Carbon Management and Reduction in Highways Asset Management: Case Studies

Introduction

Within the Midlands Highway Alliance (MHA), a strategic decision has been made to take collaborative action across the Alliance to better understand, manage and reduce the carbon impact of highways asset management activities. To help achieve this, a series of resources have been developed to help guide authorities through the better management of carbon in their highway design, construction, maintenance and operational activities in a strategic, comprehensive, holistic and most importantly, sustainable manner and to facilitate multiple, wider benefits in doing so.

This document has been produced as part of the suite of resources, and provides real-life case study examples of how organisations have recently or are currently taking action with regards to carbon management and reduction. These case studies are designed to assist MHA authorities, their contractors and supply chains in identifying appropriate and effective action to take by providing real-life examples of replicable good practice and proven approaches and techniques.

The case studies in this document are divided into four categories: Materials; Street Lighting, Signalling and Signage; Techniques and Technologies; and Operational Delivery.

1. **Materials:** including the use of low temperature asphalt, recycled/ reclaimed and other sustsinable materials.
2. **Street lighting, Signalling and Signage:** including smart street lighting and asset review and reduction strategies
3. **Techniques and Technologies:** including the use of heavy duty pavers and compaction technology
4. **Operational Delivery:** including examples of effective collaboration, sustainability within the supply chain and carbon footprinting approaches.

Materials

Low energy materials – Lafarge Tarmac and Carbon Trust [1][2]

On average, the UK produces around 25 million tonnes of asphalt per year; the carbon footprint of this production is estimated to be 786,000 tonnes of CO_2/year[3]. Low Temperature Asphalt (LTA) has the potential to reduce energy requirements and costs associated with production, and it is therefore estimated that it could cut the carbon emissions associated with asphalt production by up to 39% (when compared to conventional hot-mix asphalt). However, the use of LTA in the UK, so far, is limited. Between 2014 and 2017, Lafarge Tarmac and the Carbon Trust undertook research and trials with the objective of improving the carbon efficiency associated with the manufacture of road construction materials, with an aim of saving the UK highways sector £46.2m in energy costs and 260,000 tonnes of CO_2, between 2014 and 2024.

Figure 1: Recording the temperature of Low Temperature Asphalt (LTA)

Specifically, the project sought to develop a new approach to LTA production and application. It aims to determine if it is a viable alternative to conventional hot-mix asphalts.

The research findings state that LTA offers the following benefits when compared to conventional hot-mix asphalt:

- Reduced energy consumption during production and application
- Reduced embodied carbon footprint
- Longer workability window during application
- Allows for easier incorporation of recycled asphalt within mixes

The research also identified a number of potential barriers to the use of LTA, these being:

- Lack of evidence of long-term performance
- Concerns regarding the higher capital cost of the material
- Absence of an official specification available for the use of LTA (at the time of the research)

Four materials were tested during the trial period:

- A LTA incorporating a cold-mix bitumen emulsion and recycled asphalt planings
- Three LTA half-warm mixes incorporating virgin aggregates and foamed bitumen

A 800m trial of the four materials was carried out in Leicester, where performance was assessed and compared between conventional hot-mix asphalt and the four half-warm and cold mixes. The ten mixes trialled are shown in Figure 2.

[1] Carbon Trust. (2014). Low Temperature Asphalt: Case Study . http://www.carbontrust.com/media/506150/cts398-low-temperature-asphalt-tarmac-case-study.pdf. [Accessed 09/08/17].
[2] The Carbon Trust. (2014). Lafarge Tarmac and Carbon Trust launch low energy road building materials with potential to save industry £46m. [Online]. Available at: https://www.carbontrust.com/news/2014/01/lafarge-tarmac-carbon-trust-launch-low-energy-road-building-materials/. [Accessed 09/08/17].

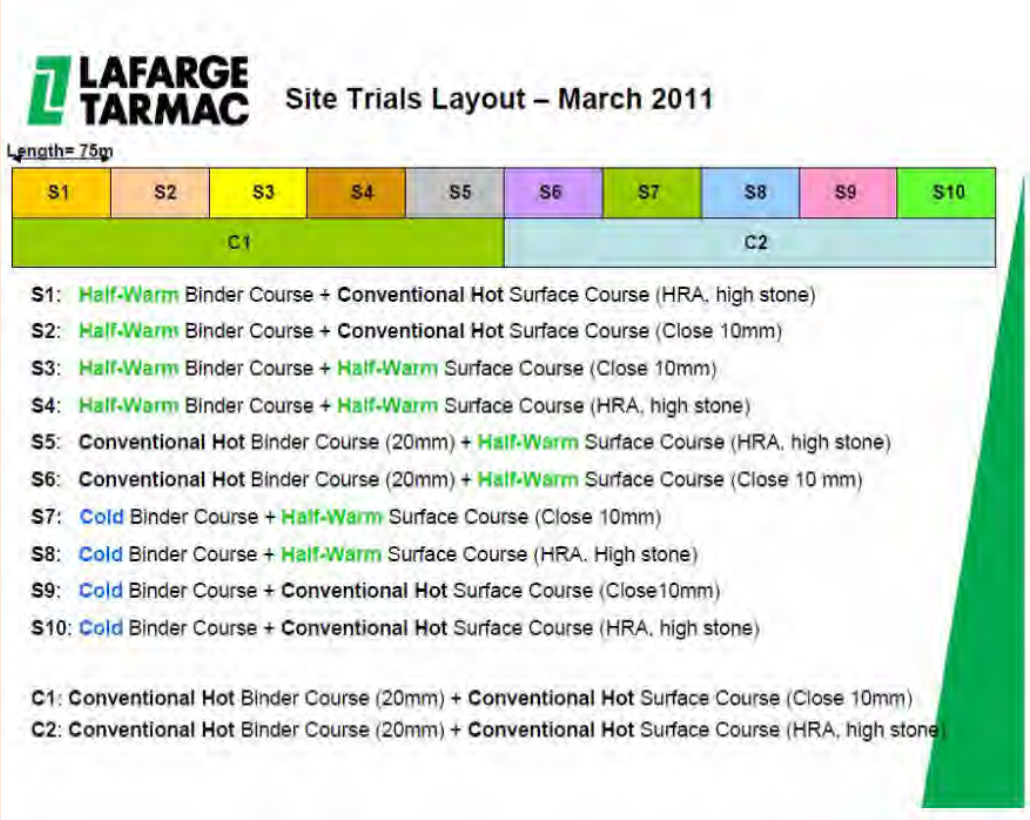

Figure 2: The ten mixes tested in the trial

The results showed that all mixes performed well, with the cold and half-warm mixes demonstrating stiffness comparable with the conventional hot-mix asphalts. The LTA mixes were also able to bond materials as effectively as the more conventional methods.

Some challenges were identified in regards to the use of foamed bitumen in the cold and half-warm mixes; this was due to in-situ water nozzles becoming blocked when switching from hot to semi-warm bitumen. The problem was overcome by adding already foamed bitumen into the mixer, and using larger spray nozzles that were less susceptible to blocking. This modification is easily adopted and costs in the region of £85,000 (one-off cost).

The results from the trial contributed to the development of the first specification for low temp asphalt mixtures in the UK[3].

Use of tar-bound planings in construction – Galliford Try[4]

Contract/scheme – Muse Phases 2&3, Nottinghamshire
Date – 2017

The project involved planing off an existing runway that had been constructed using a tar-bound material. The material was contaminated, which led to the need to investigate sustainable options for its disposal or reuse. An objective was also by the client to minimise vehicle movements with regards to the transport of the planed materials away from the site, in order to reduce fuel use (and thereby emissions) and minimise Health & Safety risks.

Early engagement with the contractor identified an opportunity to re-use the tar-bound material on-site by using the planings within a new cement-bound layer. This resulted in significant cost savings through avoiding the transport and disposal of the planings, along with a reduction in the overall carbon footprint of the project, due to reduced fuel and energy use, and less reliance on new virgin materials.

[3] J C Nicholls, H Bailey, N Ghazireh, and D H Day (2013). Specification for Low Temperature Asphalt Mixtures. [Online] Available at: https://trl.co.uk/reports/PPR666 (accessed 15 November 2017)
[4] Information provided directly by Galliford Try

The project demonstrates the need for careful planning and design management, and shows how collaborative working, particularly with the supply chain, can lead to enhanced sustainability of a project.

Use of pre-cast manhole systems – Galliford Try[5]

Contract/scheme – A116 Rolls Royce Access and Muse Phases 2&3
Date – 2016

Traditional manhole construction is resource intensive and typically requires the delivery of ready-mix concrete to site.

Figure 3: Pre-cast manhole.

Pre-cast manholes are an alternative to traditional manholes. Being pre-cast, there is no need for ready-mix concrete deliveries or re-entering a manhole at a later date to bench and/or re-seal the manhole. A pre-cast manhole is typically full installed in one day, compared to an average of three days for traditional manholes formed on-site. There is also less typically waste produced than when manholes are formed on-site. Although the pre-cast manholes have a somewhat higher capital cost, a reduction in construction time results in lower installation costs, and a lower embodied carbon footprint.

Evaluating carbon dioxide emissions from using enhanced levels of reclaimed asphalt in surfacing material – Transport Research Laboratory (TRL)[6]

In 2010, TRL carried out a study into the use of reclaimed asphalt (RA) in surfacing materials as a way of reducing the whole-life energy requirements and carbon impacts of highway resurfacing activities. The research was undertaken as part of a resurfacing scheme on the M25 between Junctions 6 and 7.

A resurfacing material containing 40% RA was trialled against a standard resurfacing material comprised of 100% virgin aggregate. The RA material used was produced by Tarmac at the request of Mouchel, and involved reclaiming asphalt from the existing worn-out surface.

The use of the 40% RA material required some modification of batching plant equipment and material handling processes so that the higher-than-usual rate of recycled material could be accommodated.

An assessment of the whole-life energy requirements and carbon impact of the RA material was undertaken, based on the process set out in PAS 2050[7]. The energy and carbon savings achieved through the use of the RA material (when compared to using 100% virgin aggregate mixes) are shown in Table 1.

[5] Information provided directly by Galliford Try
[6] Transport Research Laboratory.(2010). Enhanced levels of reclaimed asphalt in surfacing materials: A case study evaluating carbon dioxide emissions. [Online], Available at: https://trl.co.uk/reports/PPR468. [Accessed 09/08/17]
[7] PAS 2050:2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. Available at: https://shop.bsigroup.com/forms/PASs/PAS-2050/ [Accessed 03/01/2018]

Table 1: Summary of energy and carbon savings

Savings realised by the scheme as compared to alternative *MasterPave* construction:	134.3 GJ of energy
	8.75 tonnes of CO_2
Equivalent to emissions resulting from an average car travelling approximately	52,350km (32,700 miles)
Equivalent to the number of typical motorway lights (250 W) that could be powered for their entire 4,000 h average life	37 lights

The study focused on the carbon and energy requirement differences between virgin aggregate and reclaimed asphalt, rather than performance characteristics. Therefore, these results should be analyzed also against the virgin aggregate and reclaimed asphalt performance.

Sustainable Drainage Solution – Aggregate Industries[8]

Aggregate Industries developed and trialled a new sustainable drainage product as part of their Life™ range of solutions on a highways maintenance scheme in Shrewsbury (St. John's Hill). This range of sustainable solutions meet the three following benchmarks (when compared to traditional highways maintenance materials):

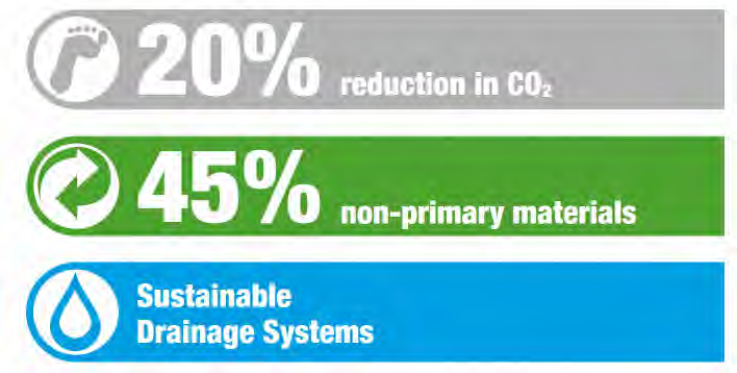

Figure 4: Three benchmarks of the Life™ range of products

The sustainable drainage system used on this scheme incorporated half-warm mix technology, which meant it was able to be produced, transported and installed at lower temperatures. The product delivered significant carbon footprint reductions, while providing performance characteristics with regards to deformation resistance, stiffness and compactability that equalled typical hot-mix products.

Promoting the widespread use of VALORCOL – COLAS[9]

VALORCOL is a cold-mix asphalt developed by COLAS, which consists of 100% reclaimed asphalt aggregate and a cold emulsion binder. VALORCOL has been used extensively in Switzerland as a sub-base and base course material, and, to a lesser degree, within surface courses. The thicknesses of the layers are comparable to traditional hot-rolled asphalt.

VALORCOL has a range of benefits in relation to both whole life financial and carbon savings, as follows:

Resource savings:

- The product contains 100% reclaimed asphalt, resulting in the saving of primary materials
- Reduced need for waste disposal

Transportation:

- Sources of reclaimed asphalt are usually closer to the scheme location than a quarry, reducing the transportation

[8]Aggregate Industries. (2013). Highways and infrastructure solutions. [Online]. Available at: https://www.aggregate.com/documents/brochures/highways-sector-guide-aggregate-industries-b.pdf. [Accessed 15/08/17].
[9]International Road Federation. (date). Innovative Practices for Greener Roads. [Online]. Available at: https://www.irfnet.ch/files-upload/pdf-files/IRF_BP_Environment_Web.pdf. [Accessed 15/08/17].

distance of materials.

Reduction in energy consumption and carbon emissions:

- The use of a cold-mix emulsion and reclaimed aggregates means that the energy consumption and carbon emissions associated with production and application are lower than traditional hot-mix materials using virgin materials.

A 12,000m^2 highway maintenance scheme in Jura, Switzerland, used 3,000 tonnes of VALORCOL in the pavement's base course. Post construction analysis showed that energy and carbon savings of 48% were achieved, when compared to if more traditional materials had been used (transported hot bitumen and primary aggregates), as presented in Figure 5.

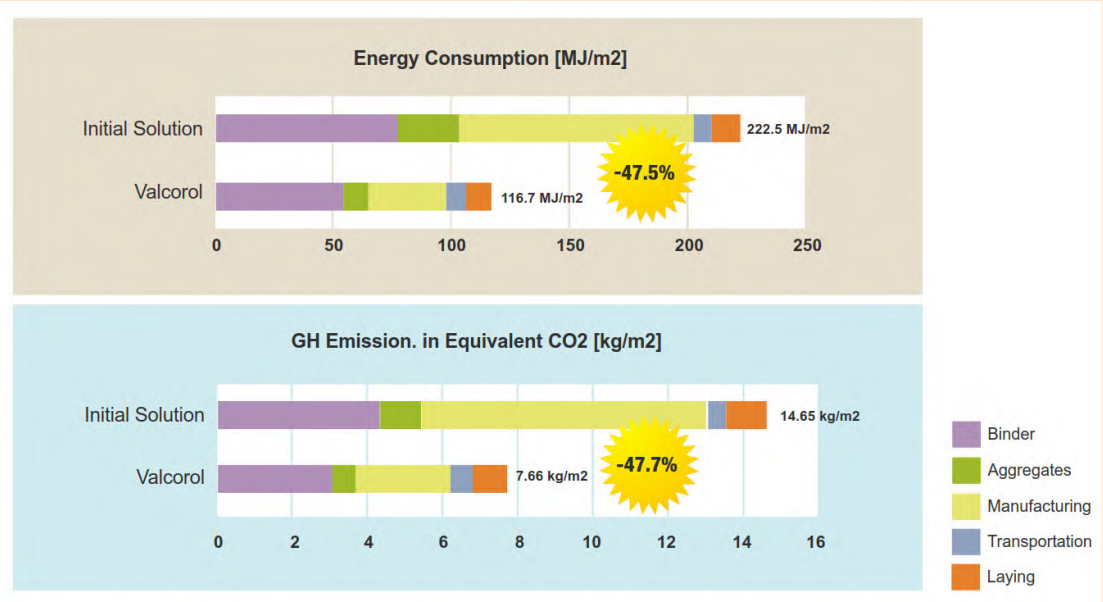

Figure 5: Comparing VALORCOL and initial asphalt solutions, with regards to energy consumption [MJ/m^2] and greenhouse (GH) gas emissions in [CO_2e[kg/m^2]].

Sheffield Private Funding Initiative (PFI); Delivering excellence in pavement solutions- Aggregate Industries[10]

The Sheffield Private Funding Initiative (PFI) is a 25 year contract, allocating £2 billion to the improvement and maintenance of the Sheffield City Highway Network. The network and assets covered by the scope of the PFI includes:

- 1,900km of carriageway;
- 3,300km of footway;
- 68,000 street lights;
- 500 traffic lights;
- 18,000 items of street furniture;
- 12,700 name plates; and,
- 30,000 trees.

The overarching aim of the PFI is to bring the network up to the standard required to minimise the maintenance required in the final 20 years of the PFI.

The challenge associated is that a significant amount of the highway network contains tar-bound asphalt, which is a hazardous material when disturbed and therefore poses issues during disposal.

An initial proposal to deal with the tar-bound asphalt was to apply a high temperature recycling process to process the planings. Although this process was previously successful in Bedfordshire, it proved to be too slow and have a too high energy requirement to make it a feasible option (economically and environmentally) for Sheffield.

[10] Direct from Aggregate Industries

A series of alternative solutions were subsequently identified and proposed, these being:

- **Foamix** as a method to recycle the tar-bound planings by reusing the material as a binder course in highways and footways. Foamix is a cold recycled bound material, manufactured from recycled aggregates that are bound with foam produced by mixing atomised bitumen and water. This makes it a suitable alternative to bitumen emulsion, producing high strength pavement material. There are two types of Foamix:
  - Foamix heavy duty (QVE); suitable for heavily trafficked applications, specifically highways.
  - Foamix standard (SVE); suitable for footpaths and cycle paths; after mixing the material can be stored for up to 28 days.
- **Cement Bound Mixtures (CBM)** where planings are incorporated into a CBM using a mobile concrete batch plant.
- Any non-hazardous planings could be used as **backfill** material or within **asphalt mixtures**.

Quick Visco-Elastic (QVE) materials typically have stiffness equal to standard dense pavement material, and an equivalent life expectancy to dense asphalt construction.

Foamix, in particular, uses much lower temperatures during production and application than standard asphalt mixes, providing significant carbon savings. Recycled materials also provide additional environmental benefits, such as a reduced demand for virgin aggregates.

Asphalt Recycling

Asphalt recycling is common practice in the US; however, uptake in the UK has, so far, been limited. This is largely due to reluctance to use recycled asphalt material in the upper-most surface course of pavements, which traditionally uses virgin aggregate with high polished stone value (PSV) to provide the required skid resistance.

FM Conway, in partnership with Transport for London, trialed the use of recycled asphalt material in the surface course on the A1 at Mill Hill[11]. This trial has so far proved very successful, with early indicators showing that skid resistance provided by the material is consistent, with high levels of PSV. As such, FM Conway proceeded to lay an asphalt surface course containing 50% high PSV recycled aggregate on the A40.

[11] Infrastructure Intelligence (2016). nnovative asphalt ramping up recycling. [Online]. Available at: http://www.infrastructure-intelligence.com/article/apr-2016/innovative-asphalt-ramping-recycling [Accessed 27/03/18]

Street lighting, Signalling and Signage

New traffic lights to help reduce carbon footprint – Lincolnshire County Council[12]

Lincolnshire County Council has recently been undergoing a transition to low energy LED light systems across both traffic lights and street lighting, in an attempt to reduce the council's carbon footprint and to achieve whole-life cost savings. At the time of writing, approximately a third of the county's lighting had been upgraded to LED technology.

The new LED light systems are expected to be six times more energy efficient than conventional street lighting options, with the potential to achieve carbon reductions of 300 tonnes per year, and energy savings of £60,000 per year.

Funding for the project is from the Lincolnshire County Council's Salix fund, which is designated to improve energy efficiency and is matched by government funding through the Carbon Trust.

Figure 6: Updated LED traffic lights on Bardney Bridge, Lincolnshire (Google Maps)

Highways Asset Review and Reduction Programme – Derbyshire County Council

Derbyshire County Council's Highways Asset Review and Reduction Programme (HARRP)[13] was created to minimise the impact of the highway network (specifically road signs) on Derbyshire's natural landscapes, heritage and townscapes. It is believed that too many signs and road markings can also reduce the effectiveness of important road safety messages by making it harder for road users to identify and process the messages. The HARRP also has the objective of identifying opportunities to reduce the environmental impact of sign production, installation and operation.

As part of the HARRP, Derbyshire County Council is reviewing traffic sign provision in certain areas of the county to determine whether any existing signage can be deemed as unnecessary and therefore removed. At the time of case study development, 75 traffic signs and 40 posts have been removed in Dronfield, North East Derbyshire. In terms of lighting provision, unnecessary lighting at traffic signs causes light pollution, drives up energy costs and generates carbon emissions. Between 2012 and 2013, lighting was removed from 344 signs across Derbyshire, accumulating to an estimated saving of 31 tonnes of carbon per year[14].

[12] Lincolnshire County Council. (2016). New traffic lights on Bardney Bridge will help reduce carbon footprint. [Online]. Available at: https://www.lincolnshire.gov.uk/news/new-traffic-lights-on-bardney-bridge-will-help-reduce-carbon-footprint/129859.article. [Accessed 08/08/17].

[13] Derbyshire County Council Highways asset review and reduction programme (HARRP). Available at: https://www.derbyshire.gov.uk/transport_roads/roads_traffic/harrp/default.asp [Accessed 03/01/2018]

[14] Derbyshire County Council. (Date). Highways asset review and reduction programme. [Online]. Available at: https://www.derbyshire.gov.uk/transport_roads/roads_traffic/harrp/default.asp. [Accessed 08/08/17].

Smart streetlighting

IoTUK commissioned a report[15] to look into the future of street lighting and the potential for new technology development. The report highlights that the switch to LED lighting alone may not be enough to meet energy consumption and reduction targets, and they propose that the low-energy progression of street lighting needs to follow three stages:

- **Stage 1** – Switch to LED bulbs
- **Stage 2** – Connected street lighting
- **Stage 3** – New service development

Connected street lighting can provide greater means of control over lighting assets; for example, by allowing operators to change light levels based on local conditions, and incorporating motion sensors to switch lights on when cars or pedestrians are in the vicinity. Central Management Systems (CMS) can be used to remotely and intelligently manage lighting, connected via wireless internet connections, radio frequency, GPRS, 3G etc.

The proposed third stage moves beyond just the lighting bulb and considers applications and opportunities for the whole lighting column. Lighting columns can act as a conduit for other 'smart' applications through the integration of data collection devices, such as sensors and cameras. Figure provides an overview of the potential applications for lamppost lighting column.

Figure 7: Applications for the modern lamppost

[15] iot UK. 2017. *The future of street lighting, the potential for new service development* [Online]. Accessed from: https://iotuk.org.uk/wp-content/uploads/2017/04/The-Future-of-Street-Lighting.pdf [Accessed 21/11/2017]

Techniques and Technologies

A465 Dualling from Brynmawr to Tredegar - Carillion[16] [17]

Figure 8: Dual-carriage-way, from Brynmawr to Tredgar.

A 7.8km dual carriageway was constructed through a valley and mountain landscape to create an important link between the Midlands and South-West Wales.

A pre-construction whole-life carbon assessment identified opportunities to achieve a 10% reduction in construction carbon footprint. Steelwork, concrete and bituminous surfacing accounted for 80% of construction carbon in the scheme, and therefore these areas in particular were identified as areas in which significant carbon savings could be made.

Furthermore, a significant amount of carbon is generated during the in-use life of a road. Bearing this in mind, the road was designed to make it as carbon efficient as possible for road users. An estimated 18,404 tonnes of carbon over the first 15 years of the road's lifetime was saved by replacing a planned viaduct with an embankment. Grade-separated junctions also led to a reduction in in-use carbon.

Furthermore, 2,000 tonnes of carbon was saved during the construction phase by using ECO welfare units (environmentally efficient site accommodation), hydrogen generators, an ePOD (electronic Proof Of Delivery) small plant distribution container and LED lighting.

Other additional good practice included the construction site access road being recycled to form part of the permanent cycle track. There was also the promotion of car sharing within the project team, which resulted in a saving of 1,334kg CO_2 during construction.

Low Carbon Innovative solutions[18]

The following case studies from Aggregate Industries present how smaller-scale interventions and solutions can lead to carbon saving benefits.

Figure 9: Eco Countryside Cycle Kerb

The Eco Countryside Cycle Kerb, which safely segregates cyclists from passing traffic, is able to withstand vehicular

[16] Carillion. (Date). A465 dualling from Brynmawr to Tredegar – a road to regeneration. [Online]. Available at: https://www.carillionplc.com/news-and-media/a465-dualling-from-brynmawr-to-tredegar-a-road-to-regeneration/. [Accessed 08/08/17]
[17] Exemplar. (Date). A465 dualling - Brynmawr to Tredegar. [Online]. Available at: http://www.cewales.org.uk/files/5514/7739/1657/Website_Version_-_CE_A465_4pp_EXEMPLAR_-_Design_Stage_Web.pdf. [Accessed 16/08/17]
[18] Aggregate Industries. (2015). Sustainability Report. [Online]. Available at: http://www.aggregate.com/pagefiles/6765/sustainability-report-2015.pdf. [Accessed 15/08/17].