Centre of Excellence
for Decarbonising Roads

WARM MIX ASPHALT LIVE TRIAL EVALUATION REPORT

Live Labs 2 North Campus

This report evaluates Warm Mix Asphalt (WMA), an asphalt additive added during mixing which reduces the manufacturing and laying temperature requirements for asphalt, as a sustainable alternative to Hot-Rolled Asphalt (HRA). WMA demonstrates overall lower carbon emissions (A1-A5) than conventional HRA primarily due to lower working temperatures reducing energy consumption at the plant and on site. Recommendations drawn from this trial include implementing a robust monitoring period to assess whole lifecycle carbon savings and deployment of WMA as an alternative to HRA in local authorities.

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Executive Summary

This report evaluates a live trial conducted as part of the Live Labs 2 project, which aims to test innovative highway solutions to reduce carbon emissions, improve road performance, reduce maintenance needs, and enhance safety. This trial focused on Warm Mix Asphalt (WMA), an asphalt mix manufactured and laid at substantially lower temperatures than conventional Hot Rolled Asphalt (HRA) by using additives that retain workability and compaction at reduced temperatures.

WMA was trialled as part of the Supersite Trial (a single stretch of highway trialling several materials and techniques), along Hirst Road in North Lanarkshire. WMA was trialled as a surface course within section 3 and section 6 of the supersite at a depth of 50mm. A control section of Hot-Rolled Asphalt (HRA) surface course was also applied to the supersite at a depth of 50mm to allow for direct comparisons to the business as usual (BAU) approach to surfacing for North Lanarkshire Council. The findings, limitations, and recommendations presented in this report aim to inform the potential rollout of WMA across UK local councils.

This report assesses carbon emissions across materials extraction to construction lifecycle stages in accordance with EN 15804, covering product stages A1-A3 of this standard (raw material extraction, transportation to processing facilities and manufacturing) and construction stages A4 to A5 (transportation of the finished material to site and installation). EN 15804 classifies carbon and establishes a modular, transparent approach to lifecycle assessment that assigns emissions to defined stages. Using EN 15804 ensures that this live trial is in line with the recognised European standard, follows accepted boundaries and allocation rules, and enables results that are comparable, auditable and consistent across products and projects.

WMA contributes to carbon saving through lowering production and lay temperatures which in turn reduces fuel consumption at the plant and during heating. Lower temperatures also reduce binder ageing, improving durability and potentially extend service life. Warm mixes can typically also accept higher Recycled Asphalt Pavement (RAP) content, reducing the demand for virgin materials.

The findings from this trial show WMA to be suitable in reducing carbon intensity when compared to conventional HRA, with trial results showing 8.39 $kgCO_2e/m^2$ for WMA versus 9.19 $kgCO_2e/m^2$ for benchmarked HRA (both applied at a depth of 50mm), indicating reduced carbon emissions when trialled under real life conditions. The primary driver of this reduction is the lower embodied carbon emissions (A1-A5) associated with lower temperatures during manufacturing and construction. Recommendations include implementing a robust monitoring plan to evaluate performance and access whole lifecycle carbon savings and the potential adoption of WMA as a carbon saving surfacing material more widely in more Local Authorities.

Introduction

This Evaluation Report provides a high-level assessment of Warm Mix Asphalt (WMA), an emerging sustainable material in highways, construction and maintenance, focusing on its environmental impact, product viability, and alignment with future infrastructure needs. WMA is asphalt manufactured and laid at lower temperatures than Hot Rolled Asphalt (HRA) by using additives to retain workability. WMA offers increased durability, reduced fuel consumption, extended service life and quicker laying than conventional HRA.

Live Labs 2 is a three-year UK-wide programme funded by the Department of Transport (DfT), with a five-year monitoring and evaluation period, focusing on how to decarbonise local highways infrastructure and assets. As part of this initiative, North Lanarkshire Council (NLC) are working alongside Transport for West Midlands (TfWM), to establish the UK Centre of Excellence for Materials Decarbonisation in Local Roads.

The Centre of Excellence will act as a central hub within Live Labs 2, supporting research, innovation, and best practices to accelerate low-carbon solutions in road construction and maintenance. By integrating findings from Live Labs 2 trials, the centre will drive sustainable advancements, enabling Local Authority Highway sectors across the UK to adopt more efficient and environmentally responsible materials and methodologies.

The purpose of this report is to present key findings from a comprehensive evaluation of sustainable materials, including their carbon intensity, potential application, and overall benefits by examining carbon appraisals, lifecycle benchmarks, and various factors such as scalability, compliance, durability and supply chain viability. The report aims to provide decision-makers with valuable insights into the material's capacity to meet sustainability goals while maintaining construction quality. The evaluation will inform ongoing efforts to balance environmental considerations with operational efficiency in infrastructure development.

The carbon profiles of materials have been calculated using the Future Highways Research Group (FHRG) tool Carbon Leadership Profiler Toolkit (previously known as Carbon Analyser), a excel-based tooled developed in collaboration with local highway authorities to provide a simple, standardised method for quantifying carbon emissions associated with transport and highways activities, and the OneClickLCA database where embodied carbon data is otherwise unavailable. All carbon profiles have incorporated a local and sector-wide baseline material to benchmark carbon savings. The WMA trial has been evaluated against conventional HRA.

The carbon evaluations for WMA incorporate whole lifecycle assessments which consider:

- Embodied Carbon;
- Transportation emissions of materials and people;
- Operation of plant and equipment during construction period;
- Operational electricity, fuel and water emissions;
- End of life emissions including deconstruction and waste processing.

Feature	Description	Carbon Intensity	Product Prospects
Material Summary	**Description of material**	**Specific emissions data (CO_2e per unit of material)**	**Brief product potential overview**
Warm Mix Asphalt (WMA) - Holcim	Warm Mix Asphalt (WMA) an asphalt concrete manufactured and laid at substantially lower temperatures than conventional Hot Mix Asphalt (HRA) by using additives that retain workability and compaction at reduced heat. WMA can contain a high percentage of recycled asphalt without deleterious change to its properties.	Initial carbon analysis of A1-A5 carbon emissions from this trial has shown that WMA produces 8.39 $kgCO_2e/m^2$. When applied on the same stretch of road conventional HRA produced 9.19 $kgCO_2e/m^2$. Both surface course materials were applied at a depth of 50mm. Comparative carbon analysis in this trial showed a 9% reduction in A1-A5 lifecycle stage carbon emissions per square metre and a 10% reduction in A1-A5 emissions per tonne. However, the baseline HRA on the supersite contained 15% Reclaimed Asphalt Pavement (RAP) while WMA contained 10%. To allow for a more complete comparison, carbon modelling of WMA and HRA 0% RAP has been completed. This modelling demonstrated a 20% reduction.	It is considered that this product has a potential in the road construction and maintenance industry, particularly in projects prioritising sustainability. Warm Mix Asphalt has shown a 7.9% lower material and 17.64% lower construction stage carbon emissions when compared to HRA in this trial, proving it can deliver reduced carbon surfacing in live environments. The results demonstrate the materials potential for widescale carbon savings across local authority networks and supports potential for easy adoption by local authorities across the country.

Methodology

Trial Design

The Warm Mix Asphalt (WMA) trail was designed to evaluate the performance, durability, and environmental impact of the material. The trial was conducted as part of the larger Supersite trial (a single stretch of highway trialling several materials and techniques), which focussed on testing innovative low-carbon surfacing materials and in-situ recycling techniques to evaluate their carbon savings and long-term performance under real-life road conditions. WMA was applied to section 3 of Hirst Road which had previously undergone cold in-situ recycling by Colas Regen and section 6 which has previously undergone cold in-situ recycling completed by Stabilised Pavements Limited SPL, to assess the material's high durability claims.

Carbon emissions have been assessed based on the whole lifecycle stages A1-A5 (material extraction to construction) in accordance with EN 15804. EN 15804 is the European standard that defines the rules and reporting format for Environmental Product Declarations (EPD) for construction products, providing a consistent, audible framework for quantifying carbon impacts across a products lifecycle. These stages cover raw material extraction, transport to and manufacture at the factory, delivery to site and on-site installation, see Figure 1. This clear separation of stages enables precise attribution of emissions to each segment of the supply chain, helping to identify areas for potential reduction measures and ensuring comparability across all trials.

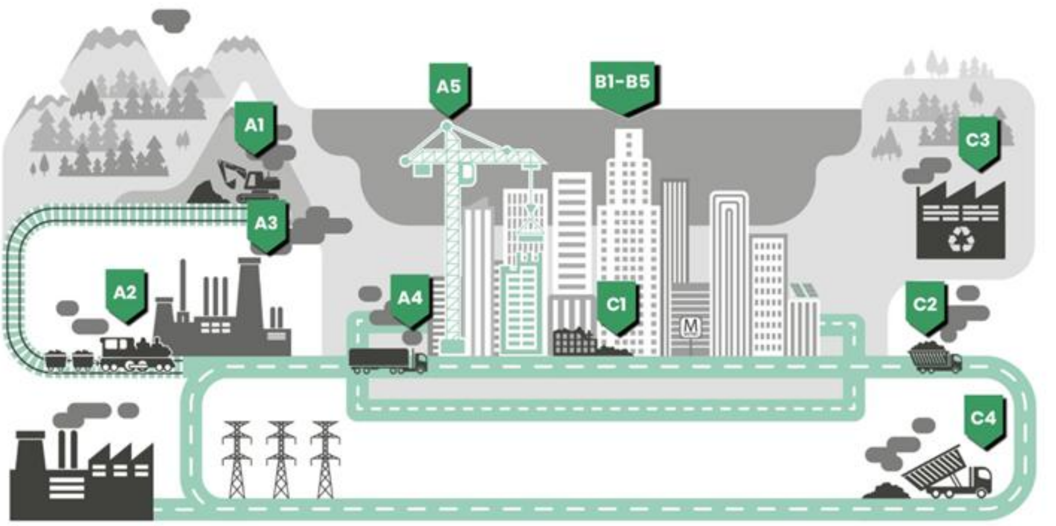

Figure 1: Carbon Lifecycle Stages[1]

[1] https://help.oneclicklca.com/en/articles/275901-life-cycle-stages

Site Selection

The trial sites were chosen based on the following criteria:

- **Traffic Volume:** The site was chosen as it experiences high numbers of both light and heavy vehicles allowing for the assessment of the material's performance under differing stress conditions.
- **Environmental Conditions:** The Supersite site was selected due to its varying weather conditions (e.g., temperature, humidity) to evaluate the surfacing material's resilience.
- **Surface Type:** Sites were all originally with hot-rolled asphalt (HRA) and had severely deteriorated, requiring urgent maintenance.

Data Collection Plan

The following data items were collected to ensure a thorough evaluation of WMA during site trials:

DATA ITEM	UNIT(S)	RESPONSIBLE	LOCATION OF DATA	PURPOSE
Trial Location	Road name, Road Type (A, B, C), Coordinates of location of WMA	Operational Staff	Site Diary	Technical comparisons
Conditions at the time of lay	Temperature (Celsius) Conditions (rain, dry, etc)	Operational Staff	Site Diary	Operational considerations and technical comparisons
Coring	Pen Softening Point DSR	University of Nottingham	Site Diary	Technical Evaluation
Road Surface Temperature	Temperature (°C)	Inspector	Site Diary	Technical Evaluation
Quantity	m^2 of WMA used	Operational staff & Carbon Lead	Site Diary	Cost and Carbon Evaluations
Cost	£ for WMA £ for conventional resurfacing	Amey Procurement and Suppliers	SAP	Purchase cost and whole lifecycle cost evaluation
Line Characteristics	Length and Width (cm)	Carbon and/or Technical Lead	Site Diary	Technical and Carbon Evaluation
Operational Experience – ease of installation	Subjective – any concerns or benefits experienced by Operations Team	Project Manager to collect on-site data with Operations Team	Case Study in knowledge bank	Scalability Evaluation
Health & Safety	Ease of installation on-site Temperature required for installation	Operational staff and supplier information	Site Diary	Health and Safety Assessment
Operational Data	Time to complete (hh:mm)	Operational Staff	Site Diary	Operational considerations and carbon evaluation
Fuel Usage	Litres of petrol used Type of plant/fleet used (electric, diesel, model)	Operational Staff	Site Diary	Carbon evaluation

Table 1: Data collection plan

Trial Location Plan

The primary aim of the Supersite trials is to undertake a comparison analysis of surface courses with the current benchmark used by NLC, traditional HRA.

There were a total of eight trial sections along one site (Hirst Road), with six surface courses and two binder courses on the main straight stretch of the carriageway and a further two surface course sections at junctions – WMA was tested on section 3 and section 6 of the trial sections. All trial sites were completed on one B classification of road (Hirst Road).

	BINDER COURSE			SURFACE COURSE			
TRIAL SECTION	MATERIAL/METHOD	DEPTH (MM)	SUPPLIER	PRIMARY MATERIAL	INNOVATION	DEPTH (MM)	SUPPLIER
1	In-situ Recycling	110	Colas	HRA	GiPave®	50	Iterchemica/ Holcim
2	In-situ Recycling	110	Colas	HRA	Styrelf bio-PMB	50	Total /Holcim
3	In-situ Recycling	110	Colas	HRA (warm mix)	HRA 35/14 Warm Mix	50	Holcim
4	In-situ Recycling	110	Colas	HRA	Traditional Surface HRA 35/14	50	Holcim
5	In-situ Recycling	4% CEM II and 4% calcined clay binder (150mm HBM recycled layer)	SPL	HRA	UltiPave Bio	50	Tarmac/ Holcim
6	In-situ Recycling	4% CEM II and 4% calcined clay binder (150mm HBM recycled layer)	SPL	HRA (warm mix)	HRA 35/14 Warm Mix	50	Holcim
Junction 1	Traditional Binder	60	Hochtief	14mm HardiPave	HardiPave®	40	Miles Macadam
Junction 2	Traditional Binder	60	Hochtief	14mm MilePave PMB	MilePave®	50	Miles Macadam

Table 2: Supersite trial information

Procedure

Site Preparation: The selected sites were cleaned, prepared and planed for the application of WMA. Loose debris and water were removed to ensure proper adhesion.

Material Application: Roads were prepped as per manufacturer's instructions prior to product application. WMA was applied by Holcim via a paver following conventional HRA processes.

Monitoring and Data Collection: The trial sites will be monitored over a period of 12 months. Data on surface condition, material performance, and environmental impact were collected at regular intervals.

Performance analysis: The performance of WMA was evaluated based on criteria such as durability, resistance to traffic stress, and environmental impact. Comparisons were made versus traditional resurfacing to benchmark performance.

Data Analysis

The collected data was analysed to determine the effectiveness of WMA as a surfacing material as an alternative to conventional HRA. Data analysis methods were used to evaluate the performance of WMA versus a control section (HRA) along the same road. The analysis focused on:

- **Durability**: Assessing the longevity of the treated site and resistance to traffic and environmental stress;
- **Environmental Impact:** Evaluating the reduction in carbon emissions and use of recycled materials; and
- **Cost- Effectiveness:** Comparing the costs associated with WMA, including material, application, and maintenance costs.

The embodied carbon factors for trialled materials have been built based on supplier product data and supported from carbon factors sourced from OneClick LCA where required. An Environmental Product Declaration (EPD) had not been produced for WMA produced by Holcim at the time of the trial. Holcim have provided A1-A3 carbon values for the manufacturing of WMA at Duntilland Quarry. Holcim's internal carbon tool was used to calculate these values. This tool follows the principles of EN 15804 and has been third party verified by Circular Ecology Ltd. The tool uses primary activity data from Holcim operations, secondary data coming primarily from the UK Government GHG emission factors and Inventory of Carbon and Energy v4.0 by Circular Ecology and University of Bath, with additional data supplied by Carbon Trust.

Circular Ecology Ltd verifies to recognised frameworks and standards used in lifecycle assessments, including ISO 14064, PAS 2050, ISO 14067, ISO 14040/44 and EN 15804.

This existence of a third party verified carbon tool provides objective verification that Holcim's carbon claims are transparent and can be independently validated. This positions Warm Mix Asphalt as a credible alternative to conventional asphalt.

Carbon Appraisal

Carbon appraisal

Drawing on data collected through trials; a carbon assessment has been undertaken. Table 3 establishes the parameters of the model, defines assumptions and outlines product specifications.

ASSUMPTIONS	JUSTIFICATION
All transportation is undertaken via diesel HGV.	Based on standard modelling assumptions from similar schemes.
Design life of pavement surface is 40 years.	Based on PAS 2080 guidance[2]. At 40 years the binder course of HRA requires replacing.
Unit of measurement used is ‘kgCO_2e/ m^2’.	Based on the best available data used to conduct carbon appraisals.
Traffic management activities were not included within this carbon assessment.	Traffic management differs between sites and local authorities so requires separate capturing, as part of standard practice.
Government emission factor transport, HGV, diesel 2025 was used to calculate A5 for plant when a specific emission factor is unknown.	Based on the best available data at the time of this carbon appraisal.
This carbon analysis does not incorporate planing out activities within this assessment.	This is a BAU activity therefore is not influenced by this innovative process.
Where specific machine hour carbon emission factors were unavailable emission factors have been selected based on average kW power, sourced from OneClick LCA.	Based on the best information available at the time of the carbon appraisal.
To calculate the CO_2e emissions per tonne of aggregate from each quarry, Holcim utilised the total energy consumption for each quarry (Duntilland and Chryston) over the previous 12 months. Each quarry’s energy use was converted to an equivalent CO_2e emission value then divided by the total tonnage of aggregate sold in that same period.	Based on the most up to date information the contractor, Holcim, had available at the time of this carbon analysis.
Holcim utilised Eurobitume’s 2025 carbon emission factor for bitumen, 530kgCO_2e/tonne.	This figure is the most recent bitumen emission factor and considered the industry standard.
Fuel consumption of dryers has been calculated by the amount of fuel used divided by the tonnage of asphalt supplied. Giving the CO_2e value per tonne of asphalt mixed can vary plant to plant based on tonnage supplied, fuel type, efficiency etc.	Based on the best available data at the time of this carbon appraisal.
The emission factor used for fibre pellets was sourced from ASPECT.	Based on the most recent emission factors available to Holcim (the contractor) for emission factor calculation. Holcim’s internal carbon calculation tool has been externally verified by Circular Ecology and follow EN 15804 principles.
The default emission factor used for RAP (reclaimed asphalt pavement) was sourced from ASPECT.	Based on the most recent emission factors available to Holcim (the contractor) for emission factor calculation. Holcim’s internal carbon calculation tool has been externally verified by Circular Ecology and follow EN 15804 principles.
The emission factor used for limestone filler was sourced from ICE V.3 2020.	Based on the most recent emission factors available to Holcim (the contractor) for emission factor calculation. Holcim’s internal carbon calculation tool has been externally verified by Circular Ecology and follow EN 15804 principles.
The carbon modelling for HRA with 0% RAP assumes equivalent material quantities and construction activities to those recorded for the supersite’s HRA control section, ensuring a like for like comparison.	This approach controls key variables, reducing modelling uncertainty and making the carbon impact of RAP omissions directly attributable.

[2] 2023-03-29-pas_2080_guidance_document_april_2023.pdf

Carbon emission factor for HRA containing no RAP was sourced via One Click LCA from an EPD for Hot Rolled Asphalt surface course mixture (HRA 35/14) manufactured by Roadstone Limited and awarded an EPD by Eco Platform in 2025 (EPD-IES-0020174).	EPDs are prepared and verified to EN15804 and ISO 14025 standards, which makes this emission factor suitable for lifecycle modelling. One Click LCA is widely used within the industry to source and apply verified EPD data in construction carbon models.

Table 3: Carbon appraisal matrix

Carbon Modelling

The carbon modelling for the trials was conducted using the Future Highways Research Group (FHRG) Carbon Leadership Profiler Toolkit to collect and analyse primary carbon data from the trials, detailing emissions from materials, transport, construction activities and equipment use. Using this information the tool generated carbon profiles that identified emission hotspots and using the toolkit's emission database providing verified emissions factors to improve data accuracy.

One Click LCA was also utilised in modelling to support the FHRG Carbon Leadership Profiler Toolkit due to its large database of emission factors supported by Environmental Product Declaration (EPD).

Indicative results from carbon modelling for the WMA works along section 1 of the Supersite on Hirst Road are presented graphically in Figure 2, Figure 3 and Figure 4:

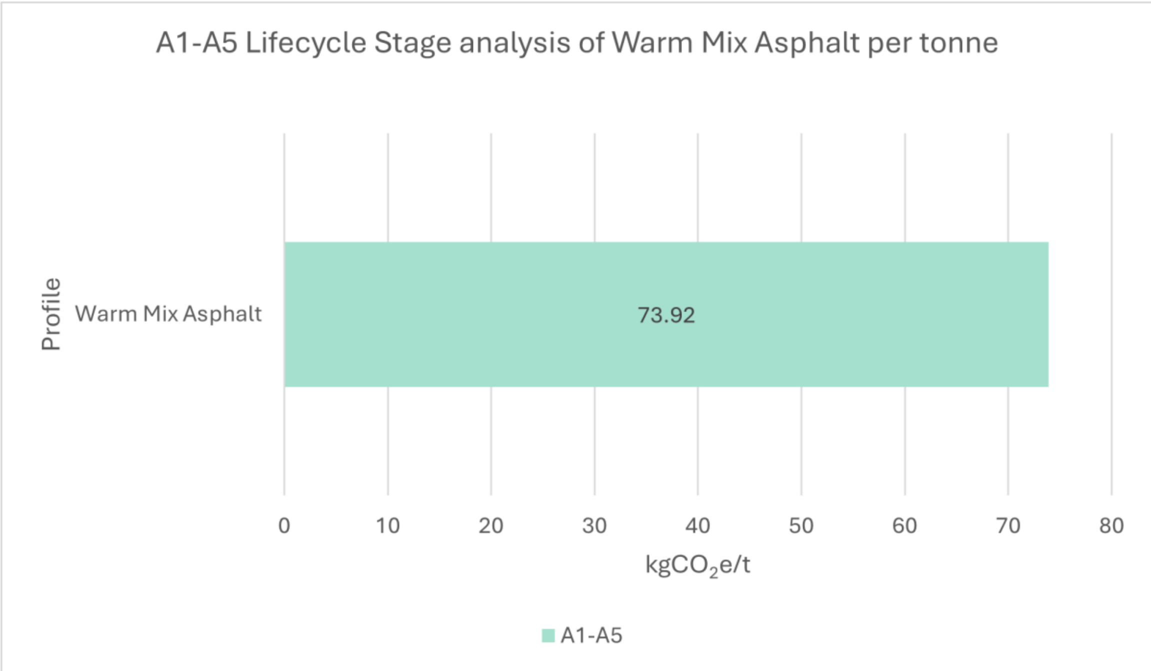

Figure 2: Carbon analysis of Warm Mix Asphalt per tonne (50mm depth)

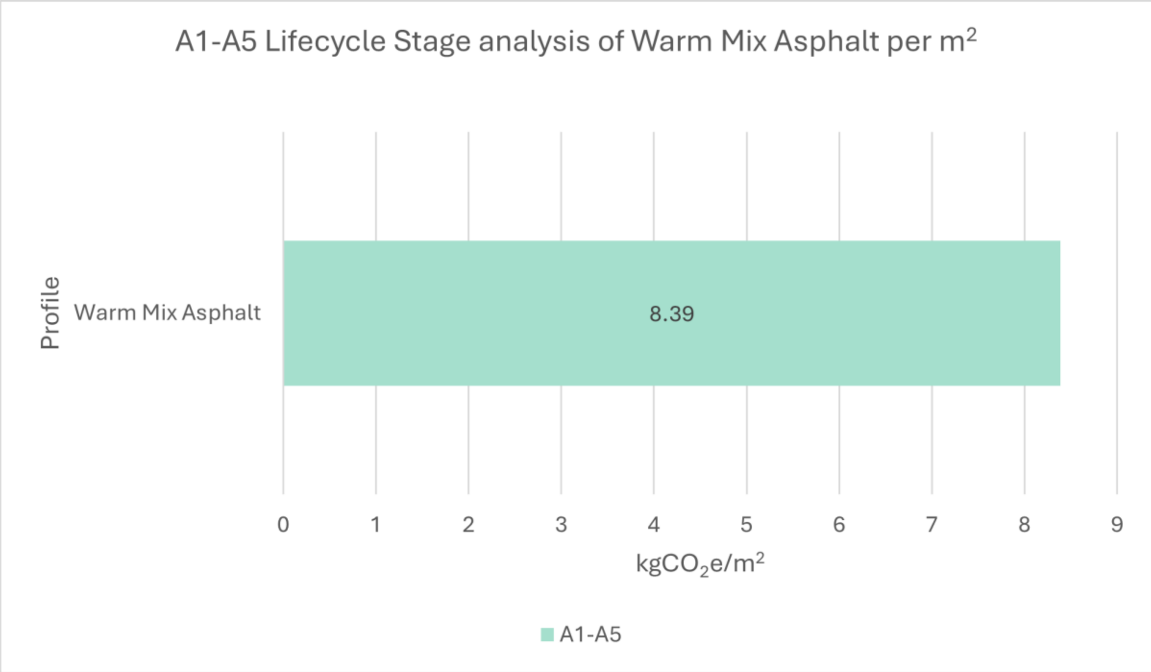

Figure 3: Carbon Analysis of Warm Mix Asphalt per meter squared (50mm depth)

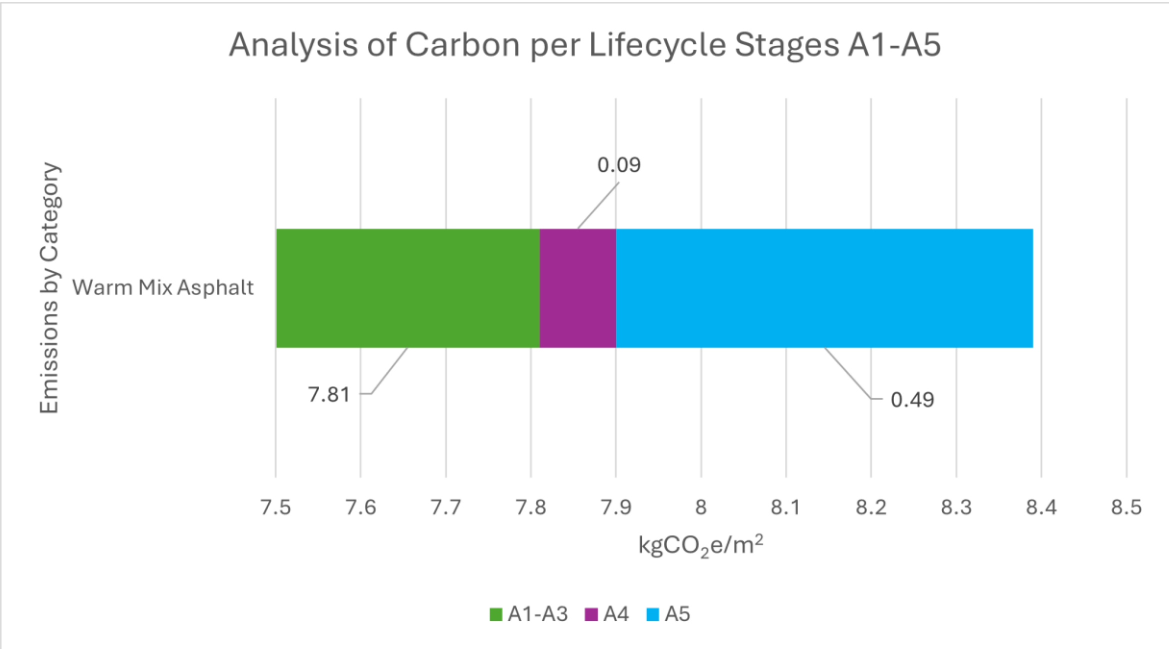

Figure 4: Lifecycle analysis A1-A5 of Warm Mix Asphalt per m² (50mm depth)

Benchmarking

Until this trial, Warm Mix Asphalt is yet to be used on North Lanarkshire Council highways. These trials are to allow for an analysis of the performance of Warm Mix Asphalt in comparison to conventional HRA on the same road of the same traffic loads. This would be the traditional option for re-surfacing if Warm Mix Asphalt was not used. This allows for comparisons between WMA versus BAU surfacing within the carbon analysis.

Comparative analysis results is presented graphically in Figure 5 and Figure 6:

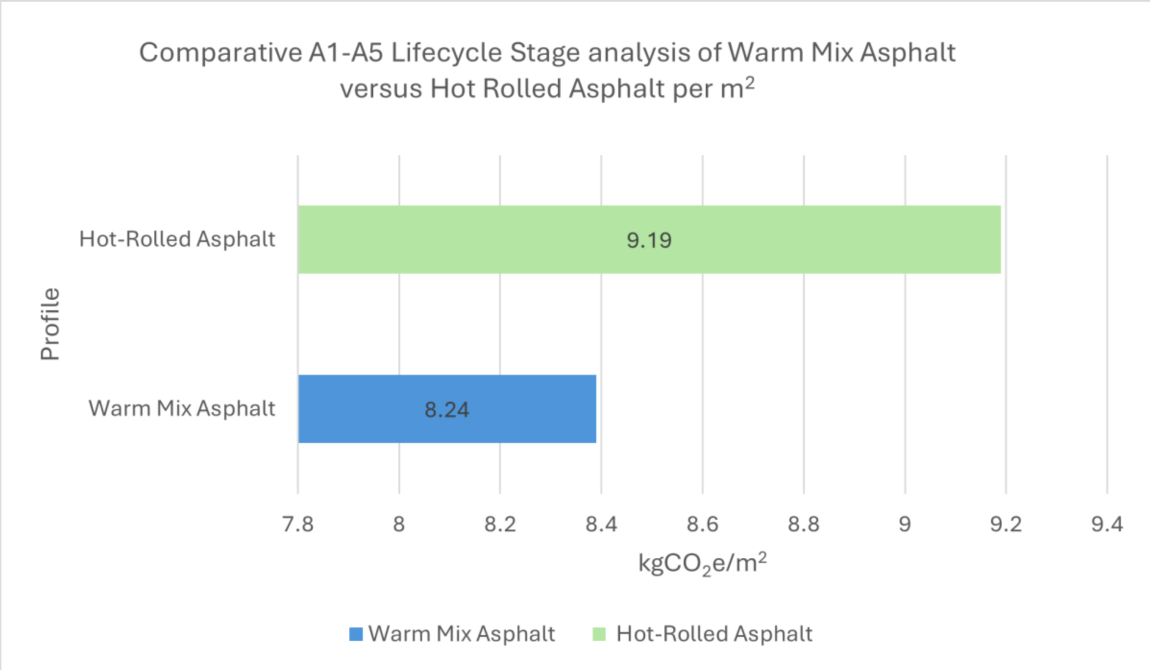

Figure 5: Comparative carbon analysis Warm Mix Asphalt versus HRA per m^2 (50mm depth).

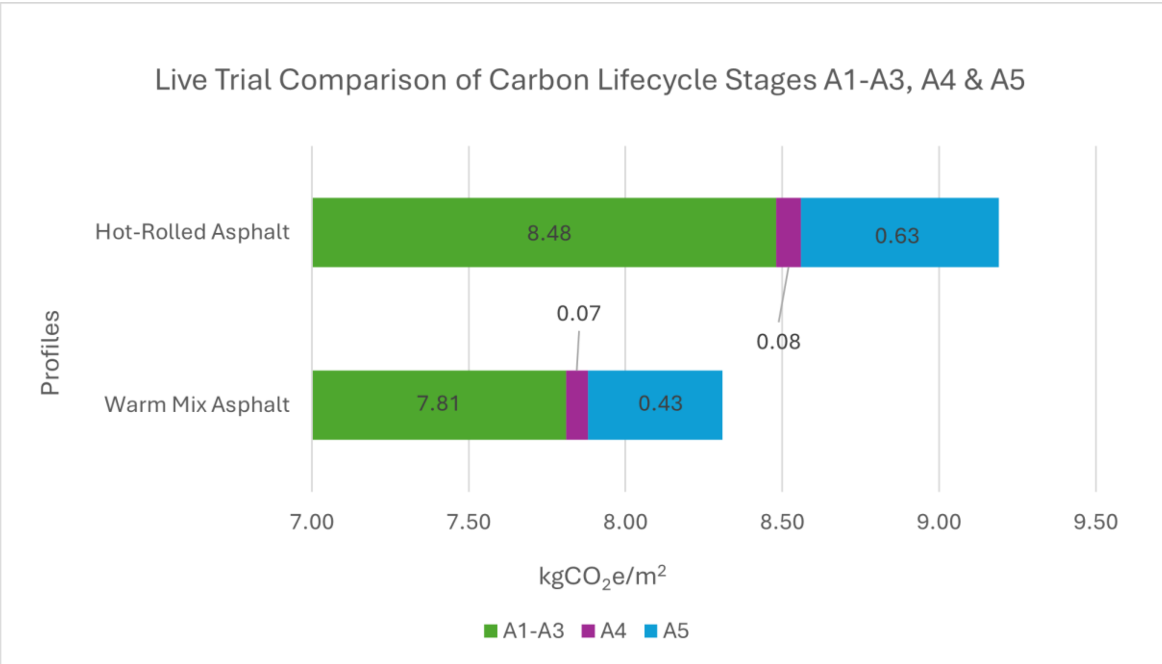

Figure 6: Comparative carbon analysis of Warm Mix Asphalt versus HRA, lifecycle stages A1-A5.

The benchmark HRA control section on the supersite contained 15% RAP while the WMA mix included 10% RAP. RAP content varies by HRA mix and by Local Authority, dependent on specifications and design. To provide a conservative, like-for-like comparison, WMA has been modelled against an HRA baseline with no RAP content to demonstrate further potential carbon savings. Results from this modelling are represented graphically below in Figure 7:

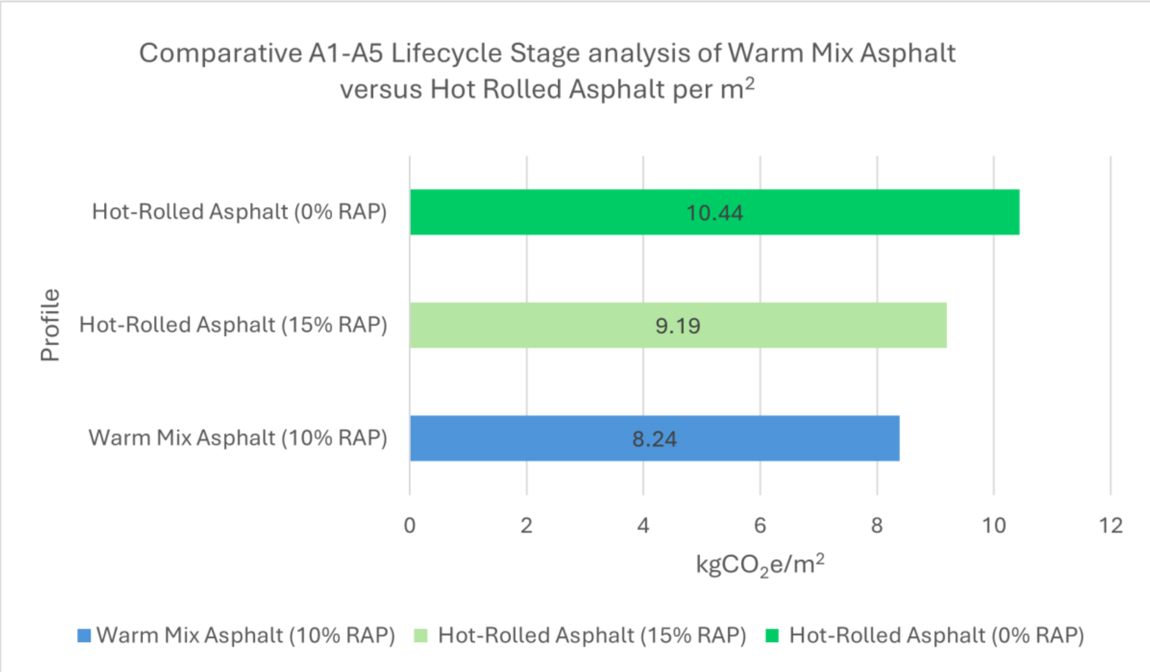

Figure 7: Comparative carbon analysis WMA versus HRA with no RAP content per m^2 (50mm depth)

MATERIAL	COMPOSITION	APPLICATIONS	PERFORMANCE	INSTALLATION	SUSTAINABILITY
HRA	HRA is a dense, gap-graded bituminous mix comprising of a mortar of fine aggregate (sand), filler and bitumen. It is hot applied via a paver. Immediately after paving, the pre-coated high-PSV chippings are rolled into the hot mix to lock in a positive texture for skid resistance.	HRA is predominately used on high-speed and heavily trafficked roads where durable, dense, low-void wearing course is required such as motorways, A-roads, bus lanes, roundabouts etc.	The densely mortared matrix makes HRA impermeable and resistant to rutting and deformation under heavy loads. Its sharp chippings protruding from the surface maximises adhesion and increases skid resistance at even at speed. HRA can be susceptible to rutting if the mix or compaction is incorrect under heavy traffic but is the proven baseline with well-understanding of mix suitability.	HRA is supplied and laid on site at approximately 160-180 °C.– at the Hirst Road site WMA was applied at approximately 155-156 °C. Laid using standard hot-mixing plant and standard paving/rolling practices for HRA. After initial compaction, pre-coated chippings are spread at a controlled rate and rolled in immediately to embed them into the mortar HRA has well-established specifications on procedures across the industry.	Traditional HRA can incorporate reclaimed asphalt pavement (RAP) percentages, though high fines and virgin bitumen grades often limit RAP rates to maintain mortar cohesion.
WMA	The aggregate and binder can be the same types as conventional HRA. The difference is the technology used to allow coating/compaction at lower temperatures. Chemical or organic additives are added during asphalt mixing that temporarily reduce binder viscosity/ improve coating.	Suitable for the same surface courses as conventional HRA when designed properly. WMA is generally used for general resurfacing, reinstatements and projects with sustainability focuses.	WMA performs at the same level as conventional HRA. Long-term performance depends on mix design, binder grade, compaction and site conditions rather than just temperature alone.	WMA production and placement temperatures are lower by approximately 20-55 °C than conventional HRA. WMA often has an extended compaction window. WMA's lower temperatures reduce fumes and steam and improve working conditions for crews, reducing thermal stress and lowering the risk of burns and less odour. Particularly beneficial in urban/close proximity works.	WMA requires reduced fuel consumption due to lower temperatures. WMA technologies can help incorporate higher percentages of RAP (reclaimed asphalt pavement) due to lower production temperatures reducing additional; ageing of the binder and improving the workability with reclaimed binder.

Table 4: Warm Mix Asphalt Appraisal

All factors assessed as part of the appraisal of WMA has been built on supplier provided material and are not drawn from the live Supersite trial.

Warm mix asphalt was produced at two Holcim quarries (Duntilland and Chryston) while HRA was only produced at Duntilland. Chryston is located further from the Hirst Road site, and the aggregated dataset combines deliveries from both quarries, which increases the average transport distance and associated A4/A5 emissions and prevents an accurate, like-for-like comparison between WMA and HRA. To address this, the comparative analysis for HRA has been standardised to the same area (2100m^2) to enable a fair assessment of Warm Mix Asphalt's carbon reduction potential (see Table 5).

Stage	Baseline Carbon Emissions (HRA) (kgCO_2e)	WMA Carbon Emissions (kgCO_2e)	Difference (%) (Increase/ R
	17,799.73	16,393.67	7.90%
	163.98	198.78	21.22%
	1,326.71	1,033.97	22.07%

Table 5: Lifecycle Stage Comparison to BAU per 2100m^2

Carbon Benefits and Considerations (Matrix)

Table 6 presents the findings of the carbon benefits and considerations matrix for Warm Mix Asphalt application. **<u>All scoring is bold and underlined.</u>**

Technical data used during benchmarking and the carbon benefits and considerations matrix were supplied by the manufacturer and are not derived from the Supersite live trial in North Lanarkshire. While reliance on supplier-provided information may introduce uncertainty in confidence levels, the information and data represent the best available evidence at the time of the appraisal. Data quality has been considered when selecting supplier information and, where possible, supplier values were chosen from manufacturers' standard test reports, specifications and product datasheets that reference recognised test methods and certification.

BENEFIT/LOAD UNDER REVIEW	CONSIDERATIONS	SCORING SYSTEM	JUSTIFICATION
Costs	Transport, operational, material procurement	1 - Significant additional costs **<u>2 - Costs approximate baseline</u>** 3 - Costs significantly lower than baseline	The fuel savings made during production offset the additional costs from additives.
Maintenance	Design life, maintenance burden, on-time for plant	1 – Significantly more maintenance/lower longevity 2- Approximately same maintenance/similar longevity **<u>3 – Significantly less maintenance/higher longevity</u>**	WMA reduces binder ageing at lower production temperatures and improve the compaction window of the asphalt. This in turn can extend surface life and reduce routine maintenance requirements.
Scalability	Manufacturing facilities	1 - Lab testing only 2 - In process of commercialisation w. small scale manufacture **<u>3 - Already has market presence with developed supply chain</u>**	There are multiple WMA technologies commercially available from UK suppliers such as Holcim. WMA cane be produced at standard asphalt plants with only minor modifications.

All factors assessed as part of the appraisal of WMA has been built on supplier provided material and are not drawn from the live Supersite trial.

BENEFIT/LOAD UNDER REVIEW	CONSIDERATIONS	SCORING SYSTEM	JUSTIFICATION
Compliance with specifications	Requirements for standards departures	1 - Requires significant departure(s) from standard and has not been used before by end client 2 - Requires some departure from standard, but has been used before by end client **3 - Does not require any departure from standard.**	WMA uses standard paving equipment and can meet HAPAS/ National Highways requirements to the same degree as HRA.
Environmental	Nature-based solution	1 - Would have significant net disbenefit for environmental factors (noise, AQ, biodiversity, landscape etc) **2 - Would have negligible net benefit/disbenefit or no overall change regarding environmental factors** 3 - Would have significant net benefit/disbenefit for environmental factors.	Environmental benefits arise from reduced site emissions due to lower fuel consumption, reducing the time plant is present on site and therefore reducing potential odour and dust related with maintenance activities.
	Road noise	1 - Would have significant net disbenefit **2 - Would have negligible net benefit/disbenefit or no overall change regarding** 3 - Would have a significant net benefit	Typical noise performance is anticipated to be close to the baseline. However, there is potential that specific texture adjustments may provide marginal improvements.
	Climate resilience/future proofing	1 - Would have significant net disbenefit 2 - Would have negligible net benefit/disbenefit or no overall change regarding **3 - Would have a significant net benefit**	WMA's lower binder ageing and ability to include modifiers improve resistance to thermal and oxidative damage, supporting resilience under climate stress.
Risk and safety	H&S impacts, safety testing data	1 - Would present increased risk or safety versus BAU option **2 - Would present no overall risk increase or safety impact versus BAU option** 3 - Would present lower risk or safety impact versus BAU option.	Lower plant and on-site temperatures reduce fume exposure and burn risk. However, overall installation risk is similar to conventional HRA when standard controls are applied.
Technology Readiness Level	Is it commercially available, is there enough R&D?	1 - Not yet commercially available 2 - Commercially available from worldwide suppliers	WMA is readily used within England and internationally with local supply chains and contractor experience in many regions.

BENEFIT/LOAD UNDER REVIEW	CONSIDERATIONS	SCORING SYSTEM	JUSTIFICATION
		3 - Commercially available from European suppliers **4 - Commercially available from UK suppliers** 5 - Commercially available from local suppliers	
Constructability	How easy is it to handle on site, install, recover, curing time, specialist equipment/training, storage?	1 - Specialist contractors, time on site and/or equipment required **2 - No considerations required above and beyond baseline solution** 3 - Significant benefits to on-site activity / ease of installation	Largely compatible with existing plant and paving practices.
Supply Chain	Material availability	1 - Novel materials used with limited supply 2 - Materials are available with some supply restrictions **3 - Materials are readily available**	Binder additives and modified production processes are readily available through established suppliers within the UK.
Circular Economy	Recycled content	1 - Virgin materials are used with little or no recycled content **2 - Materials contain a level of recycled content** 3 - Materials are predominantly recycled and/or use novel sources of recycled content that would otherwise be discarded as waste	WMA typically accepts a higher percentage of RAP (reclaimed asphalt pavement) due to less heating-related viscosity issues, enabling mixes with substantially increased recycled content.
	Ease of recycling	1 - Minimal recycling of material possible upon removal **2 - Limited recycling is possible and/or significant reprocessing required** 3 - Reuse/recycling is easy and convenient	End-of-life recycling remains compatible with standard asphalt recycling streams. The lower ageing of binder may improve recyclability and material value.

Table 6: Carbon benefits and considerations matrix

Long-Term Performance Analysis

The carbon analysis within this report do not contain lifespan analysis. This will be finalised dependent upon the publishing of longevity test results in partnership with the University of Nottingham.

These tests will focus on the following:

- Durability and Aging Resistance,
- Skid Resistance and Surface Integrity,
- Lifecycle Carbon Savings,
- Traffic and Environmental Stress Testing,
- Optimal Reapplication Intervals.

Conclusion & Recommendations

Conclusions

The Warm Mix Asphalt (WMA) live trial has demonstrated that WMA is a credible, low-carbon alternative to conventional Hot Rolled Asphalt (HRA) when produced and laid under real-life conditions. The trial showed a 10% reduction in material extraction to construction (A1- A5 lifecycle stages) emissions, driven primarily by lower production and laying temperatures and the materials potential for higher RAP content. The material is also compatible with standard plant and paving practices, while providing improved working conditions through reduced fumes and extended compaction windows.

It must be considered that A1-A3 lifecycle stage modelling inputs were supplied from the contractor's (Holcim) internal carbon tool, which while third-party verified in accordance with EN 15804 principles, does not have a third-party verified EPD for the specific WMA mix at the time of this analysis. Furthermore, for this carbon appraisal, transportation, plant-specific fuel efficiencies and some machine-hour factors were used using the best available proxies where measured data was incomplete. These factors reduce the independent confidence in reported embodied carbon values and reduces direct compatibility across authorities.

The direct comparison of the results over 2100m^2 (total area of the control HRA section) in table 5 appear to show WMA having higher A4 emissions, this difference is attributable to source location rather than the material itself. Warm mix asphalt was produced at two different quarries (Duntilland and Chryston) while HRA was only produced at Duntilland. Chryston is located further from the Hirst Road site, and the aggregated dataset combines deliveries from both quarries, which increases the average transport distance and associated A4/A5 emissions and prevents an accurate, like-for-like comparison between WMA and HRA. However, when the aggregated data is processed to demonstrate emissions per square meter, WMA does show significant carbon savings overall in A1-A5 lifecycle stages.

Overall, the trial of Warm Mix Asphalt has demonstrated credible potential to deliver meaningful carbon savings when compared to conventional HRA. The material's 7.9% lower A1-A3 lifecycle stage emissions and 22.07% lower A5 lifecycle stage emissions make it a strong candidate for local authority resurfacing across the country.

Warm Mix Asphalt also holds potential to offer further carbon savings when compared with HRA that has no Reclaimed Asphalt Pavement (RAP) content. RAP usage varies depending on the HRA mix specification and Local Authority requirements with many mixes not including high percentages of RAP. To allow for a more conservative comparison Warm Mix Asphalt has been modelled against HRA containing no RAP. This modelling demonstrated a potential to equate for 20% carbon savings across cradle to construction emissions.

Recommendations

It is recommended that robust long-term monitoring (over 5+ years) be implemented at treated sites to comprehensively evaluate performance and verify lifecycle carbon savings. This further long-term monitoring will allow for more expansive carbon modelling to assess end-of-life scenarios to provide a more comprehensive understanding of whole life carbon emissions.

It is advised that Holcim prioritise obtaining a third-party Environmental Product Declaration (EPD) for its warm mix asphalt mix. This should be a priority to verify carbon savings claims. If an EPD is obtained Holcim's WMA will be best positioned for integration into maintenance strategies within North Lanarkshire and other local authorities.