. It is important to check that aggregate producers who supply aggregates based on the Quality Protocol are applying it properly, and not using it as a cover for waste disposal rather than aggregate manufacture. This falls under the Duty of Care requirements described above.

If the pavement materials cannot be re-used on site or on another site using the methods indicated in Table 5.1 then a means of disposal has to be found. This will incur a cost. The usual methods of disposal are to send the material to a landfill site or to a site exempt from the Waste Management Licensing Regulations where the material can be used for land reclamation. It is becoming increasingly expensive to send material to landfill, particularly if it is non-inert, and the regulations associated with exempt sites have become increasingly strict in recent years, with the introduction of revisions to Clauses 9 & 19 exempt sites, the most commonly used ones, in July 2005. Summaries of the implications of these changes can be found on the Waste Management Regulations module of the AggRegain web site at [http://www.aggregain.org.uk](http://www.aggregain.org.uk).

Waste is categorised into three classes: inert; non hazardous and hazardous. Much of the arisings from highway maintenance and construction work will generally be classed as inert waste, e.g. asphalt planings, concrete kerbs and pavements, subbase and capping and subsoil. However, if the material contains biodegradable materials such as organic matter, timber, paper or material such as plastics or metals, it will be classed as non hazardous or ‘active’ waste. This attracts a much higher landfill tax (£32/tonne from April 2008, rising at £8/year, compared to £2.50/tonne for inert waste) and is much more expensive to dispose of to landfill.

Hazardous waste is not likely to be encountered in most routine highway maintenance works, which generally only affect the near-surface layers. An exception is the occurrence of tar in old asphalt pavements. Tar is a generic term for a group of organic compounds produced as a by-product of the distillation of coal to produce gas in the days before the discovery of natural gas in the North Sea. It includes
compounds such as polycyclic aromatic hydrocarbons (PAHs) which are now known to be carcinogenic, and hence it is classed as hazardous waste. Tar was widely used in roads in place of bitumen up to the early 1970s, and may still be encountered in old pavements when they are excavated as part of maintenance works. It is recognised by its pungent smell. Site testing equipment using an aerosol spray (PAC Marker) can be used to identify the extent of material contaminated by tar; if more detailed quantification is required, samples should be sent for chemical analysis.

As a hazardous waste, tar can only be sent to landfills licensed to accept such materials. With the implementation of the Landfill (England and Wales) Regulations 2002 and similar 2003 Regulations in Scotland and Northern Ireland, the number of hazardous waste landfills has decreased dramatically and it is now very expensive to send material to a hazardous waste landfill. Also, many areas of the UK, such as Scotland and the South East of England, now have no hazardous waste landfills and there are significant transport costs in sending material to landfills in other regions. It is not permitted to recycle asphalt containing tar in a hot recycling process, because this will volatilise the carcinogenic compounds and put plant workers and the public at risk.

However, it may be permissible to use cold recycling techniques to encapsulate the tar compounds in a new road construction, using in-situ or ex-situ techniques. The contaminated material is then safely stored in an engineered form where it is not accessible to the environment. Where this is done, it is essential that records should be kept identifying the areas containing tar. This can be done as part of a Pavement Management System (PMS), so that the information is available in the future when further maintenance may be required. Recycling the material containing tar on site will lead to very significant savings by avoiding charges for disposing of the material to a landfill site licensed to receive hazardous waste. The County Surveyors Society (CSS) is producing guidance for Local Authorities on how to dispose of tar-bearing materials.

Box 5.1 Ex-situ Stabilisation of Asphalt Containing Tar using Foamed Bitumen

A major ex-situ cold recycling contract was carried out for the Highways Agency on the A38: Peartree to Drybridge in Devon between September 2005 and March 2006 (http://www.aggregain.org.uk/case_studies/a38_exsitu.html). Some 70,000 tonnes of the existing asphalt pavement were recycled using foamed bitumen as the binder. Towards the end of the contract, tar was discovered in some sections of the existing road pavement. The recycling subcontractor, Roadstone Recycling, proposed to the Environment Agency that the best way to deal with this material was to treat it by the cold recycling process and replace it in the road. This was accepted by the Environment Agency and the material was treated and placed back in the road in the same way as for the rest of the work, with a new surface course on top of the cold recycled layers.

In new construction projects and maintenance operations it is possible that other materials classed as hazardous wastes may be encountered, in particular contaminated soils in urban areas. Appropriate ground investigation works should always be carried out in advance of new construction or major maintenance projects to identify any potential contaminated materials so that an appropriate strategy for dealing with them can be developed in advance of the works. If contaminated
materials (including tar) are discovered, discussion should be held with the regulatory authorities (Environment Agency in England and Wales, Scottish Environment Protection Agency in Scotland, Waste Management and Contaminated Land Inspectorate of the Environment and Heritage Service, an Agency of the Northern Ireland Department of the Environment) at an early stage to agree a strategy for dealing with them.

The methods of disposal for different arisings are summarised in Table 5.2.

### Table 5.2 Methods of Disposal of Materials Derived from the Pavement

<table>
<thead>
<tr>
<th>Material</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tar bound materials</td>
<td>Tar is a hazardous waste and must go to a hazardous waste landfill</td>
</tr>
<tr>
<td>Bituminous bound materials</td>
<td></td>
</tr>
<tr>
<td>Unreinforced and reinforced concrete, concrete blocks and pipes</td>
<td></td>
</tr>
<tr>
<td>Hydraulic bound materials</td>
<td></td>
</tr>
<tr>
<td>Wet mix / dry bound macadam</td>
<td></td>
</tr>
<tr>
<td>Unbound sub-base materials</td>
<td></td>
</tr>
<tr>
<td>Capping materials</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td></td>
</tr>
<tr>
<td>Vitrified clay pipes, clay pavers</td>
<td></td>
</tr>
<tr>
<td>Natural stone</td>
<td></td>
</tr>
<tr>
<td>Drainage bedding etc materials</td>
<td></td>
</tr>
<tr>
<td>Fill to structures</td>
<td></td>
</tr>
<tr>
<td>General fills</td>
<td></td>
</tr>
<tr>
<td>Glass reinforced plastic pipes</td>
<td></td>
</tr>
<tr>
<td>Iron pipes and furniture</td>
<td></td>
</tr>
<tr>
<td>PVC-U, PP, PE pipes</td>
<td>Generally classed as a non-hazardous waste and should be sent to a landfill registered to accept such material.</td>
</tr>
<tr>
<td>Corrugated steel pipes</td>
<td></td>
</tr>
<tr>
<td>Rubber</td>
<td></td>
</tr>
<tr>
<td>Plastic</td>
<td></td>
</tr>
<tr>
<td>Landscaping materials</td>
<td>May be classed as non-hazardous if contains organic matter</td>
</tr>
<tr>
<td>Topsoil</td>
<td>Will generally be classed as non-hazardous (active) waste. May need to check for contamination if from brownfield site</td>
</tr>
<tr>
<td>Line marking material</td>
<td>Yellow markings contain lead chromate whilst white markings contain titanium. Will be classed as non-hazardous (active) waste</td>
</tr>
</tbody>
</table>
6. Recycled and Secondary Materials

6.1 General comments

In addition to materials recovered from the road itself in the course of maintenance activities, it is possible to use a wide range of recycled or secondary aggregates in place of primary aggregates for many applications in maintenance and new construction. The possibilities for using these materials are summarised in Table 6.1 and the individual materials are described in more detail below. It is also possible to use in-situ stabilisation of soils with lime or cement as an alternative to importing capping materials; guidance is given in HA74/07 in the DMRB.

HD35/04 of the DMRB indicates the wide range of secondary and recycled materials that may be utilised in construction for trunk roads and motorways. These are also appropriate for many Local Authority roads. The applications considered for these materials are pipe bedding, embankment and fill, capping, unbound mixtures for sub-base, hydraulically bound mixtures for sub-base and base, bitumen bound layers and pavement quality concrete. HD35 also indicates factors that need considering when utilising secondary and recycled materials for these applications. These include:

- The water soluble sulphate level of materials used for drainage.
- Hazardous chemicals resulting in leachate or poor physical properties for earthwork materials.
- When using recycled rubber (shredded tyre or tyre bales) as fill, the potential for combustion.
- Unweathered steel slag may expand when hydration occurs due to the presence of free lime and/or free magnesia.
- Determination of the moisture content of asphalt planings can be difficult and needs specific consideration.
- The possibility of expansive chemical reactions need considering when using gypsum as a binder in hydraulic bound materials.

As a general rule no recycled/secondary materials are allowed in an exposed aggregate concrete surface (see Series 1001 (Clause 6) and 1044 of SHW). However, some materials, such as blast furnace slag, pulverised-fuel ash and recycled concrete aggregate (“crushed concrete”) have been widely used in pavement quality concrete (PQC) for many years and are specifically permitted in the Specification for Highway Works and other specifications. Others are restricted to specific areas, such as slate aggregate in North Wales or China Clay sand in Cornwall. The origin and availability of materials is summarised in Table 6.1.

Quality control is important for all aggregates, and a system of factory production control is required under recent harmonised European Standards for aggregates. This is particularly important for recycled and secondary aggregates, where the client may need particular reassurance that the materials will be consistent and fit for purpose. The WRAP Quality Protocol for the production of aggregates from inert waste provides this reassurance, and clients should ensure that their suppliers are producing recycled aggregates in accordance with the protocol. Waste protocols for a number of secondary materials are currently being produced by the Environment Agency and WRAP, and will provide similar reassurance for these materials. Details are available at [http://www.environment-agency.gov.uk/subjects/waste/1019330/1334884/?lang=_e](http://www.environment-agency.gov.uk/subjects/waste/1019330/1334884/?lang=_e).
Materials for which protocols are available or in progress are indicated in Table 6.1.

In some cases there may be concern about environmental issues with the use of particular materials, especially in unbound applications. These are summarised in Table 6.1 and discussed in the sections on the individual materials below.
<table>
<thead>
<tr>
<th>Material</th>
<th>Origin and availability</th>
<th>Processing requirements</th>
<th>Applications: SHW Series</th>
<th>Waste Management Regulations</th>
<th>Environmental Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast furnace slag</td>
<td>Produced from the manufacture of pig iron in a blast furnace. Current production is 3 mt/a but likely to decline.</td>
<td>Crushing and screening.</td>
<td>Waste protocol being developed by WRAP/EA.</td>
<td>Waste protocol being developed by WRAP/EA.</td>
<td>Some contaminants. A risk of leaking or contamination, some applications there is a risk of leaking or contamination, risk of pollution from leaching of some contaminants.</td>
</tr>
<tr>
<td>Burnt colliery spoil</td>
<td>Residue from coal. Current production of 7.5 mt/a but likely to decline.</td>
<td>Crushing and screening.</td>
<td>Waste protocol being developed by WRAP/EA.</td>
<td>Waste protocol being developed by WRAP/EA.</td>
<td>Susceptible to frost and may contain high concentrations of sulfates limiting its use in bound and unbound applications.</td>
</tr>
<tr>
<td>China clay sand/stent</td>
<td>Residue from the extraction of china clay in Cornwall. 22.6 mt/a arisings and 600 mt stockpiled.</td>
<td>Sand-grinding and screening.</td>
<td>Waste protocol being developed by WRAP/EA.</td>
<td>Waste protocol being developed by WRAP/EA.</td>
<td>Susceptible to frost and may contain high concentrations of sulfates limiting its use in bound and unbound applications.</td>
</tr>
<tr>
<td>Coal fly ash / Pulverised fuel ash (CFA / PFA)</td>
<td>Residue from coal. Current production of 7.5 mt/a but likely to decline.</td>
<td>Sand-grinding and screening.</td>
<td>Waste protocol being developed by WRAP/EA.</td>
<td>Waste protocol being developed by WRAP/EA.</td>
<td>Susceptible to frost and may contain high concentrations of sulfates limiting its use in bound and unbound applications.</td>
</tr>
</tbody>
</table>

Table 6.1 Summary Table for Recycled and Secondary Materials in HD35
<table>
<thead>
<tr>
<th>Waste Type</th>
<th>Description</th>
<th>TRL</th>
<th>PPR233</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundry sand</td>
<td>Residue of the metal casting industry. Current production is 1mt/a.</td>
<td>500, 600, 800, 900, 1000</td>
<td>May be contaminated with organic compounds such as phenols, therefore potential for leaching in unbound applications.</td>
</tr>
<tr>
<td>Furnace bottom ash (FBA)</td>
<td>Residue from coal burning power stations. Currently 1mt/a arisings.</td>
<td>500, 600, 800</td>
<td></td>
</tr>
<tr>
<td>Incinerator bottom ash aggregate (IBAA)</td>
<td>Residue from the combustion of municipal solid waste in incinerators. Currently production is 1.35mt/a and expected to increase.</td>
<td>500, 600, 800, 900, 1000</td>
<td>Unweathered IBA may be hazardous waste; weathered IBA likely to be active waste, not inert. A waste protocol is being produced by WRAP/EA. Concerns of leaching in unbound applications. Need to consider possibility of ASR in cement bound applications.</td>
</tr>
<tr>
<td>Phosphoric slag</td>
<td>Residue of the phosphorus making process. Imported into South East England.</td>
<td>500, 600, 800, 900, 1000</td>
<td></td>
</tr>
</tbody>
</table>
Recycled aggregate

Processed from construction demolition and excavation waste

Approx. 40mt/a in England and 4mt/a in Scotland

Crushing, screening, removal of contaminants such as paper, wood, metal, clay, plasterboard, etc.

Classed as inert waste if not produced to the WRAP quality protocol for the production of aggregates from inert waste. Exemption or WML required if not produced in accordance with the protocol.

If material contains a high percentage of crushed concrete the leachate may have high pH and this may limit its use below the water table in environmentally sensitive locations. Crushed brick may be susceptible to frost heave and gypsum plaster may result in high sulphate content. Cold foam mix may not perform well in cold or wet laying conditions.

Recycled asphalt

Asphalt planed from highways and pavements currently at least 90% is re-used.

Crushing, screening, removal of contaminants such as paper, wood, metal, clay, plasterboard, etc.

Classed as inert waste if not produced to the WRAP quality protocol for the production of aggregates from inert waste. Exemption or WML required if not produced in accordance with the protocol.

If material contains a high percentage of crushed concrete the leachate may have high pH and this may limit its use below the water table in environmentally sensitive locations. Crushed brick may be susceptible to frost heave and gypsum plaster may result in high sulfate content.
<table>
<thead>
<tr>
<th>Material Type</th>
<th>Source Description</th>
<th>Processing Description</th>
<th>Size Limits (mm)</th>
<th>Waste Protocol/Attributes</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled concrete</td>
<td>From a number of sources including the demolition of roads and runways, concrete structures, precast concrete process wastes.</td>
<td>Crushing, screening, removal of contaminants.</td>
<td>500, 600, 800, 900, 1000</td>
<td>Covered by WRAP Quality Protocol for inert waste.</td>
<td>When re-used in concrete high chloride content can corrode the steel reinforcement, whilst high sulphate content can disrupt the cement paste. In unbound applications the leachate may have high pH and this may limit its use below the water table in environmentally sensitive locations.</td>
</tr>
<tr>
<td>Recycled glass</td>
<td>Obtained from crushing glass products as fine or coarse aggregate.</td>
<td>Crushing, and screening</td>
<td>500, 600, 800, 900</td>
<td>Waste protocol being developed by WRAP/EA for flat glass. Ordinary glass is covered by the Quality Protocol for the production of aggregates from inert waste.</td>
<td>For cement bound applications need to consider the risk of ASR.</td>
</tr>
<tr>
<td>Slate aggregate</td>
<td>Residue from the production of slate for roof tiles, principally in North Wales. Stockpile of approx. 466mt and 6.3mt/a arisings.</td>
<td>Crushed and screened to fit grading requirements.</td>
<td>500, 600, 800, 900, 1000</td>
<td>Inert material, exemption or WML not required for use.</td>
<td>None</td>
</tr>
<tr>
<td>Material</td>
<td>Characteristics</td>
<td>Use(s)</td>
<td>Notes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------------------------------------</td>
<td>--------</td>
<td>-------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spent oil shale</td>
<td>The residue from the oil extraction industry occurs mainly in the Lothian region of Scotland. Approximately 100mt stockpiled, no current arisings. High sulphate content may cause attack to construction materials but unlikely to be an environmental risk. May be frost susceptible.</td>
<td>Unburnt colliery spoil</td>
<td>All materials detailed in the table above are exempt from the Aggregate Levy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel slag</td>
<td>Residue of steel production. Current arisings only in South Wales, Lincolnshire, Humberside, and the NE of England approx 4mt/a. Must be fully weathered before use or will undergo expansive reactions. Aggregate has high skid resistance. A waste protocol is being developed by WRAP.</td>
<td>Residue of steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unburnt colliery spoil</td>
<td>Residue from coal. Used as general fill or aggregate in HBM but not as selected fill or unbound aggregate in FBM or used as general fill or unbound sub-base.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All materials in the table above are exempt from the Aggregate Levy.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.2 Materials in HD 35
The following secondary and recycled materials are considered in HD35.

6.2.1 Blast furnace slag
Blast furnace slag (BFS) is a residue obtained from the manufacture of pig iron in a blast furnace. The slag occurs as a molten liquid and is mainly composed of silicates and oxides that solidify upon cooling. If the slag is left to cool slowly in the open air, a crystallized slag, suitable for crushing, is produced. This is known as air cooled blast furnace slag. If the slag is cooled quickly by water or water and air, vitrified slags are produced called granulated slag and pelletized slag (O’Flaherty, 1988). This can be ground to produce ground granulated blast furnace slag (GGBS). Dunster (2001) provides information on some frequently asked questions, together with sources of further help on codes and standards relevant to the production, testing and use of slag products. The current production of BFS is about 3 million tonnes per annum (mt/a) with increased amounts of GGBS representing about 75% of the BFS production. However, the production of BFS is declining due to trends in steel production in the UK (AggRegain, 2004a).

BFS is permitted for use in all applications. When used in unbound applications below the ground water level, the risks of pollution and corrosion of metals from potential leaching of lime and sulfur compounds from the slag need consideration. However, BFS is too valuable an aggregate to be used in unbound applications and is more likely to be used as aggregate in asphalt or concrete. When used as aggregate in asphalt, BFS has many advantages associated with its relatively porous nature and rough surface texture that improves the bond with the bitumen binder. BFS is fully utilised in the UK as aggregate, principally in asphalt with well established experience and specifications (Hassan et al., 2004a). The highest value application of slag is probably in the concrete industry as a cement replacement in concrete (GGBS) and as a binder in slag bound mixtures, with many successful applications in the UK and abroad (Nunn and Hassan, 2004). Following a European Court ruling in 2007, BFS is now considered to be a by product rather than a waste, hence a waste management licence or exemption is not required for its use in construction projects.

6.2.2 Burnt colliery spoil
Colliery spoil deposits are residues from coal mining, and are composed of quartz, mica and clay minerals as well as small quantities of pyrites and carbonates of calcium, magnesium and iron. The spoil tips are highly variable in composition as combustion changes the physical and chemical properties of the materials. The current production of colliery spoil is about 7.5mt/a, however, this is likely to decline with the reduced use of coals and cheap imports (AggRegain, 2004a).

Burnt spoils are usually susceptible to frost when used in the top 450mm layers from the pavement surface, consequently, it is not deemed suitable in the bound layers. The material is relatively weak compared to primary aggregate and could contain high concentrations of sulfates, limiting its use in unbound applications because of the risk of corrosion of concrete or structural metallic items. If used as general fill, there may also be a risk of pollution of watercourses from iron hydroxides (ochre), heavy metals, acidity and sulfates. Colliery spoil has been successfully used as a bulk fill material. In the 1970s, about 8mt/a was used in motorway construction in the
UK. Well-burnt spoil is permitted for use as fill material provided it meets the requirements of the specification (Nicholls et al., 2004).

### 6.2.3 China clay sand/stent

China clay sand/stent are residues from the extraction of china clay and are available in large quantities, approximately 22.6mt/a arisings and 600mt stockpiled in Cornwall. China clay sand is mainly composed of quartz and fine particles of mica and only needs to undergo the same basic grading and washing processes as other primary aggregate, before using. Technically, china clay sand is an inert material and suitable to replace primary aggregate in all bound and unbound applications.

Stent is a coarser material, ranging up to boulders, of undecomposed granite. Stent could be used but has less consistency than the sand. Crushed stent has been used as coarse aggregate in a concrete slab for a household waste recycling centre at Okehampton, in Devon (available at [http://www.aggregain.org.uk/case_studies/recycled_and_1.html](http://www.aggregain.org.uk/case_studies/recycled_and_1.html)). Unprocessed stent can be used as general fill.

China clay sand has been used with considerable success as bulk fill for earth works, however, compaction difficulties may arise, due to the presence of mica, but this will not necessarily have an adverse effect on the final compaction (Nicholls et al., 2004). In bound applications, china clay sand is permitted for use in bitumen bound material, hydraulically bound material and concrete provided that it meets the necessary grading requirements. Adjustment of the mixture design may be considered to accommodate a variable grading and particle shape in the material.

The main problem with the wider utilisation of the material is transport, as it is produced and used in localised areas. Some china clay sand is currently exported from Cornwall by ship to London and Southampton; however, the port facilities in Cornwall are limited. Improving the efficiency of transporting the material to market would significantly increase its use in the construction industry.

### 6.2.4 Coal fly ash (Pulverised-fuel ash) and furnace bottom ash

Coal-burning power stations produce two residues; fly ash and furnace bottom ash. The fly ash, also known as pulverised-fuel ash (PFA), has fine particles and is collected by precipitation from the flue gases in the furnaces, whereas the furnace bottom ash is of coarser particles and is obtained from the bottom of the furnaces. The current production of fly ash and furnace bottom ash is 5mt/a and 1mt/a, respectively. There are also large stockpiles of fly ash exceeding 50mt. The production of both materials is likely to decline in the long term with the increased use of other fuels, such as natural gas and nuclear, in generating electricity. The current use of imported coal could also affect the physical and chemical properties of the ash, and consequently its utilisation levels.

Fly ash can be used for all applications, with the exception of unbound sub-base. When used in upper unbound layers, the grain and particle size of fly ash make it difficult to compact as it behaves in a similar manner to silt, requiring protection during wet conditions (Nicholls et al., 2004). Guidance on the use of fly ash as general fill is given by Winter and Clark (2001). The hardening properties of the material give more added value when used as a binder in hydraulically bound mixtures and concrete.
Furnace bottom ash has a porous nature, is lightweight and has some mechanical weakness that might limit its use in unbound and bound applications. Specifications exclude furnace bottom ash from use in unbound mixtures, bitumen bound and pavement quality concrete but permit the use in hydraulically bound mixtures. However, the material is fully utilised in the block making industry.

6.2.5 Foundry sand

Foundry sand is produced in a relatively small quantity of 1mt/a as a residue of the metal casting industry. It is uniformly graded silty sand. The material could be used in all bound and unbound applications, but its grading would preclude its use in a number of applications where well graded materials are required. It should be noted that foundry sand may contain small amounts of phenols, many of which are toxic. See the glossary for further information.

Box 6.1 Applications of Foundry Sand in Highways

An example of foundry sand being used in cement bound paving at a road/rail transfer station was reported on the AggRegain website (AggRegain, 2004b), where the aggregate consisted of three parts of foundry sand with one part of incinerator bottom ash. The cement content was 160kg/m³, and the mixture had a strength of 20N/mm² at 28 days.

Foundry sand has also been used extensively in the USA for various pavement applications including pre-cast and foamed concrete (OCAPP, 1999).

Foundry sand has been used by Tarmac Quarry Products Ltd in Poole to partially replace the fine aggregate in asphalt (AggRegain, 2004c). Laboratory evaluation confirmed the density, grading and compactability for use to replace a portion of the fine aggregate in the asphalt manufacture. The quality of the products made by Tarmac has been unaffected by using foundry sand with no problems reported after eight years in service.

6.2.6 Incinerator bottom ash aggregate

Incinerator bottom ash aggregate (IBAA) is the residue of the combustion of municipal solid waste in incinerator plant (energy from waste) facilities. Several individual ash streams are produced including grate ash, siftings, boiler ash, scrubber ash and precipitator ash. The incineration residues mainly contain clinker, glass, ceramics, metal, and unburnt organic matter. In the UK, current processing of the material involves only mechanical treatment without chemical processing or washing. This treatment includes extracting metal, screening, removal of unburnt organic matters and natural drying (York, 2000). Storage of IBAA for up to 3 months under controlled conditions is recommended to allow swelling, hydration, carbonation and oxidation ageing to occur, to improve chemical integrity and structural durability of the ash. Current production of processed IBAA accounts for about 1.35mt/a and is expected to rise in future years.

IBAA is permitted for use in all bound and unbound applications within highway construction, but is not covered by specific provision in the SHW. A laboratory investigation into the mechanical properties of IBAA such as stiffness and stability,
obtained by repeated load triaxial testing, suggested potential for use in unbound applications, although there was a significant variation in the mechanical properties in terms of seasonal fluctuations and differences between incinerator plants. However, this variation was not greater than that obtained in a study of natural aggregates (Arm, 2000). There are some concerns over leaching and therefore the material has more potential for use in bound applications.

### Box 6.2 Use of IBAA in Highways

Several studies have focused on using IBAA as a partial replacement for natural aggregate in asphalt (Hassan et al., 2004a), (Reid et al., 2006). Results on asphalt concrete base showed that IBAA can be a suitable replacement for primary aggregate with no loss of performance. The relatively higher porosity of IBAA was reported to require additional bitumen content to achieve identical performance to control mixtures made with primary aggregate. Other literature indicated that the amount of binder required has been shown to be similar to that required by natural aggregate.

IBAA has been successfully used in cement bound mixtures on a 4km bypass to Waltham Abbey (Hassan et al., 2004a). However, in concrete with its higher cement content, the presence of some deleterious materials could interfere with the functions of concrete, such as glass leading to alkali-aggregate expansion. This would need to be considered in the mixture design.

### 6.2.7 Phosphoric slag

Phosphoric slag is a residue from the phosphorus making process in an electric furnace. It is mainly imported from Flushing, in the Netherlands, by J Clubb Ltd and is marketed as Flushing SBM (FSBM). On a dry weight basis this material contains 80 – 90% air-cooled phosphorous slag (APS), 3 – 15% granulated blast furnace slag (GBS) and 2 – 10% air-cooled steel slag (ASS). FSBM closely resembles Type 1 granular sub-base material and has a similar grading. It may therefore be an economic proposition in the South East of England. The chemical composition of the air-cooled phosphoric slag is predominantly mono-calcium silicate. The material has proved to give good performance in both unbound and bound applications and is essentially laid as an unbound material by paver or blade and then compacted with a vibrating roller and finished with a pneumatic tyred roller.
Box 6.3 Use of Phosphoric Slag in Highways in Kent

Kent CC has design recommendations for FSBM as road base for traffic volumes up to 20msa (Kent CC, 1996). A large trial length involving unbound phosphoric slag in sub-base and road base was incorporated in a major bypass at Pembury in Kent, constructed in 1987 which performed well with no reflective cracking and good structural performance (Walsh, 1999). There are no restrictions on the use of phosphoric slag in asphalt. It could be used successfully in the base layer but, if using it in the surface course, the material would need to satisfy the end performance requirements for hardness.

Phosphoric slag was used successfully in a hydraulically bound sub-base on the A289 Wainscott bypass (Nunn and Hassan, 2004).

6.2.8 Recycled aggregate

The definition of recycled aggregate in the Specification for Highway Works, Clause 601.12 is, “the material shall be aggregate resulting from the processing of material used in a construction process”. There is a similar definition in BS 8500-1: 2002: “aggregate resulting from the reprocessing of inorganic material previously used in construction”. Construction, demolition and excavation waste that is processed and used as a substitute for primary aggregates falls into the category of recycled aggregate (RA). It is widely available in urban areas but to a lesser extent in rural areas. RA covers a wide range of materials including concrete, masonry and asphalt road materials that arise from the demolition of buildings, airfield runways and roads. RAs potentially contain a number of impurities that need to be removed prior to use in high value applications (Reid, 2004). For most highway applications, a maximum of 1% by weight is specified for the sum of all impurities (e.g. wood, paper, metal, plastic, glass, plasterboard, clay) in the Specification for Highway Works. A Quality Protocol for the production of aggregate from inert waste such as construction, demolition and excavation waste has been developed by WRAP (2004b), and a test for classifying the composition is given in Clause 710 of the Specification for Highway Works. The allowable percentages of impurities for pavement quality concrete are given in BS 8500-2.

Crushed brick can be used as an excellent granular capping material but may be susceptible to frost heave. If used in the sub-base, RA should consist predominantly of crushed concrete. Recycled asphalt can also be used as up to 50% of RA (Table 3.3). However, the properties of crushed brick depend on the type of brick and mortar used. Lime or cement mortar will not be a problem but contamination from a gypsum plaster might result in a high sulfate content. Brick from chimneys may have particularly high sulfate content; the National House Building Council Specification limits the brick content of recycled aggregate to 20% for this reason. RA is permitted by the SHW for use in all bound and unbound applications in highway construction except for pavement quality concrete. There is a limit of 1% by mass of foreign materials (paper, wood, metal, etc.) and for some classes there are limits on the asphalt content, but there are no restrictions on the brick content. The RA will, however, have to meet all the Specification requirements for the application.

The SHW (Series 1001, Clause 10) states that where recycled coarse aggregate is used in concrete pavement construction, only crushed concrete resulting from reclamation or processing of concrete previously used in construction which
6.2.9 Reclaimed asphalt

The material is commonly referred to as recycled asphalt; however, with the introduction of BS EN 13108-8 in 2005, the correct term is now reclaimed asphalt, defined as follows: “asphalt reclaimed by milling of asphalt road layers, by crushing of slabs ripped up from asphalt pavements or lumps from asphalt slabs and asphalt from reject and surplus production”.

The concept of using existing highways as a linear quarry from which aggregates can be reclaimed has been gaining support for both environmental and economic reasons. Most of the recycled asphalt pavement (RAP) is re-used because it is readily available on site, and is composed of traditional road construction materials. About 95% of RAP is natural or by-product aggregates and the remaining is bitumen binder. An OECD survey (OECD, 1997) shows that, among EU member countries, at least 75% of RAP is reused while in the UK the figure amounts to 90% (Nicholls et al., 2004).

RAP is permitted by the SHW for all highway construction applications. When used as unbound granular material, it has additional benefit from the binder (Hassan et al., 2004a). The majority of RAP is used for hot in-situ recycling, cold in-situ recycling, ex-situ recycling, sub-base aggregate, capping or fill.

Significant amounts of RAP are incorporated in asphalt, but usually at a lower layer than those from which it is taken. Up to 50% RAP is currently permitted by the SHW in hot asphalt mixtures that are for base and binder coarse applications. RAP mixtures can offer the same durability as mixtures with 100% virgin material (Peters et al., 1986). However, the mixture design with RAP is more critical than with routine asphalt mixtures (Nicholls et al., 2004). Up to 10% RAP may be used in the surface course layer, although higher proportions have been used (e.g. 20% in Rockingham Road, Corby; see Box 1.4).

There is a harmonised European Standard for RAP, BS EN 13108-8 (CEN, 2004), Bituminous mixtures, Material specifications, Reclaimed asphalt. It is assumed that the term “Reclaimed asphalt” will replace the acronym “RAP” in due course, but RAP will be used in this report because it is more widely understood and to avoid any confusion of acronyms with recycled aggregate.
Box 6.4 Examples of use of Recycled Asphalt in Highways

RAP was used in the Newport Southern distributor road in the capping layer, and as an unbound sub-base on the M25 Junction 12 – 15 improvement (AggRegain, 2005); in both cases no problems were identified.

In Norfolk, hot rolled asphalt base and binder course mixtures have been used with 30% RAP. It has also been used in cold mixtures with foamed bitumen and cement binders for base and binder courses using 100% RAP, but for these large percentages the mixture design is important. Using recycled material produced time savings when haunching rural roads, with roads only being required to be closed for one week compared to the normal three to four weeks.

However, cold foam-mix recycling does not perform well in cold conditions and the use of recycled materials is unsuitable where the edges of the road are unsupported (AggRegain, 2004d). This technique has been employed in Hampshire (Reid et al, 2006), but there is a need to employ an experienced contractor.

The use of RAP in concrete and hydraulically bound mixtures is limited in the UK, but has been successfully used in other countries. Austrian experience indicated excellent strength and durability of concrete pavements made with 10% RAP as aggregate (Sommer, 1998). At a higher level of 35%, RAP showed economic benefits in use for hard shoulder compared to imported natural gravel. BS 8500-2 permits 5% RAP for use in pavement quality concrete when classed as recycled concrete aggregate.

6.2.10 Recycled concrete aggregate

Recycled aggregate is defined in BS 8500-1: 2002 as “recycled aggregate principally comprising crushed concrete”. RCA is defined as different from RA in BS 8500: Part 2 on the basis of composition; to qualify as RCA, the material must not contain more than 5% brick or masonry, 5% asphalt, 0.5% lightweight material and 1% foreign material.

Recycled concrete aggregate (RCA) comes from a number of sources including the demolition of roads and runways (Lamb & Griffiths, 2006), concrete bridges and buildings and surplus or damaged concrete pipes and railway sleepers. The SHW permits the use of RCA as a substitute for natural aggregates for all unbound and bound applications. RCA is particularly useful as a coarse aggregate in low strength ancillary concrete, e.g. for kerb backing and similar applications. It can also be used as aggregate in concrete up to 50 N/mm² strength under BS 8500-2. However, if recycled concrete aggregate is to be used in the construction of concrete pavements, then the SHW (Series 1001, Clause 10) states that only crushed concrete resulting from the reclamation or processing of concrete previously used in construction which originates from identified structures with a known history should be used.
Box 6.5 Examples of the use of RCA in Highways

RCA has been used as 6F1 selected granular fill (fine grading) and 6F2 selected granular material (coarse grading) in the capping material to construct a temporary building at Heathrow Terminal 5. RCA has a technical advantage over alternative primary aggregate in that it holds together better and handles well in wet weather (AggRegain, 2004e). RCA can also be used as sub-base and has the advantage of being less susceptible to frost heave than RA. RCA was used as Type 1 sub-base in the M25 Junction 12 – 15 improvement (AggRegain, 2004). Care has to be taken when using unbound RCA in applications below the water table, e.g. as a starter layer for embankments, as the presence of unreacted lime may lead to leachate with a very high pH. This may be undesirable in environmentally sensitive areas.

RCA is not generally incorporated into asphalt but it has been used in foamed bitumen on the A9 at Granish near Aviemore (AggRegain, 2004f), which is considered to experience the most severe winter conditions on trunk roads in the United Kingdom. The existing lean concrete was pulverised prior to being bound by foamed bitumen and compacted as the base. Conventional dense bituminous macadam binder course and hot rolled asphalt surface course completed the pavement. Stiffness measurements have indicated good performance.

When RCA is used in concrete, the amount of chloride and sulfate in the mixture has to be considered. Chloride ions are associated with the corrosion of steel reinforcement whilst sulfate reactions lead to expansive disintegration of the cement paste. RCA could offer improved properties when compared to primary aggregate in the construction of concrete pavements. The surface texture and particle shape of RCA result in a higher ratio of flexural to compressive strength making it more suitable for use in concrete pavements than other smooth rounded aggregates. However, the porous nature of RCA increases the water demand to achieve similar workability to primary aggregate which adversely affects the shrinkage and thermal deformation of concrete (Hassan et al., 2004a). Mixture trials should be undertaken to determine the suitability of the RCA. Consideration also has to be given to the possibility of alkali silica reaction (ASR) when using RCA (Calder and McKenzie, 2005). The allowable percentages of impurities for pavement quality concrete are given in BS 8500-2.

Texas Department of Transport (2003) has experience with utilising 100% RCA, both coarse and fine material, in concrete pavement sections. Test results of field trials were very encouraging showing no adverse effects on pavement performance. The risk of alkali-silica reaction (ASR) was minimised with the use of fly ash as a cement replacement material. The only problems that contractors experienced were that the consistency of the material was not guaranteed and the material sometimes set too quickly.
6.2.11 Recycled glass

Crushing of waste glass produces particles that are generally angular in shape with some flat elongated particles. Proper crushing can virtually eliminate sharp edges and the corresponding safety hazards associated with manual handling of the product. Consistency of supply is one of the key issues regarding the technical applications for recycled glass. Glass can be crushed to large grain sizes (larger than 5mm) and small grain sizes (smaller than 5mm). Large grain sizes have a high ‘flakiness index’, which may limit their application, whereas the small grain sizes have the greater prospect as an aggregate replacement in asphalt and concrete pavements (WRAP, 2003). BSI PAS 102, available at http://www.wrap.org.uk/manufacturing/info_by_material/glass/glass.html provides a specification for processed glass for secondary end markets.

HD35 states that although recycled glass could comply as a bulk fill and selected granular fill for earthworks applications, it is unlikely to be used in such circumstances. In the USA, glass cullet has been used as a replacement for gravel in backfill operations. It was found to be different to handle compared to primary material but the performance was similar (AggRegain, 2004g). Recycled glass has also been used for pipe bedding in the USA as a replacement for primary aggregates. The compaction and handling of the glass was claimed to be comparable to that of the primary aggregates. The only comments concerned the guarantee of supply of the material (AggRegain, 2004h).

### Box 6.6 Use of Recycled Glass as Bedding Sand in London

Recycled glass has been used as bedding sand for slabs and pavers in Surrey and some London Boroughs, where natural sand has to be brought from considerable distance and is expensive. This material is marketed as EcoSand the raw material is post-consumer waste glass collected by local authorities’ recycling programmes. The glass is crushed, graded to size and washed to produce a clean ‘washed glass sand’. As EcoSand is a manufactured product, it has a more consistent grading than many extracted aggregates (http://www.dayaggregates.com/home.htm).

A major concern about using glass in asphalt mixtures is the adhesion between the bituminous binder and the smooth glass surface (Hassan et al., 2004a). Furthermore, the potential for polishing militates against its use in the surface course layer. Trials in the UK (Nicholls and Lay, 2002) have demonstrated no significant stripping on mixtures with 30% glass, even after 3 years in service. Furthermore, anti-stripping agents can be used to improve the bond characteristics with glass particles (Texas Department of Transport, 2003).

In the USA, many highway agencies allow the use of crushed glass in hot mix asphalt with a maximum of 15% crushed glass with 100% passing the 9.5 mm sieve and a maximum of 6% passing the 0.075mm sieve. However, laboratory tests have indicated that the mixtures containing either coarse or fine crushed glass had lower Marshall Stability values than the control. Therefore, there have been proposals to add requirements for moisture conditioning and tensile strength testing (ASTM, 1993).

The use of crushed glass in concrete has a durability concern due to ASR. The amorphous silica in glass reacts with the alkalis of cement forming expansive products of silica gel, leading to concrete cracking and premature deterioration. Crushed glass is not permitted by the SHW for use in pavement quality concrete. The
susceptibility to ASR could be minimised with the use of low alkali cement and cement replacement materials. Research on glass concrete has indicated that expansion due to ASR is dependent also on the glass particle size, content, type and colour. Clear glass was the most reactive followed by amber, whereas the green glass caused no ASR expansion (Jin et al., 2000).

Box 6.7 Use of Recycled Glass in Asphalt

Although the use of recycled glass as an aggregate in base and binder courses is not specifically covered in the SHW, the Highways Agency are willing to grant ‘departures’ for its use in base and binder course mixtures and it has been widely used by Local Authorities. The inclusion of glass has proved popular with some environmentally conscious clients. Test results indicated that the use of recycled glass as a secondary aggregate had no discernible detrimental technical effect on the performance of the product and there is a case study using glass in the asphalt base and binder courses on the M50 at Junction 2 (AggRegain, 2004i).

6.2.12 Slate aggregate

Slate secondary aggregate, the surplus material from the production of slate roofing tiles, is available in large quantities of approximately 6.3mt/a arisings and 466mt stockpiles. However, the availability of the material is relatively localised to North Wales which has restricted its use. With exemption from the aggregate levy, transport of the material is becoming commercially feasible (AggRegain, 2004j). Slate aggregate is permitted for all highway applications.

Slate aggregates are used regularly as Type 1 granular sub base material, filter medium, pipe bedding, capping layers (Class 6F1 and 6F2), and Class 1A general fill. The material appears to move slightly after it has been placed; but once it has been trafficked, the particles interlock and provide a strong material, as evidenced by the high CBR values. Once contractors gain experience working with the material, they do not have further problems (AggRegain, 2004j).

Milton et al., (1997) reported the construction and early life monitoring of a full-scale road trial, using bitumen and cement bound slate waste as base materials. Whilst the trials demonstrated the construction of the layers within the required time scale, problems were experienced with level and thickness control to the extent that the designed thickness was not achieved, particularly for the cement bound mixture containing the larger nominal size aggregate. This problem was assigned primarily to the high flakiness of the aggregate and the resulting bulkiness in the uncompacted state. Site testing indicated that slate waste base mixtures are likely to perform in a comparable manner to those of primary materials.
6.2.13 Spent oil shale

Spent oil shale is the residue from the oil extraction industry and mainly occurs in the Lothian region in Scotland. There is no current production of spent oil shale but large quantities of stockpiles are available, estimated at 100mt.

The mechanical weakness and high levels of sulfate cause this material to be excluded from use in pipe bedding and in asphalt and concrete. It may also be susceptible to frost heave making it unsuitable for use as unbound sub-base. This problem can be overcome by adding small amounts of cement, however one must ensure the sulfate content is not excessive (Winter, 1998).

Box 6.9 Use of Spent Oil Shale in the M8/M9 Newbridge Interchange

Spent oil shale is permitted by the SHW for use in embankment and fill, capping and sub-base layers. It was used as a general fill on the M8/M9 Newbridge Interchange improvement to grade separated junction (AggRegain, 2004k). The sulfate content of the material meant that it was not placed within 500mm of cementitious or concrete material. Spent oil shale has been widely used as unbound fill in major road projects in Lothian Region (Winter, 1998).

6.2.14 Steel slag

Slag from the steel making process has a different composition to that produced in blast furnaces. Air-cooled steel slags result in a product that resembles igneous rock. They are usually denser and more variable in composition than BFS. The production methods produce two different slags called Basic Oxygen Steel (BOS) and Electric Arc Furnace (EAF) slag (Baldwin et al., 1997; Dunster, 2001). Both types of steel slag are used mainly as aggregate. Steel slag contains free lime (CaO) and free magnesia (MgO) with the consequent risk of expansion, and the leachate from the material may be undesirable from an environmental viewpoint (Boyle and Khati, 1998). In all applications the material needs to be weathered before use to minimise its dimensional instability.

Steel slag is permitted for use in unbound applications, hydraulically bound mixtures and asphalt but not permitted for use in pavement quality concrete. The main use of steel slag is in the upper asphalt layers of the pavement including the surface course.

Box 6.8 Use of Slate Aggregate as Unbound Sub-base on the A55 Bangor Bypass

The A55 Bangor Bypass was originally constructed in 1980/81 and is approximately 12km of dual carriageway. 150,000 tonnes of slate aggregate was used as unbound sub-base, capping and filter material. When the road was reconstructed in 1990, the slate sub-base was found to have performed very well, with a CBR of over 50% compared to the design requirement of 30%. A further 80,000 tonnes of slate aggregate was therefore used as sub-base in the reconstruction, and the road has performed well ever since. Details are available at http://www.aggregain.org.uk/case_studies/2693_use_of_slat.html.
because it possesses high skid resistance (Roe, 2003). The Highways Agency has accepted that steel slag is equivalent to a natural aggregate with a measured PSV of 60. If it is proposed to use steel slag, checks should be carried out to ensure it has been properly weathered under a quality control system and will not be subject to dimensional instability. The volume stability can be determined according to BS EN 1744-1 Clause 19. It is not advisable for slag to be placed below the water table, as it is liable to leach unreacted lime.

**Box 6.10 Use of Basic Oxygen Steel Slag (BOS) as a Surface Course Aggregate in England**

BOS slag is available from steel works in South Wales, Humberside, Lincolnshire and Teesside. Since 1999 work has been undertaken to investigate the use of this material as a road surface course aggregate. Five trial sections were laid on Local Authority roads in 1999 and 2000, and the sections have been monitored by TRL on an annual basis and the skid resistance compared with adjacent control sections and with Highways Agency standards for skid resistance (Roe, 2003, 2005). The results indicate that the BOS slag performs well in comparison with natural aggregates in a wide range of situations. There are indications that the skid resistance of BOS slag may improve over time but more detailed analysis of seasonal variation is required to confirm this.

The initial work (Roe, 2003) found that, for BOS slag aggregate, the measured PSV (polished stone value) did not sufficiently characterise the material and that it had the potential to provide better skid resistance than indicated by the standard laboratory test. Site measurement using SCRIM (Sideways-force Coefficient Routine Investigation Machine) provides a better indication of the actual skid resistance. Based on the evidence from initial on-road studies over a period of three years, the Highways Agency permitted the use of BOS slag in surface courses without the need for PSV tests, with the proviso that its performance continued to be monitored. Details of the monitoring results after five years are given in Roe (2005) and show that the material continues to perform satisfactorily. Monitoring is continuing on an annual basis.

Steel slag has a high specific gravity; therefore it is generally uneconomic to use it as an unbound fill material unless there is a source very close to the project. This was the case on the Newport Southern Distributor Road in South Wales, where about 47,000 tonnes of steel slag was used as capping. Details are available at [http://www.aggregain.org.uk/case_studies/2720_performance.html](http://www.aggregain.org.uk/case_studies/2720_performance.html).

### 6.2.15 Unburnt colliery spoil

Unburnt colliery spoil arises in a similar manner to burnt colliery spoil with different physical and chemical composition. It consists of a mixture of mudstone, siltstone and sandstone with fragments of coal from the strata surrounding the coal seams, and will vary from colliery to colliery and from seam to seam within a colliery; hence it is likely to be a highly variable material. These changes affect the utilisation of the material in different applications. There is no technical reason to exclude unburnt colliery spoil from use as general fill, provided that it meets the appropriate grading requirements and is compacted appropriately. It is, however, excluded from use as a granular capping layer and as a stabilised material. It is also excluded from pipe
bedding, backfill to structures and unbound sub-base because of the potential attack to concrete pipes from sulfates, sulfides and chlorides and low pH and because it is a relatively weak material compared to primary aggregate.

Winter (1998) reported on a survey of the use of unburnt colliery spoil as fill on twelve contracts, indicating that the materials used formed sound embankments and provided excellent fill material with advantages over most soils particularly during inclement weather.

Unburnt colliery spoil (and burnt colliery spoil and spent oil shale) could be permitted as selected granular fill, capping, unbound and hydraulically bound sub base if they could be shown to have low contents of sulfates and other chemical contaminants by a rigorous programme of testing. Not all colliery spoils have high concentrations of chemical contaminants. The strength and durability of the material would also have to be satisfactory. The slake durability test (Franklin, 1970) is often used for this purpose; if more than 96% of the sample remains intact after two cycles, the material is taken to be sufficiently durable.

The SHW permits the use of unburnt colliery spoil as an aggregate in hydraulically bound mixtures, although cement stabilised unburnt spoil is not permitted for use in capping layers. The material is also not permitted in pavement quality concrete due to the presence of sulfides and sulfates. Again, if the particular materials to be used could be shown to be free of chemical contaminants and to meet the requirements of the SHW for the proposed application, they could be used. However, because of the potential consequences of failure, a rigorous testing programme would have to be implemented.
Box 6.11 Use of Colliery Spoil in A63 Selby Bypass

Unburnt colliery spoil was used as general granular fill in an embankment on the A63 Selby bypass (AggRegain, 2004). The embankment was constructed using pulverised fuel ash (PFA) with the unburnt colliery spoil used to encapsulate the PFA. The materials were both found to be very consistent and no problems occurred with the unburnt colliery spoil.

Unburnt colliery spoil has also been used as bulk fill on the A64: Colton Lane and A63: Melton Bypass schemes in Yorkshire in recent years. The material had high sulfate and sulfide content, but it was possible to use it as general fill by ensuring that it did not drain onto any susceptible materials such as concrete, metal or Chalk or limestone fill.
6.3 Secondary and recycled materials not included in HD35

6.3.1 Introduction
Although HD35 indicates materials of which there are significant quantities either stockpiled or as arisings, there are other materials that could be considered for use in highway construction.

6.3.2 Construction and demolition waste fines (RA fines)
Whilst RA derived from coarse construction and demolition waste is permitted by many specifications for various applications in highway construction, there is a need to develop a high-value market for the RA fines. RA represents the largest materials arising, approximately 45mt/a in the UK, and the fine fraction, passing the 5mm sieve, could contain high levels of contaminant materials such as paper, metal, clay, wood, plastic and plasterboard. In many instances, separation of coarse and fine RA is not considered due to cost implications of processing the material and concerns about suppliers being left with large volumes of fines for which there is no market. However, there is a potential for a higher market price for RA fines due to their binding properties. Some RA fines possess hardening properties, such as recycled concrete aggregate, whilst others have pozzolanic properties, such as bricks and ceramic waste. In both cases the binding capacity of these materials will contribute significantly to the cost benefits, for example by reducing the binder requirement in hydraulically bound mixtures. Separation of RA fines will increase the initial cost and could contribute to more dust generation if not carried out in controlled environments. However, it will provide a high-value market for both the coarse and fine fractions of RA (Hassan et al., 2004a).

In Germany, Winkler and Mueller (1998) carried out an experimental study to examine the effect of brick, masonry and concrete fines on the hydration and strength development of mortars. The materials were ground to fineness similar to that of cement and used to replace up to 60% by weight of cement. The brick powder replacement up to 20% was found to improve workability, generate additional pozzolanic reactions, but resulted in a slight reduction in strength. No signs of pozzolanic reactions were detected for the masonry powders, which therefore gave lower strength. The hardening properties of the recycled concrete powder were related to its fineness; when ground very fine, it improved the workability and strength of the mortars.

Dutch experience on the use of RA fines indicated potential use as fine aggregate in concrete. At the same effective water content, replacement of river sand with recycled sands did not affect the workability of the fresh concrete, but reduced bleeding. Full replacement of river sand with 100% washed RA fines or 25% unwashed material showed only a slight reduction in strength (Van der Wegen and Haverkort, 1998).

6.3.3 Recycled concrete aggregate fines (RCA fines)
RCA fines were used as the main binder to produce low-strength cementitious composites in Sweden (Karlsson, 1998). RCA from a residential building in Gothenberg had been separated into fine and coarse fractions. The fine RCA fraction was ground and mixed with a surface activator additive and then mixed with coarse
RCA and sand. With a ground RCA fines content of 350 kg/m³, the resultant composite gave a 28-day compressive strength of 2.8 MPa.

In the 1990s, parts of the Vienna-Salzburg motorway were reconstructed by fully recycling the old concrete pavement into a new pavement (Sommer, 1998). The original concrete pavement was shattered, crushed and screened. The coarse fraction, particles ranging in size from 32mm to 4mm, representing about 70% of the crushed concrete, was reused as aggregate in the new concrete pavement layer. The remaining 30% fine fraction, size 0 to 4mm, was blended with some of the original granular sub-base and cement to form the new cement bound sub-base. The stabilised sub-base was covered with a thin layer, 50mm, of asphalt regulating layer before placing the concrete pavement and no problem with reflected cracking has been reported.

6.3.4 Recycled tyres

The DTI's Used Tyre Working Group (UTWG: www.tyredisposal.co.uk) estimates that the total waste tyre arisings in the UK amount to 0.44mt, with around 70% being recovered. In 1996, 37 million tyres were scrapped in the UK with 30% being re-treaded, 27% used for energy recovery, 30% sent to landfill and 3% were physically re-used for other purposes. Around 50% of the weight of the scrapped tyre consists of rubber and these tyres could be used in road construction (Sherwood, 2001). However, the tyres do need processing before they can be used and there are significant differences between car tyres, which are generally synthetic rubber, and lorry tyres, which are generally natural rubber.

European specifications exist for rubber crumb produced from waste tyres (CEN, 2002), which could be adopted to partly specify this material as an aggregate. Another form of re-use is for energy recovery, for instance in cement kilns. From April 2003 EC directives prevented whole tyres going to landfill and from July 2006 shredded tyre waste was banned from landfill sites. Therefore, the quantity of waste tyres needing to be recovered will increase.

Recycled tyres are suitable for a wide range of applications in civil engineering. Their low density and free-draining nature makes them suitable as lightweight fill in areas of soft ground and as backfill to retaining structures. They can be used in a variety of forms, including tyre bales, whole tyres, shred, chips and granulate, and in a variety of applications including lightweight fill, soil reinforcement, drainage, erosion control, landfill engineering, artificial reefs and use in asphalt and concrete. Many of these applications are common in various parts of the world, and they are being increasingly used in the UK, particularly in the form of tyre bales. Potential applications of used tyres in civil engineering are described by Hylands and Shulman (2004). There are a number of examples of used tyres being used in road projects in the UK, including the use of tyre bales to enable road construction over very soft ground (Reid and Winter, 2004). A design guide for use of tyre bales in construction (Winter et al., 2005a) and case studies (Winter et al., 2005b) have recently been published. Publicly Available Specifications (PAS) shredded tyres (PAS 107 (BSI, 2007a)) and tyre bales (PAS 108 (BSI, 2007b)) have been prepared for the Waste and Resources Action Programme (WRAP). A Waste Protocol for shredded and crumbed tyres is being prepared by Environment Agency (EA) and WRAP.

In asphalt, the rubber acts both as a binder modifier (particularly the finer particles) and as a fine aggregate. However, vulcanisation reduces the effectiveness of the rubber as a modifier. The processing of the rubber involves crushing and grinding the
tyres using either the wet or dry process (OECD, 1997), with the wet processing
producing more binder modification and the dry process more fine aggregate.

Information on the use of tyre rubber in bituminous layers can be obtained from the
WRAP website (www.wrap.org.uk/construction/tyres).

Most of the work on the use of rubber in asphalt has been done in the USA, where its
use was made mandatory at one time before practicality removed the requirement,
whilst it has not been widely used in Europe. Asphalt rubber concrete (ARC) is the
term used in the USA for asphalt in which the rubber is primarily used as a binder
modifier, whilst rubber modified asphalt concrete (RUMAC) is the term for asphalt
where the rubber has replaced between 2% and 5% of the aggregate.

Rubber has a potential use in concrete as aggregate replacement with improved
properties in certain applications. Compared to primary aggregate, rubber is of light
weight and has an elastic nature that allows the concrete to withstand large
deformations. Rubber concrete has the ability to absorb energy, possibly making it
suitable for use in concrete safety barriers with reduced damage incurred by vehicle
collisions. It is also suitable for applications with an upper strength limit, such as
foamed concrete in trench instatement (Hassan et al., 2004b). However, the costs of
producing the rubber aggregate are significantly higher than for most conventional
concrete aggregates, primary, secondary or recycled, and this may limit uptake for
this application.

Box 6.12 Use of Tyre Bales in a Minor Road over Peat, Northern
Scotland
The B871 road in Sutherland, Northern Scotland is typical of the lightly
trafficked roads found in this isolated area. Like many roads in the area, it
is constructed over soft peat and a section at Loch Rosail had settled to
below water table level. It was necessary to reconstruct the road to allow
heavy vehicles to use it to clear a large conifer forest. Tyre bales were
used to ‘float’ the central 55m section over the softest ground in December
2002. Two layers of tyre bales were placed wrapped in geosynthetic fabric,
overlain by a 250mm layer of rock fill with a layer of reinforcing mesh to
provide additional stiffness. A 100mm layer of Type 1 sub-base was
compacted on top of the rockfill, with a further 50mm of fine sand and two
layers of surface dressing after a period of some months, when settlement
had slowed down. The use of tyre bales successfully enabled the
reconstruction of this vital transport link for a remote rural area (Reid and
Winter, 2004).

6.3.5 Recycled plastic
The amount of waste plastic generated is about 2.5mt of which about 0.2mt of plastic
is recycled each year in the UK. Single polymer recycled plastics have typical values
of £10 to £200/t. Other waste plastic arisings exist, which are difficult to separate and
process and these are potential sources of plastic ‘aggregates’, including mixed
plastics and shredder wastes. However, the infrastructure to provide these materials
to be used as aggregates does not currently exist. With the changing waste
management situation, it may be that disposal of these materials will be less
economic in the future and a need to find methods of re-use, such as alternative
aggregates, will be required. No form of specification of recycled plastic exists which would be suitable to specify their use as aggregate.

Potential uses for recycled plastic in highway construction include geogrids or separation membranes, soil stabilisation, lightweight aggregate, sheet piling and asphalt binder. Work by Hassan et al. (2004b) indicated that asphalt binder course incorporating plastic aggregate showed adequate fatigue and deformation resistance. The use of waste plastic was justified if an adequate and economic supply of material can be established. However, the mixture showed a degree of moisture sensitivity which would limit its use in surface courses.

Conigliaro Industries (www.conigliaro.com) produce lightweight aggregate from recycled mixed plastics. The plastic was predominantly sourced from packaging waste. Concrete incorporating plastic aggregate, Plas-Crete, is a substitute for conventional concrete products in various applications of low-density insulating concrete, moderate-strength lightweight concrete, as well as structural lightweight concrete. Plas-Crete has been an immediate success in the marketplace through use in manufacturing large lightweight concrete wall blocks for temporary and easily constructed retaining walls.

6.3.6 Ferro-silicate slag (zinc slag)

Until early 2003 the BZL works was the UK’s only primary zinc smelter and had been at the site at Avonmouth, near the Severn Estuary, for 50 years. BZL produced on average 90,000 tonnes of zinc and 35,000 tonnes of lead a year, and 80,000 tonnes per annum of ferro-silicate slag (Imperial Smelting Furnace slag, ISF slag) as a residue. ISF slag is a granulated, glassy material that has the appearance of dark coloured sand. There are still significant quantities of this material, 2mt stockpiled and landfilled, available at the Avonmouth site. However, this material is probably only economically viable for use in the South West of England and South Wales.

Zinc slag contains a number of heavy metals in high concentrations, including cadmium and arsenic (Dijkink, 1994). It is considered that the environmental implications of any secondary aggregates containing heavy metals such as cadmium and arsenic will probably inhibit their use in asphalt. However, zinc slag has been used in an asphalt pavement and showed satisfactory performance (Dunster, 2005).
Box 6.13 Use of Zinc Slag in an Asphalt Trial Road, Avonmouth
A road trial was undertaken in Avonmouth of a Dense Bitumen Macadam (DBM) material comprising 30% ISF slag (% replacement of primary aggregate by volume) and 4.0% 50 penetration grade binder were used. The trial panel comprised two sections, the test and the control sections (with and without ISF slag respectively). These sections were visually monitored over a one year period with a final detailed assessment at 30 months. This showed that asphalt mixes containing ISF slag can be successfully made, and that it is feasible to use ISF slag as a partial replacement for sand (up to 30% by volume) in DBM in typical coated macadam base/binder course mixtures without compromising environmental or mechanical performance. The field trials confirmed that the slag asphalt can be easily laid with conventional equipment, and the in situ properties are similar to those of conventional mixtures. In addition, the case study illustrates that contaminants within ISF slag are effectively bound when the slag is used as aggregate in asphalt, and that a properly designed and constructed road will minimise water ingress and percolation through its structure. This, therefore, provides reassurance that contaminants in the ISF slag would be effectively immobilised in the matrix of an asphalt road structure in service (AggRegain, 2005).

Recently, zinc slag has been used in the foam bitumen process, where foam bitumen is added to loose moist granular material. Foam bitumen can immobilise waste material, which was confirmed by a number of tests where samples of treated zinc slag were taken to check the immobilising effect of foam bitumen. The tests showed that the zinc slag was very well fixed and the immobilisation effect was very high (more than 95%).

6.3.7 Cement-kiln dust
Cement kiln dust (CKD) is carried by hot gasses in a cement kiln and collected by a filter system during the production of cement. The kiln dust differs from cement in that the raw material has not been fully burnt. The chemical composition and reactive properties of CKD make it useful for a number of applications. Cement kiln dust works well as a stabilizer for certain types of soils because of its calcium oxide content. Its high alkalinity promotes its use as an activator in hydraulically bound mixtures, but could increase the potential for alkali-silica reactions with reactive aggregate in concrete.

Fresh CKD can be used as filler in asphalt (Kraszewski and Emery, 1981). The use of CKD as the filler in asphalt mixtures gives properties comparable to that of conventional filler. Gradation, organic impurities and plasticity requirements normally associated with mineral filler specification can usually be met without difficulty. With the integration between cement manufacturers and asphalt producers, it is anticipated that CKD will be used in asphalt more frequently in the future.
A research project at TRL found that CKD could be used as filler in asphalt as a replacement for limestone dust. Laboratory tests on samples of CKD from three plants were carried out. All performed similarly, though there were significant differences in composition between the samples. Only one sample complied with the grading and density requirements for filler in BS EN 13043. A site trial was carried out with this sample in binder and surface course, with control sections using conventional limestone filler. The pilot-scale trial demonstrated that it is practical to use CKD as the added filler in stone mastic asphalt mixtures without increasing the mixing time or temperature. When taken together with the laboratory results, the trial demonstrated that CKD can be successfully used as the added filler, replacing limestone filler, in routine mixtures of macadam, stone mastic asphalt and hot rolled asphalt. A quality protocol for CKD was drafted (Nicholls et al., 2007).

### Box 6.14 TRL Research Project on use of CKD as Filler in Asphalt

According to the ODPM survey of secondary aggregates for 2001 (ODPM, 2002b), there are annual arisings of about 1.31 million tonnes of spent railway ballast in England and Wales. Locally, these can make a significant contribution to the aggregate requirements of an area, for example in Hampshire where approximately 140,000 tonnes per annum is used as capping, unbound sub-base and general fill (Reid et al., 2006).

Specifications for railway ballast normally involve size, shape and rock quality requirements, the aim being to obtain a coarse angular material, the particles of which will interlock to form a layer of good dimensional stability. The BR Ballast Specification (BR 1203: 1988) requires aggregates to be finer than 63 mm and not more than 0.8% finer than 1.18 mm with most of the material lying between 50 and 28 mm. The material is otherwise required to be hard, durable stone, angular in shape with all dimensions nearly equal and free from dust. It is mostly supplied by igneous rock such as granite, with small amounts of hornfels and quartzitic sandstone (Smith and Collis, 2001). If the subgrade is weak, a layer of blanketing sand may be required below the ballast.

Railway ballast is thus a high quality material. However, by the time it is replaced it may be contaminated by the blanketing sand or weak soil in the subgrade, material deposited from trains, and fines produced by attrition of the coarse angular particles under repeated loading. The grading of the original material, a coarse gravel, is markedly different from the well-graded fills required for applications such as capping and sub-base, and it may be contaminated by clay or organic material picked up in the course of its working life. The grading can be adjusted by crushing and screening to meet the requirements for highway applications, but if the material is seriously contaminated, for instance with diesel or PCBs, it may require to be washed before use.
6.3.9 Quarry fines and surplus material

The production of primary aggregates from sand and gravel and hard rock inevitably results in some surplus material, mostly fines. Coarser material, known as ‘scalpings’ is often used as a low-grade rockfill. Some of the fines can be used as filler is asphalt; limestone fines are particularly used for this purpose. However, much of the fines remains and is either used for restoration or clutter up the quarry, until in the extreme it can prevent further excavation of aggregate. However, there may be opportunities to use this material in specialist applications in highways, footways and associated works.

Applications for quarry fines involving highways include:

- Landscape bunds and noise bunds;
- Artificial soils, when mixed with green waste compost;
- Surfacing for footways and cycleways in country parks;
- Mixing with cement to form stabilised capping or sub-base;
- Use as sand in low strength ancillary concrete;
- Use as filter or drainage material, if the fines have been separated;
- Bedding sand for block paving;
- Fibre reinforced soils for occasional vehicle access routes in country parks and heritage sites.

The particular uses that will be possible will depend on the characteristics of the material from individual quarries and the location of the sources compared to the applications. Quarry fines vary considerably in their composition, depending on the nature of the parent materials and the processes being used to extract aggregate.

The fines from hard rock quarries tend to be well-graded sand, from 3mm down, with variable proportions of silt and clay depending on the rock type, but the material from a single source will generally be very consistent. The fines from sand and gravel quarries are more dependent on the nature of the parent materials, and may contain significant proportions of silt and clay. The grading will clearly affect their suitability for the applications listed above. In some quarries the silt and clay is separated from the sand by washing. This is expensive, but yields a high value free-draining sand that can be used for a number of applications.

The transport distances for the materials from the quarries to the point of use compared to alternative sources will also affect the economics, and sustainability, of using them. It should be noted that, unlike the other recycled and secondary aggregates discussed in this chapter, quarry fines are not exempt from the Aggregates Levy. However, where these materials can be used economically, this will contribute to the overall sustainability of the mineral workings, and can prolong the working life of the quarry.

There may be opportunities for synergies with activities being carried out by other departments of the Council, such as waste management and countryside and heritage. Examples include mixing with green waste compost to produce manufactured soils or use in footways and cycleways in country parks.
Box 6.15 Use of Sandstone Quarry Sand in South Wales

A detailed study was undertaken of potential applications of surplus quarry sand from five quarries for high PSV aggregates in the Pennant Sandstone of South Wales. The material was a well-graded silty sand and was very consistent with time and between the quarries. A number of applications were identified, including bedding sand for pavers, concreting sand, manufactured soils when mixed with green waste compost, and surfacing for footways and cycleways in country parks. The last application was particularly successful, as the material compacted well and formed a good surface, with or without the addition of cement. The material was similar in colour to the country rock, from which it was derived, and was felt to more appropriate than imported limestone fines. Full details are given in Lamb (2005).
7 Distribution and Availability of Aggregates in the UK

7.1 Regional availability of recycled and secondary aggregates

Information on the availability of recycled and secondary aggregates was given in Table 6.1. Many of the secondary aggregates in particular are only available in specific geographic areas, whereas recycled aggregates are widely available in urban areas across the UK, but may not be available in rural areas. The distribution of these materials on a regional basis is shown on Figures 7.1 to 7.7 as a general guide to their availability. These maps are based on surveys carried out by Capita Symonds for the former Office of the Deputy Prime Minister, now the Department for Communities and Local Government, and WRAP for construction and demolition waste arisings (surveys for 2005 for England (Department for Communities and Local Government, 2007a), 2003 for Scotland (Capita Symonds, 2004), 2001 for Wales (Office of the Deputy Prime Minister, 2002a) and secondary aggregates (2005 for England (Department for Communities and Local Government, 2007b), 2001 for Wales (Office of the Deputy Prime Minister, 2002b). Scrap tyres were not included in the 2005 survey of secondary materials, so all the tyre data is from the 2001 survey and is for England and Wales only (Office of the Deputy Prime Minister, 2002b). Data on construction and demolition waste arisings in Northern Ireland for 2001 was obtained from a survey by Enviros (2003) for the Environment and Heritage Service. Data on secondary aggregates in Scotland was obtained from a study by Winter and Henderson for 1999 (Winter and Henderson, 2001).

The maps show the current annual production of these materials. In addition there are large stockpiles of some materials, in particular slate, China Clay Sand, PFA and to a lesser extent colliery spoil. These may also potentially be available for use in highway maintenance or new construction works.

One of the major sustainability considerations when selecting materials for highway works is minimisation of transport distances. Thus if recycled and secondary aggregates are available locally and can perform the required functions satisfactorily, it is sustainable to use them in preference to primary aggregates. It may also be sustainable to adapt specifications to make best use of the available materials, so long as an adequate standard of performance is maintained; for example, the Highways Agency has produced specific clauses for the use of materials such as pulverised-fuel ash (PFA), China clay sand and slate aggregate in a number of applications. However, it is not sustainable to transport recycled and secondary aggregates over considerable distances if suitable primary aggregates are available close to the works. Transport is a major cause of CO₂ emissions, and minimising these is a major aim of sustainable construction. This can be quantified by using the CO₂ calculator tool available on the AggRegain web site (http://www.aggregnain.org.uk/sustainability/try_a_sustainability_tool/co2_emissions.html); this enables different options for constructing a road to be compared to see which causes the lowest CO₂ emissions. This tool is described in more detail in Chapter 9. The option with the lowest transport distances will also usually be the most economic.
Figure 7.1 - Total Production of Recycled Aggregates and Soil (million tonnes), England and Wales

- Recycled Aggregates
  - Total: 6
  - North East: 3
  - South West: 2
  - East Midlands: 5
  - Northern Ireland: 0.0

Data for England are for 2005 (DCLG, 2007a)
Data for Wales are for 2001 (ODPM, 2002a)
Figure 7.2 - Total Production of Recycled Aggregates and Soil (million tonnes), Scotland, Northern Ireland and Northern England

Data for Scotland are for 2003 (Capita Symonds, 2004); data for Northern Ireland are for 2001 (Enviros, 2004); data for England are for 2005 (DCLG, 2007a)
Figure 7.3 - Total Production of PFA, FBA and IBA (million tonnes) in the UK

- **Power Station Pulverised Fuel Ash (PFA) or Fly Ash**
  - England: 2 million tonnes
  - Wales: 1.5 million tonnes
  - Scotland: 0.3 million tonnes

- **Power Station Furnace Bottom Ash (FBA)**
  - England: 1.5 million tonnes
  - Wales: 0.3 million tonnes
  - Scotland: 0.0 million tonnes

- **Municipal Solid Waste Incinerator Bottom Ash**

Data for England are for 2005 (DCLG, 2007b)
Data for Wales are for 2001 (ODPM, 2002b)
Data for Scotland are for 1999 (Winter and Henderson, 2001)
No data for Northern Ireland
Figure 7.4 - Total Production of Colliery Spoil, Slate and China Clay Sand (million tonnes) in the UK

England 2005 (DCLG, 2007b); Wales 2001 (ODPM, 2002b); Scotland 1999 (Winter and Henderson, 2001); no data for Northern Ireland
Figure 7.5 - Total Production of Slag (million tonnes) in the UK

- 1 million tonnes: Blast Furnace Slag
- 0.8 million tonnes: Basic Oxygen Furnace Steel Slag
- 0.6 million tonnes: Electric Arc Furnace Steel Slag

Data for England for 2005 (DCLG, 2007b); data for Wales for 2001 (ODPM, 2002b); no arisings in Scotland (Winter and Henderson, 2002); no data for Northern Ireland
Figure 7.6 - Total Production of Railway Ballast, Waste glass and Tyres (million tonnes) in England and Wales

- Railway Ballast: 0.6
- Waste Glass: 0.5
- Scrap Tyres: 0.4

Data for England are for 2005 (DCLG, 2007b) except for tyres, which are for 2001 (ODPM, 2002b); data for Wales are for 2001 (ODPM, 2002b)
Figure 7.7 - Total Production of Railway Ballast, Waste Glass and Tyres (million tonnes) in Scotland and Northern England (no data for Northern Ireland)

Data for Scotland are for 1999 (Winter and Henderson, 2001); data for England are for 2005 (DCLG, 2007b) except for tyres, which are for 2001 (ODPM, 2002b)
7.2 Primary aggregates

7.2.1 Sand and gravel and crushed rock

Primary aggregates can be broadly divided into sand and gravel and crushed rock. Sand and gravel includes both land-won and marine-dredged material. Crushed rock comprises a range of rock types, of which the principal categories are:

- limestone (including dolomite);
- igneous (including metamorphic rock);
- sandstone (including greywacke, gritstone and quartzite).

Sand and gravel is used mainly as concreting aggregate. Crushed rock has a wider range of uses, and is particularly used in highway construction and maintenance, both as unbound material for capping and sub-base and as coarse aggregate for asphalt and concrete. Recycled and secondary aggregates will thus be predominantly competing with crushed rock for use in highways. The relative availability of crushed rock and recycled and secondary aggregates across the UK is therefore crucial to the extent that the latter will be used in highway maintenance and new construction.

Data on the distribution and utilisation of primary aggregates in England and Wales at a regional level is given by Highly et al. (2003), based on the 2001 aggregate minerals survey. Some areas of England, particularly London, the South East, East of England and parts of the North West have limited reserves of crushed rock, particularly of high quality material. There are large flows of crushed rock into these regions from adjacent areas with large reserves of crushed rock, particularly from the East Midlands, South West and North Wales. There are also significant imports of crushed rock from Scotland into the South East.

The distribution of recycled and secondary aggregates, shown on Figures 7.1 to 7.7, does not neatly match the gaps in availability of crushed rock. However, there is significant production of recycled aggregates in the areas with low crushed rock production, and these materials are likely to be economically favourable in these areas provided they are of adequate quality (see Chapter 8.1). In urban areas throughout the UK, recycled aggregates are often likely to be economically favourable compared to crushed rock because of the reduced distances they have to be transported. This also aids their sustainability compared to primary aggregates (see Chapter 9).

Data for primary aggregates is also available at the level of individual Mineral Planning Authorities (MPAs). These range from County Councils to Unitary Authorities and some District and City Councils and Metropolitan Boroughs. Some Regional Assemblies also publish Aggregates Monitoring Reports, with data broken down to County level or lower, e.g. the South East England Regional Assembly (2003). These can help in identifying areas where use of recycled and secondary aggregates would be particularly beneficial economically and environmentally.
7.2.2 Aggregates for specialist applications: high specification aggregates for skid-resistant road surfacing

Many aggregates, whether primary, recycled or secondary, will be satisfactory for the majority of applications in highways and footways. The exception is the surface course, where the aggregate will be in direct contact with vehicle tyres. Skid resistance is the essential requirement for aggregates in this layer, but the degree of skid resistance required depends on the road geometry and the anticipated traffic load and speed. The aggregate must maintain a high roughness over time and exposure to traffic to be suitable for use in surface course applications.

The skid resistance of an aggregate is generally measured by a laboratory test called the Polished Stone Value (PSV). An accelerated polishing apparatus simulates the action of dust-laden tyres on samples of aggregate set in a polyester resin backing mounted in standard moulds on a rotating ‘road wheel’. A 200mm diameter by 38mm broad tyre bears on the aggregate with a total force of 725N. The polish of the specimens is measured using a standard pendulum arc friction tester. The coefficient of friction is expressed as a percentage, and this is the PSV; a higher value signifies greater resistance to polishing. Values over 65 indicate highly polish-resistant rocks especially suitable for road surface courses in high-risk areas.

High specification aggregates (HSA) are defined as (Thomson et al., 2004):

“natural and artificial coarse aggregates (≥ 3mm) that meet the physical test criteria set out below and that are suitable for use in road surfacing (including surface dressing) applications at the more difficult and/or heavily trafficked sites where high levels of skidding resistance and aggregate durability are required.”

The specific thresholds used to define HSA by Thomson et al. (2004) are set out in Table 7.1.

<table>
<thead>
<tr>
<th>Property</th>
<th>Limiting Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polished Stone Value (PSV)</td>
<td>≥ 58</td>
</tr>
<tr>
<td>Aggregate Abrasion Value (AAV)</td>
<td>≤ 16</td>
</tr>
<tr>
<td>Los Angeles Coefficient (LA)</td>
<td>≤ 30</td>
</tr>
<tr>
<td>Magnesium Sulfate Value (MS)</td>
<td>≤ 25%</td>
</tr>
</tbody>
</table>

Thomson et al. (2004) estimated that the total 'specified' demand for PSV 58+ HSA in England in 2002 was 6.1 million tonnes. This was 2.3 times greater than the corresponding figure for England in 1992. There is considerable uncertainty about future demand, but Thomson et al. (2004) considered it would be prudent to anticipate a modest increase in demand over the next decade. The proportion of this demand supplied from sites within England was estimated to be 3.8 million tonnes (62%). The remainder is supplied from sites in Wales, Scotland, Northern Ireland and Northern France.

Despite the remarkable diversity of rock types in the UK, relatively few formations possess all of the characteristics needed to meet HSA requirements. Clastic sedimentary rocks of Carboniferous age or older are particularly important sources of HSA, because the component grains generally have differing degrees of hardness and individual grains can be plucked out of the aggregate particles as they wear away, thus maintaining a rough, sandpaper-like micro texture that is of vital importance to the maintenance of skid resistance. Of these, greywackes and related
rock types have the highest overall quality in terms of measured PSV/AAV categories. Optimum combinations of strength and resistance to polishing are found in a very limited number of formations, foremost among which are the Carboniferous Pennant Sandstones of South Wales. Maps showing the location of formations and quarries capable of producing HSA are given in Thomson et al. (2004). In particular, it should be noted that for the highest category of HSA with PSV ≥ 68, there are a very limited number of sources outside South Wales; one quarry in Northern Ireland, one in Southern Scotland and two in the North West of England.

Steel slag has been shown to have high skid resistance in practice, despite giving relatively low values of PSV (see Chapter 6.2.14), and BOS steel slag is accepted by the Highways Agency as equivalent to primary aggregate with a measured PSV value of 60. EAF steel slag has a typical measured PSV of around 63, but is produced at only one plant, Templeborough in South Yorkshire. BOS steel slag was produced in 2002 at Teesport, Santon, Port Talbot, Llanwern and Sheerness on the Thames Estuary. The Llanwern works has subsequently closed, but some stockpiles may still be available. Other stockpiles are held at Workington and Barrow in Cumbria and Ravenscraig in Scotland. Steel slag has to be weathered before use to allow hydration and expansion reactions to take place, and should always be obtained from a supplier with a quality control system in place.

Blast furnace slags typically yield PSVs in the range 59 to 64. Calcined bauxite, a manufactured aggregate, gives PSVs greater than 65.

7.3 Detailed studies of materials available at local level
Most Local Authorities will have a good general idea of the materials available in their local area, for example any secondary aggregates such as slag, colliery spoil, slate or China clay sand. However, detailed studies of all the aggregates available in an area such as a county or smaller are relatively rare. Such studies can be very valuable as part of an overall strategy by a Local Authority to assess the material resources in its area, and can enable targets to be set for uptake of specific materials.

An example of such an approach is the Materials Resource Strategy (MRS) carried out by Hampshire County Council, Portsmouth City Council and Southampton City Council (Hampshire County Council et al., 2005). This was a stakeholder consultation process involving community and industry representatives, working in partnership with the councils to address the issues of minerals and waste using a material resources management approach. This involved a review of all the materials and waste streams in the area, an assessment of current recycling rates and potential recycling rates in 2010 and 2020. As part of this process, a thorough review of the current and potential arisings of all primary, recycled and secondary aggregates in the area was carried out, including arisings from highway maintenance (Sowerby et al., 2005). The findings are summarised in Table 7.2, including targets under two scenarios:

- “business as usual”; and
- “stretching best practice”.

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Table 7.2 Estimates of Future Use of Recycled and Secondary Materials as Aggregates in Hampshire (from Sowerby et al., 2005)

<table>
<thead>
<tr>
<th>Material</th>
<th>Estimated Amount Recycled in 2004 (tonnes per year)</th>
<th>Scenario</th>
<th>Estimated Amount Recycled in 2010 (tonnes per year)</th>
<th>Estimated Amount Recycled in 2020 (tonnes per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled Aggregates (from Inert CD&amp;EW)</td>
<td>500,000</td>
<td>Stretching Best Practice</td>
<td>654,00</td>
<td>750,00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>525,00</td>
<td>550,00</td>
</tr>
<tr>
<td>Highway New Works and Maintenance</td>
<td>45,000</td>
<td>Stretching Best Practice</td>
<td>100,00</td>
<td>102,00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>47,500</td>
<td>50,000</td>
</tr>
<tr>
<td>Railway Ballast</td>
<td>140,000</td>
<td>Stretching Best Practice</td>
<td>140,00</td>
<td>140,00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>140,00</td>
<td>140,00</td>
</tr>
<tr>
<td>Incinerator Bottom Ash Aggregate</td>
<td>1,000</td>
<td>Stretching Best Practice</td>
<td>90,000</td>
<td>90,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>2,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Recycled Glass</td>
<td>0</td>
<td>Stretching Best Practice</td>
<td>15,000</td>
<td>15,400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Recycled Plastic</td>
<td>0</td>
<td>Stretching Best Practice</td>
<td>1,000</td>
<td>2,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Recycled Tyres</td>
<td>0</td>
<td>Stretching Best Practice</td>
<td>5,000</td>
<td>5,130</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>686,000</td>
<td>Stretching Best Practice</td>
<td>1,005,000</td>
<td>1,104,530</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>714,500</td>
<td>745,000</td>
</tr>
<tr>
<td>Total Aggregate Use in Hampshire</td>
<td>5,119,500</td>
<td>Zero growth in total aggregate use assumed</td>
<td>5,119,500</td>
<td>5,119,500</td>
</tr>
<tr>
<td>Proportion of Recycled and Secondary Aggregates</td>
<td>13.4%</td>
<td>Stretching Best Practice</td>
<td>19.6%</td>
<td>21.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business as Usual</td>
<td>14.0%</td>
<td>14.6%</td>
</tr>
</tbody>
</table>
The proportion of recycled and secondary aggregates currently used was less than expected; the average for England as a whole is thought to be about 23%, with the potential to rise to about 30% (Barritt, 2003).

The MRS was used to develop a vision for Hampshire, Portsmouth and Southampton that “We will change the way we use material resources to maximise efficiency and minimise wastage”. This holistic approach to sustainability is now being used to guide the development of the statutory joint minerals and waste development framework for the area, and feeds down through council objectives into actions at highway maintenance level (see Box 1.2 and Appendix 2).
8 Standards and Specifications

8.1 General comments and quality control

In order to carry out highway and footway maintenance and new construction works, standards and specifications are required to ensure that the materials and methods are suitable and will produce the required performance. They provide a contractual framework within which the work must be carried out, and against which the end product can be assessed. In the past, many standards and specifications excluded most recycled and secondary materials, largely because of concerns about their quality and consistency. With the rise of the sustainability agenda in the 1990s, there was a change of attitude and most standards and specifications now permit the use of recycled and secondary aggregates subject to safeguards about their quality. It is therefore now possible to use a much wider range of materials.

Assurance about the quality of recycled and secondary materials can be given by the use of Quality Protocols, which demonstrate that the supplier has procedures in place to ensure the consistency and quality of his product. The WRAP Quality Protocol for the production of aggregates from inert waste (WRAP, 2004b) is an example; versions of this protocol for England and Wales, Scotland and Northern Ireland are available on the AggRegain web site, www.aggregain.org.uk. This covers many of the materials likely to be encountered in arisings from highway and footway works, including asphalt planings, concrete and brick, and soil and stones. Waste Protocols are currently being developed by the Environment Agency and WRAP for a number of secondary materials that could be used in highway works, including pulverised-fuel ash, steel slag, incinerator bottom ash, flat glass and shredded or crumbed tyres. Details are available at http://www.environment-agency.gov.uk/subjects/waste/1019330/1334884/. Local Authorities should encourage their suppliers to use these protocols; indeed, they could become a requirement for supplying materials for Local Authority highway works. This is also important to ensure that the materials have been fully recovered and are no longer subject to waste controls (see Section 5.2).

It should not be considered that recycled and secondary aggregates are being unfairly singled out for special requirements in terms of quality control. Under the harmonised European Standards for aggregates (see following section), all aggregates have to be produced under a system of Factory Production Control. Aggregate producers are used to working with such systems; the issue is that some small recycling companies, often coming from a waste recovery perspective, are not and resist what they see as unnecessary impositions and costs on their operations. However, the materials that they are producing have to fulfil the same functions as primary aggregates produced by aggregate companies, so the same standards should apply. All aggregates are equal under the harmonised European Standards, whether primary, manufactured or recycled, so it is reasonable that they should all come with the same assurance on quality.

As there have been a number of developments in the standards and specifications used for highway works in recent years, they are reviewed briefly in the following sections with specific reference to the use of recycled and secondary aggregates.
Box 8.1 Source Approval Scheme in Teeside

In a move to improve user confidence and encourage greater use of recycled materials, some Local Authorities have established a “source approval” regime which includes implementation of a quality scheme by the producer, product testing at agreed frequencies and plant audits, also inspections by Local Authority representatives.

One example of such a scheme is that operated on Teesside by Middlesbrough Council’s Laboratory for four Local Authorities in the area. Six plants in the area have now joined the scheme producing materials ranging from general fills to sub-base.

User confidence is considered to have increased significantly in the two years that the scheme has been in operation. (Source: O’Farrell, 2006)
8.2 Standards

8.2.1 Standard specifications for aggregates
Harmonised European Standards for aggregates were adopted by the aggregate industry from 1 January 2004, and the corresponding old British Standards were withdrawn from 1 June 2004. A series of Published Documents (PDs) were issued by the British Standards Institution (BSI) to give guidance on the use of these European Standards. The relevant standards and PDs for new civil engineering work, road construction and maintenance are shown below.

<table>
<thead>
<tr>
<th>Standard (Year)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS EN 12620: 2002</td>
<td>Aggregates for concrete. Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas</td>
</tr>
<tr>
<td>BS EN 13043: 2002</td>
<td>Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas.</td>
</tr>
<tr>
<td>PD 6682-2: 2003</td>
<td>Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas – Guidance on the use of BS EN 13043.</td>
</tr>
<tr>
<td>BS EN 13242: 2002</td>
<td>Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction.</td>
</tr>
<tr>
<td>PD 6682-6: 2003</td>
<td>Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction – Guidance on the use of BS EN 13242</td>
</tr>
</tbody>
</table>

These standards cover the properties of natural, manufactured and recycled aggregates and mixtures of aggregates and filler aggregates. The European Standards do not impose any barriers to the use of alternative materials; they define how all aggregates are to be tested and specified. The end-product standard for use in road construction remains the relevant specification for the construction; on many projects this is the Specification for Highway Works, and it is in the specification that restrictions on the use of particular materials can be introduced. However, the specification must specify aggregates in accordance with the European Standards.

The scope and relevant clauses for aggregates in these standards for various requirements are indicated in Table 8.1. Table 8.2 is a similar table for fillers which are relevant to BS EN 12620 and BS EN 13043. The notes in these tables indicate whether the property requirement is a designated value, a category, maybe with a tolerance, or a declared value.
<table>
<thead>
<tr>
<th>Essential characteristic</th>
<th>BS EN12620 Clause</th>
<th>BS EN 13043 Clause</th>
<th>BS EN 13242 Clause</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle shape, size and density</td>
<td>4.2 Aggregate size</td>
<td>4.1.2 Aggregate size</td>
<td>4.2 Aggregate size</td>
<td>Designation</td>
</tr>
<tr>
<td></td>
<td>4.3 Grading</td>
<td>4.1.3 Grading</td>
<td>4.3 Grading</td>
<td>Tolerance/Category</td>
</tr>
<tr>
<td></td>
<td>4.4 Shape of coarse aggregate</td>
<td>4.1.6 Shape of coarse aggregate</td>
<td>4.4 Shape of coarse aggregate</td>
<td>Category</td>
</tr>
<tr>
<td></td>
<td>5.5 Particle density/water absorption</td>
<td>4.2.7.1 Particle density</td>
<td>5.4 Particle density</td>
<td>Declared value</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>4.5 Shell content-coarse aggregate</td>
<td>4.1.5 Fines quality</td>
<td>4.6 Fines content</td>
<td>Category</td>
</tr>
<tr>
<td></td>
<td>4.6 Fines</td>
<td>4.7 Fines quality</td>
<td>4.7 Fines quality</td>
<td>Category</td>
</tr>
<tr>
<td>Percentage of crushed and broken surfaces in coarse aggregate</td>
<td>4.1.7 Percentage of crushed and broken surfaces</td>
<td>4.5 Percentage of crushed or broken, and totally rounded particles</td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td>Affinity of coarse aggregates to bituminous binders</td>
<td>4.2.11 Affinity to bituminous binders</td>
<td></td>
<td>Declared value</td>
<td></td>
</tr>
<tr>
<td>Resistance to fragmentation, crushing of coarse aggregate</td>
<td>5.2 Fragmentation</td>
<td>4.2.2 Fragmentation</td>
<td>5.2 Fragmentation</td>
<td>Category</td>
</tr>
<tr>
<td>Resistance to polishing, abrasion or wear</td>
<td>5.3 Wear</td>
<td>4.2.3 Polishing</td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.4.1 Polishing</td>
<td>4.2.4 Surface abrasion</td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.4.2 Surface abrasion</td>
<td>4.2.5 Wear</td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.4.3 Abrasion from studded tyres</td>
<td></td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td>Resistance to thermal shock</td>
<td></td>
<td>4.2.10 Thermal shock</td>
<td>Declared value</td>
<td></td>
</tr>
<tr>
<td>Composition/content</td>
<td>6.2 Chlorides</td>
<td>4.3.2 Chemical composition</td>
<td>6.2 Acid soluble sulphate</td>
<td>Declared value</td>
</tr>
<tr>
<td></td>
<td>6.3.1 Acid soluble sulfates</td>
<td></td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.3.2 Total sulfur</td>
<td></td>
<td>Pass/fail threshold value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.4.1 Constituents which alter rate of setting/hardening of concrete</td>
<td>6.4.1 Constituents which alter rate of setting/hardening of hydraulic bound mixtures</td>
<td>Pass/fail threshold value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.5 Carbonate content of fine aggregate for concrete surfacing</td>
<td>6.3 Total sulphur</td>
<td>Declared value</td>
<td></td>
</tr>
<tr>
<td>Volume stability</td>
<td>5.7.2 Vol. stability-drying shrinkage</td>
<td>4.4.3.1 Dicalcium silicate disintegration of air-cooled BFS</td>
<td>6.2 Acid soluble sulphate</td>
<td>Category</td>
</tr>
<tr>
<td></td>
<td>6.4.2 Constituents which effect Vol. stability of air-cooled BFS</td>
<td>4.3.4.2 Iron disintegration of air-cooled BFS</td>
<td>Pass/fail threshold value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.3.4.3 Vol. stability of steel slag aggregates</td>
<td>4.3.4.3 Vol. stability of steel slag aggregates</td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td>Water absorption</td>
<td>5.5 Particle density/water absorption</td>
<td>5.5 Water absorption</td>
<td>Declared value</td>
<td></td>
</tr>
<tr>
<td>Durability against freeze/thaw</td>
<td>5.7.1 Freeze/thaw resistance of</td>
<td>4.2.9.2 Resistance to freezing and</td>
<td>7.3.2 Resistance to freezing</td>
<td>Category</td>
</tr>
</tbody>
</table>
## Table 8.2 Scope and Relevant Requirement Clauses for Fillers

<table>
<thead>
<tr>
<th>Essential Characteristic</th>
<th>BS EN 1324 Class</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffening properties</td>
<td>5.5.2 Bitumen number of added filler aggregate for bituminous mixtures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.4.3.3.2 'Delta ring and ball' of filler aggregate for bituminous mixtures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.3.3.1 Voids of dry compacted filler aggregate</td>
<td></td>
</tr>
</tbody>
</table>
| Water solubility and water solubility of 
  either aggregate or 
  binder | 5.4.1 Water solubility and water solubility of either aggregate or binder |      |
| Cleanliness | 6.2.2 Flakiness |      |
|            | 5.5.6 Blaine test |      |
|            | 5.5.5 Blaine number of added filler aggregate |      |
|            | 5.5.1 Blaine number of added filler aggregate |      |
|            | 5.5.3.1 Voids of dry compacted filler aggregate |      |

### Passing Category

<table>
<thead>
<tr>
<th>Category</th>
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<tbody>
<tr>
<td>Category</td>
<td></td>
</tr>
</tbody>
</table>

### Declared Value

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
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### Pass/fail threshold value

<table>
<thead>
<tr>
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<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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### Volume Stability

<table>
<thead>
<tr>
<th>BS EN 1324 Class</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

### Durability against freeze/thaw

<table>
<thead>
<tr>
<th>BS EN 1324 Class</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Durability against weathering

<table>
<thead>
<tr>
<th>BS EN 1324 Class</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Durability against alkali-silica reaction

<table>
<thead>
<tr>
<th>BS EN 1324 Class</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

### Durability against alkali-silica reaction

<table>
<thead>
<tr>
<th>BS EN 1324 Class</th>
<th>Notes</th>
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<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Durability against freeze/thaw

<table>
<thead>
<tr>
<th>BS EN 1324 Class</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
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<td></td>
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</tbody>
</table>

### Durability against weathering

<table>
<thead>
<tr>
<th>BS EN 1324 Class</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

### Durability against alkali-silica reaction

<table>
<thead>
<tr>
<th>BS EN 1324 Class</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8.2.2 Standard test methods for aggregates

The above aggregate standards utilise a number of further standards for the actual testing of aggregates. These tests are for general properties (BS EN 932), geometrical properties (BS EN 933), mechanical and physical properties (BS EN 1097), thermal and wearing properties (BS EN 1367) and chemical properties (BS EN 1744). Each of these standards is divided into a number of parts for the individual tests as indicated below.

BS EN 932 Tests for general properties of aggregates.
1. Methods for sampling.
3. Procedure and terminology for simplified petrographic description.
5. Definitions of repeatability and reproducibility.

BS EN 933 Tests for geometrical properties of aggregates.
2. Determination of particle size distribution. Test Sieves, nominal size of apertures.
5. Determination of percentage of crushed and broken surfaces in coarse aggregate particles.
10. Assessment of fines. Grading of fillers (air-jet sieving)

BS EN 1097 Tests for mechanical and physical properties of aggregates.
1. Determination of the resistance to wear.
3. Determination of loose bulk density and voids.
4. Determination of the voids of dry compacted filler.
5. Determination of the water content by drying in a ventilated oven.
7. Determination of the particle density of filler. Pyknometer method
8. Determination of the polished stone value.
9. Determination of the resistance to wear by abrasion from studded tyres. Nordic test
10. Determination of water suction height.

BS EN 1367 Tests for thermal and wearing properties of aggregates.
1. Determination of resistance to freezing and thawing
2. Magnesium Sulfate test
3. Boiling test for Sonnenbrand basalt
4. Determination of drying shrinkage
5. Determination of resistance to thermal shock.

BS EN 1744 Tests for chemical properties of aggregates.
1. Chemical analysis
2. Determination of resistance to alkali reaction (in preparation)
3. Preparation of eluates by leaching of aggregates.
4. Determination of susceptibility of fillers for bituminous mixtures.
5. Determination of acid soluble chloride salts
8.2.3 Standard specifications for mixtures incorporating aggregates and test methods for mixtures incorporating aggregates

These standards for aggregates and aggregate testing are complemented by standards for unbound, hydraulic bound, bituminous bound and concrete mixtures and for specific constituents of the mixtures. Some of the more relevant standards are as follows:

**Unbound and hydraulic bound mixtures**
- **BS EN 13055-2: 2004** Lightweight aggregates. Lightweight aggregates for bituminous mixtures and surface treatments and for unbound and bound applications.
- **BS EN 13286** Unbound and hydraulic bound mixtures - Test methods (in 20 parts).

**Bituminous bound mixtures and surface treatments**
- **BS EN 58: 2004** Bitumen and bituminous binders – Sampling bituminous binders.
- **BS EN 12272** Surface dressing – Test methods (in 3 parts).
- **BS EN 12274** Slurry surfacing - Test methods (in 8 parts).
- **BS EN 13055-2: 2004** Lightweight aggregates. Lightweight aggregates for bituminous mixtures and surface treatments and for unbound and bound applications.
- **BS EN 13179** Test for filler aggregate used in bituminous mixtures (in 2 parts).

**Concrete**
- **BS EN 450-1:2005** Fly ash for concrete. - Definition, specifications and conformity criteria.
- **BS EN 12350** Testing fresh concrete. (in 7 parts).
- **BS EN 12390** Testing hardened concrete. (in 8 parts).
- **BS EN 13055-1: 2002** Lightweight aggregates. Lightweight aggregates for concrete, mortar and grout.
- **BS EN 13877-1: 2004** Concrete pavements. Materials.
- **BS EN 13877-2: 2004** Concrete pavements. Functional requirements for concrete pavements.

**Surface characteristics**
- **BS EN 13036** Road and airfield surface characteristics – Test methods.

8.3 Specifications
There are a number of specifications that are applicable to highway engineering construction and maintenance activities.

8.3.1 British Standards
Some specification of materials, mixtures and construction activities are undertaken through the use of British Standards. Examples of these are given below:
8.3.2 Specification for Highway Works

The Specification for Highway Works (SHW) (Highways Agency et al.) is probably the foremost document for specifying materials and the method of operation for highway construction. It is published as Volume 1 of the Manual of Contract Documents for Highway Works and contains 27 Series and 8 Lettered Appendices relating to different aspects of highway construction. It is published by the Stationery Office and is available online at www.standardsforhighways.co.uk. This document is often either adopted as it stands or used with specific modifications dependent upon the client authority. The document is divided into a number of series and the relevant series for pavement construction are as follows.

500 Series – Drainage and service ducts
600 Series – Earthworks
700 Series – Road pavements - General
800 Series – Road pavements – Unbound, cement and other hydraulic bound materials
900 Series - Road pavements – Bitumen bound
1000 Series - Road pavements – Concrete materials
1100 Series Footways

500 Series – Drainage and service ducts
This Series covers all items relating to drainage, including pipes (which may be cast iron, concrete, vitrified clay or plastic), pipe bedding and surround material, filter drains, gullies, chambers, surface water channels and drainage channel blocks. Recycled coarse aggregate and recycled concrete aggregate are permitted constituents for pipe bedding and surround material. It shall have been tested in accordance with Clause 710 and comply with the requirements of Table 8/3. This specifies a maximum of 1% by mass for foreign materials including wood and plastic and a limit of 50% for asphalt. In practice it is likely that high values of asphalt would not be desirable in pipe bedding material, as it would prevent the material flowing freely into the trench and potentially lead to long term settlement.
600 Series - Earthworks
This series defines acceptable and unacceptable materials, bedding material for pipes, fill for structures and general fills, capping materials, materials for stabilisation, topsoil material, landscape material and methods of determining material properties.

The SHW requires that all recycled aggregates (RA) and recycled concrete aggregates (RCA) must be produced in accordance with the Quality Protocol for the production of aggregates from inert waste published by WRAP (2004b). Clause 601.12 requires that all recycled aggregates used shall have an upper limit of 1% on other materials (Class X); this is the sum of contaminants such as metal, wood and plastic. Where recycled aggregates except recycled asphalt are permitted, Clause 601.12 states that the aggregate “shall not contain any mineral aggregate with a bituminous binder, and the content of all foreign materials shall not exceed 1%”.

The 600 Series has been much less affected by the change to harmonised European Standards than the other Series. Other than the introduction of Class 6F4 & 6F5, in which the requirements are set out in accordance with BS EN 13242, the only other change has been the replacement of the ten percent fines value test with the Los Angeles test for resistance to fragmentation. Other than composition, the requirements for recycled and secondary aggregates are exactly the same as for primary aggregates for all applications. The only exception is Classes 6F4 and 6F5, capping imported to site, where test methods and limiting values for volume stability of blast furnace and steel slag are given. These classes were introduced in May 2004 in response to the introduction of harmonised European Standards for aggregates.

700 Series Road Pavements – General
This series contains a clause (Clause 710) on testing for constituent materials in RA and RCA. The material is sorted into 6 classes, the proportions of which are recorded:

- Asphalt (Class A)
- Masonry (brick and block other than lightweight block masonry) (Class B)
- Concrete and concrete products (Class C)
- Glass (Class G)
- Lightweight block masonry or particles (Class L)
- Unbound aggregates (Class U)
- Other materials (Class X)

These categories are slightly different from those suggested in Annex A of BS EN 13285: 2003, and the classification scheme set out in BS EN 13285 for mixtures containing recycled aggregates is not used.

800 Series – Unbound Mixtures
There are five types of unbound sub-base mixtures, each with slightly different permitted constituents:

- Type 1 unbound mixture shall be made from crushed rock, crushed slag, crushed concrete, recycled aggregates or well burnt non-plastic shale. Recycled aggregate shall not contain more than 50% asphalt.
- Type 2 unbound mixtures shall be made from natural sands, gravels, crushed rock, crushed slag, crushed concrete, recycled aggregates or well burnt non-plastic shale. Recycled aggregate shall not contain more than 50% asphalt.
- Type 3 (open graded) unbound mixture shall be made from crushed rock, crushed blastfurnace slag or recycled concrete aggregate. Recycled concrete aggregate shall not contain more than 5% asphalt.

- Category B (close graded) unbound mixture shall be made from crushed rock, crushed blastfurnace slag or recycled concrete aggregate. Recycled concrete aggregate shall not contain more than 5% asphalt.

- Type 4 (asphalt arisings) asphalt arisings shall be either asphalt road planings or granulated asphalt and shall have an asphalt content of greater than 50%. They may also contain crushed rock, crushed slag, crushed concrete and well burnt non-plastic shale.

800 Series – Hydraulically Bound Mixtures
Hydraulic bound mixtures may use cement, slag fly ash or other hydraulic binder as the binder and lime, in the form of hydrated lime or quicklime, as an activator. A range of recycled and secondary aggregates can be used as the coarse aggregate in these materials. The 800 Series also deals with soils treated with binders for use as sub-base; soils treated with binders for use as general fill or capping are covered by the 600 Series.

900 Series – Bituminous bound materials
The 900 series of clauses in the SHW permits the use of RA and RCA in asphalt. Reclaimed asphalt (recycled asphalt, RAP) may be used in the production of asphalt surface course, binder course, regulating course and base. The maximum amount of RAP permitted is 10% in the surface course and 50% in all other layers. There is no requirement to check the quality of the aggregate in the RAP. It is presumed that, because the aggregate come from existing pavements or from a material that was intended for new works, the aggregate quality is adequate for re-use.

1000 Series – Concrete materials
The 1000 Series of the SHW is concerned with concrete road pavements. There are currently a number of restrictions on the use of aggregates in Clause 1001 of the SHW. All aggregates must comply with the requirements of BS EN 12620 (2002).

1100 Series – Kerbs, footways and paved areas
Kerbs are generally of concrete. Footways may be either asphalt (bituminous bound materials) or concrete, and the requirements are similar to those for road pavements (900 and 1000 Series). Requirements for sub-base are also similar to those for road pavements (800 Series). Slabs for paved areas may be precast concrete slabs, natural stone, insitu concrete, clay pavers, concrete blocks or grass concrete.

8.3.3 Specification for the Reinstatement of Openings in Highways
This Specification was produced by the Highway Authorities and Utilities Committee (HAUC) and is used in England and with slight modifications in Wales. The current edition was published in 2002 Department for Transport, 2002). In Northern Ireland and Scotland it also has slight modifications and is called the Specification for the Reinstatement of Openings in Roads. The current editions were published in 2003.

This specification states that:

"An Undertaker may adopt alternative materials, layer thickness and compaction methods to take advantage of new or local materials and/or alternative compaction equipment, subject to prior agreement of the Authority"
which shall not be withheld unreasonably. There shall be no departure from the performance requirements during the guarantee period.

Recycled, secondary or virgin materials, or any combination thereof, are permitted by this Specification, provided they meet the performance requirements and any compositional details required in this Specification for the relevant material.

Stabilised materials shall be permitted for use as surround to apparatus, and as backfill and sub-base layers, provided they meet the relevant performance required in this Specification.

An Alternative Reinstatement Material (ARM) may be used for the entire surround to apparatus and/or the entire backfill layer."

The Notes for Guidance to the Specification state that in order to allow ‘new materials’ to be proven, by development testing, or ‘local materials’ that are known to give acceptable performance in service, the materials and relevant layer thickness quoted in the Specification may be amended or supplemented, subject to prior agreement.

For backfill applications
Alternative aggregates, such as slag, fly ash, clinker and furnace bottom ash, that fail the 10% fines requirement may still be acceptable if satisfactory performance can be proved. Chalk may be used as backfill, the application being dependent upon the density of the material.

For sub-base and base reinstatements
For these reinstatements CBM3 or ARMs may be used. In the new designation of hydraulic bound mixtures in BS EN 14227-1, a CBM3 would be equivalent to a CBGM B (C10/12 or T3). It may also be possible to use other mixtures with binders such as slag (SBM B1), fly ash (FABM1) or hydraulic road binder (HRBBM1) of a similar class; these mixtures are specified in BS EN 14227 Parts 2, 3 and 5 respectively. These materials have a slower rate of gain of strength and remain workable for a longer period of time. Thickness designs for these materials are based on one year strength and the mixtures can be designed to give a range of strengths.

Permanent cold-laysurfacing materials (PCSMs)
Problems can occur with hot-lay materials when only small quantities are required or the site is remote from the nearest plant. Cold-lay surfacing materials can be formulated to give performance equivalent to hot laid materials (Burtwell, 1995). However, the materials need to be adequately compacted to give satisfactory performance.

Alternative reinstatement materials (ARMs)
New or alternative materials have been, or may be, developed that allow more rapid, reliable and cost-effective reinstatements, with less dependence on the skill and physical effort of the operators and have significant environmental and practical advantages. ARMs require Approval Trials carried out by formal agreement between the Undertaker and the Authority under Appendix A9 of the Specification for the Reinstatement of Openings in Highways. Trials have to be carried out to find the best way of handling the materials to obtain satisfactory performance. Local Authorities should share the results of such trials with each other and use them as ‘building blocks’, so that with more experience the best methods of working are determined and used for the benefit of all parties. In an advice note issued in 2007,
HAUC state that hydraulic mixtures and foamed bitumen mixtures manufactured and used against the detailed requirements given in the Specification for Highway Works should not be regarded as ARMs (HAUC (UK), 2007).

ARMS are categorised into two groups:

**Structural Materials for Reinstatements (SMRs)**
This generic group of materials may be proprietary or alternative bound materials and may be used as sub-base on any reinstatement or as sub-base and base in Road Types 1, 2, 3 and 4, that is up to 30msa traffic loading. These may be:
- Foamed Concretes for Reinstatements (FCRs)
- Flowable SMRs (FSMRs)
- Non-flowable SMRs (NFSMRs)

FCRs are cement bound materials prepared off-site, as ‘prescribed’ mixtures and are flowable with low strengths from 2MPa or 4MPa up to 10MPa at 90 days. FSMRs and NFSMRs may comprise any type/or combination of aggregates and binders but may only be used on a trial basis by prior agreement.

**Stabilised Materials for Fills (SMFs)**
SMFs include materials derived from excavated spoil, virgin, secondary or recycled materials, or any combination thereof, that have been improved by processing, re-grading and/or by the inclusion of a binder. They are usually prepared on site and are non-flowable but may be only used on a trial basis by prior agreement. They are classified by their ‘soaked’ CBR value and may be used as surround to apparatus, backfill and/or as sub-base.

**8.3.4 TRL 611 – Cold recycling**
TRL 611 (Merrill *et al.*, 2004) is a guide to the use and specification of cold recycled materials for the maintenance of road pavements. It utilises the linear quarry concept where the existing highway is used as a source of materials and has gained considerable favour in recent years following the introduction of the first nationally consistent guidelines in TRL Report TRL 386 (Milton and Earland, 1999).

Cold recycling is evolving into a major construction activity. *In situ* and *ex situ* variants of hot and cold techniques are now all feasible and many organisations can offer these services. Cold recycling allows for screening and crushing of aggregates and the *ex situ* process allows the use of alternative aggregates from sources other than the existing pavement.

This guide is aimed at ‘end performance’ requirements and sets out design guidelines and specifications applicable to both *in situ* and *ex situ* recycling techniques. Materials have been divided into families based upon the binder or binder blend being used in the construction. The guide covers a wide spectrum of road types from lightly trafficked roads to heavily trafficked trunk roads.

The pavement designs encompass the latest design methodology which utilises the material properties at one year. This enables the slower curing materials to be used in an equivalent manner to traditional materials. The material specification focuses on quality control of the material to ensure that proposals for end-performance made at the mix design stage are achieved in the permanent works. A Quality Plan, prepared by the contractor and agreed with the client, forms the core of the Specification for
cold recycled materials. It covers the entire production process of cold recycled materials from mix design through to *in situ* end-product testing.

### 8.3.5 HD 39 Footway design

HD 39 provides guidance on new footway construction. It suggests various locally available materials which may be suitable for use as sub-base for footways. These include:

- Initial sweepings from 10mm and 14mm surface dressing.
- Bituminous planings.
- 20mm and 28mm nominal single sized aggregates (0/20 and 0/28).
- Spent railway ballast screened to remove the 20mm down material which may contain contaminants.
- China clay sand.
- Crushed kerbstones.
- Slate waste.

When using the above materials, some considerations that should be taken into account are:

- The blending of aggregates may be beneficial where there is a single size material as these may be difficult to compact.
- Bituminous planings exhibit considerable resistance to compaction due to friction of the bitumen coated aggregate; hence, they must be compacted at optimum moisture content with maximum layer thicknesses of 150mm.
- SHW durability requirements for sub-base still apply.
- Materials that may not remain well drained throughout their design life should be stabilised.

### 8.4 Variations to specifications and design guidance

Many Local Authorities have developed variations to the Specification for Highway Works over the years to suit the materials and conditions prevailing in their area. Examples are given in Box 8.2 and 8.3.

Design guidance for trunk roads and motorways is given in the Design Manual for Roads and Bridges, available at [http://www.standardsforhighways.co.uk/dmb/index.htm](http://www.standardsforhighways.co.uk/dmb/index.htm). Guidance on the use of specific techniques and materials is given in a number of TRL Reports; those dealing specifically with recycling and recycled and secondary aggregates are shown in Box 8.4.

If an Authority does not wish to use the SHW then the approach would be to develop a specification based on functional requirements i.e. what is the finished product required to do?

This is an approach that draws on performance as the means of specification and in recent years has become easier to adopt with the development of new test procedures and the introduction of European Standards. Functional requirements can be attributed to each of the elements in a road structure as illustrated in Table 8.3.
In addition to the individual layer requirements specifications should also address:-

- Health and Safety issues for installers and end users,
- End of life issues,
- Minimising the environmental impact of the material,
- Quality Control,
- Acceptance criteria.

Further guidance can also be found on the WRAP AggRegain website.
Box 8.2 Variation of Specification to Enable use of Recycled and Secondary Aggregates by Devon County Council

This case study involved the renovation of a household waste recycling centre at Okehampton by Devon County Council. The Specification for Highways Works was used with additions to certain clauses to specifically reference how and where the sustainable construction materials were to be used. It was stated that preference must be given in sourcing products to those which have been produced in a sustainable manner. Products in this category were classed as those including significant use of recycled and secondary materials, where minimum energy was used in manufacture, and where minimal contaminants are used or produced and where transportation is kept to a minimum. Overriding these conditions was the criterion for retention of ‘normal’ durability and service life.

The contract was carried out with no additional cost or perceived reduction in durability. The contractor was encouraged to adopt sustainable policies through a written agreement and a bonus payment scheme. Recycled and secondary aggregates were used in several applications, including:

- Recycled asphalt planings as unbound sub-base for flexible and concrete pavements;
- Recycled glass as coarse aggregate in asphalt binder course;
- Recycled concrete aggregate as coarse aggregate in asphalt base;
- Coarse aggregate from China clay spoil in concrete pavement

The scheme has been a success in various ways – the construction of a user-friendly and attractive recycling centre has led to a large increase in the use of the facility. The project has been recognised with a Merit Award Commended from the Institute of Civil Engineers and a Devon Environmental Business Initiative Award for Sustainable Development.
Box 8.3 Aberdeenshire County Council

Aberdeenshire County Council has developed their own set of specifications based on the Specification for Highway Works and the Design Manual for Roads and Bridges. The specifications include the following statement about the use of recycled/secondary materials:

“The use of recycled materials in carriageway and footway construction will be favourably considered regarding the following situations, at the discretion of the Local Roads Authority’s Representative:

1. Recycled bituminous materials on the base layer of roads designed to carry up to 1.5 MSA.
2. Recycled granular materials in sub-base layers and capping layers if in accordance with the appropriate specifications for grading and frost susceptibility.
3. Both recycled bituminous and granular materials will be allowed in footway, footpath and cycletrack construction.”

The full specification can be viewed at http://www.aberdeenshire.gov.uk/roads/developments/part123.pdf

Design standards used in the UK have tended to focus on a limited range of materials which has not encouraged designers to consider alternatives. Recent work at TRL, sponsored by the Highways Agency, has examined a much wider range of materials and has developed a versatile design approach to enable their use. This was published in October 2004 as TRL 615 (Nunn, 2004) and this approach has been incorporated into the latest revisions of HD25 and HD26.

In recent years there have been developments in the use of hydraulically bound materials, which can have a number of applications in major and minor roads and heavy duty paving. Hydraulically bound materials include cement bound material and materials with secondary binders such as pulverised-fuel ash and steel slag. Recycled aggregates can often be used as the coarse aggregate for these materials. They are covered by Series 800 of the SHW and BS EN 14227. WRAP has produced a technical guidance document and case studies of the use of recycled and secondary aggregates in hydraulically bound materials, available at www.aggregain.org.uk.

Further guidance, specific to Scotland, has been developed as part of the Net Pave project and is available on the AggRegain web site. The document, “A design and specification guide for Scotland’s road authorities to facilitate use of RSA” (SCOTS, 2006), reflects the desire of the Scottish Executive to encourage the use of recycled and secondary aggregates in sustainable resource use and to reduce the demand for primary aggregate extraction. The guidance is based on TRL Reports 611 (Merrill et al., 2004) and 615 (Nunn, 2004) and introduces the concept of performance specifications based on analytical design techniques. This guidance could equally well be used by other Local Authorities as a way of introducing new concepts that encourage recycling and sustainable construction methods into their own specifications.
<table>
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<th>Layer</th>
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| Surface Course           | The running surface which seals the construction and provides a smooth ride, skid resistance and some resistance to wear | • Deformation resistance  
                           |                                                                            | • Fatigue resistance       |
|                          |                                                                             | • Skid resistance                                  |
|                          |                                                                             | • Riding quality                                   |
|                          |                                                                             | • Workability                                      |
|                          |                                                                             | • Impermeability                                   |
|                          |                                                                             | • Noise reduction                                  |
|                          |                                                                             | • Spray reduction                                  |
| Binder Course & Base     | The main structural layer whose purpose is to distribute stresses induced by repeated loading over the foundation and to withstand internal stresses without deformation or excessive cracking | • Stiffness                                       |
|                          |                                                                             | • Deformation resistance                          |
|                          |                                                                             | • Fatigue resistance                               |
|                          |                                                                             | • Workability                                      |
|                          |                                                                             | • Impermeability                                   |
| Sub base                 | A regulated platform of consistent strength capable of supporting the subsequent construction activities. It contributes to the overall structural strength and should protect the subgrade from the ingress of water | • Strength/Stiffness                               |
|                          |                                                                             | • Stability                                        |
|                          |                                                                             | • Durability                                       |
|                          |                                                                             | • Permeability                                     |
| Capping                  | Provides a working platform for construction and in the longer term contributes to overall structural strength | • Strength/Stiffness                               |
|                          |                                                                             | • Stability                                        |
|                          |                                                                             | • Durability                                       |
### Box 8.4 TRL Reports Dealing with Recycling

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### Published Project Reports

| PPR080    | Tyre bales in construction, by M G Winter, G R A Watts and P Johnson.                       |
| PPR057    | Optimising the use of recycled and secondary aggregates in Hampshire, by C R Sowerby, J Lovell and J M Reid. |
| PPR045    | Tyre bales in construction: case studies, by M G Winter, J M Reid and P I J Griffiths.      |
| PPR057    | The susceptibility of recycled concrete aggregate to alkali silica reaction, by AJJ Calder and M McKenzie. |
| PPR036    | The use of recycled concrete aggregate in structural concrete, by AJJ Calder and CP Roberts. |
| PPR012    | Design guide for pavements incorporating slag-bound mixtures (SBM), by M Nunn and K E Hassan. |

### Viridis Reports

| VR8       | Design guide for applications of sandstone quarry sand in South Wales, by M J Lamb.         |
| VR5       | Civil engineering applications for tyres, by K Hylands and V Shulman.                        |
| VR4       | The construction industry mass balance: resource use, wastes and emissions, by R A Smith, J R Kersey and PJ Griffiths. |

### Other

Recycling in transport infrastructure, by JM Reid and JWE Chandler.
9 Selecting Materials on the Basis of Environmental and Sustainability Factors

9.1 General considerations
The previous chapters have considered the technical, contractual and logistic aspects of recycling and the use of recycled and secondary aggregates. This chapter considers how the environmental and sustainability effects can be brought into the decision-making process when selecting materials for highway and footway maintenance and new construction.

Securing the Future is the UK sustainable development strategy launched by DEFRA in 2005. It identifies a number of priority areas where action is needed, including:

- Sustainable consumption and production;
- Climate change and energy;
- Natural resource protection and environmental enhancement;
- Sustainable communities.

The Government also developed Building a Better Quality of Life (DETR, 2000), a strategy for sustainability in construction which is currently under review. A draft strategy for sustainable construction was issued in 2007 (BERR, 2007), and the final version is due to be published in June 2008 (see http://www.berr.gov.uk/sectors/construction/sustainability/page13691.html).

In March 2005 the National Audit Office (NAO) published its report “Improving Public Services through better construction” (HC 364-1 Session 2004-05, www.nao.org.uk/publications/nao_reports/04 - 05/0405364.pdf). The document makes a number of recommendations on sustainable construction:

- Recommendation d: “Consider the development of a sustainability action plan to cover all aspects of construction activity, and to demonstrate how the department is contributing to the Government’s objectives for sustainable development. In particular, the development of appropriate project-specific key performance indicators such as reduced carbon dioxide emissions and reduced waste to landfill.”

- Recommendation e: “Make decisions about construction projects based on sustainable whole-life value, using a structured and robust decision-making process from the outset that identifies the trade-offs between capital costs, running costs, and social and environmental impacts.”


Local Authorities are crucial to the promotion and implementation of sustainable development through their activities, including highways maintenance. This is achieved through setting out high level sustainability objectives and targets and measurement frameworks. One of the difficulties encountered is however to ensure that those objectives translate into policies and actions that each department can implement to contribute effectively to the overall targets.
Highways maintenance has an important role to play in delivering sustainability, through provision of a network of local roads fit for purpose that serves the community and supports economic prosperity but with minimum impact to the environment.

This section provides information on the environmental issues to be taken into account to decide upon materials and techniques which maximise sustainability. It should be noted that by addressing environmental issues, there are a number of economic and social benefits to be realised for the Council and the local community.

This section also describes some existing tools that can help local authorities’ highways engineers to make the most sustainable decision. The tools also provide a way to demonstrate and report on how the option contributes to the sustainable development agenda at local and national level.

The review of those tools has inspired the list of performance indicators and the sustainability checklist that could be used for monitoring and demonstrating the sustainability performance of highways maintenance activities and materials. These tools tie in with existing checklists and indicators used at Council level and by industry, and take into account existing good practice implemented by local authorities to improve the sustainability of their highway maintenance operations.

9.2 Maximising the environmental contribution made by highway maintenance materials

Section 15 of Well maintained Highways identifies a range of relevant issues affecting the environment including a few directly related to materials and maintenance techniques:
- noise;
- materials utilisation;
- waste management and recycling; and
- pollution control.

9.2.1 Noise

Noise pollution from traffic can be a very relevant issue for local communities. Alongside structural intervention such as noise barriers, specific surfacing materials can be chosen to mitigate the effects of the noise. Porous asphalt, stone mastic asphalt and some proprietary thin surfacing systems provide a road surface on which tyres will generate less noise. However, the choice of quieter surfacing materials will also need to take into account other engineering and maintenance requirements such as skid resistance and whole life value, including maintenance cost. Furthermore, although quieter surfacing materials might be a more expensive option, benefits for the local community are likely to outstrip the cost. Tools to quantify the benefits are discussed later.

Road maintenance operations cause nuisance to local communities, and noise can be a major issue particularly during night closures. A solution is to try and shorten the times of the operations. Recycling processes can often be quicker and require less machinery/trucks movements than traditional methods: for example, in-situ or ex-situ cold recycling reduces time by around 25% and does not require trucks to take away planed materials.
9.2.2 Materials utilisation

Careful choice of materials, considering factors such as the way they are supplied, location of sources and review of specifications, can contribute to the sustainability objectives of the Council. The inherent risks associated with adopting new or alternative materials and/or techniques have been successfully addressed in many cases throughout the country.

The use of primary materials contributes to the depletion of natural resources and therefore, wherever possible, their use should be minimised. This implies reviewing the specifications to consider less stringent requirements and the use of recycled materials, providing the whole life value and safety performance of the road can be guaranteed and there are not secondary undesirable effects such as an increase in pollution from increased transport distances.

Many local authority highways specifications are often based on the Highways Agency’s Specifications for Highways Works (Moulinier et al., 2006). On one hand this ensures that safe and tried constructions are adopted but on the other can lead to cases of over-specification.

Box 9.1 Adopting Leaner Specifications
Cornwall County Council has recognised that safety of local roads where speed is restricted can still be maintained using aggregates at lower polished stone value. This has the main advantage of reducing costs, transport requirements and depletion of very precious natural resources.

Years of research and technological advances on recycled and secondary materials have concluded that they can be used as substitute to virgin materials whilst maintaining similar performance and often providing cost benefits.

- Road furniture items such as road signs, bollards, lampposts and benches containing a percentage of recycled materials are now widely available.
  Plastic items, made with post-consumer waste offer the advantage of being low maintenance, thus realising cost savings.
- Similarly, compost and mulching materials for landscaping are likely to be available from local suppliers, including the Council’s own waste collection and disposal operations.

Box 9.2 Using Recycled Plastics & Compost in Street Furniture and Landscaping
- Blackpool Borough Council specified over fifty recycled plastic benches for use around the town. The benches use 100% plastic recovered from post-consumer waste. They yield cost savings of £50 a year each compared to a ‘conventional’ bench, as they do not require repainting or regular maintenance. They also tend to be more vandal- and graffiti-resistant than the conventional products.
- Cheshire County Council used a locally-produced high quality soil improver from their waste management contractor for a 1.5 km stretch of hedgerow and trees along the length of a new £1 million improvement scheme to widen the A538. The compost is fully certified under the Composting Association’s certification scheme.
Source: The Big Picture
Recycled and secondary aggregates have been successfully used in road construction and the Highways Agency’s specifications now allow for alternative aggregates to be used within unbound, hydraulically bound and bituminous bound layers and pavement quality concrete, as indicated in previous chapters.

Specific protocols for particular materials such as the production of recycled aggregates from inert waste have been developed by WRAP, and protocols for a number of secondary materials are currently being developed by the Environment Agency and WRAP (see section 8.1)

The use of these protocols should give clients confidence that the materials and techniques are fit for purpose. Where necessary, internal procedures, such as establishing a panel of experts or setting up controlled trials, could be adopted by the Council to test and evaluate new products and techniques. If the results of trials carried out by other Local Authorities with similar conditions are available, there may not be a need for every Local Authority to carry out its own trials. Councils should be willing to share information with each other and work together to develop sustainable solutions.

When choosing any material, careful consideration should be given to where it is supplied from and how it is delivered to the site or depot. Buying recycled materials really contributes to the sustainability objectives of the Council if:

- there are not leaner construction techniques available, e.g. in situ recycling;
- the recycled materials are sourced locally, to minimise travel distances and to sustain the local market; and
- they are delivered (or at least part of the delivery journey is made) by a sustainable mode of transport, e.g. by rail or water rather than by truck, to minimise pollution, congestion and nuisance. WRAP’s CO₂ tool (see subsection 9.3.3 below) will help in assessing the emissions associated with transporting aggregates and materials.

9.2.3 Waste management and recycling

Highways maintenance operations can contribute to the Council’s statutory targets on waste minimisation and recycling. There are also economic drivers and regulatory constraints, including the cost of disposing of waste at landfill and the need for separating hazardous waste for disposal in specialist landfills.

Waste minimisation opportunities can be realised through the choice of in situ or ex-situ recycling techniques, from stabilisation to cold/hot methods for bituminous layers (shallow and localised for pothole repairs and rejuvenation of surface or deep and extensive for carriageway reconstruction). They have the additional positive effect of reducing the need for importing new materials.

Waste that cannot be reused on site should be recycled into the highest value materials. This means for example ensuring that waste is properly segregated and stored:

- surface layers containing high value aggregates should be planed away separately and set aside for recycling into surfacing materials;
- top soil, green waste, bituminous materials, concrete items should be taken up and kept separated as they yield high value reusable/recyclable feedstock;
- lightweight contaminations, such as plastic, organic matters, should be separated from the feedstock for recycling.
Although potentially more expensive, the above practices are cost effective, through reducing costs of recycling operations – potentially cutting down on sorting and/or screening – and obtaining higher quality recyclate – less contaminated, homogeneous in quality and therefore useable in higher value applications.

Ensuring that waste generated in highways maintenance is recycled back into highways complements the drive from Council’s objectives and targets on using recycled materials when they are part of a closed loop, where wastes arising locally are recycled locally. The benefits of this are:

- both sets of statutory targets on recycling and using recycled can be met;
- the local market is stimulated, creating both demand and supply;
- transport is minimised for both waste disposal and sourcing of recyclates.

### 9.2.4 Pollution control

Materials for highways maintenance can generate pollution through the way they are transported and/or applied.

As reduction of emissions and improvement of air quality are likely to be sustainability objectives of the Council, the highways engineers should consider the construction and maintenance practices which minimise energy use and air pollution. These include:

- Preferring cold recycling methods to new hot asphalt, which is more energy intensive;
- Choosing construction practices which require fewer machinery movements and are quicker;
- Considering how the materials are supplied: transport by road over long distances generates the most CO₂ emissions as well as contributing to congestion, which in turns affect local air quality.

WRAP’s CO₂ tool (see section 9.3.3 below) can be used to compare the emissions of different construction and materials options.

There are concerns in relation to potential adverse implications deriving from the chemical composition of some of those materials. Recycled and secondary aggregates can for example:

- Contain substances that are soluble in water, such as quick or slacked lime, calcium sulfate, sodium, potassium and magnesium sulfates, iron sulfates, chlorides and heavy metals;
- Produce fine particles when pulverised during milling off and/or crushing, which are hazardous when ingested;
- Produce hazardous fumes or exceed their flash point when heating e.g. during mixing.

Hazardous fumes and dusts and leaching of harmful constituents are both environmental and health and safety hazards.

Various test methods are available to assess the environmental compatibility of and health and safety risks associated with aggregates, depending on how and where the material is to be used and whether the material is collected from known or unknown sources. Specific limit values for tests and potential uses are determined in function of the different construction applications (e.g. bound or unbound) and the hydrological background conditions. Furthermore, the European Directive on the landfill of waste proposes three levels of test: basic characterisation, compliance testing and onsite verification.
British Standards, Highways Agency’s specifications, private and public organisations such as Shell, TRL and the National Institute for occupational Safety and Health have published standard test methods to assess hazardous content of fumes, dust and aromatic compounds, sulphur and sulphide and leachate. A list of tests is provided in Table 9.1, however the highways engineers should consult contractors, experts and/or a UKAS- certified test house for the latest test methods.

Table 9.1 Examples of Tests for Hazardous Content and Leachability

<table>
<thead>
<tr>
<th>Test</th>
<th>Description or standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAH from coal tar: rapid on site spray test</td>
<td>Particles of the material to be tested are sprayed with a chemical from an aerosol can. The particles turn a different colour if PAH is present.</td>
</tr>
<tr>
<td>PAH from dust</td>
<td>Collect dust samples during various processes (milling, cleaning, crushing, etc.) and send for analysis for PAH and inhalable dust.</td>
</tr>
<tr>
<td>Personal exposure to gaseous emissions</td>
<td>Shell method AMS 1086-1</td>
</tr>
<tr>
<td>Personal exposure to bituminous fumes</td>
<td>Shell method AMS 861-3</td>
</tr>
<tr>
<td>Determination of sulfates and sulfides</td>
<td>BS EN 1744-1 except materials for structural backfill TRL447 for materials for structural backfill</td>
</tr>
<tr>
<td>Test on air-cooled blast furnace slag</td>
<td>BS EN 1744-1</td>
</tr>
<tr>
<td>Leachability tests</td>
<td>BS EN 12457-3 BS EN 1744-3</td>
</tr>
</tbody>
</table>

Details on the risk of potential environmental pollution of specific materials are summarised below;

- Coal tar contains polycyclic aromatic hydrocarbons or PAHs (see Chapter 5.2). PAHs are liberated only if the tar asphalt is heated up, i.e. during hot plant mixing or hot in-situ recycling. If the material is encapsulated in a cold mix process, PAHs will not be liberated.
- No other recycled or secondary material other than recycled asphalt can potentially produce noxious fumes when heated.
- Hazardous materials can leach out of the pavement after construction due to contact with moisture and water, particularly from unbound mixtures. However, leaching from bituminous bound or hydraulically bound materials (including concrete) is unlikely.
- Consult any COSHH information available from the producer of recycled or secondary aggregates.
- Recycled aggregates produced under WRAP Quality protocol for the production of recycled aggregates are regarded as inert by definition and will therefore not pose any pollution risk.
- Ensure secondary aggregates covered by Environment Agency/WRAP Waste Protocols (Chapter 6) are handled in accordance with the protocols.
- Avoid the use of secondary aggregates such as slags, ashes and colliery spoil in unbound form below the water table.
• Ensure all slags and ashes are properly weathered in accordance with quality protocols before use
• For materials that contain high concentrations of contaminants, such as slags, ashes and colliery spoil, consider undertaking a site specific assessment of the risks of pollution of surface and ground water if the construction is in sensitive areas such as major aquifers or Sites of Special Scientific Interests (SSSIs). Knowing the provenance of recycled materials is very important if pollution or contamination is to be avoided.
• If there are potential concerns, contact the Environment Agency and other relevant bodies such as Natural England as soon as possible.
• Decide the testing and monitoring regime and acceptable limits on contaminants on a site specific basis.

9.3 Tools for deciding upon and demonstrating sustainability

The tools reviewed in this section consider different aspects of sustainability in construction. They are tools already available and/or adopted by contractors either as voluntary schemes or as compulsory requirements under Highways Agency contracts. Some of the tools have been specifically built to address sustainability in choice of materials, while others consider materials within the assessment of the whole project. Furthermore, some tools consider only some issues while others take into account a number of environmental, social and economic aspects. Finally, two WRAP guides illustrate the procurement mechanisms for implementing sustainability in highways maintenance projects.

Table 9.2 provides an indication of the different applicability and focus of the tools reviewed.

<table>
<thead>
<tr>
<th>TOOL</th>
<th>Focus/applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>SilVia - Sustainable Road Surfaces for Traffic Noise Control</td>
<td>Cost benefits analysis of noise control measures</td>
</tr>
<tr>
<td>Site Waste Management Plans, defra</td>
<td>Waste management and recycling in construction projects</td>
</tr>
<tr>
<td>CO₂ estimator, WRAP</td>
<td>CO₂ emissions associated with construction</td>
</tr>
<tr>
<td>ESRSA tool, WRAP</td>
<td>Sustainability assessment of aggregates supply</td>
</tr>
<tr>
<td>CEEQUAL</td>
<td>All environmental aspects of a civil engineering project</td>
</tr>
<tr>
<td>The Big Picture, WRAP</td>
<td>Choice of materials in highways maintenance</td>
</tr>
<tr>
<td>Recycled Roads, WRAP</td>
<td>As above, concentrating on procurement</td>
</tr>
</tbody>
</table>

The review of these tools has informed the list of performance indicators and the sustainability checklist that could be used for monitoring and demonstrating the sustainability performance of highways maintenance activities and materials.

9.3.1 SILVIA - Sustainable road surfaces for traffic noise control

This European funded project (www.trl.co.uk/silvia) aims to provide decision-makers with a tool allowing them to rationally plan traffic noise control measures. The main
deliverable of the project is a "European Guidance Manual on the Utilisation of Low-Noise Road Surfacing", which integrates low-noise surfaces with other traffic noise control measures including vehicle and tyre noise regulation and traffic management. The project also developed a cost benefit analysis procedure in a downloadable Excel spreadsheet (http://www.trl.co.uk/silvia/silvia/pages/contents_part1.html) which evaluates low-noise surface against other means of noise reduction and provides a cost benefit balance of implementing each measure. It is also complemented by a number of guidance documents on specification of low-noise surfaces, measurement methods and safety.

The cost / benefits balance is calculated on the basis of inputs such as area and traffic data (e.g. density of dwellings, traffic levels and speed) and road data (construction costs, noise characteristics etc.) and takes into account the whole life cost of the low noise surface layer, as compared to alternative noise mitigation measures such as noise barriers and double glazing. An example of the output is shown on Figure 9.1.

9.3.2 Site Waste Management Plans


The aim is that construction companies will use SWMPs throughout a project to keep a record of the waste arising on sites and the way they are managed (reused/recycled on site, sent for reuse/recycling off site, disposed of). This allows clients to monitor the performance of the project against recycling targets, as well as verify compliance with environmental regulations and acknowledge minimisation of costs and risks. It also allows contractors to track their waste arisings and quantify savings from waste minimisation and recycling.

SWMPs are compulsory in England for all construction projects above £300,000 (excluding VAT). A simplified version is required for projects between £300,000 and £500,000 in value, and a full SWMP for projects above £500,000. For many routine highway maintenance activities therefore SWMPs will not be applicable. However, they are likely to be required for major maintenance and new construction.
Figure 9.1 Sample of the Output Sheet from SilVia’s Cost Benefit Analysis Toolkit. Source: Guidance Manual for the Implementation of Low-Noise Road Surfaces.
schemes, and have been used by contractors on a voluntary basis on some major schemes for the Highways Agency.

9.3.3 CO2 Estimator tool
The CO2 estimator tool has been developed by C4S for WRAP and it is freely available for download from the Sustainability module of the AggRegain website ([www.aggregain.org.uk](http://www.aggregain.org.uk)), which also contains the user guide and some case studies exemplifying its application.

The tool aims at estimating the savings in CO2 emissions that can be realised by using recycled and secondary aggregates (RSA) and/or in situ recycling techniques in unbound, bituminous bound, hydraulically bound and concrete applications. The users input technical details of the construction project (such as quantities of and distances travelled by the materials used) for one or all of the applications and can choose up to three different construction options (e.g. using hot or cold asphalt mixing, mix-in-place or mix-in-plant mixtures, different % of RSA, different binders etc.). The calculations are performed using the users’ data and information held in a database that the users can access and improve through adding any process data (e.g. energy consumption of certain pieces of equipment) they might have.

The tool provides estimates of CO2 emissions associated with each option and demonstrates which of the alternative constructions will minimise CO2 emissions. The results are shown in an output sheet that provides details on the savings realised for each application and for the whole project. Users can also access the background calculations to find out which processes contribute the most to the total emissions. In general, road transport and hot techniques are the most energy intensive processes: the choice of local materials and cold techniques can therefore contribute substantially to the minimisation of CO2 emissions.

9.3.4 Environmental Sustainability of Recycled and Secondary Aggregates (ESRSA) Tool
Developed by Viridis (now part of C4S) for WRAP, this tool is freely downloadable from the Sustainability module of the AggRegain website ([www.aggregain.org.uk](http://www.aggregain.org.uk)), which also contains a walkthrough example and a user guide. The tool assesses the sustainability of the supply of aggregates to a construction site. The users input their details in a number of on-screen forms choosing amongst e.g. alternative suitable materials, geographical origin of the supplies, different scoring on the suppliers’ environmental and health and safety record etc.

For each alternative aggregates supply, the tool uses the information to assign a score to each of nine indicators covering environmental, social and economic sustainability (Table 9.3). The nine scores, opportunely weighted to reflect the users’ priorities, are used to draw a radar diagram. The scoring system is built so that the smaller the area of the resulting diagram, and the lower the overall score, the more sustainable the choice of supply.

The indicators, which were agreed with a panel of industry experts, consider the environmental, social and economic impacts of the chosen aggregates and their supply. So for example, materials that are sourced locally would score better on local employment than materials sourced from far away; recycled/ secondary materials score the lowest (i.e. the better) on natural resources used etc.
Box 9.3 Rehabilitation of the A6116 Rockingham Road

The stretch of A6116 north of Corby was in structurally poor condition and required major reconstructive intervention. The client, Northamptonshire County Council worked with the supply chain to find a solution that was fit for purpose whilst having a high component of material reuse. On-site ex-situ recycling for the base and binder course materials and a hot-mix surface course that included 20% recycled materials were selected in preference to conventional reconstruction.

The WRAP CO₂ estimator tool was used to compare the recycled material option chosen by the team with a traditional primary material alternative to estimate any difference in carbon dioxide emitted. The tool was employed to analyse two options as follows:

- Option 1 – The traditional maintenance option with primary aggregates for the bituminous bound materials (hot mix).
- Option 2 – As built option with recycled asphalt used for 100% of the base course aggregates (cold mix) and 20% for the hot mix surface course.

The outputs generated are:

<table>
<thead>
<tr>
<th>Bituminous application</th>
<th>Comparison with the As built option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Maintenance Option (Hot mix base course)</td>
<td>184 t CO₂</td>
</tr>
<tr>
<td>As Built cold recycled option (100% recycled Cold mix base course 20% recycled hot mix surface course)</td>
<td>57 t CO₂</td>
</tr>
</tbody>
</table>

A large proportion of the difference in CO₂ emissions, 127 tonnes, results from the different method of producing the base course. The standard full reconstruction with all primary aggregates would have used a hot mix process and the as built used a cold mix process incorporating the recycled aggregate. Source: AggRegain

Table 9.3 Indicators used in the ESRSA Tool

<table>
<thead>
<tr>
<th>Environmental</th>
<th>CO₂ emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural resources used</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>Environmental / Social</td>
<td>Road transport equivalent</td>
</tr>
<tr>
<td>Environmental Management System</td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>Health and Safety</td>
</tr>
<tr>
<td>Social / Economic</td>
<td>Local employment</td>
</tr>
<tr>
<td>Economic</td>
<td>Price per tonne</td>
</tr>
</tbody>
</table>
Box 9.4 Sustainable Supply of Aggregates to a Road Construction Site in the West Midlands
The ESRSA tool is used to demonstrate the different sustainability rating of primary, recycled and secondary materials that could be supplied to a road maintenance project in a rural setting in West Midlands. The tool identifies automatically which aggregates are likely to be available for the application chosen: in this case, rolled asphalt binder course. The user selects asphalt planings as recycled materials and primary aggregates sourced within the West and East Midlands. It is assumed that the primary aggregates travel by rail to a railways depot within 20 miles from the construction site, and are delivered to the road works by truck.

The user provides some information on likely relative price of aggregates, on likely effect on the local employment and on performance of the suppliers on health and safety and environmental management system - the tool however provides some defaults based on common industry’s practice. The results of the sustainability assessment are shown below in Figure 9.2. The use of recycled asphalt clearly gives the lowest overall score, and is the most sustainable option out of those tested.

9.3.5 The Civil Engineering Environmental Quality and Assessment Scheme (CEEQUAL)
This scheme, developed by a team led by the Institution of Civil Engineers with public financial support and highly recognised within the industry, assesses and awards high environmental quality on civil engineering projects. It can also be used as a checklist to ensure the delivery of high environmental quality within a project. More information on how to apply for an award can be found at www.ceequal.com.

The checklist used within CEEQUAL is very comprehensive and can be used at different stages of the project, with the involvement of the client, the designer and the contractor. It considers, within others, the following issues:

- Project environmental management: on the need for environmental risk assessment, the influence of procurement and contractual processes, minimisation of emissions, the human environment;
- Water issues: control of a project’s impact on, and protection of, the water environment, minimising water usage, legal requirements;
- Energy: in use and performance on site;
- Use of materials: minimising quantity and impacts of materials used, waste minimisation, reuse and recycling, durability and maintenance;
- Waste: legal requirements, on-site waste management;
- Transport: minimising impacts of construction transport;
- Nuisance to neighbours: including minimisation of nuisance from construction noise, vibrations, and pollution to air.

An example of the scoring system used by CEEQUAL with regard to recycled aggregates is shown on Figure 9.3.
Figure 9.2 Sustainability Assessment of Aggregates Supply using the ESRSA Tool
Sections 8 and 9 of CEEQUAL deal with materials and waste respectively. The maximum score available under the Material Use section is 95 points, whilst up to 88 points can be scored in the Waste Management section. Direct, yes/no questions obviously score 0 for negative answers, while open questions reward achievements proportionally, as shown above in Figure 3. Relevant CEEQUAL questions and maximum scoring are:

<table>
<thead>
<tr>
<th>CEEQUAL reference</th>
<th>Question</th>
<th>Maximum points scenario (points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.2.3:</td>
<td>Percentage of non contaminated excavated material beneficially reused:</td>
<td>100% reused on site (7)</td>
</tr>
<tr>
<td>8.2.4</td>
<td>Separation of topsoil and subsoil for reuse after construction</td>
<td>Yes (5)</td>
</tr>
<tr>
<td>8.2.5</td>
<td>Beneficial reuse of topsoil</td>
<td>All on site (3)</td>
</tr>
<tr>
<td>8.4.2</td>
<td>Percentage by volume of materials (excluding bulk fill and sub-base) made from reclaimed or recycled materials</td>
<td>90% and above (8)</td>
</tr>
<tr>
<td>8.4.3</td>
<td>Percentage by volume of bulk fill and sub-base material made from recycled material</td>
<td>60% and above for material generated on site (6)</td>
</tr>
<tr>
<td>8.7.2</td>
<td>Percentage by volume of components used that can be easily separated at demolition stage into material types suitable for recycling</td>
<td>90% and above (6)</td>
</tr>
<tr>
<td>9.1.2</td>
<td>Principles of waste minimisation incorporated in the design of the project and for the construction work</td>
<td>Yes (5)</td>
</tr>
<tr>
<td>9.1.3</td>
<td>Documented mechanism for adopting waste hierarchy to waste minimisation</td>
<td>Adopted and adhered to (8)</td>
</tr>
<tr>
<td>9.3.3</td>
<td>Proportion by volume of material present on site that has been incorporated into the project</td>
<td>60% and above (4)</td>
</tr>
<tr>
<td>9.3.4</td>
<td>Percentage by volume of waste from demolition taken to landfill</td>
<td>10% and less (10)</td>
</tr>
<tr>
<td>9.4.3</td>
<td>Percentage of inert and other non-hazardous waste materials segregated on site and/or sent for reprocessing or recovery</td>
<td>85% and above (7)</td>
</tr>
</tbody>
</table>
9.3.6 The big picture: specifying recycled in local authority contracts for highways maintenance

This good practice guide, published by WRAP in 2004, is specifically aimed at Local Authorities and provides practical information on the sustainability benefits of specifying recycled, the cost-competitive options available and the contractual arrangements that help in maximising the benefits of using recycled. Numerous good practice examples demonstrate how local authorities throughout the country specify and procure recycled while dealing with any associated risk.

The guide also contains a section on Quick Wins – i.e. product options with recycled content that are currently available and offer significant cost and performance advantages – in carriageway and non-carriageway (e.g. landscaping, street furniture) applications, with case studies illustrating their use.

9.3.7 Recycled roads: a step-by-step guide to local authority procurement

Recycled Roads is a procurement guide that presents a model approach to ensure that recycling and reuse of road materials is embedded in all highways contracts and schemes. The document built on a series of events for Local Authorities (Recycled Roads) that ran in 2005 and 2006 around the UK. The two series of workshops, with national and local experts as invited speakers, addressed the benefits of using recycled materials in highways and street maintenance. The presentations from the 2006 series of events and the procurement guide can be downloaded from the Recycled Roads section of the AggRegain web site (http://www.aggregain.org.uk/recycled_roads_1.html).

The guide identifies phases and players in the procurement process where measures should be implemented to ensure sustainable materials and construction practices are used:

- The three procurement phases start from the setting of strategic objectives on waste minimisation and recycling and targets for highways construction. The guide illustrates how the objectives and targets are embedded into tender specifications and evaluation and contracts. Finally, the guide considers the construction phase and deals with supply chain management and risk.
- The chain of players illustrate how objectives set at local authority level become policies and actions in the environment, highways and procurement department and are implemented at contract managers/engineers and contractors level.

9.4 Proposed Key Performance Indicators

Appendix 1 contains a list of key performance indicators (KPIs) developed in consultation with the DfT, the UK Roads Board, Local Authorities and industry representatives. The proposed indicators have been drawn from previous studies and examples of best practice within Local Authorities. They tie in with statutory indicators and KPIs adopted by the construction industry (materials producers and contractors) (Parry, 2005).
The summary companion document to this publication, “Sustainable Highways” (DfT, 2008) contains a set of Key Performance Indicators for sustainability and a proposed sustainability index, based on milestones for sustainability with respect to different layers of the roads structure and KPIs.

9.5 Climate Change
In the near future, it is likely that climate change will influence the choice of materials that are used in construction and maintenance. Current research indicates that climate change will take the form of wetter but warmer winters with less ice and snow, with drier and hotter summers with higher, more extreme temperatures. There may also be increased storminess. Consequently, the Local Authority Engineer will need to consider these long term factors, as well as sustainability, when selecting materials to be used in a construction or maintenance project. Another research project being carried out for DfT has identified seven aspects of climate change that are likely to have significant effects on road construction and maintenance over the next 50 years. These are listed in Table 9.4 with an indication of the issues affecting choice of materials that the Engineer may need to consider when making his final decision. It should be noted that this list is not definitive and is likely to change as time goes by and as research into the long term effects of climate change develops.
Table 9.4 Climate change issues to be considered for selection of materials

<table>
<thead>
<tr>
<th>Climate change prediction/forecast</th>
<th>Possible sustainability considerations for choice of materials</th>
</tr>
</thead>
</table>
| Wetter winters                    | • How durable is cold recycled pavement material if there is more moisture around?  
|                                  | • Advantages of lime/cement stabilisation of subgrade (but caution with respect to sulfates).  
|                                  | • Check adhesion of RA and RCA to bitumen compared to primary aggregates, consider other RSA as well.  
|                                  | • Free draining materials may be more suitable for unbound applications; need to adjust grading envelopes to reduce fines. |
| Warmer winters (less ice & snow)  | • Frost heave less of an issue with fine grained materials e.g. PFA, crushed brick.  
|                                  | • Increased moisture levels in the pavement structure may cause problems. |
| Drier summers                     | • May need more stabilisation of clays in embankments to avoid shrinkage and swelling |
| Hotter summers                    | • May cause problems with bitumen but not with aggregates.  
|                                  | • May want to choose light coloured aggregates or those with low coefficient of thermal expansion. |
| Increased storminess              | • No perceived implication for choice of materials as yet. |
| Changed seasons                   | • Principally affects surface course; most RSA not suitable for use in surfacing |
| Diurnal & other cyclical fluctuation | • Durability of materials important, especially those with high water absorption values (includes most RSA) |
9.5 Conclusions on environmental and sustainability factors

Highways maintenance contributes to the achievement of the Council’s sustainability objectives and targets through for example selecting materials and construction practices which maximise environmental, social and economic benefits.

The guiding principles in choosing a sustainable material should be:

- Review local specifications to ensure over-specification is minimised and leaner construction adopted where applicable: this will contribute to reduce cost and save precious resources;
- Consider construction techniques that use less imported materials, such as soil stabilisation and in situ recycling: this will realise savings in landfill charges and use of natural resources and considerable reduction of truck movements;
- Consider the environmental impact of using recycled and secondary materials, e.g. potential for leaching from unbound materials in areas of sensitive surface or groundwater.
- Seek to maximise the opportunities for recycling highways maintenance waste: this is a cost effective way to minimise waste disposal and contribute to the Council’s recycling targets;
- Where possible use locally recycled materials: this will contribute to the local economy as well as helping the Council towards its targets;
- Carefully consider the secondary effects of using recycled materials imported from distant sources: emissions from transport and associated congestion need to be taken into account.
- Consider the impact of climate change on your choice of materials and techniques over the long term.
- Use the milestones and KPIs in “Sustainable Highways” to set targets and measure progress.

A number of tools to help in assessing and/or measuring the sustainability of highways construction project, materials and/or techniques are available (see Table 9.1). They can help in quantifying the sustainability indicators which this guide proposes (Appendix 1), as developed in cooperation with the DfT, the UK Road board and industry stakeholder.

Figure 9.4 is a decision-making support matrix which summarises the issues considered in this section and highlights areas where the tools described can be used.
Figure 9.4 Decision Support Matrix for Sustainable Selection of Materials for Highway Works
10 Conclusions: how to build a sustainable road

The previous chapters have shown in some detail how sustainable choices of materials can be made for individual layers in a highway or footway pavement or particular techniques for maintenance and new construction. The availability of recycled and secondary aggregates has been described, issues of appropriate standards, specifications, quality control and design methods presented and ways of quantifying the environmental benefits with various tools discussed. The overarching issues of corporate objectives and procurement strategies to deliver them have been described and a range of possible Key Performance Indicators presented. Throughout, a number of case studies have been presented to illustrate particular aspects and a decision support process map has been included. The answers to specific questions on the detail of how to build a sustainable road can, hopefully, be found in the report. A general overview of the process is now given.

The first point is that making sustainable choices about materials for highway and footway maintenance and new construction is not something that should be done in isolation or on a case-by-case, opportunistic basis. This will result in only limited improvements and will soon run up against the many barriers to innovation that exist in Local Authorities and all large organisations such as:

- lack of appropriate standards, specifications and design guides;
- concerns about quality and variability of recycled materials;
- concerns about experience and ability of contractors with new techniques;
- concerns about long term durability of new materials or methods;
- concerns about adequate supplies of suitable materials;
- in some cases, concerns about waste management regulations or public reaction;
- concerns about increased costs;
- logistical difficulties in making changes when most works are small scale and geographically spread out;
- difficulties with changing established ways of working and term contracts to accommodate new methods – why make life difficult?

These are just some of the obstacles that can be encountered by the enthusiastic convert to recycling; Biczysko (2006) provides a more detailed analysis of the problems and also the potential solutions.

The solution lies in approaching the problem from the top down, rather than from the bottom up. By making a link to Local Authority corporate objectives, which generally include sustainability, a focus can be brought on the whole process of highway and footway maintenance, what it is for and how it can be achieved, which allows sustainability to influence the whole process, rather than trying to tack it on at the end. The choice of materials and techniques can then be looked at logically in this overall context, as part of the process, and much greater changes can be achieved as a result. Some examples of Local Authorities that have followed this route are given in Chapter 1, and many more are given in the WRAP publications “recycled roads: a step-by-step guide to local authority procurement” (2005a) and “The big picture” (2004a). Readers are referred to these publications for details of how to set up and carry through this process, including methods of procurement and the setting of Key Performance Indicators. Suggestions are given below for the key steps in the process:
• **Get support from the top** for the key objectives; if the senior officers and elected members can see the benefits and approve the strategy, there is much more chance of making significant changes. Recycling is in tune with public concerns and expectations, so is something that most Local Authorities will be keen to promote to demonstrate their commitment to sustainability.

• **Get all the key players involved at an early stage** to discuss how the process of highway and footway maintenance can be made more sustainable. Whether this is through a formal partnering arrangement or informal working groups is less important than making sure that meaningful discussions take place. This will not only generate more ideas for recycling, it will make it easier to implement new methods than imposing them on reluctant officers, contractors and suppliers who do not see the reason for the changes and have not been involved in the process. This is in line with Early Contractor Involvement on more major contracts.

• **Consider appointing a ‘champion’** to lead up sustainability within the highways department and ensure liaison between all internal and external stakeholders (see Box 10.1). Learn from the experience of the Waste Management and other departments in terms of encouraging recycling.

• **Look at what is appropriate for your area**, in terms of available materials and techniques in relation to the network and traffic loads you are likely to experience. Learn from the experience of neighbouring Local Authorities and bodies such as the Highways Agency who may be carrying out relevant works in or near your area. This may involve making a quantitative assessment of likely arisings from your own highway and footway works and the availability of recycled, secondary and primary aggregates in the area.

• **Liaise with other departments in your Local Authority** to maximise value. The Planning Department will have information on sources of primary aggregates and recycling facilities for other materials. Parks and Countryside Departments may be carrying out small scale works and may either be able to supply materials from their works or use surplus materials from yours. Departments such as Estates, Waste and Education may be constructing access roads and car parks for various facilities, and these provide opportunities for recycling.

• **Ensure that you have adequate logistic support** for recycling activities. The first priority is to maximise value from the arisings from highway and footway maintenance. This involves segregating the materials, either on site or at storage facilities where the materials can be crushed and screened for reuse in new works. Strategically located recycling facilities are required, and these will need appropriate planning permission and waste management licences or exemptions. Senior officers, elected members and the Planning Department must understand the need for these facilities and be willing to support new ones where necessary.

• **Work out a plan for maximising recycling** in the light of the available facilities. This should start with reusing arisings at as high a level as possible, and then extend to using recycled or secondary aggregates in preference to primary ones where appropriate. The WRAP CO₂ estimator tool can be used to compare various options and provide evidence for senior officers, elected members and the public as to which are more environmentally sustainable. This has to be balanced against the cost, but there will generally be agreement between the most economic option and the one generating the lowest CO₂ emissions, as transport is one of the main factors in the generation of emissions.

• **Do not be afraid to use primary aggregates** if analysis shows this to be more sustainable. The source of materials with the least transport distance to
the works will generally be the most sustainable. Especially in many rural areas, this may be local sand and gravel or hard rock quarries.

- **Agree a strategy and set appropriate Key Performance Indicators.** These should be selected with care to be relevant, easy to measure and as close as possible to information that is already being recorded. They also should be as few as possible to be consistent with getting a good measure of progress; if too many KPIs are set, they will inevitably start to work against each other at some point and cause confusion.

- **Insist on an appropriate level of quality control** from suppliers of recycled or secondary aggregates. This should not be an issue with large national companies, but may be more of a problem for small local companies with a waste management rather than aggregate production background. Go through the WRAP quality protocol with them and agree an appropriate level for the works in which the materials will be used. It is a tool to be used, not a stick to beat them with, and will enable them to produce higher quality materials for a wider market.

- **Keep track of materials use** on your projects, either through site waste management plans for larger projects or simpler materials use sheets (see Box 10.2).

- **Create a recycling culture** throughout your department, and in particular encourage the people at the sharp end who have to carry out the work or inspect it. This may involve formal training sessions, but it is most important to get the atmosphere right and demonstrate commitment. Most people will be keen to do something to reduce CO₂ emissions, and many will have pressure from the local population to act more sustainably. Be open to suggestions for ways to make things work better on the ground, so that it is not just something imposed from above.

- **Monitor progress and celebrate success,** both within the team and more widely throughout the Local Authority; this will help to enthuse people and build wider support for the strategy.

- **Aim for continual improvement**, but set realistic targets. After a few years the “quick wins” will be exhausted and more fundamental changes may be required. Plan for these, and involve key stakeholders at an early stage so that an appropriate strategy can be developed and implemented.

If these principles are followed then considerable advances in recycling can be achieved, as many Local Authorities have already shown. The specific choice of materials and techniques fits logically within this larger overall process, and can be advanced by the methods described in this document.
Box 10.1 Implementing Recycling in Gloucestershire County Council’s Highway Maintenance Works

Gloucestershire County Council had a term maintenance contract with Ringway until 2006 and a term consultancy contract with Halcrow till the same date. To bring a fresh approach to cooperative working in the provision of highway maintenance services, in July 2000 these three organisations established the Gloucestershire Highways Partnership. Following a Best Value review in 2002, a new policy was developed on using recycled materials:

“The Partnership shall incorporate as much reused and recycled material as possible into construction and maintenance works on the Gloucestershire network where this can be done without undue detriment to the permanent work or significant increase in overall cost.”

Measures were put in place to implement the policy through design procedures, measurement and payment and by setting targets for the amount of material recycled over a three year period. A ‘champion’ was appointed in May 2003 from within the Partnership in order to lead and steer the recycling initiatives and report to the Partnership Board. The champion has been instrumental in increasing the rate of recycling. The Partnership has proved highly effective at recycling, and targets for future years were revised upwards after the success of the first year.

Key lessons:
- Appoint a champion;
- Get buy-in/ownership from a partnership agreement;
- Agree priorities and secure commitment within the Council, at a high level.

Source: recycled roads (WRAP, 2005)
**Box 10.2 Material Data Sheets used by Hampshire County Council**

To ensure highway maintenance projects are delivered in a sustainable way a best practice checklist with supporting tools is under development. Currently only being used in-house on a few trial schemes, the checklist and tools are intended to be cascaded to other sections in the Environment Department at Hampshire County Council.

The checklist is based upon Hampshire’s 12 themes of sustainable development. It is a project based audit form recording progress and development of best practice to ensure the project is sustainable for the full life of the scheme.

The supporting tools include Material Use sheets which are to be completed at key project stages with:
- Preliminary Design Quantities
- Detailed Design Quantities
- Tender Quantities
- Start Quantities
- Completion Quantities

The record sheets split materials on a project into three categories:
- Materials on site for reuse
- Materials on site for disposal
- New materials required for site

The benefits of recording this information derive from the ability to:
- Link surplus materials from one site to another
- Reduce new material requirement
- Promote increased lifecycle

The system has the advantage of being compatible with the requirements for site waste management plans (see Chapter 5.2), although many of the individual projects will be below the threshold for which these would be compulsory. They enable the Council to keep track of their material arisings and ensure they are used in the most sustainable manner.
Acknowledgements

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References


Dunster A (2005). Use of manufactured plastic aggregate and ISF slag from zinc manufacture in asphalt. 4th International Conference on “Latest development in sustainable aggregates and asphalt technology”. Liverpool JMU.


Hampshire County Council, Portsmouth City Council and Southampton City Council (2005). More from Less: How to make better use of Hampshire’s material resources. Hampshire County Council, Winchester.


- Volume 4: Section 1: Part 6: HA 74/07: Treatment of Fill and Capping Material Using Either Lime or Cement or Both
- Volume 7: Section 2: Part 3: HD 26/06: Pavement Design
- Volume 7: Section 1: Part 2: HD 35/04: Conservation and the Use of Secondary and Recycled Materials
- Volume 7: Section 3: Part 3: HD 30/08: Maintenance Assessment Procedure


- Volume 1: Specification for Highway Works (MCHW1)


APPENDIX 1 Sustainability Key Performance Indicators

A.1 Introduction
This appendix presents a list of sustainability Key Performance Indicators that can be used by Local Authorities’ officers to monitor and enhance the performance of their highways maintenance operations, in particular with respect to choice of materials and construction techniques.

The list has been originally prepared by reviewing existing Local Authorities’ and industry’s practices as well as recent guidance developed by the DfT and WRAP. The KPIs are also to be discussed by a panel of stakeholders in a dedicated workshop. It is important that KPIs are selected that are relevant to the work, easy to measure and meaningful. KPIs should only be set where they can help to improve the process and demonstrate progress; they are not an end in themselves.

A.2 How to use the KPIs effectively

The OGC –Defra’s Joint note on environmental issues in purchasing (www.ogc.gov.uk) shows how environmental issues can be considered at each stage of the procurement process (Figure A.1).

Figure A.1: Including Environmental Issues in the Procurement Process
Source: Joint note on environmental issues in purchasing, OGC – DEFRA 2003

Considering environmental and wider sustainability issues as soon as possible in the procurement process is crucial to ensuring their delivery. KPIs should be set/used at the “Identifying needs” stage of the process to inform the setting of requirements in the “Specification” stage. Informing the tenderers about the KPIs/checklist and/or
using the information from the tenders to estimate, if possible, what performance could be achieved can help in adding value to the tendering, selection and evaluation process. Finally, the KPIs will be used during and/or at the end of the contract to monitor and manage its performance.

While the indicators are useful to measure and monitor performance, a sustainability checklist should be used to appraise single schemes or the maintenance service as a whole so as to ensure that the effects of the construction are considered and mitigation actions taken. This is also part of the improvement process and fits in with sustainability assessments of local plans which Councils are required to conduct under the Strategic Environmental Assessment Regulations.

### A.3 Key Performance Indicators

The Recycled Roads guide (WRAP, 2005a) provides clear guidance on how to go about setting targets and KPIs. Elected members, Chief Executives and Heads of Departments set targets as part of the core objectives of the local authority. Targets at high level will then need detailed contributions from all the departments, including highways maintenance. Therefore the highways department will set its appropriate targets e.g. on recycling, waste minimisation, responsiveness in interventions within the framework of the Council’s own targets. Heads of highways and contract managers then set KPIs to measure the performance against those targets.

The targets can be outcome based or specific. Outcome-based targets (e.g. overall recycling targets, considering all materials used in highways maintenance) leave the initiative to the supply chain partners’ technical expertise. More specific targets (e.g. percentage of asphalt planings recycled into binder course; percentage of compost to be used in landscaping works) give more control to the authority to stress certain needs (e.g. to use local arisings, to ensure that recycled materials are used in high value applications).

Setting targets needs to take into account:

- What is already achieved, i.e. the baseline: e.g. average closure hours for resurfacing works; recycled materials use in bituminous layers; site waste reused; etc.
- What good and best practice targets are achievable, considering technical constraints and local situation/market: e.g. limits set by the specifications for surface course; workability limits; available local materials; type of contract; ability of the supply chain; etc.
- What timeframe is to be set to achieve best practice targets, e.g. setting year on year improvement targets?

### Examples of target settings

The following table shows an example of targets setting for a highway maintenance contractor who has been given annual percentage targets.

<table>
<thead>
<tr>
<th>KPI</th>
<th>Minimum KPI</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction waste to landfill</td>
<td>x tonnes</td>
<td>x-5%</td>
<td>x-10%</td>
<td>x-20%</td>
</tr>
<tr>
<td>Value of construction material used from secondary and recycled sources, as % of total material value</td>
<td>y%</td>
<td>y+7%</td>
<td>y+15%</td>
<td>y+23%</td>
</tr>
</tbody>
</table>
The targets constitute one of three elements defining the KPIs, the other two being (Recycled Roads, WRAP 2005a):

- A clear definition of the KPIs, e.g. percentage of recyclate by value (or by weight, as percentage of the total value (or weight) of materials used; amount of waste sent for recycling;
- How will it be measured and by whom, e.g. using Bill of Quantities, Waste Transfer Notes.

The following is a list of KPIs which refers directly to sustainability in construction layers, i.e. to either material choices or construction choices. The list is a portfolio of suggested KPIs to choose from through a scoping exercise, i.e. by considering the relevance to the local situation or the scheme. The KPIs shown are either outcome based or specific; they might either be suitable to measure the performance of the whole service (usually for a financial year, but also on a monthly basis; it could also be applied to partnering contracts) and/or are applicable more specifically to a certain scheme. The proposed KPIs are subdivided into primary, related directly to waste, recycling and materials use, and secondary, related to secondary effects.

<table>
<thead>
<tr>
<th>PRIMARY KPIs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WASTE</strong></td>
<td></td>
</tr>
<tr>
<td>o Percentage of arisings to landfill;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of arisings that are not disposed of to landfill;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of waste reused;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of waste recycled;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of savings realised;</td>
<td></td>
</tr>
<tr>
<td>o Construction waste.</td>
<td></td>
</tr>
<tr>
<td><strong>RECYCLING</strong></td>
<td></td>
</tr>
<tr>
<td>o Percentage of recycled materials used by volume or value;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of imported recycled materials by volume or value;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of recycled and secondary materials in each construction application;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of <em>in-situ</em> recycling;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of <em>ex-situ</em> recycling;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of work (value) specified for recycling;</td>
<td></td>
</tr>
<tr>
<td>o Satisfaction in relation to recycling.</td>
<td></td>
</tr>
<tr>
<td><strong>MATERIALS</strong></td>
<td></td>
</tr>
<tr>
<td>o Percentage of all aggregates sourced within a XX miles/km radius;</td>
<td></td>
</tr>
<tr>
<td>o Natural material savings:</td>
<td></td>
</tr>
<tr>
<td>o Cost savings in comparison to conventional methods/materials.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECONDARY KPIs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>o CO$_2$ emissions savings;</td>
<td></td>
</tr>
<tr>
<td>o Vehicle movements savings;</td>
<td></td>
</tr>
<tr>
<td>o Disruption;</td>
<td></td>
</tr>
<tr>
<td>o Percentage of heavy vehicles taking back haulage to and from site;</td>
<td></td>
</tr>
<tr>
<td>o Number of innovations;</td>
<td></td>
</tr>
<tr>
<td>o Public awareness of recycling;</td>
<td></td>
</tr>
<tr>
<td>o Environmental policies and plans.</td>
<td></td>
</tr>
</tbody>
</table>
EXAMPLE OF SPECIFIC KPIs
The following is a list of specific, recipe-based KPIs that are used by Devon County Council for monitoring the performance of their contractor.
- Percentage by mass of recycled and secondary material in unbound aggregates used for all sub-base and capping works;
- Percentage by mass of recycled and secondary material in bituminous-bound aggregates used in all footway and pavement works;
- Percentage by mass of recycled and secondary material in cement-bound aggregates in all structural and non-structural concreting works;
- Percentage by mass of all bituminous-bound aggregate derived from recycled glass of domestic origin;
- Percentage of all kerb and edging length laid that is derived from reused or factory seconds sources.

Source: Recycled Roads

A.4 Further information on the Key Performance Indicators

Waste KPIs:
- Percentage of arisings to landfill;
- Percentage of arisings that are not disposed of to landfill;
- Percentage of waste reused;
- Percentage of waste recycled;
- Percentage of savings realised;
- Construction waste.

KPI: PERCENTAGE OF ARISINGS SENT TO LANDFILL

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND: Decreasing to demonstrate that waste minimisation, reusing and recycling measures have been successfully implemented.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of waste generated during highways maintenance operations that is disposed of to landfill compared with total arisings.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of waste as reported in Waste Transfer Notes for disposal to landfill, for the scheme/project or during a month or year. Total arisings of waste (as recorded), for the scheme/project or during a month or year.</td>
<td>Quantity of waste as reported in Waste Transfer Notes disposed of to landfill as percentage of the total quantity of waste arisings (as recorded).</td>
<td></td>
</tr>
</tbody>
</table>
### KPI: PERCENTAGE OF ARISINGS THAT ARE NOT DISPOSED TO LANDFILL

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of waste generated during highways maintenance operations that is not disposed of to landfill, compared with total arisings.</td>
<td>Increasing to demonstrate that waste reusing and recycling measures have been successfully implemented.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of waste as reported in Waste Transfer Notes for disposal to landfill, for the scheme/project or during a month or year. Total arisings of waste (as recorded), for the scheme/project or during a month or year.</td>
<td>Quantity of waste as reported in Waste Transfer Notes not disposed of to landfill as percentage of the total quantity of waste arisings (as recorded). Waste not landfilled equals to total waste arisings minus waste landfilled.</td>
</tr>
</tbody>
</table>

### KPI: PERCENTAGE OF WASTE REUSED

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of waste generated during highways maintenance operations that is reused, compared with total arisings.</td>
<td>Increasing to demonstrate that waste reusing measures have been successfully implemented.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of waste as reported in Waste Transfer Notes for disposal to landfill, for the scheme/project or during a month or year. Quantity of waste as reported in Waste Transfer Notes for recycling off site, for the scheme/project or during a month or year. Quantity of waste recycled on site as recorded, for the scheme/project or during a month or year. Total arisings of waste (as recorded), for the scheme/project or during a month or year.</td>
<td>Quantity of waste as reported in Waste Transfer Notes not disposed of to landfill and not recycled as percentage of the total quantity of waste arisings (as recorded).</td>
</tr>
</tbody>
</table>
### KPI: PERCENTAGE OF WASTE RECYCLED

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND: Increasing to demonstrate that waste recycling measures have been successfully implemented.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of waste generated during highways maintenance operations that is recycled, compared with total arisings.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of waste as reported in Waste Transfer Notes for recycling off site, for the scheme/project or during a month or year. Quantity of waste recycled on site as recorded, for the scheme/project or during a month or year. Total arisings of waste (as recorded), for the scheme/project or during a month or year.</td>
<td>Quantity of waste recycled off site and on site as reported in Waste Transfer Notes and other records as percentage of the total quantity of waste arisings (as recorded).</td>
</tr>
</tbody>
</table>

### KPI: PERCENTAGE OF SAVINGS REALISED

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND: Increasing to demonstrate that economic benefits of diversion of waste from landfill.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost savings realised through avoidance of waste landfilling compared to potential total costs of landfilling.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charges for landfilling, per tonne. Actual cost for landfilling waste disposed of (both hazardous and non-hazardous), for the scheme/project or during a month or year. Actual cost for recycling and reusing waste, for the scheme/project or during a month or year. Total arisings of waste (as recorded).</td>
<td>Savings realised through not disposing of waste as percentage of the potential cost of disposing to landfill the total waste arisings. Savings are calculated as the difference between potential landfilling costs if all waste arisings were landfilled and the actual costs of reusing, recycling and landfilling waste.</td>
</tr>
</tbody>
</table>
**KPI: CONSTRUCTION WASTE**

**DEFINITION:**
Amount of material wasted as a proportion of amount of materials/products purchased.

**TREND:**
Decreasing to demonstrate that waste minimisation measures have been successfully implemented.

**MEASURE:**
Charges for landfilling, per tonne. Actual cost for landfilling waste disposed of (both hazardous and non-hazardous), for the scheme/project or during a month or year. Actual cost for recycling and reusing waste, for the scheme/project or during a month or year. Total arisings of waste (as recorded).

**CALCULATION:**
Savings realised through not disposing of waste as percentage of the potential cost of disposing to landfill the total waste arisings. Savings are calculated as the difference between potential landfilling costs if all waste arisings were landfilled and the actual costs of reusing, recycling and landfills waste.

Recycling KPIs:
- Percentage of recycled materials used by volume or value;
- Percentage of imported recycled materials by volume or value;
- Percentage of recycled and secondary materials in each construction application;
- Percentage of *in-situ* recycling;
- Percentage of *ex-situ* recycling;
- Percentage of work (value) specified for recycling;
- Satisfaction in relation to recycling.

---

**KPI: PERCENTAGE OF RECYCLED AND SECONDARY MATERIALS USED**

**DEFINITION:**
Amount of recycled and secondary materials purchased for highways maintenance operations compared to total materials purchased.

**TREND:**
Increasing to demonstrate commitment to improvement.

**MEASURE:**
Quantity/value of recycled and secondary materials bought for the scheme/project or during a month or year. Total quantity/value of materials bought for the scheme/project or during a month or year.

**CALCULATION:**
Quantity/value of recycled and secondary materials bought as percentage of the total quantity/value of materials purchased.
<table>
<thead>
<tr>
<th>KPI: PERCENTAGE OF IMPORTED RECYCLED AND SECONDARY MATERIALS^2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEFINITION:</strong></td>
</tr>
<tr>
<td>Amount of recycled and secondary materials imported within the total amount of recycled and secondary materials purchased.</td>
</tr>
<tr>
<td><strong>TREND:</strong></td>
</tr>
<tr>
<td>Decreasing to demonstrate commitment to recycling on site and/or of waste generated on site.</td>
</tr>
<tr>
<td><strong>MEASURE:</strong></td>
</tr>
<tr>
<td>Quantity/value of recycled and secondary materials bought from elsewhere for the scheme/project or during a month or year.</td>
</tr>
<tr>
<td><strong>CALCULATION:</strong></td>
</tr>
<tr>
<td>Quantity/value of recycled and secondary materials bought for the scheme/project or during a month or year as percentage of the total quantity/value of recycled and secondary materials purchased.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KPI: PERCENTAGE OF RECYCLED AND SECONDARY MATERIALS IN EACH CONSTRUCTION APPLICATION^3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEFINITION:</strong></td>
</tr>
<tr>
<td>Amount of recycled and secondary materials in each construction application compared to total components.</td>
</tr>
<tr>
<td><strong>TREND:</strong></td>
</tr>
<tr>
<td>Increasing to demonstrate commitment to using recycled.</td>
</tr>
<tr>
<td><strong>MEASURE:</strong></td>
</tr>
<tr>
<td>Quantity/value of recycled and secondary materials bought for each application within the scheme/project or during a month or year.</td>
</tr>
<tr>
<td>Total quantity/value of materials bought for each application within the scheme/project or during a month or year.</td>
</tr>
<tr>
<td><strong>CALCULATION:</strong></td>
</tr>
<tr>
<td>Quantity/value of recycled and secondary materials bought for each application as percentage of the total quantity/value of materials in each application.</td>
</tr>
</tbody>
</table>

^2 This indicator aims at encouraging recycling on site and/or of waste generated on site, therefore closing the loop for waste management on site. This indicator should be associated with the KPI on locally sourced materials (see below).

^3 See the example of specific KPIs in Section A.3 above.
### KPI: PERCENTAGE OF IN-SITU RECYCLING

**DEFINITION:** Quantity of materials recycled on site compared to total materials recycled.

**TREND:** Increasing to demonstrate commitment to maximise close loop recycling and minimisation of secondary effects (e.g. lorry movements).

**MEASURE:** Amount of materials recycled on site in the scheme/project or during a month or year. Total materials recycled.

**CALCULATION:** Amount of materials recycled on site in the scheme/project or during a month or year as percentage of total materials recycled.

### KPI: PERCENTAGE OF EX-SITU RECYCLING

**DEFINITION:** Quantity of materials recycled off site compared to total materials recycled.

**TREND:** Decreasing to demonstrate commitment to maximise close loop recycling and minimisation of secondary effects (e.g. lorry movements).

**MEASURE:** Amount of materials recycled off site in the scheme/project or during a month or year. Total materials recycled.

**CALCULATION:** Amount of materials recycled off site in the scheme/project or during a month or year as percentage of total materials recycled.

### KPI: PERCENTAGE OF WORK SPECIFIED FOR RECYCLING

**DEFINITION:** Percentage of recycling specified as value of work, for a scheme/project or during a period of time.

**TREND:** Increasing to demonstrate commitment to maximise recycling.

**MEASURE:** Value of recycling Total value of work in the period or for the project specified.

**CALCULATION:** Value of recycling as percentage of total value of work.
## KPI: SATISFACTION IN RELATION TO RECYCLING

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>Client satisfaction that recycling targets have been met.</th>
<th>TRENDS:</th>
<th>Increasing to demonstrate the delivery of recycling.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEASURE:</td>
<td>Achievement of recycling targets set by the client.</td>
<td>CALCULATION:</td>
<td>Number of recycling targets met.</td>
</tr>
</tbody>
</table>

### Materials KPIs
- Percentage of all aggregates sourced within a XX miles/km radius;
- Natural material savings;
- Cost savings in comparison with conventional methods/materials.

## KPI: PERCENTAGE OF ALL AGGREGATES SOURCED WITHIN A XX\(^4\) MILES/KM RADIUS.

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>Quantity of aggregates (primary, secondary and recycled) that have been quarried/processed in locations within a set distance, as compared to total aggregates bought.</th>
<th>TRENDS:</th>
<th>Increasing to demonstrate commitment to using local materials.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEASURE:</td>
<td>Amount of primary, secondary and recycled aggregates sourced from materials recycled off site in the scheme/project or during a month or year. Total aggregates used for the scheme/project or during a month or year.</td>
<td>CALCULATION:</td>
<td>Quantity of aggregates sourced locally as percentage of all aggregates supplied to the scheme or during a set period.</td>
</tr>
</tbody>
</table>

---

\(^4\) Distances should be set by the user of the KPI taking into account the setting of the project or the character of the area under consideration.
**KPI: NATURAL MATERIALS SAVINGS**

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of natural materials saved by using recycled and secondary aggregates and/or sustainable/lean construction techniques.</td>
<td>Increasing to demonstrate that waste recycling and minimisation of natural resource use measures have been successfully implemented.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of recycled and secondary aggregates used in the scheme/project or during a month or year.</td>
<td>Sum of recycled and secondary aggregates plus amount of materials that would have been needed with conventional techniques (as opposed to lean construction).</td>
</tr>
<tr>
<td>Amount of materials that would have been needed with conventional techniques (as opposed to lean construction).</td>
<td></td>
</tr>
</tbody>
</table>

**KPI: COST SAVINGS IN COMPARISON WITH CONVENTIONAL METHODS/MATERIALS**

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savings realised by using recycled and secondary aggregates or other sustainable/lean construction techniques in the scheme/project or during a month or year, compared to traditional aggregates and techniques.</td>
<td>Increasing to demonstrate that sustainable construction methods realise economic benefits.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of recycled and secondary aggregates and/or sustainable/lean construction techniques used in the scheme/project or during a month or year.</td>
<td>Difference between costs for conventional and cost for sustainable aggregates and techniques.</td>
</tr>
<tr>
<td>Cost of conventional aggregates and/or construction techniques that would have been used in the scheme/project or during a month or year.</td>
<td></td>
</tr>
</tbody>
</table>

**Secondary KPIs**
- CO₂ emissions savings;
- Vehicle movements savings;
- Disruption;
- Percentage of heavy vehicles taking back haulage to and from site;
- Number of innovations;
- Public awareness of recycling;
- Environmental policies and plans.
### KPI: CO2 EMISSIONS SAVINGS

**DEFINITION:**
Savings in CO2 emissions realised by using recycled and secondary aggregates or other sustainable/lean construction techniques in the scheme/project or during a month or year, compared to traditional aggregates and techniques.

**TREND:**
Increasing to demonstrate that sustainable construction methods realise additional environmental benefits.

**MEASURE:**
CO2 emissions associated with the use of recycled and secondary aggregates and/or sustainable/lean construction techniques used in the scheme/project or during a month or year.

**CALCULATION:**
Difference between CO2 emissions associated with the “as-built” (i.e. including recycled aggregates and sustainable/lean techniques) and the “business as usual” (i.e. conventional techniques and materials) scenario.

### KPI: VEHICLE MOVEMENTS SAVINGS

**DEFINITION:**
Savings in vehicle movements realised by using recycled and secondary aggregates or other sustainable/lean construction techniques in the scheme/project or during a month or year, compared to traditional aggregates and techniques.

**TREND:**
Increasing to demonstrate that sustainable construction methods realise additional environmental benefits.

**MEASURE:**
Vehicle movements to and from site associated with the use of recycled and secondary aggregates and/or sustainable/lean construction techniques used in the scheme/project or during a month or year.

**CALCULATION:**
Difference between vehicle movements associated with the “as-built” (i.e. including recycled aggregates and sustainable/lean techniques) and the “business as usual” (i.e. conventional techniques and materials) scenario. NB: vehicle movements are number of times trucks enter or leave the site for delivering of materials and equipment or collection of waste. A truck delivering materials to site and leaving it empty accounts for two vehicle movements.
### KPI: DISRUPTION

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND: Decreasing to demonstrate that sustainable construction methods realise additional benefits.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative length of time roads are closed during daytime for a scheme/project or during a month or year.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION: Sum of number of day-time hours of closure for a project or during a month/year.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hours between 7am and 7pm roads are closed due to works.</td>
<td></td>
</tr>
</tbody>
</table>

### KPI: PERCENTAGE OF HEAVY VEHICLES TAKING BACK HAULAGE TO AND FROM SITE

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND: Increasing to demonstrate that sustainable construction methods realise additional environmental benefits.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles both entering and leaving the site full during the works for a scheme/project or during a month or year, as compared to total vehicle movements.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION: Number of vehicles that take back haulage (e.g. delivering recycled aggregates and tasking back suitable waste for processing) as proportion of total number of vehicles that enter the site.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles delivering goods to site and taking back waste during the works for the scheme/project or during a month or year. Total number of good vehicles entering the site.</td>
<td></td>
</tr>
</tbody>
</table>

### KPI: NUMBER OF INNOVATIONS

<table>
<thead>
<tr>
<th>DEFINITION:</th>
<th>TREND: Increasing to demonstrate commitment to innovation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of new techniques and materials that are implemented during a year.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASURE:</th>
<th>CALCULATION: Each new material and/or new technique account for one innovation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of techniques and materials that had never been used by the Council before for highways maintenance.</td>
<td></td>
</tr>
</tbody>
</table>
### KPI: PUBLIC AWARENESS OF RECYCLING

**DEFINITION:**
Number of publications that publicise the use of recycling in highways maintenance operations for schematic/projects or during a year.

**TREND:**
Increasing to demonstrate commitment to communication of achievements.

**MEASURE:**
Number of articles in local or national newspaper and magazines, leaflets, public presentations, press releases where recycling in highway maintenance operations is reported.

**CALCULATION:**
Sum of number of publications focusing on recycling activity.

### KPI: ENVIRONMENTAL POLICIES AND PLANS

**DEFINITION:**
Policies and plans demonstrating the commitment of the supply chain to environmental sustainability.

**TREND:**
Increasing to demonstrate commitment to sustainability throughout the supply chain.

**MEASURE:**
Number of contractors with sound environmental policy and/or Environmental Management System in place; number of environmental action plans (e.g. waste management plans, biodiversity) implemented during the works for a project/scheme or during a year.

**CALCULATION:**
Sum of number of contractors within the supply chain who have or implement sound environmental policies and plans.

---

**A.5 Key Performance Indicators used by the construction industry**

The construction industry has adopted KPIs to monitor measure and benchmark their performance, within the framework for the delivery of continuous improvement and accountability. The most relevant schemes and selected KPIs are described in the following subsections.

**A.5.1 Constructing Excellence in the Built Environment**
(www.constructingexcellence.org.uk), a cross sectoral organisation which involves government, industry, clients and research bodies, publishes each year a series of KPI Wallcharts. The KPIs, developed from the late ‘90s, are used by the construction industry to measure its performance. Constructing Excellence collects those data each year through a survey to generate graphs, contained into appropriate wallcharts, which can be used by organisations to benchmark their performance against the rest of the industry or sector. The available wallcharts are:

- All Construction,
- Respect for People,
The most relevant set of indicators that contractors involved in highways maintenance might use for measuring the sustainability of the choice of materials and construction techniques are included in the Environment and Construction Products Industry wallcharts (the latter is described in the following subsection). Other indicators are available on economic and social impacts and performance of the whole construction project and contractor respectively.

The environment KPIs are:
- Impact on the environment of the product and the construction: based on client’s satisfaction that the building/structure has been built in respect of the environment (e.g. emissions, water usage, energy usage has been minimised from design and/or on site);
- Energy use: forecast/design energy used by the facility;
- Energy use in construction;
- Mains water use (forecast/design);
- Mains water use in construction;
- Waste: materials removed from site during construction;
- Commercial vehicle movements: number of vehicles coming into site to deliver e.g. materials and plant and to collect e.g. waste;
- Impact on biodiversity: based on client’s satisfaction that impacts on biodiversity were taken into account/minimised in the delivery of the facility;
- Area of habitat created or retained: difference between wildlife valuable space before and after the construction;
- Whole life performance: based on client’s satisfaction that the issue has been taken into account in the delivery of the facility.

A.5.2 The Construction Products Industry KPIs

The Construction Products Industry (CPI, http://www.constructionproducts.org.uk/), in its drive for improvement within the Constructing Excellence initiative, has set up a series of key performance indicators and a sector-wide benchmark system, similarly to the wider construction industry’s system described above. The industry measures the indicators annually, and the CPI collects the information from its members to produce the benchmark for the following year. These indicators can be used by the construction products’ suppliers to demonstrate their performance to the clients, as demonstration to their commitment to sustainability and improvement.

Alongside KPIs on client satisfaction (e.g. on product quality, after sales, value for money) and respect for people (e.g. on safety, training, equality and diversity of people within the industry), there are five main KPIs and five secondary performance indicators SPIs (indicators of the performance of an activity that is of secondary importance to success) described in Table A.1 below.
### Table A.1 CPI's Environmental KPIs and CPIs

<table>
<thead>
<tr>
<th><strong>Key Performance Indicator</strong></th>
<th><strong>Details</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption</td>
<td>Energy efficiency, measured as the energy consumed at manufacturing sites (converted in kg of CO2) per tonne of production output.</td>
</tr>
<tr>
<td>Packaging management</td>
<td>Amount of packaging used per tonne of production output.</td>
</tr>
<tr>
<td>Transport movements</td>
<td>Number of transport movements by road, rail, water or other for transporting products and by-products from the site per tonne of production output.</td>
</tr>
<tr>
<td>Waste reduction</td>
<td>Level of waste leaving the site as a percentage of the total production output.</td>
</tr>
<tr>
<td>Water usage</td>
<td>Water efficiency, measured as volume of water brought into site from controlled waters (mains, abstracted water) per tonne of production output.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Secondary Performance Indicator</strong></th>
<th><strong>Details</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption – renewable and alternative sources</td>
<td>It is measured as the percentage of kWh bought from renewable sources of energy, e.g. wind power, solar power, hydroelectric.</td>
</tr>
<tr>
<td>Water usage – water recycling on site</td>
<td>Amount of water recycled on site being kept within a closed loop system.</td>
</tr>
<tr>
<td>Waste reduction – waste avoidance</td>
<td>Amount of material being recycled on site and used again in the manufacturing process against the total amount of output.</td>
</tr>
<tr>
<td>Waste reduction – use of recycled materials</td>
<td>Amount of recycled material from other processes used as raw materials in the manufacturing processes.</td>
</tr>
<tr>
<td>Packaging management – reuse of packaging</td>
<td>Amount of packaging returned and reused by the company (e.g. pallets, drums)</td>
</tr>
</tbody>
</table>

### A.5.3 The Highways Agency’s”motivating success” performance management toolkit

The HA has developed this toolkit to measure and manage the performance of the supply chain involved in the delivery of the Agency’s contracts within the Early Contractor Involvement scheme. Contractors for local highways maintenance schemes who are/have been involved in major HA projects are likely to be already measuring a number of performance indicators which can be useful for monitoring aspects of sustainability linked to their culture, e.g. health and safety and environmental awareness of the personnel. There are also some project specific indicators on whether environmental impacts of the whole project have been taken into account – although detailed sustainability impacts linked with the choice of materials are not as yet taken into account.
A.5.4 Proposed asphalt industry sustainability Key Performance Indicators

TRL Report 638 (Parry, 2005) suggests a list of sustainability KPIs for the asphalt industry. The indicators recommended have been sourced and opportunely adapted from the CPI's set of indicators, considering those that are relevant and discarding those not really applicable (e.g. “Packaging Management”). The most relevant ones are shown in Table A.2.

Table A.2 Selected Proposed KPIs for the Asphalt Industry

<table>
<thead>
<tr>
<th>Key Performance Indicator</th>
<th>Measurement diagnostic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Energy consumption in production of asphalt per tonne of production</td>
<td>Energy consumed at manufacturing sites (converted in kg of CO2) per tonne of asphalt produced. Energy consumption includes electricity, gas oil, fuel oil, natural gas, any other source of energy (e.g. residual fuel oil).</td>
</tr>
<tr>
<td>2. Transport movements of asphalt per tonne</td>
<td>Number of transport movements by road, rail, water or other for transporting products and by products from the site per tonne of production output.</td>
</tr>
<tr>
<td>3. Secondary and recycled material used in production (expressed as a percentage of total production)</td>
<td>Recycled asphalt (not including planings); Secondary materials: glass, steel slag, blast furnace slag; foundry sand, asphalt planings, any other.</td>
</tr>
</tbody>
</table>

A.5.5 Quarry Products Association Performance Indicators

In March 2006 the Quarry Products Association (QPA, [www.qpa.org](http://www.qpa.org)) produced the first Sustainability Report of the aggregates industry, following on from its Sustainable Development Strategy published one year before. The QPA compiled the report through a survey of the UK industry for the year 2004, obtaining a response rate equivalent to 64% of the total UK market share. The performance indicators used for this first Sustainability Report are listed below, subdivided in indicators for social progress, environmental protection, natural resources and economic prosperity.

The QPA is committed to produce this report every year and improve the response rate of its members, in the understanding that the collection and monitoring of the data for this report involves significant managerial commitment by the QPA members.
Table A.3: QPA Sustainability Performance Indicators

<table>
<thead>
<tr>
<th>SOCIAL PROGRESS</th>
<th>ENVIRONMENTAL PROTECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health and safety:</td>
<td></td>
</tr>
<tr>
<td>• Number of RIDDOR incidents</td>
<td></td>
</tr>
<tr>
<td>Working with the community:</td>
<td></td>
</tr>
<tr>
<td>• Recorded complaint from the local community per location</td>
<td></td>
</tr>
<tr>
<td>• Sites with a community/liaison group</td>
<td></td>
</tr>
<tr>
<td>• Percentage of quarries with community/liaison groups</td>
<td></td>
</tr>
<tr>
<td>• Educational visits</td>
<td></td>
</tr>
<tr>
<td>Partnership with stakeholders:</td>
<td></td>
</tr>
<tr>
<td>No performance indicators at present</td>
<td></td>
</tr>
<tr>
<td>Heritage:</td>
<td></td>
</tr>
<tr>
<td>• Number of archaeological investigations per annum</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NATURAL RESOURCES</th>
<th>ECONOMIC PROSPERITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource conservation:</td>
<td></td>
</tr>
<tr>
<td>• Tonnage of aggregates produced and landed</td>
<td></td>
</tr>
<tr>
<td>• Volume from land sources</td>
<td></td>
</tr>
<tr>
<td>• Volume from marine sources</td>
<td></td>
</tr>
<tr>
<td>• Proportion from recycled and secondary sources</td>
<td></td>
</tr>
<tr>
<td>• Per capita production in GB</td>
<td></td>
</tr>
<tr>
<td>• Water use metered/charged consumption per tonne of total production</td>
<td></td>
</tr>
<tr>
<td>• Energy use, CO₂ kg per tonne of total production (NB: excludes transport)</td>
<td></td>
</tr>
<tr>
<td>• Aggregates sector share of UK carbon emissions</td>
<td></td>
</tr>
</tbody>
</table>

| Natural environment: |
| • Sites with certified environmental management system |
| • Number of convictions for pollution and planning infringements for locations surveyed |
| • Tonnage of quarry waste (non-mineral waste) going to landfill as a proportion of production tonnage |

| Restoration of land: |
| • Land being quarried |
| • Land restored |
| • Land prepared for quarrying by soil removal |
| • Ratio of land restored to land prepared to quarrying by soil removal |

| Biodiversity and geodiversity: |
| • Trees planted |
| • Hedgerow planted |
| • Designated Sites of Special Scientific Interest (SSSIs) in each condition category |

| Transport of aggregates: |
| Under development |

| Providing essential materials: |
| • Tonnage of aggregates produced |
| • Volume from land sources |
| • Volume from marine sources |
| • Proportion from recycled and secondary sources |
| • Per capita production |
| • Primary aggregates use relative to construction |
| • Total aggregates use relative to construction |
| Employment, total |

| Employment: |
| • Employment levels (direct and indirect) |
APPENDIX 2 Linking corporate objectives to highway maintenance practice: Hampshire County Council

Hampshire County Council is a prime example of how sustainability aims and objectives can be fed down the chain from a Corporate Strategy to Highways Maintenance operations. All information displayed below was taken from the Hampshire County Council website (www.hants.gov.uk) prior to July 2006.

Until July 2006 Hampshire County Council outlined six strategic aims in their Corporate Strategy. These are:

1. Maximising life opportunities;
2. Stewardship of the environment;
3. Achieving economic prosperity;
4. Building strong and safe communities;
5. Improving services; and,
6. Developing councillors and staff.

Aim 2 of the Council’s Corporate Strategy was to protect the environment by promoting the principles of sustainable development. This aim was further broken down into three themes:

1. Shaping our surroundings;
2. Travel and transport; and,
3. Natural resources.

Theme 3 contains the most relevant objectives to Highways Maintenance operations (see Table A.4 below).

The objectives outlined in Table A.4 have been fed down to the Highways Policy Document, which outlines what sustainable development means for highways operations (Box A.1). In addition, it describes how these factors should be taken into account whenever designing a maintenance scheme or planning a maintenance operation.

The Corporate Strategy mentioned above applied up until July 2006. Hampshire County Council has updated this strategy but retains a strong focus on sustainability, focused on the Aalborg commitments (see Box 1.2).

Box A.1 Hampshire County Council Sustainability Objectives for Highway Maintenance

Sustainable development implies the following principles which can be adopted for highway maintenance operations:

- A reduction in the consumption of natural resources, including energy. Non renewable resources should be substituted with renewable resources.
- Waste should be reduced.
- Waste should be re-used or recycled.
- Biodiversity should be preserved or enhanced.
- Valuable natural and physical assets and amenities should be preserved and protected.
### Table A.4 Hampshire County Council Corporate Objectives

#### Aim 2: Stewardship of the environment

<table>
<thead>
<tr>
<th>Priority areas</th>
<th>Measurement</th>
<th>What we aim to achieve</th>
</tr>
</thead>
</table>
| Developing a material resources strategy and land use plan to achieve the following: | Work to reduce the production of waste and increase the amount re-used and recycled through the Project Integra partnership. | 30% of household waste to be recycled by 2006  
420,000 tonnes a year to energy recovery by 2005 (45%)  |
| - Minimising the use of virgin resources by promoting greater emphasis on the use of renewable and recyclable resources | Reduction in volumes of waste to landfill        | Additional 40,000 tonnes of commercial, industrial and construction waste a year diverted from landfill by 2005 |
| - Minimising the creation of waste and ensuring that the waste that is created is dealt with in accordance with the hierarchy of re-use, recycling, recovery of resources and final disposal as a last resort | Making the County Council an example of best practice in the sustainable procurement and consumption of natural resources | Achieve targets in Corporate Sustainable Development Strategy |
| - Promoting the sustainable use of water, energy, air and soil                | Reduction in the consumption of energy, water and consumables and impact on climate change |                                                                                       |
| - Ensuring that the factors contributing to climate change such as the use of fossil fuels to produce energy and power vehicles are fully taken into account and meaningful reductions achieved |                                                                                       |                                                                                       |
| - Raising awareness in the community of the impact of lifestyles and business activity |                                                                                       |                                                                                       |
| - Ensuring best practice in the County Council's own use of natural resources |                                                                                       |                                                                                       |
APPENDIX 3 Linking corporate objectives to highway maintenance practice: Durham County Council

A.3.1 Corporate objectives
Durham County Council is another example of how sustainability aims and objectives can be fed down the chain from a Corporate Strategy to Highways Maintenance operations. All information displayed below is taken from the Durham County Council website (www.durham.gov.uk), the Building-In-Sustainability website (www.buildinginsustainability.co.uk) and WRAP Recycled Roads: Local Authority Strategic Objectives Guidance note 1.

Durham County Council has five corporate aims, each supported by a number of objectives.

1. **Promoting Strong, Healthy and Safe Communities**
   - To enhance the capacity of communities and enable people to participate in community life.
   - To support and protect vulnerable adults, young people and children.
   - To help to reduce crime and fear of crime.
   - To help to improve the health of local people.
   - To invest in our children and young people.

2. **Building a Strong Economy**
   - To create and retain jobs in County Durham
   - To create a diverse and robust employment structure with high quality jobs.
   - To create the physical conditions necessary to enable flourishing economic activity.
   - To foster an enterprise culture.

3. **Looking after the Environment**
   - To revitalise, conserve and protect the County's settlements, countryside and historical features.
   - To manage waste and resources sustainably, reduce pollution and adapt to climate change.
   - To provide an integrated, effective and safe transport system in support of access for all.

4. **Developing Lifelong Learning**
   - To improve provision for early learning for our children.
   - To improve educational attainment for all children in our schools and inspire them to enjoy learning throughout their lives.
   - To provide high quality learning opportunities for all to gain enjoyment, achievement, progression and enhanced employment prospects.
   - To support the development of an adaptable and skilled workforce.
   - To improve recreational, creative and cultural opportunities and promote a sense of cultural identity.

5. **Effective corporate leadership**
   - To enhance community leadership and improve the way we communicate, listen and respond.
• To use our resources effectively.
• To continually improve the delivery of our services and implement solutions that support local needs, priorities and aspirations.
• To develop our capacity to embrace change and improve the way our services are provided.

Aim 3 above has been fed into a number of documents including Building in Sustainability (2002). The Building in Sustainability (2002) document and sustainability case studies can be viewed at www.buildinginsustainability.co.uk. The website also contains checklists for all who are involved in design and construction processes. This document states that in the development of new road maintenance schemes the potential for in-situ recycling and the use of secondary/recycled materials should be assessed.

Durham County Council has used the principles outlined in this document in all of their road maintenance operations. Two examples are shown below. These illustrate how choice of materials is one factor in the overall picture of sustainability, and how all the factors have to be considered together to get the most effective results.

A.3.2 A689 Sedgefield to Wynyard Improvement

Throughout this £9million improvement scheme sustainability was taken into account at all stages of design and construction. This was achieved by using the 13 Rules of Thumb described in the document “Building in Sustainability”.

1. Think About Re-Using Buildings and Land
The alignment of the dual carriageway is such that the previous A689 corridor has been incorporated into the new route wherever possible to minimise land take from the surrounding green fields, thereby retaining maximum use of farmland.

2. Design for Minimum Waste
The design of the vertical alignment of the proposed road was such that all of the material from cuttings was used as suitable fill, thereby eliminating the need for material to be taken off site to landfill sites. Construction of the road embankments was redesigned to make full use of poorer quality fill that would otherwise have had to be disposed of off-site.

3. Aim for Lean Construction
In areas where it was necessary to remove the existing carriageway to achieve the proposed vertical alignment, the surfacing has been planed out and the resultant material stored on site for re-use in footpath construction.
All stone for road construction came from local quarries and the labour force was drawn mainly from the local area. As fewer heavy vehicles would use the outside lane of the dual carriageway, a thinner road pavement was specified compared to the inside lane. Piped surface-water systems were replaced by ditches wherever this was feasible.

4. Minimise Energy in Construction and Use
By using local quarries, the transport distances have been minimised, thereby reducing the amount of fuel needed to deliver materials to site, with a resultant saving in consumption of natural resources.

Site activities and the policy of the main contractor Balfour Beatty ensured that all motorised plant was switched off during periods of non-use, again saving on fuel consumption.

Two options were available for the edge of carriageway detail - either kerbed with gullies or a free edge with a 0.5 metre wide hard strip. Both options would have cost approximately the same to construct but the free edge would take considerably less time to construct and so was adopted as the preferred alternative.

5. Do Not Pollute
During the construction phase, all refuelling was carried out by designated trained operatives using double-skinned, lockable bowsers to prevent spillages.

Watercourse protection measures were put in place to monitor run-off from stockpiles and a silt filtration system was used in over-pumping works on an existing stream.

A petrol and oil interceptor was used where one of the surface water drainage systems outfalled into a vulnerable watercourse. The Environment Agency was fully consulted on the potential for effect of the scheme on the nearby aquifer and water extraction point at Waterloo Plantation.

6. Conserve and Enhance Bio-diversity
Prior to any works commencing, all existing hedgerows that lay on the line of the proposed carriageway were carefully dug up and transplanted along the site boundaries to ensure as far as possible that the existing habitat was maintained. An advance contract was undertaken to ensure that this element of the work was undertaken outside of the bird-nesting season.

A survey was carried out to determine which trees could be retained and how best to integrate the proposed planting scheme with the existing landscape.
7. Conserve Water Resources
Within the site compound establishment, all WCs were fitted with low volume flush units and all self-flush urinals had flow controls to minimise water wastage. Throughout the construction period, all existing road gulleys were lined with a filter medium to prevent silt from the works running off into the existing outfall system.

To reduce the effect of the surface water discharge from the scheme on the receiving watercourses, storage structures were constructed to attenuate the flow in line with the requirements of the Environment Agency. The outfall from these structures will be monitored with a view to reducing the discharge even further.

8. Respect People and Their Local Environment
Throughout the works, the need for traffic management was been carefully planned to reduce as far as possible delays and effect on both the travelling public and business patrons using this part of the network.

Regular letter drops were carried out to inform local residents of changes to the traffic management arrangements as well as providing information to local radio stations. Part of the County Council’s web site was used to provide information on progress as the construction phase was underway.

Close liaison between farmers, designers and construction staff was maintained throughout the planning, design and construction phases to ensure that inconvenience was kept to a minimum.

The Local Transport Plan Partnership Forum (consisting of some 25-30 organisations with transport/travel interests) were also consulted during the design period to ensure that the views of their members were taken into consideration and included in the scheme where possible.

9. Think about the Whole Place
Previously the A689 passed through a rural agricultural area, with farmers on both sides of the road carrying out both livestock and/or arable farming, both of which called for the use of rigid and articulated haulage vehicles to move livestock or feedstuffs. The design of the new dual carriageway incorporated a central reserve width of up to 14 metres to accommodate long vehicles turning across the carriageway, together with acceleration and deceleration lanes for access/egress at all crossing points.

Facilities for pedestrians, horse riders and cyclists have been provided beyond the extent of the dualling scheme to improve links to Sedgefield and the new County Durham Gateway Bridge that carries Route 1 of the National Cycleway Network across the A689.

10. Give People Transport Choices
As well as providing an upgraded east-west route across the County, one of the objectives of providing the new scheme has been to reduce the potential for accidents along its length and improve the previous accident record.

A path has been provided throughout the length of the scheme to encourage walking, cycling and equestrian use. The extended link to the Gateway Bridge will promote use of and access to a much wider network of cycleway and walkway routes. The deceleration tapers provided to the farm accesses off the A689 have been designed to allow buses to use them as informal bus stops.
11. Minerals
Throughout the construction phase, all surplus hard materials were recycled for use either on site or on adjacent works, reducing the requirement for new materials.

The environmental management system in place on site calls for strict control of wastage, again reducing the amount of imported raw materials.

12. The Countryside
The land take for the scheme is such that it minimises the amount of greenfield land needed to build the road thereby minimising the impact on local agriculture. The upgrading of this key part of the highway network will encourage traffic to utilise this as an east-west route and the avoidance of potentially attractive alternative routes that may pass through surrounding small villages and settlements.

13. Sustainable Regeneration
The upgrading of the existing road could encourage industry to utilise the facilities of local industrial estates, hopefully to relocate to them.

Local people will be encouraged to remain in the area if employment prospects are enhanced as a result of attraction of industry seeking transport of goods by way of efficient access and minimum journey times to the motorway and trunk road networks.
A.3.3 A167 Durham City Park and Ride

Durham City Park and Ride has improved access and reduced congestion in the historic World Heritage Site of Durham City.

The scheme involved the construction of a 400 space car park at Belmont on the outskirts of the City where new buildings provide the additional facilities to accommodate the car park operators, a CCTV control room, ticket machine and public toilets. Car parks were also constructed at two other sites on the outskirts of the City providing 295 spaces at Howlands Farm and 300 spaces at Sniperley each with amenity buildings housing ticket machines and public toilets.

In construction emphasis has been on the practical use of materials rather than high specification to deliver a durable, functional product. Environmental consideration was given a high priority with maximum use of on-site materials and recycling.

The sites all incorporate a sustainable surface water drainage system. All surplus construction materials were recycled and used as suitable fill or formed into landscaping to avoid the need for disposal of materials to landfill sites. Road planings were re-used on public footpaths in the area. Lightweight kerbs made from recycled household plastic were used where possible.
Abstract

Over the past ten years there has been an increasing appreciation of the importance of sustainability in government policy. This has required Local Authorities to review their operations and look for ways to make them more sustainable. The maintenance and construction of highways is an area that presents many opportunities for increased sustainability, by the use of materials and methods that minimise the impact of these activities on the environment. This document provides a detailed description of how to make sustainable choices in the selection of materials and methods for Local Authority highway works, including maintenance and new construction. It is designed to support “Sustainable Highways”, the summary guidance that constitutes a daughter document to “Well-maintained Highways”, the Code of Practice for Highway Maintenance Management. This reference document offers detailed practical guidance for Local Authority highway engineers, their contractors, designers and suppliers on how to choose materials and methods of work for highways taking into account sustainability and environmental factors.
Sustainable choice of materials for highway works: A guide for Local Authority highway engineers

Over the past ten years there has been an increasing appreciation of the importance of sustainability in government policy. This has required Local Authorities to review their operations and look for ways to make them more sustainable. The maintenance and construction of highways is an area that presents many opportunities for increased sustainability, by the use of materials and methods that minimise the impact of these activities on the environment. This document provides a detailed description of how to make sustainable choices in the selection of materials and methods for Local Authority highway works, including maintenance and new construction. It is designed to support “Sustainable Highways”, the summary guidance that constitutes a daughter document to “Well-maintained Highways”, the Code of Practice for Highway Maintenance Management. This reference document offers detailed practical guidance for Local Authority highway engineers, their contractors, designers and suppliers on how to choose materials and methods of work for highways taking into account sustainability and environmental factors.

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