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Promoting sustainable and climate resilience materials for rural roads.
UK case studies

International Conference on 'New Technologies and Sustainable Materials in construction of Rural Roads (Low Volume Roads) and Bridges', 4th to 6th May 2022, Hall No 2, Pragati Maidan, New Delhi, India

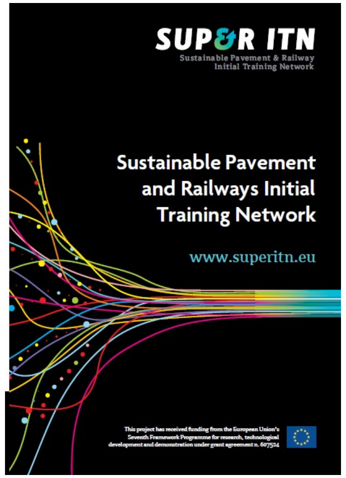
Iswandaru Widyatmoko

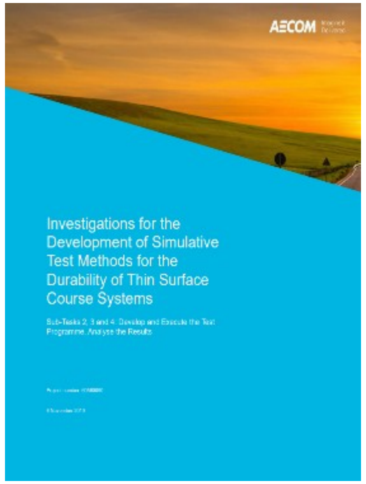
Technical Director, Pavement and Materials Research (Europe – UK & Ireland)

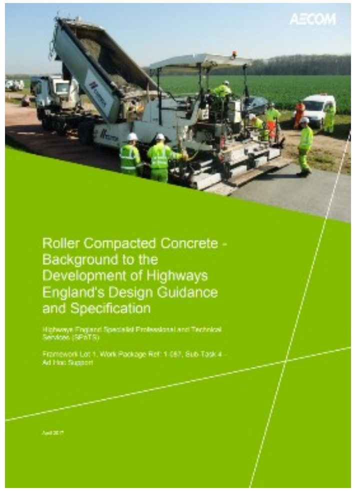
Practical research: Improve whole life cost through materials innovation

- Next generation of road surfacing
- Pavement construction automation
- Smart pavement infrastructure
- Surface characteristics and safety policy
- Specification for road and airfield pavement
- Concrete pavement asset management
- High temperature resistant concrete for vertical landing aircraft

WRA UK Award for “Automation in Construction”, Westminster Abbey, London







ADEPT Association of Directors of Environment, Economy, Planning & Transport
Defence Infrastructure Organisation
highways england

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Outline

- Climate resilience and innovation in materials
- Low energy construction
- Promoting sustainability with higher recycle contents
- Case studies

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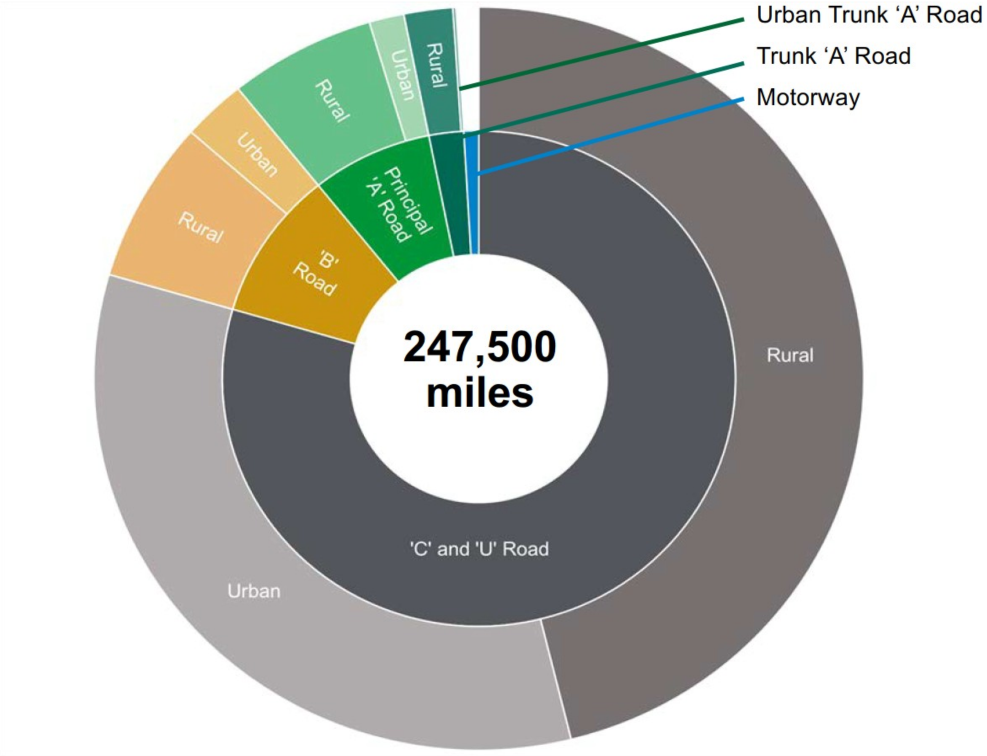
Rural roads in the UK

Classification: major roads and minor roads outside urban areas (but excluding motorways) and having a population of less than 10 thousand.



Category	Description
01	Motorways in holiday areas
02	Motorways in other rural areas with an estimated AADF of of up to 59,999
03	Motorways in other rural areas with an estimated AADF of 60,000 or more
04	Motorways in part rural and part urban areas and conurbations
05	Motorways in mostly urban areas and Greater London
06	Rural A roads in holiday and very rural areas with an estimated AADF of up to 4,999
07	Rural A roads in holiday and very rural areas with an estimated AADF of between 5,000 and 7,999
08	Rural A roads in holiday and very rural areas with an estimated AADF of 8,000 or more
09	Rural A roads in all other areas with an estimated AADF of up to 13,999
10	Rural A roads in all other areas with an estimated AADF of 14,000 or more
11	Urban A roads in holiday areas
12	Urban A roads in all other areas except Greater London with an estimated AADF of up to 19,999
13	Urban A roads in all other areas except Greater London with an estimated AADF of 20,000 or more
14	Urban A roads in Outer London
15	Urban A roads in Inner London
16	Urban A roads in Central London
50	Minor rural roads in holiday areas with an estimated AADF of up to 399
51	Minor rural roads in holiday areas with an estimated AADF of 400 or more
52	Minor rural roads in all other areas with an estimated AADF of up to 2,499
53	Minor rural roads in all other areas with an estimated AADF of 2,500 or more
54	Minor urban roads in all areas except Greater London
55	Minor urban roads in Greater London

Annual average daily flow (AADF) is the number of vehicles estimated to pass a given point on the road in a 24 hour period on an average day in the year
https://www.gov.uk/government/statistics/road-lengths-in-great-britain-2020
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/524848/annual-methodology-note.pdf

Rural roads in the UK

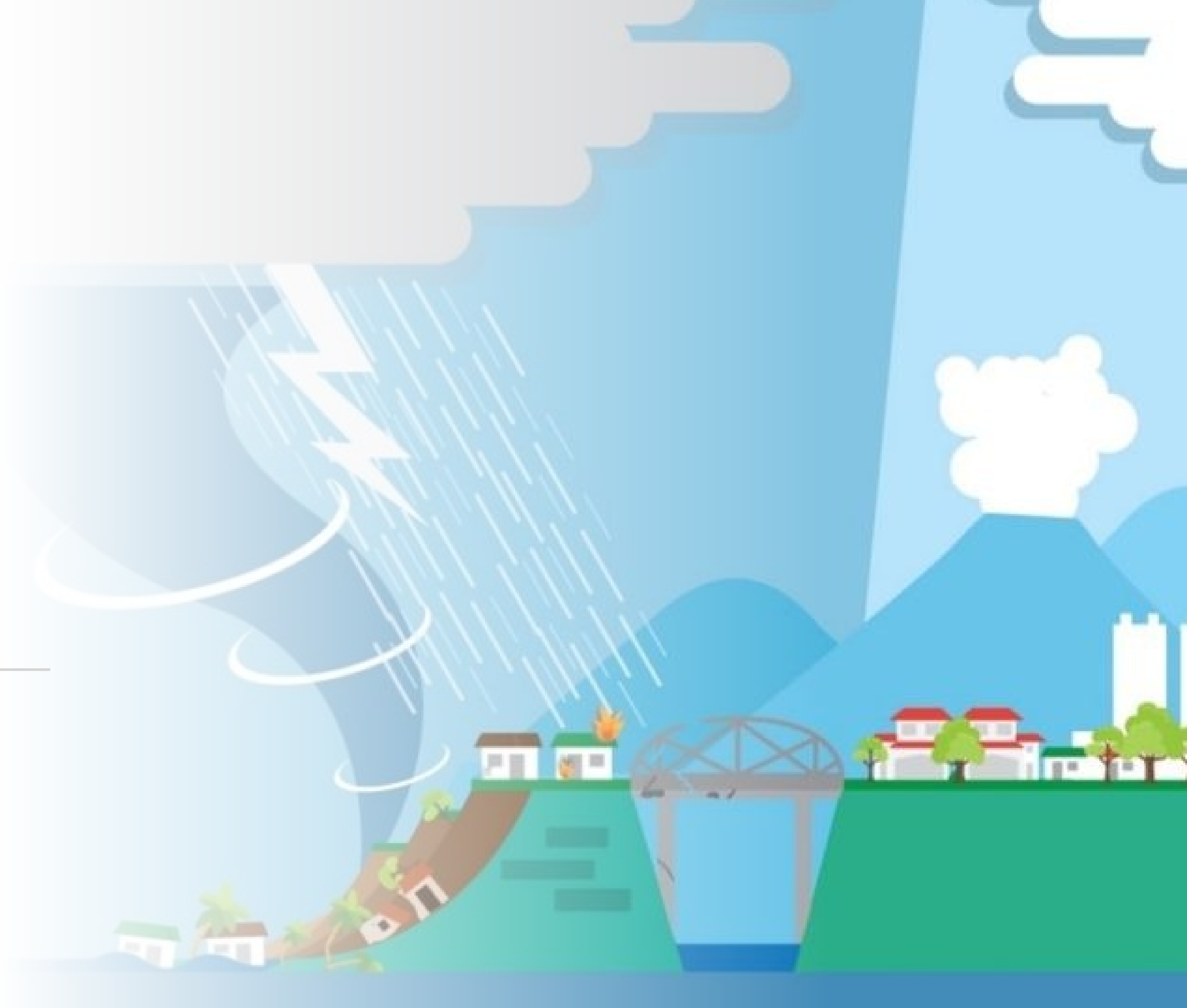
Design:

- Drainage: adequate? close or open?
- Surface condition: sealed or unsealed?
- Structure (thickness), dimension (width)
- Single lane or dual lanes?
- Single carriageway or dual carriageways?

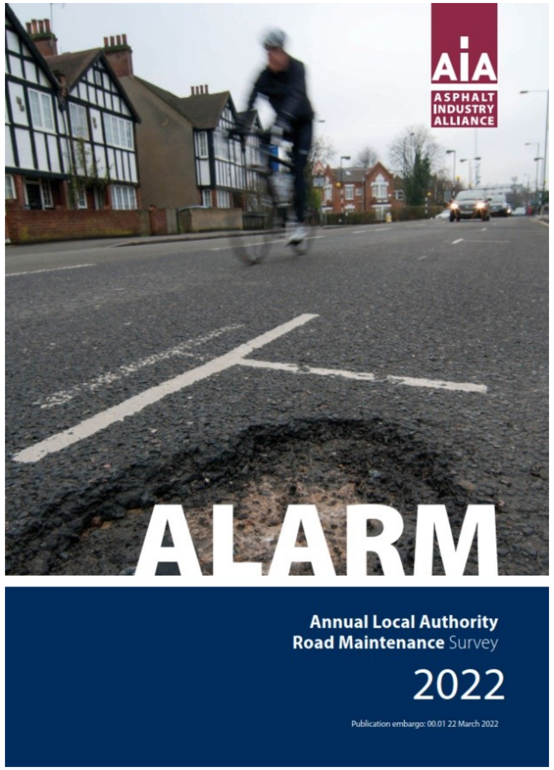
Traffic condition, very low to very high:

- Volume
- Load
- Speed

Climate resilience and innovation in materials



Climate resilience - challenges



Source: ALARM 2022

Local roads in England and Wales

Proportion by type:

- Principal roads: 10%
- Non principal roads: 29%
- Unclassified roads: 61%

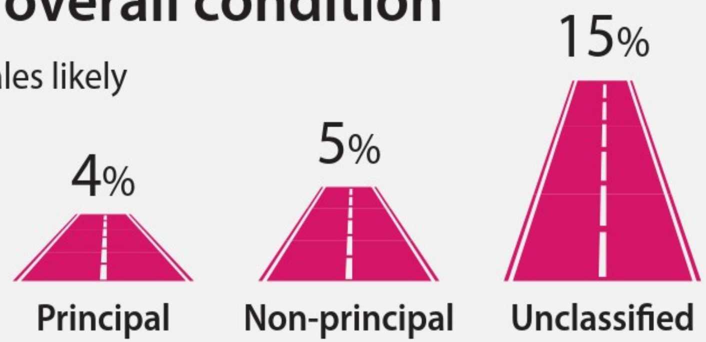
Adverse weather

Adverse weather conditions, particularly wetter winters with more intense downpours and storms and hotter, drier summers, coupled with increased traffic volumes and axle weights and the age of the network can result in accelerated deterioration and unpredicted failures.

The impact is more acute on evolved and less well maintained – and therefore less resilient – roads, where water can penetrate existing cracks or defects, leading to the formation of potholes and, in time, undermine the entire structure of the road.

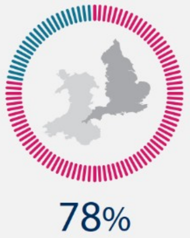
Roads in poor overall condition

Roads in England and Wales likely to require maintenance in the next 12 months



Pothole-related claims

% of road user compensation claims in England and Wales (average per authority)



Recent innovation in materials

Materials innovation

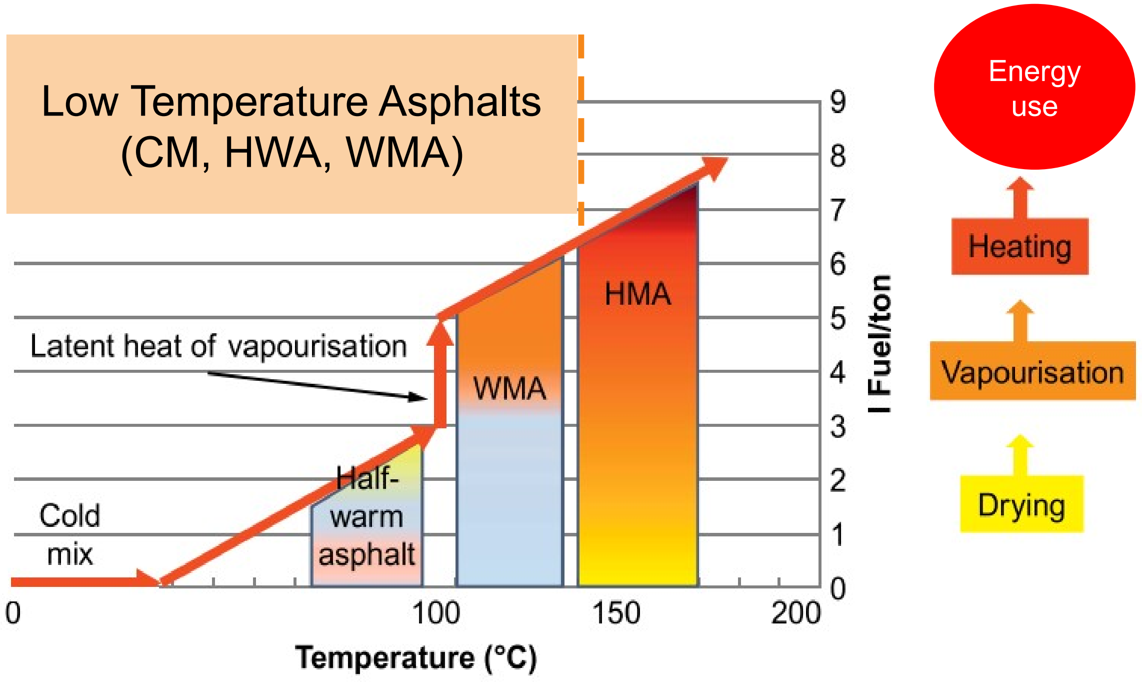
Percentage of responding local authorities in England and Wales implementing measures to reduce their carbon footprint including, or combinations of:

- **67%** using Warm Mix Asphalts
- **39%** specify other recycled content
- **66%** promoting more efficient working to reduce emissions
- **33%** specify reclaimed asphalt
- **40%** choosing materials with lowest initial carbon footprint
- **66%** selecting surfacing materials with longer life

Source: ALARM 2022

Low energy construction

Low Temperature Asphalts (LTA) to reduce emission and energy



- **The environment**: less energy needed and less emissions
- **The paving operations**: better workability, extending the construction season and earlier opening of the road
- **Asphalt workers**: reduced potential for exposure to fumes and odours and a cooler working environment
- **Economical issues**: Less fuel needed

Widyatmoko (2016), "Chapter 14: Sustainability of Bituminous Materials", in Sustainability of Construction Materials 2nd Edition, Khatib eds., Woodhead publisher. doi: 10.1016/B978-0-08-100370-1.00014-7

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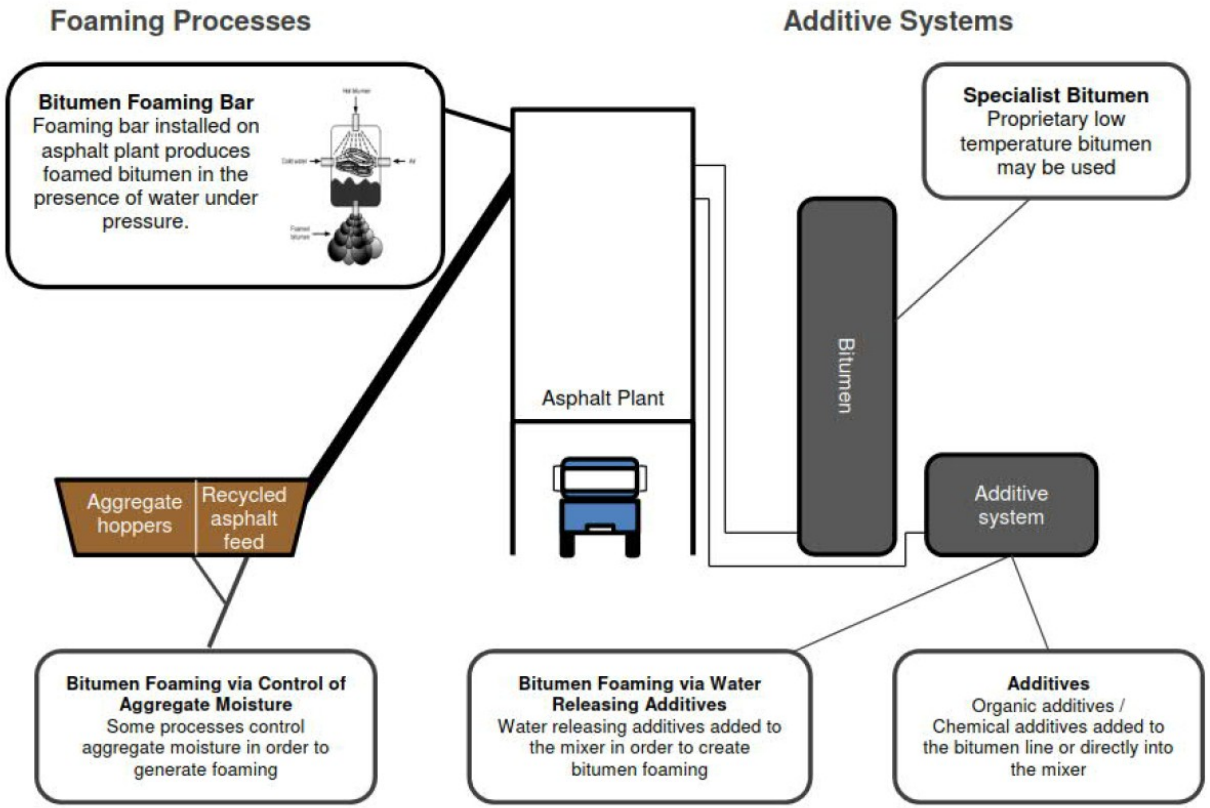
Broad approach to manufacturing WMA



Technology		How does it work?	Typical Temperature range
Additive systems	Specialist bitumen	Additives are pre-blended into the bitumen to alter bitumen viscosity or modify frictional resistance to compaction	100°C to 130°C
	Additive technology (chemical or organic additives)	Some technologies alter bitumen viscosity, whilst others act as surfactants at the bitumen-aggregate interface to enhance mixing and compaction	100°C to 130°C
Foaming Processes	Foaming bars	Some technologies use bespoke bitumen foaming bars fitted at the asphalt plant. Bitumen is sprayed through nozzles in the presence of water and under pressure to create foamed bitumen containing micro air bubbles	70°C to 130°C
	Moisture releasing additives	Moisture releasing additives cause a foaming action creating micro bubbles in the bitumen	70°C to 130°C
	Control of aggregate moisture content	Control of aggregate moisture creates a foaming action of the bitumen when cold RAP or aggregates are combined with hot aggregates and bitumen components.	90°C to 100°C

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Where	Product	Technology	Year of installation / testing	Layer	Performance (overall)	Air voids	Moisture susceptibility	Resilient/ Dynamic modulus	Resists. to Permanent Deform.	Fatigue life	Low temp. cracking
UK	Patented 'Injection foaming technique' [10]	Foaming	2014	Binder/ Surface	WMA=HMA	WMA<HMA	WMA=HMA			WMA=HMA	
UK	N/A [11]	Foaming	2014	Binder/ Surface		WMA=HMA	WMA=HMA	WMA=HMA			
UK	Evotherm MA3 [11]	Chemical additive	2014	Binder/ Surface		WMA=HMA	WMA=HMA	WMA=HMA			
UK	Advera [12]	Foaming	2010	Binder/ Surface	WMA=HMA	WMA<HMA		WMA<HMA	WMA > HMA		
World-wide	Aspha-Min	Foaming	N/A	N/A		WMA=HMA	WMA<HMA	WMA=HMA			WMA<HMA
USA	Advera	Foaming	N/A	N/A			WMA<HMA	WMA<HMA	WMA<HMA		
USA	Double Barrel Green	Foaming	N/A	N/A	WMA=HMA		WMA=HMA		WMA=HMA		
USA	Ultrafoam GX	Foaming	N/A	N/A			WMA<HMA		WMA=HMA		
Worldwide	WAM - Foam	Foaming	N/A	N/A		WMA=HMA		WMA=HMA	WMA=HMA	WMA=HMA	
Germany, and 20 others	Sasobit	Organic additive	N/A	N/A		WMA=HMA	WMA=HMA	WMA=HMA	WMA > HMA	WMA=HMA	
Germany	Asphaltan B (created for HRA layers)	Organic additive	N/A	N/A			WMA > HMA		WMA > HMA		WMA=HMA
Germany	Licomont	Organic additive	N/A	N/A					WMA=HMA	WMA=HMA	
USA, France, Worldwide	Evotherm	Chemical additive	N/A	N/A		WMA=HMA	WMA<HMA	WMA=HMA	WMA=HMA		
USA, France	Cecabase RT	Chemical additive	N/A	N/A		WMA<HMA	WMA<HMA	WMA<HMA	WMA<HMA		
USA, Norway	Rediset	Chemical additive	N/A	N/A		WMA=HMA	WMA=HMA				

Legend

- WMA > HMA in terms of performance
- WMA=HMA or adequate
- WMA<HMA or inadequate
- Not available information

Performance requirements

- The main criteria the same as hot mix asphalts but with additional requirements

- Specification for Highway Works

908 (07/21) **Warm Mix Asphalt (WMA)**

(07/21) **WMA General**

1 (07/21) WMAs shall be installed in accordance with the producer's instructions.

(07/21) **WMA Permitted Mixtures**

2 (07/21) Mixtures produced as Warm Mix Asphalts shall fulfil the requirements given in:

(i) Clause 906 for Dense Base and Binder Course Asphalt Concrete with Paving Grade Bitumen (Recipe Mixtures);

(ii) Clause 912 for Close Graded Asphalt Concrete Surface Course;

(iii) Clause 929 for Dense Base and Binder Course Asphalt Concrete (Design Mixtures);

(iv) Clause 930 for EME2 Base and Binder Course Asphalt Concrete;

(v) Clause 937 for Stone Mastic Asphalt (SMA) Binder Course and Regulating Course;

(vi) Clause 942 for Thin Surface Course Systems; and

(vii) Clause 901 and Clause 903 and contract specific Appendix 7/1.

Design

Table 9/1B (07/21) **Minimum Water Sensitivity Values for Warm Mix Asphalts**

Material Clause and Description	SHW Clause	$ITSR_{min}$	BS EN 12697 12 Test Method
Dense Base and Binder Course Asphalt Concrete (Design Mixtures)	929	80	A
Stone Mastic Asphalt (SMA) Binder Course and Regulating Course	937		
Thin Surface Course Systems	942		
EME2 Base and Binder Course Asphalt Concrete	930	See sub-clause 930.21	B

Construction

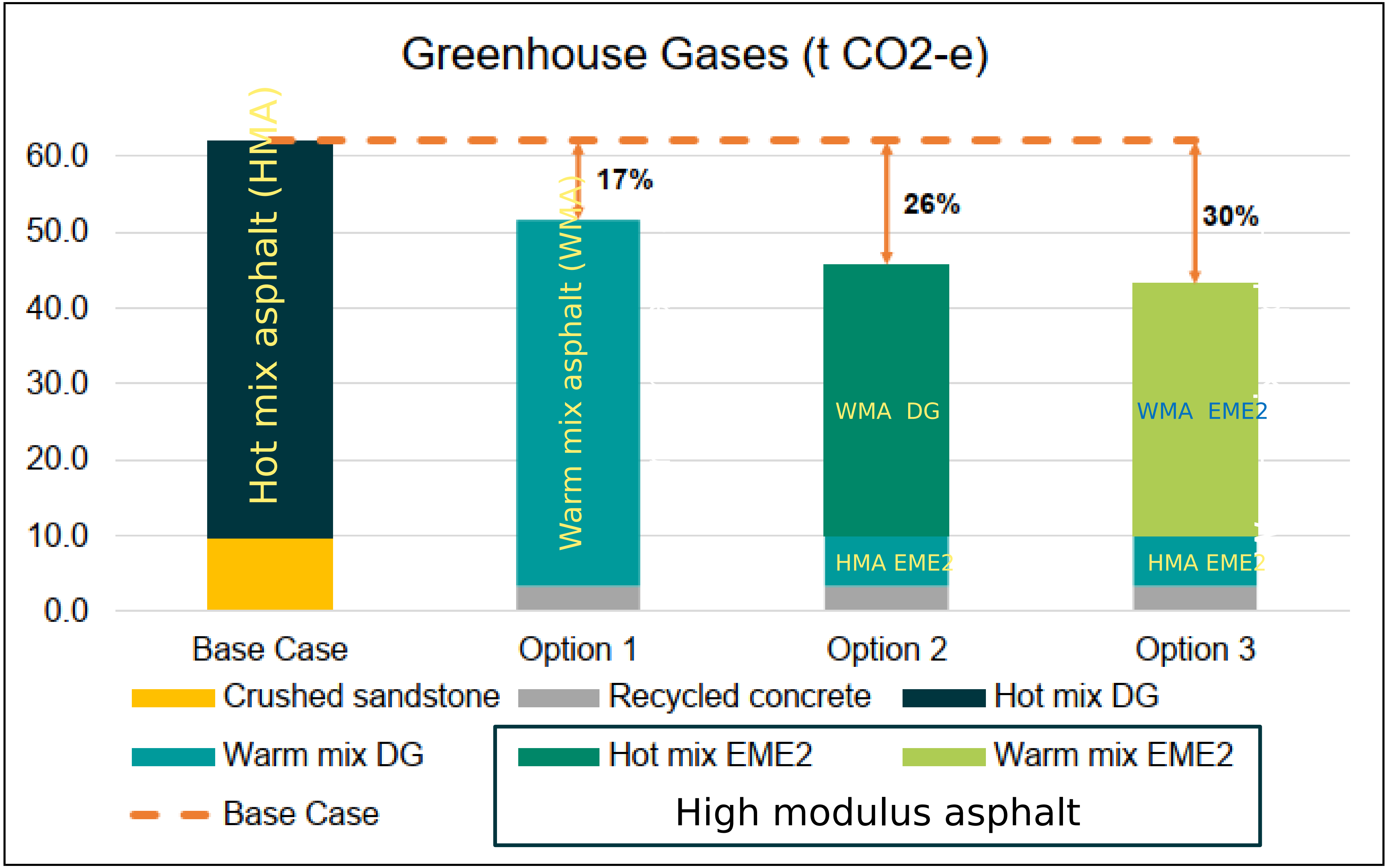
Table 9/1A (07/21) **Maximum production temperatures for WMAs incorporating paving grade binders, hard paving grade binders or Polymer Modified Binders**

Binder grade	Maximum Temperature (°C) (at any stage)
Paving grade conforming to BS EN 12591	150
Hard paving grade conforming to BS EN 13924-1	160
Polymer Modified Binder conforming to BS EN 14023	Documented and declared by the producer

Table 9/1C (07/21) **Minimum Rolling Temperatures for WMAs Incorporating Paving Grade Binders, Hard Paving Grade Binders or Polymer Modified Binders**

Binder grade	Minimum Temperature (°C) (immediately prior to rolling)
Paving grade conforming to BS EN 12591	90
Hard paving grade conforming to BS EN 13924-1	110
Polymer Modified Binder conforming to BS EN 14023	Documented and declared by the producer

https://www.standardsforhighways.co.uk/ha/standards/mchw/vol1/index.htm



Greenhouse Gases (t CO2-e)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Hot mix asphalt (HMA)
Warm mix asphalt (WMA)
17%
26%
30%
WMA DG
WMA EME2
HMA EME2
HMA EME2
Base Case
Option 1
Option 2
Option 3
Crushed sandstone
Recycled concrete
Hot mix DG
Warm mix DG
Hot mix EME2
Warm mix EME2
Base Case
High modulus asphalt

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Promoting sustainability with higher recycle contents

Waste derived materials

Binder modifier

- Crumb Tyre Rubber
- Waste plastic
- Waste cooking oil
- Waste engine oil
- Recycled shingles

Mixture additive

- Power station wastes
  - ✓Pulverised fly ash (PFA)
  - ✓Furnace bottom ash (FBA)
- Domestic wastes (IBA)
- Waste paper

Aggregate replacement

- Reclaimed aggregate
- Reclaimed asphalt
- Reclaimed concrete
- Rubber & plastic waste
- Concrete & demolition waste

Artificial (processed) aggregate

- Steel slags:
  - ✓BOS – basic oxygen slags
  - ✓EAF – electric arc furnace
- Blast furnace slags, including GBBS (granulated)
- Non-ferrous slags
  - ✓Phosphorous slags
  - ✓ISF – aluminium/zinc slags
- Geopolymer aggregate

Papers dan reports are available from:
https://www.researchgate.net/profile/Daru-Widyatmoko

Challenges with waste derived materials

- Waste = risk = liability = ownership
- New process = risk = liability = ownership
- Environmental regulation, permitting, licensing
- Risk averse approach?
  - Quality requirements not less than natural aggregate
  - Physical and chemical characteristics
  - Leaching potential

Innovative materials

- Track records
- Durability
- Physical/chemical properties
- Limitations & benefits

Environmental aspects

- Carbon footprint
- End of Waste
- Permitting / certification
- Processing cost
- Environmental impact
- Local availability
- Location and coverage
- Consistency of stockpile/supply

Refs:

1. Thom and Dawson (2019). "Sustainable Road Design: Promoting Recycling and Non-Conventional Materials". doi: 10.3390/su11216106
2. Widyatmoko (2016). "14 - Sustainability of bituminous materials". doi: 10.1016/B978-0-08-100370-1.00014-7
3. Lacalle H, Tuck J, Widyatmoko I, Hudson-Griffiths R, Khojinian A, Simms M and Giles (2021). "Filtering protocol for innovative paving materials, including waste derived materials". Proceedings of the 7th Eurasphalt & Eurobitume Congress.

Case studies

Use of rubber and RA in warm mix asphalt

Climate resilience

Sustainability

- Bypass improvement schemes on the A426 at Blaby, the A6 at Market Harborough and the A47 at Hinckley
  - Rubber modified warm mix asphalt
    - 500 - 750 tyres per kilometre of road
    - 5,000 recycled tyres, preventing them going to landfill
    - carbon emission savings from a reduction in the energy used, typically 8% lower than the equivalent conventional asphalt mixture
  - 3,700 tonnes of RA
    - 25% RA in base
    - 10% RA in surface course
- Higher recycle contents on major highways, M3 Hampshire
  - 1,800 tonnes of reclaimed asphalt (RA)
    - 70% RA in base
    - 50% RA in surface course

> "Across all three bypass projects, Leicestershire County Council is saving a total of 32 tonnes of carbon, estimated to be the equivalent of the emissions generated by travelling over 165,000 miles in a standard car."

Source: www.asphaltuk.org

Climate resilience

Sustainability

Performance comparison

Laboratory tests shows the performance of rubber modified asphalt compared to equivalent standard asphalt mixes

Typical properties	Air voids	Water sensitivity	Stiffness	Wheel tracking	
Standard	BS EN 12697-8	BS EN 12697-12	BS EN 12697-26	BS EN 12697-22 Procedure B at 60°C	
	%	ITSR	ITSM	WTS_{AIR}	PRD_{AIR}
10mm SMA 10 rubber modified	3%	90%	3200 MPa	0.2mm/10^3 load cycles	10%
10mm SMA 40/60 pen	4%	80%	3400 MPa	0.2mm/10^3 load cycles	10%
AC close graded 100/150 pen	8%	80%	1300 MPa	0.6mm/10^3 load cycles	27%

Compaction

Durability

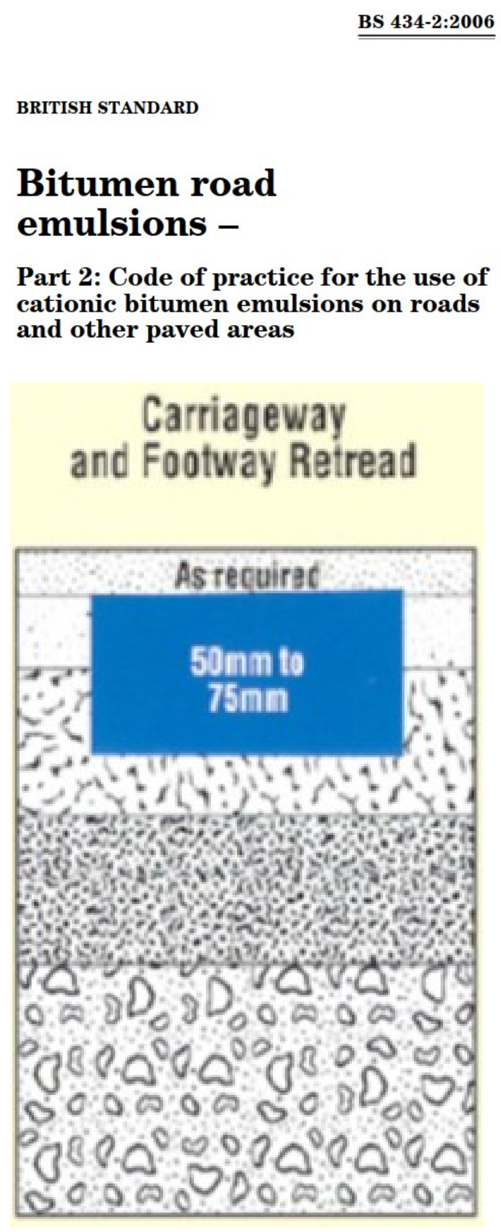
Stiffness

Rutting resistance

Source: Tarmac

Retread Cold in situ recycling

- One of the oldest in situ recycling techniques (since 1948). Currently in BS 434-2.
- Retread is a cold recycling process for pavements with low traffic or sidewalks for pedestrians
- If the existing road construction is suitable, then it is scarified to a specified depth to produce a uniformly graded material.
- Usually, the surface layer is crushed to a depth of about 75mm, then levelled, and scattered emulsion bitumen along with some new/additional rocks, re-mixed and compacted before finishing it by surface dressing.

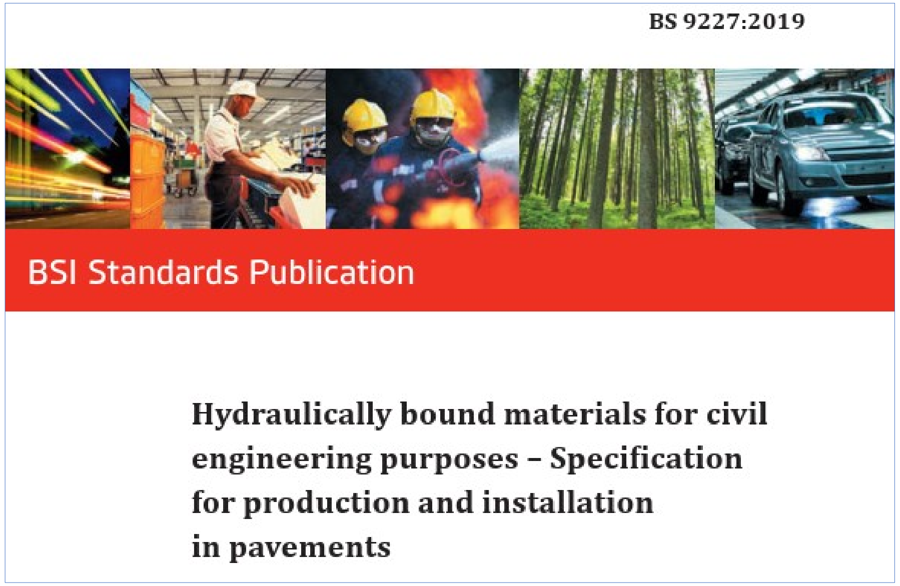


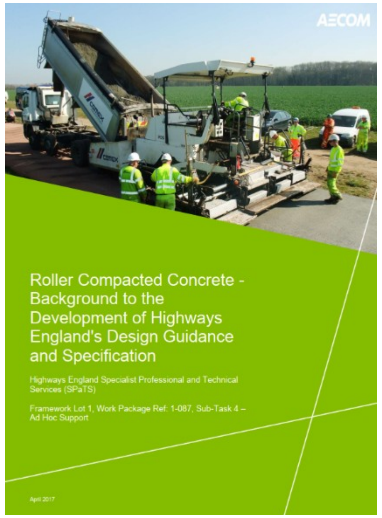
Source: Troeger, J and Widyatmoko, I. "Development in Road Recycling", 11th Annual International Conference on Pavement Engineering and Infrastructure, Liverpool, 15 – 16 February 2012. ISBN 978-0-9571804-0-6.

Retread

cold in situ
recycling process
extensive
rutting, cracks and potholes
required grade of material
Retread emulsion
14mm chippings
surface
compacted
two applications
of emulsion
6mm chippings

In situ and ex situ recycling methods – HBM





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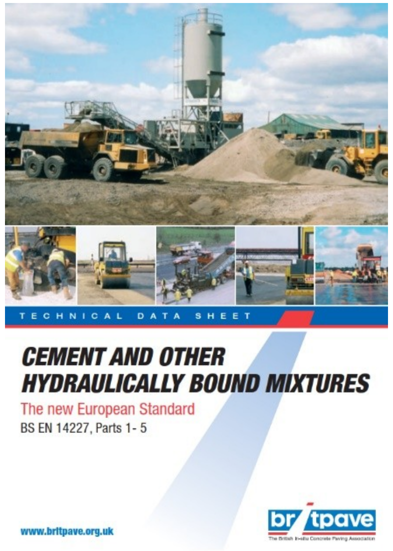

- Requirements for the production, installation, testing and conformity of hydraulically bound materials (HBM) conforming to BS EN 14227 for pavement applications, whether constructed by the ex-situ or in-situ methods.
- Requirements for preliminary work at the laying site, needed to ensure that the substrate is fit to receive the HBM.
- HBM is the generic term to describe the wide range of materials comprising aggregates or soil, hydraulic binders and water; including:
  - ✓ roller compacted concrete (RCC),
  - ✓ hydraulically bound granular material (HBGM),
  - ✓ hydraulically stabilized soils (HSS),

  which are available for use in the construction and the maintenance of roads and other paved areas.

In situ and ex situ recycling methods – Bituminous Mixtures


BS 9228:2021

BSI Standards Publication

Recycling of roads and other paved areas using bitumen emulsion, foamed bitumen or hydraulic material — Materials, production, installation and product type testing — Specification

Table 1. Comparison of tests on in situ recycled and plant-mixed base pavements.

Description	Test Method	Plant-Mixed		In-Situ Recycled	
		Mean	Coefficient of Variation	Mean	Coefficient of Variation
Modulus from tests on cores	Indirect tensile; BS-EN 12697-26 [40]	4960 MPa	17%	3930 MPa	58%
Modulus over a larger area	Falling weight deflectometer	3890 MPa	24%	2460 MPa	28%

Thom and Dawson (2019). "Sustainable Road Design: Promoting Recycling and Non-Conventional Materials". doi: 10.3390/su11216106

- Requirements for materials conforming to BS EN 14227 for pavement applications,
  - ✓ processed with either bituminous emulsion, foamed bitumen or hydraulic material, including their design and composition, production, installation and performance testing.
  - ✓ includes requirements for mixtures prepared using bituminous binders that may also contain hydraulic material
- Describes a number of processes and methods by which existing material in the road or other paved areas is either processed in-situ or uses recycled material processed ex-situ.

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Thank You

Iswandaru Widyatmoko

Technical Director, Pavement and Materials Research, AECOM (Europe – UK & Ireland)

Daru.Widyatmoko[AT]aecom.com

Promoting sustainable and climate resilience materials for rural roads. *UK case studies*

CLIMATE RESILIENCE AND INNOVATION IN MATERIALS

LOW ENERGY CONSTRUCTION

PROMOTING SUSTAINABILITY WITH HIGHER RECYCLE CONTENTS

CASE STUDIES