INTERNATIONAL SEMINAR
NATURAL RUBBER
IN ROADS

A BRIEF HISTORY OF BITUMEN MODIFICATION AND THE IMPORTANT ROLE OF MODIFIED BITUMEN IN THE 21ST CENTURY

Presented by

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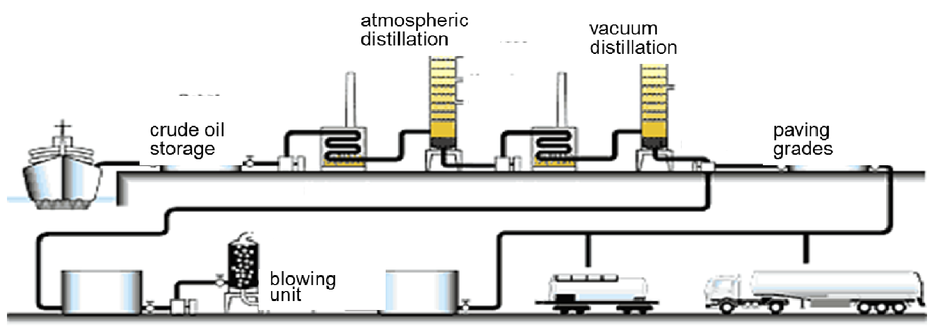
Overview

- How is bitumen made and why do we need to modify bitumen?
- Early ways of modifying bitumen - 1900's to 1940's
- UK experience with Natural Rubber modified bitumen - 1950's to 1970
- The Birth of Polymer Modified Bitumen - 1970's to 1980's
- Sustainability considerations - 1990's to 2010's
- The future for bitumen modification

How is bitumen made and why do we need to modify bitumen?

Bitumen Manufacturing



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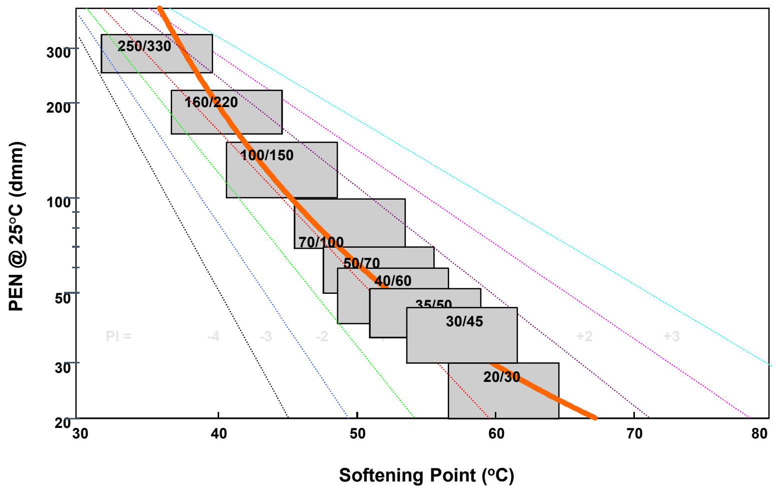
Typical Bitumen Grades



Rheology and material responses

Rheology is the "Science of the deformation and flow of matter"

Two key concepts

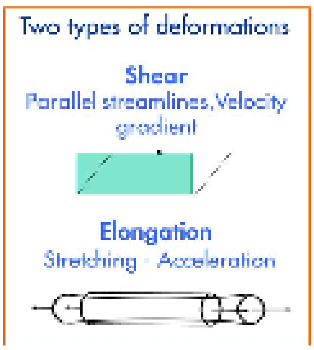
Elasticity: Reversible deformation, energy stored and released when loading/unloading

Viscosity: Irreversible deformation/flow when loading applied; dissipation of energy (resistance to flow)

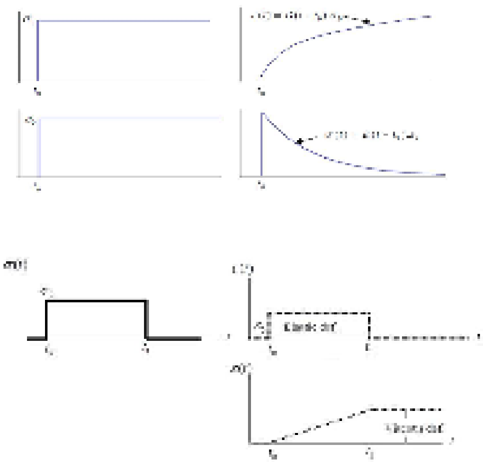
Viscoelastic material responses

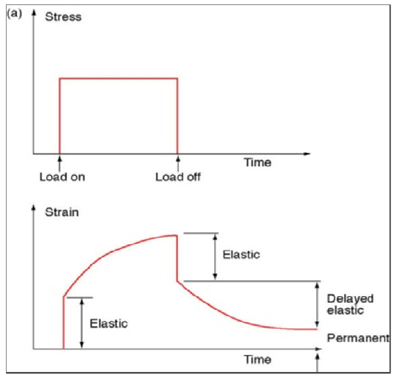
Other properties e.g. yield stress, thixotropy

Ways to measure the properties



Rheology and material responses





The Need For Modification

Climatic conditions

- improved balance between low and high temperature properties

Increasingly aggressive traffic conditions

- More heavy vehicles, slower traffic
- Increasing axle loads & tyre pressures
- Fuel spillage

Economic issues

- Development of thinner Mix Designs, reduction in structural thickness
- Improve durability of road network

Sustainability issues

- Lower operating temperatures
- Resource use, recycled materials
- Bio-based components

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The Need For Modification

User → Pavement → Asphalt Mixture → Binder

User
- **Safety**
- **Good ride quality**
- **Low noise**
- **No Delays (Construction Works)**

Pavement
- **Plane Surface (rut resistant, no cracks)**
- **Skid Resistance**
- **No Aquaplaning**
- **No Spraying**
- **Durable**
- **No Ravelling**

Asphalt Mixture
- **High Temperature Stability**
- **Low Temperature Flexibility**
- **Fatigue Stability**
- **Durability / no ageing**
- **Moisture sensitivity**
- **Mineral Aggregate Quality**
- **Workability**

Binder
- **Stiffness**
- **Cold Flexibility**
- **High Temp flow resistance**
- **Elastic Recovery**
- **Ageing**
- **Volatility**
- **Homogeneity**
- **Adhesion/Cohesion**
- **Visco - Elastic Rheology to workability**

Modified asphalt binders – some of the basic requirements

- To increase the resistance of the asphalt to ***target distresses*** without *adversely affecting other properties* of the asphalt binder or HMA at other temperatures and loading conditions.
- Maintain its premium properties during long term storage, application and in service.
- Be capable of being processed by conventional equipment – transportation, storage, handling, manufacture, laying and compaction.
- Be physically and chemically stable during long term storage, application and in service.
- Resist degradation at HMA mixing temperatures and processing conditions
- Achieve a coating or spraying viscosity at normal *or reduced application temperatures.*

Early ways of modifying bitumen - 1900's to 1940's

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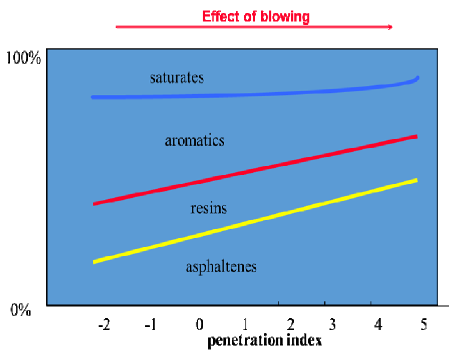
Modification of bitumen by blowing

- First bitumen blowing patents appeared around the turn of the 20th Century, in commercial use by 1904
  - Rubber first added to bitumen in 1898 (France)!!

By 1907, production of refined asphalt had outstripped the use of natural asphalt (NAPA) ("birth of modification")

- Blowing of bitumen Improves the quality of final bitumen
  - Reduction in penetration
  - Increase in softening point
  - Increase in PI (Lower temp. susceptibility)



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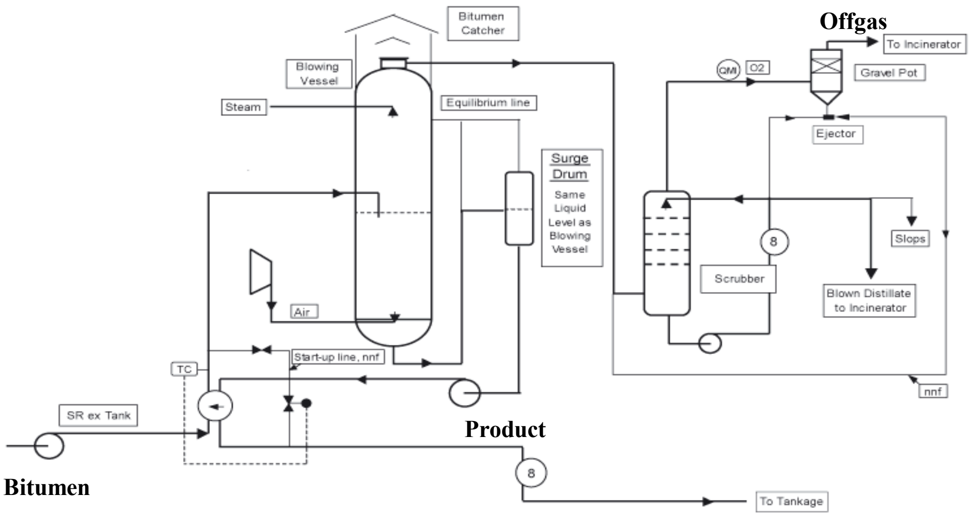
Bitumen blowing



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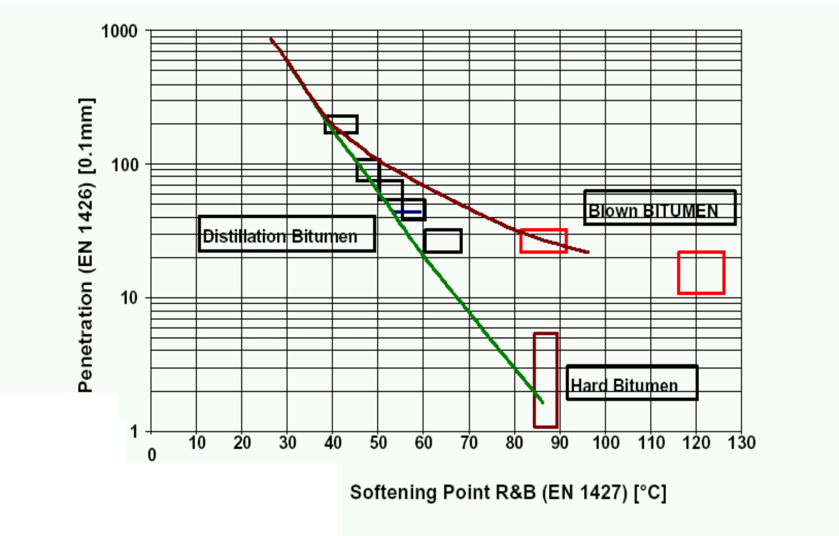
How does blowing modify bitumen?



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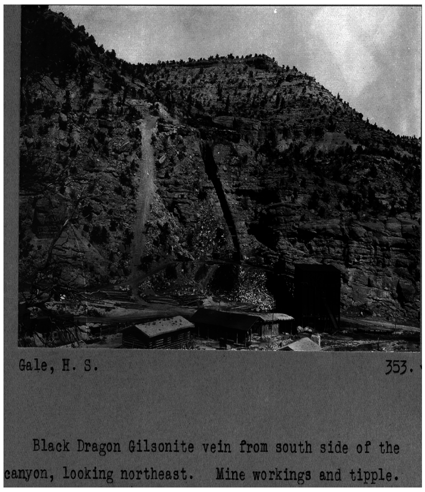
Natural asphalt modification

Natural Asphalt has been used to modify bitumen since the 1930's

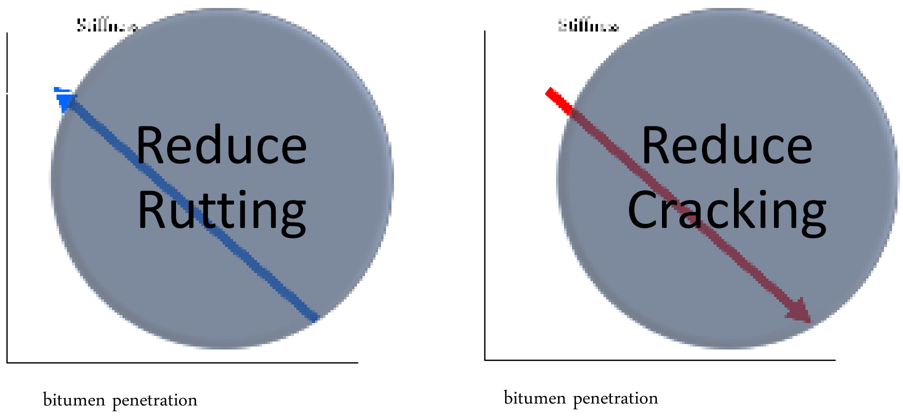
It can be an effective way of stiffening bitumen and raising the softening point

There are many sources of natural asphalt globally, the most famous being USA, Trinidad, Albania, Indonesia, Venezuela



Source: USGS

Pavement performance: the dilemma



UK experience with Natural Rubber modified bitumen - 1950’s to 1970

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UK Development of NRmB

Monitored road trials started in 1955 (England, Road Research Laboratory, Surface Dressing Trials)

Earlier experimental sections were placed over concrete pavements.

W aide range of applications were investigated during that period including

- Surface Dressing
- Hot Rolled Asphalts
- Sand Carpets
- Cutbacks
- Dense Macadams

Shell Bitumen participation!

Fig. 2 — Rubberized bitumen surface-dressing experiment: cutback bitumen (background) at 4½ sq. yd/gal has fatted up; rubberized bitumen (foreground) at 4½ sq. yd/gal is in fairly good condition. (R.R.L., U.K. photo crown copyright reserved; reproduced by permission of the Controller, H.M.S.O.)

DISCUSSIONS-CLOSURE/NATURAL RUBBER IN BITUMINOUS ROAD SURFACINGS

DISCUSSIONS

P. NICHOLS, Shell International Petroleum Company (see Introductory Remarks to this Session)

O. T. O'FLYNN, Country Roads Board, Victoria

49. Little information is available concerning the effect of rubber on bituminous concrete type mixes which are in use in Australia. Such mixes depend largely, for their mechanical properties, on the good particle interlock and friction of a well graded material and rather less on the characteristics of the binder than do B.S. rolled asphalt or mastic asphalt. In the light of this it is probable that of all dense bituminous mixtures bituminous concrete will be the least affected by a change in characteristics of the binder. This has been confirmed to some extent by the performance of three experimental sections of bituminous concrete of differing compositions which were laid 1 in. thick over an extensively cracked sealed flexible pavement. Cracking reappeared in all three sections of the experimental work.

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UK Development of NRmB - Findings

TABLE III

RESULTS OF A FULL-SCALE EXPERIMENT USING RUBBERIZED BITUMEN MACADAM NORMAN CROSS - PETERBOROUGH ROAD A15, HUNTS, ENGLAND

Aggregate		¾-in. Max. Dolerite*	
Fines content (%)		10-13	
Binder	Binders contents (%)†	Length of life (years) without rubber	Length of life (years) with rubber‡
Cutback bitumen	2.75	4	4
	3.0	5	5
	3.5	5	7
	3.75	6	8
100 sec at 40°C	4.25	5	7
300 pen. bitumen	2.75	6	6
	3.0	6	6
	3.5	6	8
	3.75	6	9§
	4.25	6	9§

Source: Smee & Thompson, HMSO 1964

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Natural Rubber modification in the UK – Road Note 36, 1968

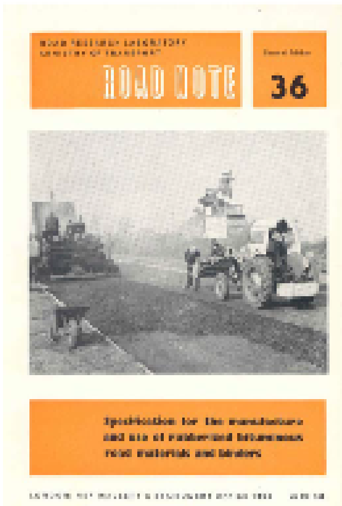
'Road Note 36'.

Practical advice on the use of Natural rubber in asphalt pavements,

Applications

Blending rules, test methods for determining rubber content

The first mainstream (natural) polymer modified bitumen



The Birth of Polymer Modified Bitumen - 1970's to 1980's

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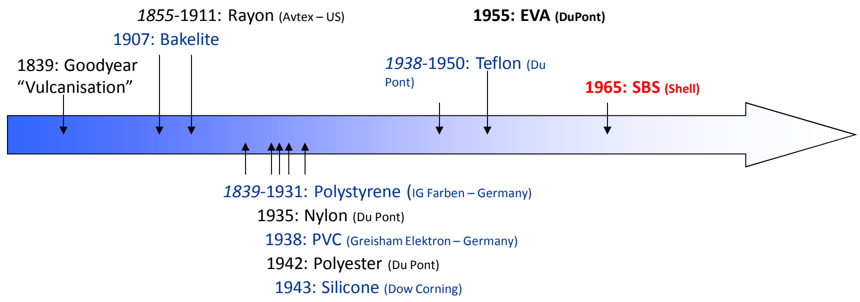
A Polymer timeline



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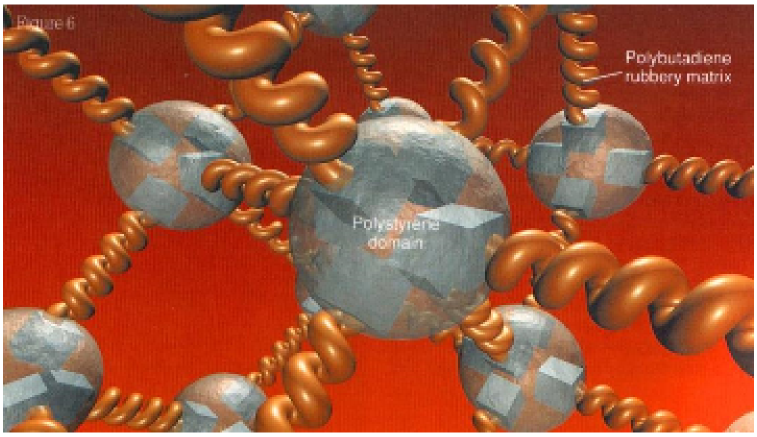
Styrene Butadiene Styrene: Elastomer



SBS (Styrene Butadiene Styrene): **Innovated in Shell laboratories**

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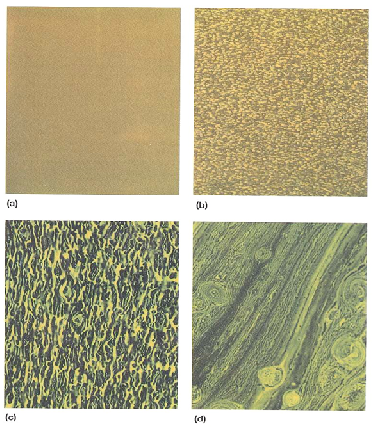
POLYMER MODIFICATION

Traditionally used to improve temperature susceptibility – In service temperatures

Polymers create a lattice within the mixture

Polymers can be separated into 2 broad categories

- Elastomers
  - High elastic response
  - Resist deformation by stretching with quick recovery
  - Block copolymers, homopolymers and random copolymers
- Plastomers
  - Tough, rigid 3D Network
  - Exhibit high strength under initial loading but may fracture with accumulated strain



a = compatible
b, c = semi-compatible
d = incompatible

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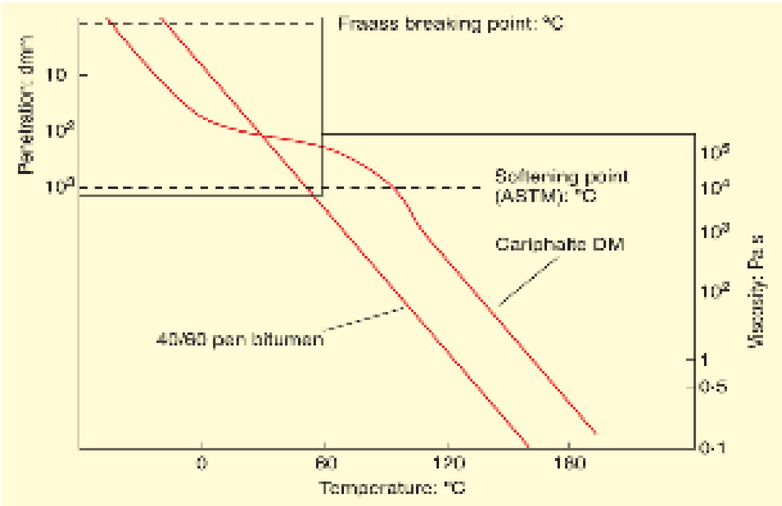
Temperature Susceptibility



Characteristics of Polymer Modified Bitumen

Good elasticity which reduces the tendency for pavements to crack, - *durability.*

Improved adhesion and cohesion properties for more durable asphalt, *durability.*

Higher softening point to resist permanent deformation without adversely affecting the properties of bitumen, *durability.*

Lower temperature susceptibility for better performance in both high and low temperature environments, *durability.*

Storage stable due to compatible blend of bitumen and polymer that reduces likelihood of material drifting off-spec during storage, *reliability.*

Easy handling without major plant change and ease of stock management, *adaptability.*

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1984,1987 TRL Trials; NRMB and PmB worlds meet.

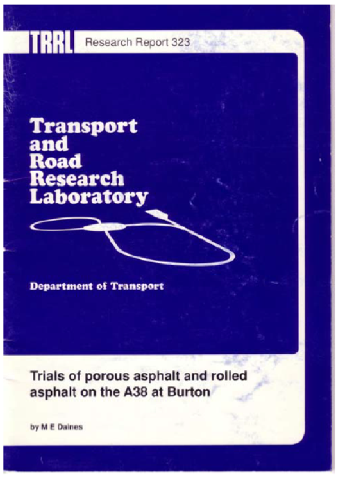

TABLE 1

Designation of sections

Year laid and material	Section Number	Binder supplier	Specification	Aggregate grading (See Table 2)	Target binder content (per cent)
1984 Porous asphalt	1	Contractor (BP)	70 pen bitumen	1	3.7 ± 0.3
	2	Contractor (BP)	100 pen bitumen, no hydrated lime (4.5% limestone filler)	1	3.7 ± 0.3
	3	Shell International	Bitumen + epoxy resin, no hydrated lime	1	3.7 ± 0.3
	4	Contractor (BP)	100 pen bitumen + Inorphil fibres (9% of binder), no hydrated lime	1	5.0 ± 0.3
	5	Contractor (BP)	100 pen bitumen + 5% 18-150 EVA*	1	4.2 ± 0.3
	6	Contractor (BP)	100 pen bitumen + 5% 18-150 EVA*	1	3.7 ± 0.3
	7	Mobil Oil Co Ltd	Mobilplast grade CI	1	4.2 ± 0.3
	8	Contractor (BP)	200 pen bitumen + 5% 18-150 EVA*	1	3.7 ± 0.3
	9	Esso Chemical Ltd	100 pen bitumen + Esso modified EVA	1	4.2 ± 0.3
	10	Philmac Oils Ltd	200 pen bitumen + SBS***	1	4.2 ± 0.3
	11	Shell International	200 pen bitumen + SBS***	1	4.2 ± 0.3
	12	British Petroleum Ltd	100 pen bitumen + SR****	1	5.0 ± 0.3
	13	Contractor (BP)	100 pen bitumen	2	3.7 ± 0.3
	14	Contractor (BP)	100 pen bitumen + Pulvatex natural rubber crumb (8.3% of binder#)	1	5.0 ± 0.3
	15	Contractor (BP)	CONTROL - 100 pen bitumen	1	3.7 ± 0.3
1987 Porous asphalt	1	Exxon Chemicals	200 pen bitumen + 5% ULO2133 EVA**	1	4.2 ± 0.3
	2	Tarmac Oils	70 pen bitumen + SR****	1	4.7 ± 0.3
	3	Contractor (Tarmac)	100 pen bitumen + Arbocel zz 8/1 cellulose fibres (0.3% in mix)	1	4.7 ± 0.3
	4	Shell International	Bitumen + epoxy resin	3	4.5 ± 0.3
	5	BP	SB2/100	1	5.0 ± 0.3
	6	Contractor (Tarmac)	200 pen bitumen + 7.4% Revertex LCS natural rubber latex#	1	4.7 ± 0.3
	7	Contractor (Tarmac)	CONTROL - 100 pen bitumen	1	3.7 ± 0.3
	7A	Contractor (Tarmac)	100 pen bitumen, 6.5% filler, no hydrated lime	1	3.4 ± 0.3
1987 Rolled asphalt	8	Tarmac Oils	50 pen bitumen + SR****	5	7.2 ± 0.6
	9	Contractor (Tarmac)	100 pen bitumen + 2% U1-49 Chemcrete	4	8.1 ± 0.6
	10	Shell Bitumen	Medium PI bitumen	5	7.2 ± 0.6
	11	Contractor (Tarmac)	CONTROL 1 - 50 pen bitumen (BS 594: 1985, column 9)	5	7.2 ± 0.6
	12	Shell Bitumen	Cariphalte DM (SBS***)	5	7.2 ± 0.6
	13	Shell Bitumen	Cariphalte DM (SBS***)	6	6.9 ± 0.6
	14	Contractor (Tarmac)	70 pen bitumen + 2% U1-49 Chemcrete	4	8.1 ± 0.6
	15	Exxon Chemicals	70 pen bitumen + 5% UL15019 EVA*	4	8.1 ± 0.6
	16	Contractor (Tarmac)	CONTROL 2 - 50 pen bitumen (BS 594: 1985, column 15)	6	6.9 ± 0.6
	17	Contractor (Tarmac)	CONTROL 3 - 70 pen bitumen	4	8.1 ± 0.6

* EVA: Ethylene vinyl/acetate (18 to 19 per cent vinyl acetate, 150 melt flow index)
** EVA: Ethylene vinyl/acetate (33 per cent vinyl acetate, 21 melt flow index)
*** SBS: Styrene-butadiene-styrene block co-polymer
**** SR: Synthetic rubber
\# equivalent to 5 per cent natural rubber in the binder

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1984,1987 TRL Trials; NRMB and PmB worlds meet.

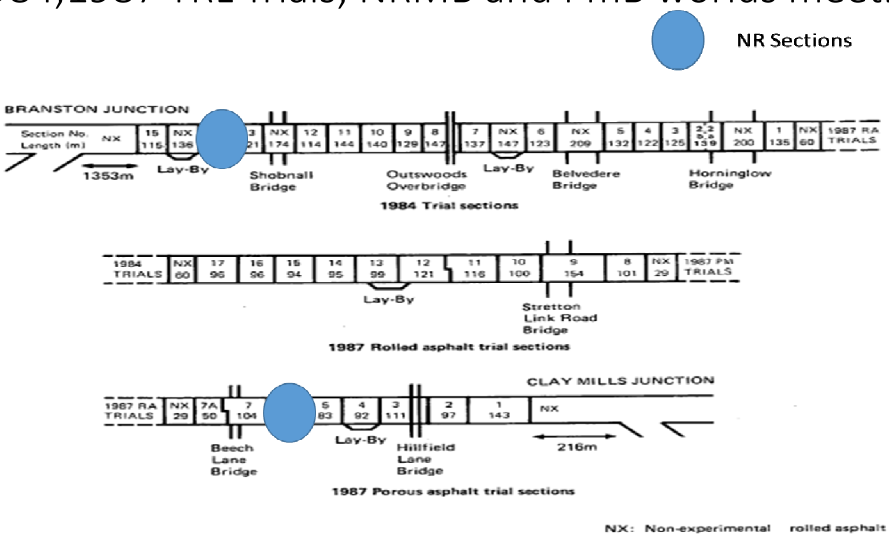

Fig.1 Location and layout of trials on A38 Burton by-pass, Southbound carriageway

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Conclusions from RR323 & the A38 trials

In the present work, it has been possible to specify materials with higher binder contents using the following additives: ***natural rubber (in powder and latex form),*** *fibres (inorganic and cellulose), styrene-butadiene styrene (SBS) and other proprietary synthetic rubbers.*

Ethylene vinyl acetate co-polymers (EVA) are less effective in increasing the binder carrying capacity of porous asphalt, and their use has not led to improved durability in the 1984 trials.

Full Report (and many others) is free at trl.co.uk

Sustainability considerations - 1990's to 2010's

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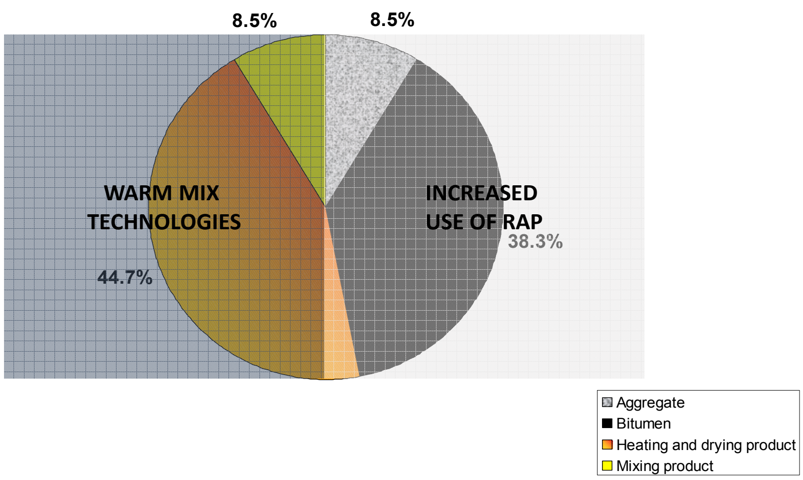
1990's to 2010's the changing needs of asphalt

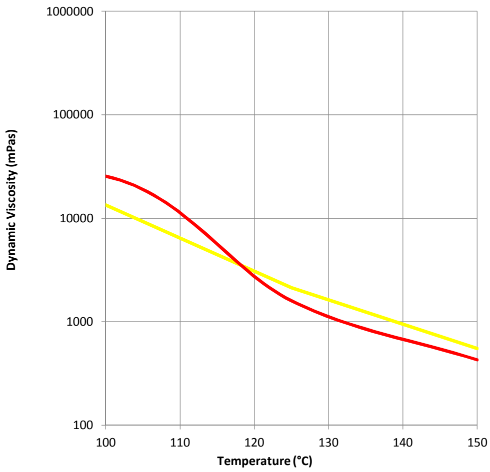
Increased environmental awareness and the rise of sustainable development agenda led to new developments , and new needs for modification in asphalt outside of modification to improve pavement performance

Asphalt Mixtures – % of CO2 generated per tonne (generic example)



New focus for modification - WMA

- Binder viscosity is reduced
- Workability is improved at application temperatures
- Compaction is improved
- Stiffness is increased in early life – resistance to deformation



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Resource efficiency – Recycling and recycled modifiers

- Use of ground tyre rubber since the 1960's
- Large scale use today in some US states
- Also some use of waste plastics for bitumen modification
- Modification techniques to use RAP in increased quantities

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The future for bitumen modification

Emerging trends and the importance of bitumen modification

- Increased traffic intensity – axle loading and volumes
- Severe and adverse climatic conditions
- Changing refining landscape
- Variability in bitumen properties
- Stringent requirements around health, safety, social and environmental compliances

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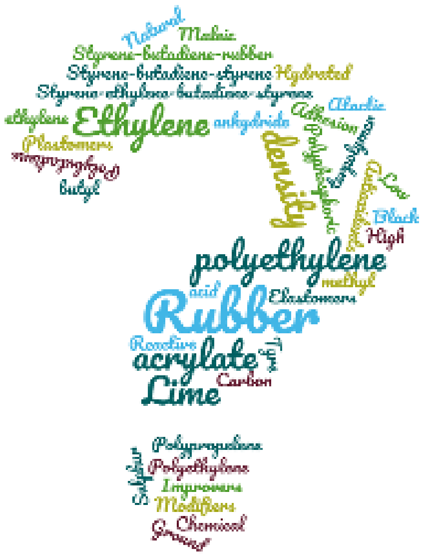

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Drivers for modifier choice

- Health, safety, social and environmental compliances
- Influence on end Performance
- Cost
- Availability
- Political

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Shell modified bitumen today

- A wide range including SBS, GTR, Low Temperature and recycling, fuel resistance, odour reduction and Natural Rubber
- More than one modifier becoming increasingly common to provide both performance and environmental benefits

Development of NR modified bitumen in Thailand

Summary

- Bitumen modification has taken place for over a century and many techniques have been developed
- These include
  - Blowing and addition of natural asphalt
  - Natural Rubber
  - Synthetic polymers
- Initial modification techniques focussed on pavement performance but later modification to reduce temperatures and increase recycling became common
- The drivers for bitumen modification are varied and there is a case for many types of modified bitumen