The objects of the Institute are:-

- To promote generally the knowledge of asphalt technology and to make it available to all members of the Institute.
- To encourage and promote improvements in the practice and standards of the technology.
- To promote the consideration and discussion of all questions affecting asphalt technology.
- Generally to watch over, support and protect the status of members of the Institute.

National activities include the publication of a bi-monthly journal *Asphalt Professional* and the organisation of conferences. Seminars and technical and social meetings are arranged by ten branches that cover the United Kingdom and the Republic of Ireland.

The Institute publishes *The Asphalt Yearbook*, containing papers concerned with the manufacture and use of asphalt in highway engineering, civil engineering and building construction.

The Institute supports managerial and technical staff training schemes in asphalt technology and moderates qualifying examinations. Courses are available at:

**Doncaster College**  
APS Section, School of Minerals Engineering  
Waterdale, Doncaster  
tel: 01302 553553  
fax: 01302 553923

**Highways Open Tech**  
City of Bath College  
Avon Street, Bath BA1 1UP  
tel: 01225 328689  
fax: 01225 444213

**University of Nottingham**  
University Park  
Nottingham NG7 2RD  
tel: 0115 9513935  
fax: 0115 951 3898

**PUBLICATIONS COMMITTEE**  
I D Walsh, MIAT (Chairman)  
A Hannah, FIAT  
Dr R N Hunter, FIAT  
I S Menzies, MIAT  
A P Morter, FIAT  
J T Richardson, MIAT  
C D Whiteoak, FIAT

**Who’s Who in the IAT**

**PRESIDENT**  
S M Child, FIAT

**VICE-PRESIDENT**  
C A Cluett, FIAT

**MEMBERS OF COUNCIL**  
R Bolden, FIAT  
J M Brashaw-Bullock, FIAT  
J E P Childs, FIAT  
Dr R N Hunter, FIAT  
B Larter, FIAT  
J Laitinen, FIAT  
C Lycey, MIAT  
A P Morter, FIAT  
F Patterson, MIAT  
C Rose, FIAT  
I D Walsh, MIAT  
C D Whiteoak, FIAT

**MEMBERS OF SENATE**  
F M L Akeroyd, Hon FIAT  
A W Christie, FIAT  
I J Dussek, OBE, Hon FIAT  
V Moore, FIAT  
W B Nickson, FIAT  
H R Perkins, FIAT  
G J Rayner, Hon FIAT  
K A Riley, Hon FIAT

**PAST PRESIDENTS**  
2001 J M Brashaw-Bullock, FIAT  
1999 H R Perkins, FIAT  
1997 A W Christie, FIAT  
1996 V Moore, FIAT  
1994 C Rose, FIAT  
1993 A T Pakenham, FIAT  
1992 I J Dussek, OBE, Hon FIAT  
1990 K A Riley, Hon FIAT  
1988 W B Nickson, FIAT  
1986 F M L Akeroyd, Hon FIAT  
1983 A W M Burman, FIAT  
1980 G F Brantingham, DFC  
1979 G J Rayner, Hon FIAT  
1974 R G Martin  
1966 Sir H Manzoni, CBE

**HON FELLOWS (Hon FIAT)**  
F M L Akeroyd  
G Brantingham, DFC  
G Bromage  
Prof S F Brown, OBE  
G J Rayner  
K A Riley  
A F Constantine  
Mr F S Baxter  
A P Morter, FIAT

**ACCOUNTANTS**  
TMA

**BANKERS**  
Lloyds TSB Bank Plc
Hard graft, lots of fun and juggling with the day job describes my experience as President so far and now it is downhill to National Conference at the end of May. Those of you that sit on Council and Branch Committees will no doubt agree with the above because any involvement in the running of the Institute is reflected in those comments. Yes of course we enjoy it, socialising networking, talking asphalt but it does require commitment and for that I take this opportunity to thank all those involved in this Institute for all their excellent effort in making it what it is.

As you read this to the left you will find the objectives of the Institute and as with any project it is important to review objectives in order to focus on what we are here for. The Institute is in good shape. Its membership is committed, officers are seeking to deliver against the Corporate Plan and all this at a time when the asphalt industry is asking questions of itself centred on organisational change and future workload. At every opportunity I seek to ensure that our objectives are fulfilled and I am pleased to say that this Institute has certainly promoted knowledge of asphalt technology through the wide range of training provided from a local evening meeting to National Conference. Through such forum we encourage and promote improvements; this also occurs through representation on various bodies and projects. Furthermore there is no doubt that we promote discussion on asphalt technology as my wife can confirm from various functions, where asphalt is the only topic of conversation!

So this leads me to our responsibility to the Members and how Council has sought to watch over and support you as much as possible. I have sought at every opportunity to promote you as Asphalt Professionals and hopefully this will continue long after my presidency has ended. In these changing times it may appear that the asphalt industry has been marginalised, far from it! Our industry has a huge influence on the infrastructure of this country from the highway network to airports. You cannot leave the front door for work or leisure without encountering asphalt and being dependent upon its properties for safe and comfortable travel.

On behalf of this Institute I have been discussing with IHT and IHIE how we might work together more to enhance the service and support to all our members. We must recognise as an Institute that we cannot operate in a vacuum or be isolated however those that seek to promote a single body must be made aware of the strength of feeling for retaining an identity around specialist aspects of the engineering business. Numbers and visibility are not an indicator of value and worth as our Institute can demonstrate.

Small in numbers of members compared to others our evening meetings and other functions are as well, if not better, attended than other bodies. This is not a criticism of others but an encouragement for you to continue membership of this Institute and encourage colleagues to join.

I have had an enjoyable time over the last year and just a few of the highlights include:

- The North-South Irish Conference
- A trip with the East Pennines branch to Dynapac in Sweden
- National Conference 2004
- Northern Conference in Edinburgh
- IHT Luncheon

As I look forward to the remainder of my time I will as ever seek to promote this Institute wherever I go. I have a trip planned to Northern Ireland where I hope to meet Members of the Institute from across the province and also meet with industry and government leaders who can influence the asphalt industry and its effect on you as asphalt professionals.

My thanks go to all those who have supported me in my time as President, particularly my wife, children, employer and the South East Branch (funding!). I take this opportunity to wish all members and their families the very best for 2005 and I look forward to the continued success and development of the IAT.

FROM THE PRESIDENT
IAT Council 2004/2005

S M Child
President

C A Chuett
Vice-president

C D Whiteoak
Hon Treasurer

R C Bolden

J M Bradshaw-Bullock

J E P Childs

R N Hunter

J Laitinen

B W Larter

C Lycett

A P Morter
Secretary

F J Patterson

C Rose

I D Walsh
BRANCHES OF THE INSTITUTE
Chairmen and hon secretaries, August 2004

East Midlands
Chairman: R Wood, FIAT
Hon Secretary: A Broomfield, MIA T
20 Mill Hill Road, Bingham, Notts NG13 8UG
tel: (office) 0115 846 7223
(home) 07789 273045
email: andy.broomfield@shell.com

East Pennines
Chairman: N Taylor, MIA T
Hon Secretary: S Rimmington, FIAT
108 Intake Lane, Pogmoor, Barnsley S75 2HY
tel: (office) 01302 553920
(home) 01226 243839
fax: 01302 553923
email: steve.rimmington@don.ac.uk

Irish
Chairman: T O’Leary, MIA T
Hon Secretary: Ms Geraldine Walsh, MIA T
Roadstone, Dublin, Fortunestown, Tallaght, Dublin 24
Republic of Ireland
tel: (office) 00 353 240 41368
fax: 00 353 14041392
mobile: 00 353 876 814 7508
email: gwalsh@roadstone.ie

North Eastern
Chairman: J Jeffrey, FIAT
Hon Secretary: D Jones, FIAT
c/o Alston Limestone Co Ltd,
PO Box 8, Fell Bank, Bolsterby,
Chester-le-Street, Co. Durham DH3 2SX
tel: (office) 0191 410 9611
(mobile) 07836 231649
email: david.jones@alston.limestone.co.uk

Northern Ireland
Chairman: K P McCormack, MIA T
Secretary: L Andrew, MIA T
8 Old Ballybracken Road, Dough, Ballyclare,
Co Antrim BT43 0SE
tel: 028 9250 1000
mobile: 07789 757187
email: 028 9250 1100
email: kpmccormack@lagan-group.com

Scottish
Chairman: A Ferguson, MIAT
Secretary: N Hardy, MIAT
East Campedown Street, Dundee DD1 3LG
tel: (office) 01382 468026
(mobile) 07721 754670
fax: 01382 450308
email: nigel.hardy@nynas.com

South Eastern
Chairman: J Gibb, MIAT
Hon Secretary: I D Walsh, FIAT
Jacobs Rattler Laboratory,
St Michael Close, Aylesford, Kent ME20 7BO
tel: (office) 01622 605285
(mobile) 07899 063370
fax: 01622 710621
email: ian.walsh@jacobs.com

West Midlands
Chairman: R Buchanan, AIA T
Secretary: A Wint, MIA T
8 Dovedale Avenue, Ashbourne,
Derbyshire DE6 1FT
tel: (mobile) 07887 635708
email: andrew.wint@tarmac.co.uk

West Pennines
Chairman: A Sewell, MIAT
Hon Secretary: S Armstrong, MIAT
22 The Hawthorns, Audenshaw, Tameside
Manchester M34 5LU
tel: (office) 0151 326 2948
(home) 0151 612 3271
fax: 01503 276195
email: steve.armstrong@nynas.com

Western
Chairman: G D N Bishop, FIAT
Hon Secretary: M D Haswell, MIA T
5 The Knowle, Corsham SN13 9NQ
tel: (office) 01249 713927
(fax) 01249 713927
email: haswellm2@bp.com

NOTE: If dialling any of the above numbers from outside the United Kingdom, omit the first 0 in front of the number and substitute the international code 0044
(except for numbers in the Republic of Ireland which are already shown with the relevant prefix 00353).
Since its inception in 1992, the certificate of Merit “in recognition and appreciation of exceptional services in support of the Institute” has been awarded to the following:

- 1992: William C Moulton (West Midlands Branch), A J (Doc) Foster (Pennies Branch)
- 1993: F S (Derek) Baxter (Northern Ireland Branch), Terry W Holton (South Eastern Branch), Basil W Lutter (North East Branch)
- 1994: John L Sullivan (West Midlands Branch), Ken J Powell (Western Branch), Roy E Price (East Midlands Branch)
- 1995: Peter Heron (Western Branch), Peter Wheeldon (North East Branch)
- 1996: F S (Derek) Baxter (Northern Ireland Branch), Terry W Holton (South Eastern Branch), Basil W Lutter (North East Branch)
- 1997: John L Sullivan (West Midlands Branch), Ken J Powell (Western Branch), Peter Wheeldon (North East Branch)
- 1998: Peter Heron (Western Branch), Peter Wheeldon (North East Branch)
- 1999: A J (Doc) Foster (Pennies Branch), Terry W Holton (South Eastern Branch), Basil W Lutter (North East Branch)
- 2000: Peter Wheeldon (North East Branch), Ray Wood (East Midlands Branch)
- 2001: F S (Derek) Baxter (Northern Ireland Branch), Terry W Holton (South Eastern Branch), Basil W Lutter (North East Branch)
- 2002: John L Sullivan (West Midlands Branch), Ken J Powell (Western Branch), Peter Wheeldon (North East Branch)
- 2003: John L Sullivan (West Midlands Branch), Peter Wheeldon (North East Branch)
- 2004: Roy E Price (East Midlands Branch), Peter Wheeldon (North East Branch)

A small improvement in Foundation year successes has not been matched in the Intermediate year. Once again, the Intermediate year Engineering proved to be the main problem closely followed by Geology, Surveying and Earthworks. The failure to return coursework contributed significantly to lack of success in both Foundation and Intermediate years but there were also poor examination results. There were only four failed in the Professional and Specials years. Two failed to sit the examinations, one returned insufficient coursework and the other was not given leave of absence to sit the examination by his employer. Candidates fail to return coursework at their peril and their employers ought to be aware of this fact. This year the coursework contribution has been raised from 30% to 40% to encourage candidates to return more work. Evidence suggests the message has still not got through. Coursework is a crucial element and should not be taken lightly.

### SHELL BITUMEN AWARD OF EXCELLENCE

- Winner: Peter Cox (South West highways Ltd)
- 1st Runner Up: David Aubrey (Stanger testing Services Ltd)
- 2nd Runner Up: Aiden McDonagh (Roadstone Provinces)

### PAVIORS AWARDS

- Asphalt Technology: Shirley Everett (Hanson Aggregates)
- Contracts: Rachel Ball (Hanson Aggregates)
- Business and Administration: Nicholas Roberts (Nicholls Cohn & Partners)
- Materials Testing: Mark Till (Brett Aggregates)
- Applied Engineering: Brian Allan (R Lindsay & Co (Contractors) Ltd)

### PAVIORS AWARD IN MATERIALS TESTING

- One Year Bituminous Materials Testing Course:
  - 16 candidates were enrolled and one subsequently withdrew. Of the remainder, two failed. Lack of coursework contributed significantly in both cases but there was one poor exam. Nevertheless, an 87% achievement rate is more than acceptable.

Doncaster College is grateful for the support it has had over many years from companies sponsoring both students and prizes. The School of Minerals Engineering would like to thank Shell Bitumen UK, the Worshipful Company of Paviors, RMC Roadstone and Foster Yeoman for their continuing donations.

### CITY OF BATH COLLEGE

Highways Open Tech: Distance learning for the highways industry

Our distance learning courses allow highways students to qualify while working at their job. The courses are written and tutored by people working in the industry:
- designed and administered by City of Bath Distance Education Unit;
- accredited by Edexcel (BTEC);
- recognised by professional institutions.

By studying in their own time and working at their own pace (we allow up to two years per course), our students can qualify for the Professional Development Certificate or for registration with the Engineering Council for Eng Tec. Our courses are used by students working to qualify through work, or by already qualified civil engineers who want to acquire the specialist knowledge needed for working in the highway field.

Highways Open Techniques get updated regularly

Details from Mary-Anne Couzins, Distance Education Programme co-ordinator, City of Bath College, Avon Street, Bath, BA1 1UP.
Tel: 01225 328690, e-mail couzinsma@citybathcoll.ac.uk
web site www.citybathcoll.ac.uk/courses/distlearn.htm
The Nottingham Asphalt Research Consortium (NARC) is a research-led collaboration between the Universities of Nottingham and Cambridge and organisations in the asphalt and related industries. NARC meets at regular intervals and provides the opportunity for a co-operative dialogue between academia and industry with a view to developing innovative solutions to asphalt pavement problems. As NARC is an open organisation, new members with an interest in asphalt technology are always welcome to join the consortium.

In NARC’s seventh year (January 2004 to December 2004) there were three formal meetings, each with a specific technical theme introduced by a series of speakers. The theme for the first meeting (in April) was “Geosynthetics” where Chris Jenner (Tensar International) gave a summary of the EuroGeo3 conference held in Munich in March 2004, which contained 109 papers with 5 papers on road construction incorporating geosynthetics. A second presentation by Joe Kwan (NCPE) gave an overview of a Royal Society, Brain Mercer project on geogrid reinforcement in railway ballast. The second meeting (September) consisted of a series of presentations by members of NARC reviewing some of the International conferences that had taken place during 2004. The conferences that were covered included the 3rd Eurasphalt & Eurobitume Congress that took place in Vienna in May 2004, the RILEM 5th International Conference on Cracking in Pavements held in Limoges, France, the Inaugural EATA Conference and 6th International Symposium on Unbound Pavements (UNBAR) both held in Nottingham in July and the 8th Conference on Asphalt Pavements for Southern Africa (CAPSA) held in Sun City, South Africa in September 2004. The final meeting of the year (December) on “Versatile Pavement Design” included presentations from Dr Mike Nunn (TRL), Martyn Jones and Robert Armitage (SWPE) detailing the increased flexibility of the new design approach, the new foundation design classes and the use of the new NAT Springbox to assess the performance of pavement foundation material.

In addition to the themes, each of the meetings have included reports from the two NARC research students, Alex Ossa (University of Cambridge) and York Lee (University of Nottingham) detailing their progress on the cyclic behaviour of bitumen and discrete element modelling of asphalt mixtures respectively. During the year, NARC also arranged three successful one-day courses on “Reinstatements around Road Ironwork” coordinated by Bob Noakes (Norfolk County Council), “Recent Developments in Asphalt Paving Materials and Applications” chaired by Jukka Laitinen (Nynas) and “PMBs and Performance Testing”. Further events are being planned for the coming year and are open to both NARC members and non-members.

NARC has enjoyed another successful year and the members look forward to an extremely productive and lively range of meetings and symposia, which are planned for the future. The current industrial members of the Consortium are:

- Acland Investments Ltd
- Aggregate Industries UK Ltd
- AMEC Group Limited
- Asphalt Reinforcement Services
- Atkins, Babtie Engineering Laboratories
- BP
- CAPITAdbs
- Chris Britton Consultancy
- Colas Ltd
- Cooper Research Technology
- Dynatest UK Ltd
- Essex County Council
- Excel Industries Ltd
- Foster Yeoman Ltd
- Highways Agency
- Jean Lefebvre
- Lafarge Aggregates Ltd
- Lincs County Council
- Macciferri Ltd
- Mott MacDonald
- Mouchel Parkman Ltd
- NCPE
- Norfolk County Council
- Nynas UK
- Rhodia
- RMC Materials Ltd
- Scott Wilson Pavement Engineering
- Scottish Executive Development Department
- Shell Bitumen
- Surrey County Council
- Tarmac
- Tensar International
- Total Bitumen
- TRL Limited.

Further details can be obtained on the Web at www.nottingham.ac.uk/narc or from: Dr G D Airey, Nottingham Centre for Pavement Engineering, University of Nottingham, University Park, Nottingham, NG7 2RD, tel 0115 9513913, e-mail: gordon.airey@nottingham.ac.uk.
ASPHALT INDUSTRY ALLIANCE

Jim Crick
Chairman of the Asphalt Industry Alliance

Introduction

At the start of this year the Asphalt Industry Alliance reviewed its priorities and redefined its three main objectives so as to: convince local councillors of the importance of road maintenance funding; influence central government to increase road maintenance funding; and, increase public awareness of the benefits of asphalt roads and the need for sustained maintenance funding.

To realise these objectives the Alliance of the Quarry Product Association and the Refined Bitumen Association has run a campaign focusing on both national and local issues and aimed at bringing the implications of under-funding of road maintenance home to grassroots level.

These activities have included two Making Roads Work regional forums. The events, organised by the AIA in conjunction with local authorities, bring together central government with councillors, local government officers, business representatives and road-user groups from across the region. Open and constructive support from the DfT has helped ensure the forums’ success. The events represent an opportunity for a frank discussion amongst users and providers to ensure that a region’s network is best equipped to serve business, residents and visitors alike.

The Alliance meets regularly with central government and national organisations to raise its concerns over funding. But, despite the fact that more funds have been made available from Westminster, these are still not getting through to roads and are being diverted at local authority level. This is why we need to take the message to a local level and why we plan more regional forums for 2005.

The AIA’s active media relations campaign has continued to raise media awareness and produce newspaper, magazine, television and radio coverage on various aspects of road maintenance, its funding and other asphalt-related issues including traffic noise.

The findings of the Alliance’s Annual Local Authority Road Maintenance (ALARM) survey this year achieved the most widespread coverage to date which helped considerably in highlighting the need to invest more funding in road maintenance. Over 80 radio station broadcasts, including the Today programme on BBC Radio 4, featured interviews or information on the survey. Newspaper coverage with a combined circulation of 4.5 million in the week the results were published included articles in The Times, Sunday Times, The Observer and the Daily Telegraph.

Throughout the summer and autumn of 2004 the AIA met and consulted with a number of key organisations to gather their views on how the ALARM survey should develop. This is part of the process of remodelling the ALARM survey to ensure that the 2005, the tenth, is the most accurate, comprehensive and incisive to date.

Over 200 delegates attended the Annual Asphalt Conference in Birmingham in October. Themed Asphalt – the sustainable way ahead, the conference represented an excellent opportunity to network while hearing of the latest developments.

Also, the Alliance continues to produce Asphalt Now, the twice-a-year newsletter circulated to 14,000 contacts within the industry and further afield; the AIA continues to make submissions to the government and its agents on issues which might impact on the asphalt industry, and continues to liaise with local authority highways engineers and consult with other groups and interested parties to promote the benefits of asphalt and the need for adequate maintenance funding.

As ever, the AIA recognises the valuable contribution the IAT makes to the asphalt industry as a whole and to the general awareness of the quality and high standards by which it operates.
Looking back over the past year of activity in QPA's asphalt sector, it is not hard to see why the time appears to have flown. Apart from the regular activities of dealing with technical enquiries, revising QPA asphalt publications, organising the annual asphalt conference and co-organising the Newcastle course, responding to proposed government and EU legislation affecting the industry and holding liaison meetings with client bodies such as HA and CSS, there were a number of specific topics to be progressed. In addition, QPA's move to new offices in June also helped to contribute to an extremely busy year.

The 31st annual asphalt course at Newcastle University in September attracted a good attendance of around 70 delegates and feedback from them was very positive. The feedback from delegates who attended the annual asphalt conference, held on 29 September at the National Exhibition Centre under the banner of the Asphalt Industry Alliance on the subject of sustainability of asphalt roads, was also very positive.

One major development of the year was the completion of the Sector Quality Management Scheme Document for the laying of asphalt by the Sector 16 Scheme Committee, which is made up of representatives from industry, client and certification bodies including QPA. Highways Agency has indicated that it will require asphalt laying on its contracts from 1 July 2005 to be undertaken by contractors accredited against the scheme and it is likely that local highway authorities will follow this HA lead. The scheme document is available to download from the UKAS website.

On the research front, 2004 saw completion of the three-year joint HA/QPA/Refined Bitumen Association research project at the Transport Research Laboratory on the sustainability of asphalt road construction and maintenance and the start, in November, of a new jointly-sponsored project to study surface requirements for asphalt roads, durability of asphalt pavements and the design of asphalt overlays to concrete roads.

QPA asphalt staff and staff of member companies represent the industry on a very wide range of topics and thanks are due to all of those in QPA member companies who have given their valuable time and assistance to contribute to the work of the association on behalf of the UK asphalt industry. It would be invidious to name individuals, but they know who they are and their considerable input is greatly appreciated. During 2004, QPA representatives contributed industry input to consideration of amendments to the HA Specification for Highway Works and to British Standards 594 Hot Rolled Asphalt, 4987 Coated Macadam and as well as to the amendments needed in the specifications for asphalt for airfields and for tennis courts to accommodate the European standards for aggregates. In addition, liaison meetings on technical and policy issues continued to be held with Highways Agency and County Surveyors’ Society. QPA also contributed to studies being undertaken on high-specification aggregates for roads, safety of temporary traffic management operations, the road needs of motorcyclists, development of new test methods for asphalt and development of HAPAS certification procedures for proprietary asphalt products.

All of this UK-related activity is, however, only part of the story. QPA representatives are also very involved in European asphalt affairs, the importance of which cannot be stressed too strongly. For the past 12 or more years, work has been underway on developing European Standards for asphalt mixes, test methods and conformity procedures. Many of the test methods are already available, but 2004 saw the final touches being put to the mix specifications and conformity procedures. Publication of these is anticipated in mid-2005 with their formal implementation likely in 2007/8. During 2005 there will be need to develop national guidance as well as a process of “education” for both industry and client personnel to ensure the smoothest possible change-over to the new standards when the time comes. QPA will naturally be taking a leading role in this activity.

QPA is also active in a number of other European asphalt areas, including being a major member of the European Asphalt Pavement Association (EAPA) and contributing to UK input to the development of a European Technical Approvals guideline for the assessment and certification of Ultra-thin Layer Asphalt Concrete through the British Board of Agrément. In May, EAPA and sister bitumen trade body Eurobitume held the latest in the 4-yearly series of European Asphalt Congresses in Vienna and this attracted a good attendance from UK industry, client and research organisations.

Looking forward, it is not surprising that 2004 was rather hectic and with the need in the near future to start preparations for the introduction of the European asphalt standards, there is likely to be little let-up in 2005. On behalf of the QPA Asphalt Producers and Contractors Group, may I take this opportunity of wishing the members of the Institute of Asphalt Technology good fortune and prosperity for the coming year.

David Cather, (Technical Director of the Tarmac Group and Chairman of the QPA Asphalt Committee)
The Refined Bitumen Association

In 2004 the RBA elected a new chairman; Jim Christie of Nynas Bitumen took over the role from Louis Wheeler, and at the end of the year there were two further changes on the RBA Council, when Greg Thomas replaced Ruth Leach as the Shell representative and Kevin Maw replaced Louis Wheeler for BP.

The Association continues as the voice of the UK bitumen business with the key objective of promoting the effective use of bituminous materials, with a focus on high standards in health, safety and environmental practices, and on high quality bitumen technical advice and developments.

As usual, the RBA HSE committee has been extremely active on the practicalities of ensuring the UK leads the way in safe handling and use of bitumen. In 2004 we have been revising the RBA Code of Practice for bitumen delivery, and a new version will appear on the RBA website early in 2005. This document contains the best advice available, and includes site checklists that enable us, in conjunction with our customers, to regularly audit operations and to plan continuous improvements in procedures and equipment.

This year we have been focussing on reduction of spillages (which are of course potential personal accidents) together with the harmonisation of delivery driver training and the production of training material on bitumen tankage design and operations.

Best practice information on HSE issues is also continuously exchanged with Eurobitume (the European suppliers’ organisation) and our opposite numbers in the Bitumen Associations in other countries (GPB, France; Arsit, Germany; Benelux Bitume, Belgium; AOP, Spain). Bitumen is essentially a safe and environmentally friendly material and our aim is to maintain the good safety image for the industry.

The RBA technical activities have always been at the core of the Association’s work. In 2004 the members were heavily involved in establishing the new UK Sector Scheme for bitumen supply (15) and compliance with this quality scheme will be a requirement for bitumen suppliers to HA (and probably many local authority) contracts in future.

An ongoing issue these days for the technical committee members is assessing the developments on European bitumen standards that are being produced by various CEN committees. RBA members take an active part in the relevant BSI and CEN groups to ensure the UK views and issues are properly considered. Our standard for paving bitumen (EN 12591) is currently being revised, after 5 years of use, and also new standards for hard grades, modified binders and bitumen emulsions are all reaching the end of the CEN pipeline (watch this space, or consult the RBA website for more details).

The RBA works closely with HA and QPA on our joint research projects at TRL. Over the past three years the theme of the R&D was “Sustainable Asphalt” and summaries of the outcomes of that project were presented during the annual AIA Asphalt Conference at the NEC in September.

The RBA is a key contributor, together with QPA, to the Asphalt Industry Alliance, which was formed to promote the use of asphalt and to lobby local and central government for increased road maintenance funding. For information on AIA activities in 2004 see page 10, and also the website: http://www.asphaltindustryalliance.com

RBA members also support the Road Users’ Alliance, RUA, which is run by Tim Green (ex Shell Bitumen manager) and has a wider remit, to promote UK infrastructure developments, and increased transport spending. See the RUA website: http://www.rua.org.uk.

This is just a quick summary of RBA activities in 2004. You can see that most of the effort is on joint activities, in coordination with other parts of the UK asphalt/roads industry, to ensure that the advantages of the black stuff are properly recognised. This also, of course, entails the usual close links with the IAT and its numerous activities. This will continue in 2005 when we look forward to another challenging and rewarding year.
THE NEW COLD MIX TECHNIQUE, RECYCLING AND VIRGIN COLD-MIX PRODUCTION

Ulf Lillbroända
Nynäs AB

Roger Lundberg
NCC AB, NCC Roads

Matz Wiklund
Nynäs AB

Kenneth Olsson
Skanska Sverige AB

Per Redelius
Nynäs AB

Introduction

At the end of the 1980s, concerns were being levelled against the conventional hot asphalt technique, mainly on environmental grounds. Nynäs decided to further develop a more environmentally friendly technique – the cold mix technique. A project was set up to develop a bitumen emulsion for cold-produced asphalt paving which could eventually replace the hot asphalt types without compromising on performance, or even improving on it. The development work lasted ten years (1990-2000) and was carried out in partnership with road construction companies and road owners. The work was mainly carried out in cooperation with Skanska and NCC. The development project therefore not only resulted in new emulsions but also in new mixing and laying techniques and a new mix design.

The unbroken system

Retaining full strength of the binder has always been the major problem in the production of cold emulsion mixture. Conventional, cationic emulsions break too quickly on contact with the aggregate material and therefore make production of a homogeneous, easily laid mix impossible. If the emulsion begins to break as early as during the mixing stage, the increase in cohesion cause the material to start separating. The fine material coagulates with the bitumen from the broken emulsion and the larger stones in the mixture are left uncoated. However, if the emulsion remains unbroken, it will function as a lubricant in the mixture instead. The material becomes easy to handle and does not separate when mixed and laid.

The new emulsions

Two groups of cationic emulsions have been developed and are in current use in production. Both are solvent-free and therefore satisfy one of the toughest requirements imposed when the project was launched. Nyrec is used for cold recycling, and Nymix for virgin cold-mix production. A unique, newly developed emulsifier is used in these emulsions which not only provides electrostatic stabilisation but also introduces a steric stabilisation mechanism to the emulsion. As stated above, the unbroken system is necessary for producing homogeneous asphalt. After the addition of a breaking and thickening agent, Nybreak M, the emulsions break very quickly on compaction, and the cohesiveness of the mixture starts to increase.

Nyrec and Nymix can be manufactured in conventional emulsion plants from bitumen of different grades. The emulsions are similar, differing only in that Nymix (for virgin cold-mix production) requires the addition of the breaking and thickening agent, Nybreak M.

The breaking and thickening agent

The breaking and thickening agent Nybreak M is a water-in-oil emulsion of a water/basic salt solution in an oil phase. When Nybreak M is added to Nymix, the emulsion does not begin to break immediately since the water drops, which contain the pH-raising basic salt, must first diffuse through the oil phase.

The length of this delay depends on the external conditions influencing the system. If Nybreak M is mixed carefully in a can of Nymix in the laboratory it takes a long time for the breaking to start. However, if the mixing takes place in
a conventional asphalt plant, the added energy can be extremely high, which means that the mixture breaks too quickly. This is most likely caused by the steric stabilisation, which also explains why the emulsion breaks very quickly, in 15–30 minutes, when the laid mixture is compacted.

The additive also contains an associative thickening agent which makes the emulsion thixotropic. This prevents the emulsion from running off the aggregate in the ready-mixed asphalt.(2,3)

Asphalt paving with the unbroken, cold mix technique

As with the hot production technique, detailed procedures have to be followed in the manufacturing process in order to achieve the desired results. The following sections give a brief outline of these procedures.

The manufacture of cold – mix asphalt, recycled and virgin. Recycled material

Given that as much as 70% of the result depends on preparation, care in this phase pays off. The crushed or milled asphalt is pulverised and sorted into two fractions, normally 0-8 mm and 8-16 mm. The gradation of the granulate in both fractions is determined, as are the amounts and properties of the binder in terms of penetration, softening point and kinematic viscosity. The water ratio is also determined for each of the granulate fractions.

Virgin material

As with recovered compounds, given that much of the final result depends on preparation, care in this phase pays off. It is important when choosing aggregate to make sure that it has the right moisture ratio and that the adhesive characteristics are correct.

Virgin cold-mix asphalt are made with the same machinery as cold recycled asphalt, and using the same unbroken cold technique.

Mix design-recycled material

The proportioning of the mix design is governed by the expected traffic load on the road in question and the existing roadbed superstructure. The object is to optimise the required functional characteristics of the finished road surface, such as durability, stability, fatigue strength, flexibility and friction. This also governs the hardness of the bitumen. The technique best suited to this is the unbroken cold mix technique, in which the emulsion breaks only once it has been compacted on the road.

A suitable mixture of constituent materials is developed on the basis of an ideal curve that meets the requirements for the functional characteristics. When using recovered paving it is advisable to include a certain proportion (10-30%) of new aggregate in order to make the mixture easier to handle and reduce the amount of binder in the input material to allow greater admixture of the emulsion. The ideal curve should be one that gives smooth, easily compacted mixture of high stability.(1)

Virgin material

As is the case with cold recycled asphalt, the proportioning of the mix design is governed by the expected traffic load on the road in question and the existing road structure. A suitable composition of constituent material is produced on the basis of an ideal curve that meets the requirements for the functional characteristics.

Production of samples

Laboratory samples are now being produced with four different amounts of binder for the chosen mix of input material. The total content of bitumen residue must be between 4.5 and 7.5 per cent by weight (7% is the normal target for recycling, 5 – 6% for virgin mixtures). As with the production of hot compounds, the admixture ratio should be increased when using harder binders. The production of samples also takes into account the water ratio of the recovered asphalt, which must be 2.0–4.0 per cent by weight. The samples are produced using a gyratory compacting method at room temperature.

Testing of samples

The samples are tested for total binder content, void content, tensile strength, stiffness and adhesion. Once the results of the analysis have been carefully studied, the mixture that best fulfils the desired criteria is chosen.
Mobile Cold-Mix Plant - production

Recycled material

The mobile asphalt plant used for this is compact and consists of five components: 1) three bin dosing and mixer for the input material; 2) control cabin with paddle mixer; 3) binder tank; 4) water tank; and 5) generator with laboratory. The capacity of the plant is 150 tonnes/hour.

The three dosing bins are filled with two fractions of granulate and stone aggregate. A combined weigh-scale and roller belt feeds the mixed materials into the paddle mixer, where the material is dispersed in preparation for the addition of the emulsion.

The emulsion is added from a row of nozzles and to achieve careful mixing, the material is aerated and folded rather than mixed very vigorously. The speed of the paddles is determined by the type of mixture and the amount of binder in the finished product. The entire production process is controlled and monitored by a computer in the control cabin.

Since the process is unheated, energy consumption is low (the generator consumes only one litre of diesel oil per tonne of asphalt.). The noise level of the plant is also low.

Virgin material

The production of virgin cold-mix differs from cold recycled asphalt in that it also involves the addition of a breaking agent to the emulsion. The breaking additive, which is described elsewhere in the report, has both breaking and thickening properties. Otherwise, production takes place using the same machinery and methods as for cold recycling, all the aggregate being coated with the emulsion without there being any run off.

Other stages, such as transport and laying of mixtures, are the same as for recovered compounds. However, in the compacting process, a static compactor replaces the tyred compactor used with recovered materials.

The final result is a paving that possesses a thick, durable binder film with good coverage of both granulate and aggregate, and no run-off. Traffic can be allowed on the road without any risk of initial wheel tracking.

Storage and transport

The asphalt plant can be moved at a low cost, which means that production can be undertaken close to the laying site. This means the process is also profitable with low volumes. After production, the finished asphalt-mixture is stored or transported direct to the laying site. It is often a good idea for the mixture to be relifted and moved before being loaded and transported to the laying site.

When loading, the operator must remember not to press the ladle onto the load to divide it up. This is similar to rolling and will therefore trigger the breaking process in part of the mixture, which will render the mixture more difficult to lay.

The mixture must be covered during transport to prevent the water evaporating.

Paving

The asphalt-mixture is laid by a paver fitted with a combination screed with an extra feed control, which helps to prevent separation and keeps the mixture moving. The paver produces a homogeneous surface.
Compaction

Two kinds of compactor are used: a rubber-tyred roller and a vibrating roller. Only once the tyred roller has passed over the laid mixture does the emulsion start to break. This means that the mixtures have time to compact and the aggregate has a chance to orientate itself within the asphalt. The vibrating roller then passes over the paving to compact it further. A total of 4 to 6 such compaction operations are normally required, followed by a light sanding of the surface with a plate spreader.

The finished paving has a thick, durable binder film with good coverage of both granulate and aggregate, and no run-off.

Reduction of voids

The existence of excessive voids has long been a problem in the production of cold mixtures, both virgin and recycled. This has been because the cold-mixtures have been too stiff and therefore hard to compact. However, several methods for reducing voids have been developed, and this has mitigated the problem even if it cannot be said to have been completely eliminated.

Recycling

The use of rubber-tyred rollers can reduce voids to 12-14 per cent by volume, a method that is also recommended in the above procedural description.

Virgin cold-mix

By sealing the surface, voids can be reduced from the normal 12-20 per cent to 8-10 per cent by volume. By replacing the 0-4 mm stone fraction with asphalt granulate of the same size, it has been possible to reduce voids down to 4 volume per cent. Trials have shown that it is a good idea to mix in as much as 40 per cent by weight of asphalt granulate of a 0-4% fraction range when producing new asphalt. This does not impair the characteristics of the mixture, and opens up exciting new possibilities.

Conclusion

Paving made with the unbroken cold-mix technique based on recycled asphalt and virgin cold-mix are today delivered with a performance guarantee and satisfy all Swedish standards. The paving is dimensioned and proportioned with the help of laboratory tests on samples, made of the same material as that used in the actual paving.

The unbroken emulsion system means that the emulsions remain stable throughout the entire production process and only break once they are compacted. In turn, this has made it possible to use a harder base bitumen able to take higher traffic loads. This expands the area of application for this more environmentally friendly, low-energy cold production method.

Typical results

The roads that have been repaved using the unbroken system have been tested in the laboratory. As preliminary trials are discussed elsewhere in this report, we shall here give an account of the results for finished roads.

![Graph showing stiffness modulus of different mixtures](image)

The results of surveys show conclusively that stability characteristics, in the form of indirect tensile strength as well as stiffness modulus, are markedly better with Nymix 630/240 and Nyrec 630/240 than with conventional emulsions of the BE 60M/2000 type. Deformation characteristics, as reflected in wheel-tracking, are also significantly improved.

Cold recycling with Nyrec

In 1997, 3,000 tonnes of cold recycled mixture were used to pave a road 100 km south of Stockholm. The stretch of road is used by about 1,500 vehicles a day, 10% of which is heavy traffic.

The road was monitored over the year, and measurements show that rut development had reduced markedly on the stretches paved with Nyrec 630. This has been verified by core samples, examination with wheel tracking, and by a visual analysis with a straight edge.

![Graph showing rutting with Nyrec](image)

The service life of the Nyrec 630 paving will be about 25% longer than for a similar paving using conventional cold recycling.

![Wheeltracking on cores from Sillekrog](image)

Ruts, measured with a straight-edge

The performance of the Nyrec 630 paving will be about 25% lower than for a similar paving using conventional cold recycling.
Virgin cold-mix production with Nymix

A number of road sections have been paved with Nymix, and it is clear that stability increases significantly in relation to conventional emulsions. In the autumn of 1998, a stretch of road (Highway 524 Hösö – Overboda, just west of Umeå in northern Sweden) was paved with a new cold asphalt. This stretch of road has heavy traffic but, in relative terms the number of heavy vehicles is high. The binding agent in the paving was Nymix 630, and after three years of use the rut depth (measured with a straight edge) was only 1 mm. This can be compared with conventional paving using MJOG(8) 16/V5000, which was laid the next year (1999) and which had a rut depth of 11 mm after only two years. In this case, the service life of the Nymix paving will greatly exceed that of the conventional paving.

(*) MJOG = surface course with soft bitumen

Cold binder and surface course

Another road was paved in the vicinity of Umeå. For this Nymix 630 was used as the binding agent in the binder course, and Nymix 50 in the surface course. Core samples from the road were examined with wheel-tracking equipment. The commonly used MJAG*) 22/V12000 (binder course) / MJAB(*) 16/V12000 (surface course) mixture was used as a control, both compounds being produced in a hot asphalt plant.

The results from wheel-tracking tests show that there is twice as much deformation in the control paving as in the Nymix paving.

Wheel-tracking on cores from Umeå

If these stretches of road are used by heavy traffic, the Nymix paving will last longer than the control paving before having to be resurfaced or filled.

Ageing of bitumen

The ageing of the bitumen has also been studied. The pavements we have been examining have been relatively open (voids = 10%). This means that the bitumen ages quite quickly. We have been able to show that the ageing process is slower than that found in conventional mixtures, for example, after 3 years a penetration 180 bitumen has a penetration of ≈ 140 mm/10.

References


MJOG = soft surface course
EMAG = emulsion binder course
MJAB = soft surface course
MJAG = soft binder course

Wheeltracking on cores from UME
THE PERFORMANCE OF OLEXOBIT 100 IN POROUS ASPHALT, 11 YEARS ON

J Carswell MIAT
Research Leader, BP Bitumen

Introduction

Porous asphalt (PA) surface courses have been developed in the UK since road trials in the late 1960s. They were a development from friction courses used on runways to reduce the incidence of aquaplaning. The various road trials in the UK culminated in the A38 Burton Bypass trials (laid in both 1984 and 1987), from which a number of important conclusions were made. These were (based on a nominal 20 mm grading):

- PA can have an acceptable life in excess of 10 years using additives or modifiers at traffic levels of about 4000 cv/d (commercial vehicles per lane per day);
- PA tends to have a longer service life if the binder content is high (>4%) provided binder drainage does not occur during the mixing and laying operations; and
- the life of porous asphalt is ultimately limited by binder hardening when its penetration falls below about 15 pen.

In the SHW (Specification for Highway Works), Clause 938 addresses the requirements for PA surface courses.

It should be noted that the original reason for the development of PA as a road surface course was to significantly reduce the incidence of spray in wet weather. As such, the most promising material was that which had a nominal 20 mm coarse aggregate, which optimised both spray and noise properties. With such a large aggregate, it was clearly the case that the thickness of the surfacing layer would be at least 45 mm (if it is assumed that the preferred thickness equals 2 times the nominal size aggregate). At the same time when PA surfacings were being proposed for use, it was considered that 50 mm of PA gave the same structural contribution to the road pavement as 40 mm HRA (hot rolled asphalt) surface course, the premier surface course being used at the time. The net result of these considerations (and others) led to PA costing nearly twice that of HRA in the late 1980s, meaning that an extremely good case needed to be made for its use.

It is an interesting debating point that had the requirement originally been focused on noise rather than spray, it is doubted whether 20 mm PA would have seen the light of day as a road material. Nevertheless, a number of contracts using the 20 mm PA have been laid in the UK, although the primary benefit normally cited has switched from spray reduction to noise reduction. In 1993, the then Welsh Office (now the Welsh Assembly Government) proposed PA between Junctions 33 and 34 of the M4 in South Wales as a trial to deal with a surface water problem. The trial was laid in 1993, using BP Bitumen's proprietary binder (later branded Olexobit 100) and such was the success that the stretch between 32 and 33 was surfaced with PA in 1994 and a further stretch between 34 and 35 laid in 1996, both also using Olexobit 100.

Since the laying of the materials, the two earliest contracts have been monitored for the Welsh Assembly Government by TRL Ltd. Further, since 1996, BP Bitumen has carried out additional testing on the recovered binders and provided reports to both the Welsh Assembly Government and the TRL Ltd. The year 2000 was the last year in which cores were taken to enable binder analysis to be carried out.

As part of a recycling of a PA project (consortium consisting of TRL, Shell Bitumen and Lafarge), planings of part of the 1994 Contract (taken in March 2004) were made available to BP Bitumen. The planings were taken from a number of the carriageway lanes from the M4 site (32-33) and combined. The evaluation of Olexobit 100 after 10 years in service is presented in this paper together with some conclusions on PA materials in general. The results obtained were fitted to those from previous years and also compared with the general trends observed from the A38 porous asphalt road trials (laid in 1984).

M4 materials

The nominal size 20 mm PA material used a 68 PSV coarse aggregate (ex-ARC, now Hanson) and BP Porous Asphalt Binder (now Olexobit 100 - ex-BP Bitumen). For the initial Contract (Junction 33/34), based on a nominal 20 mm grading with no oversize, over 1,000 tonnes were laid per day and the Contract was finished in half the scheduled time. The two further contracts, also laid by Hanson, were made using the same materials but manufactured to meet the prevailing SHW Clause.

Material from the planings from the second Contract awarded (Junction 32/33) was recovered in March 2004 (approximately 10 years after laying) and made available to BP Bitumen.
Recovered binder properties

The binder was recovered from the material planings and the following test programme was carried out (which was similar to earlier evaluations) and included:

- Penetration at 5°C and 25°C;
- Softening point;
- Ductility at 5°C;
- Bending beam rheometer (BBR) (temperature at which stiffness = 300 MPa, a low temperature performance parameter);
- Dynamic shear rheometer (DSR) \((G^*/\Omega)\) at 1.6 Hz (temperature at which stiffness = 1 kPa, a nominal high temperature performance parameter).

The last two tests were used purely on a research basis, as a result of so-called performance information coming from the US SHRP (Strategic Highway Research Program). The idea was to assess whether these new parameters would help in assessing the binder’s performance in PA mixtures. A summary of the empirical results for the binders supplied to the M4 Contracts in 1993 and 1994 is shown in Table 1 (note the results include those obtained from previous core investigations). For completeness, assumed values of initial penetration after laying (approximately 70 dmm at 25°C) are included in the relevant figures. Plots of change in penetration and softening point with time are shown in figures 1 and 2 respectively. Fig 1 also shows results for the BP binder (subsequently branded as Olexobit 100), which was used in the 1984 PA trials on the A38 (refer to Section 3 of this report). The nominal “critical limit” of 70°C softening point was derived from the A38 PA trials and was related to the corresponding “critical limit” of 15 dmm, considered to be the failure criteria for binders in PA.

Table 2 shows the trend in results from the fundamental tests that have been described in earlier Reports (DSR and BBR)\(^1,2,3,4\) for the 1994 Contract only. The changes in the BBR results with time (in years) are shown in fig 3.

Comparison with A38, Burton PA Trials

It is recognised that there is a considerable degree of uncertainty associated with the recovery of binders from coated materials, especially those produced with polymer modified binders. Further, the uncertainty involved is such that it is difficult to accurately predict the residual life of the porous asphalt on the M4 trial sections.

The 1984 PA road trials carried out on the southbound carriageway of the A38 Burton Bypass by TRL have been widely reported\(^5,6\). It was largely from these trials that the “critical performance parameter” of 15 dmm was proposed as the critical penetration value after which the porous asphalt would fail in the next harsh winter. A generalised “hardening model” based on this criterion (and 70°C softening point) has been reported, although it is known that there was “a large scatter in the results”.

For comparison purposes, the current trends observed for the M4 binders are compared with the generalised hardening model for 100 pen bitumen derived from the A38 trials. Figure 4 shows the changes in penetration value of the recovered binders from the M4 with time compared with two generalised models for 100 pen bitumen, one based on a starting penetration of 100 dmm, the other based on a starting penetration of 70 dmm, after initial placement on the road. Both models assume a 20% hardening per year thereafter. Figure 4 also shows the possible hardening model for a softer grade of Olexobit (Olexobit 150), based on that obtained...
with the Olexobit 100. The reason for showing this particular binder is that experience gained since these PA contracts have been laid has shown that Olexobit 150 can perform satisfactorily in thin porous type surfacing in similar trafficking environments to those on the M4 PA sections.

Discussion

Olexobit 100 has performed successfully in all PA contracts where it has been used. Monitoring the in-service performance of the M4 PA Contracts has been carried out in the past by TRL Ltd where part of the monitoring has been to recover the binder in order to predict the residual life of the PA pavement. As stated, trials on the A38 in 1984 and 1987 indicated that a PA material would become “critical” once the binder penetration value fell to 15 dmm (and softening point of 70°C). The results from the M4 Contract laid in 1994 indicate that the Olexobit 100 binder is hardening similarly in line with the general trends observed for the BP PMB binder used in the A38 trials. In terms of change in penetration value between 2000 and 2004, the 1994 binder has hardened by a further 30% (7% annually).

The PA sections on the M4 (Junction 32/34) are both still serviceable, although relatively minor remedials have been carried out which are understood to have been principally required because of accident damage. However, it is noted that the performance of the surfacings has deteriorated, principally in the most heavily trafficked lanes, but not at a rate to cause undue concern. Although binder results have only been presented from the 1994 Contract, where the “critical” limits have been reached, it is noted the 1993 Contract is still performing and it is assumed the binder used is now harder than that used in the 1994 Contract.

The low temperature properties (as measured by the BBR) continue to show a hardening effect (Fig 3) and it may be that the “critical in-service” level is also related to this property. At the current rate of hardening, the BBR temperature (for a stiffness of 300 MPa) equivalent to 0°C will be reached after about 12-13 years in service. It would seem that the high temperature properties (measured by the DSR), which effectively relate to rutting susceptibility, are of no relevance in PA materials given that the aggregate grading skeleton dominates.

However, because a binder may reach the “critical” values, this does not necessarily mean imminent failure. It is postulated that this would largely be dependent on the severity of the winter following the summer months; if the winter was to be severe (i.e. cold and with numerous freeze/thaw cycles), the PA would probably not last; if the winter was to be moderate (or mild), the material would probably survive. At best, upon reaching these values it would indicate to the relevant Highways Authority that a maintenance, or re-surfacing, plan would be advisable. Apart from the areas that have already been the subject of remedial measures, the in-service lives are now 10 and 11 years. Table 3 shows historical weather data for Cardiff Bute Park since 1993 (courtesy of the Meteorological Office). In brief, it shows the mean monthly maximum air temperature, T(max) and mean monthly minimum air temperature, T(min), in any given year. Where recorded, the mean monthly minimum grass temperature (G(min)) is also given. The Table serves only as a guide as the actual temperatures on the road site are likely to be more adverse (higher elevation and further inland) than those reported from Bute Park.

It is noted that the eastbound carriageway of the 1993 Contract has, earlier in 2004, been realigned as a four-lane carriageway with consequent changes to the road-marking lines. The existing white lines were removed by planing with little or no deleterious effect on the surface course.

Experience now gained with the use of the softer Olexobit 150 grade in porous thin surfacing would indicate that this binder would perform satisfactorily in PA on heavily trafficked roads, and this should further extend the life expectancy by a further 2-3 years. It is generally agreed that PA performance, in terms of longevity, is improved through using a binder with as soft a grade as possible together with a thick binder film, provided binder drainage and hydraulic conductivity properties are not adversely affected. It is now possible to postulate that, in similar traffic conditions, the use of Olexobit 150 would provide a more durable surfacing than one produced with Olexobit 100.

Of course, the rationale for PA surfacings has changed dramatically since the early contract days of PA and it is now somewhat rare for 20 mm PA to be used. The main reason for the move away from 50 mm PA has been the introduction, since the early 1990s, of a new generation of surface courses, mainly proprietary, which are laid much thinner than conventional surface courses (typically 15-35 mm).

<table>
<thead>
<tr>
<th>Year</th>
<th>T(max) (°C)</th>
<th>T(min) (°C)</th>
<th>G(min) (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>21</td>
<td>2.8</td>
<td>-0.4</td>
</tr>
<tr>
<td>1994</td>
<td>23</td>
<td>1.3</td>
<td>-1.4</td>
</tr>
<tr>
<td>1995</td>
<td>26</td>
<td>1</td>
<td>-2.2</td>
</tr>
<tr>
<td>1996</td>
<td>22</td>
<td>0.3</td>
<td>-3.5</td>
</tr>
<tr>
<td>1997</td>
<td>23.3</td>
<td>-0.1</td>
<td>-2.2</td>
</tr>
<tr>
<td>1998</td>
<td>21</td>
<td>1.9</td>
<td>0.2</td>
</tr>
<tr>
<td>1999</td>
<td>23.1</td>
<td>1.9</td>
<td>-0.1</td>
</tr>
<tr>
<td>2000</td>
<td>21.9</td>
<td>1.2</td>
<td>-0.7</td>
</tr>
<tr>
<td>2001</td>
<td>21.6</td>
<td>1.3</td>
<td>-</td>
</tr>
<tr>
<td>2002</td>
<td>21.7</td>
<td>3.7</td>
<td>-</td>
</tr>
<tr>
<td>2003</td>
<td>24.5</td>
<td>1.9</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3. Climatic data from Bute Park

of Olexobit 150 would provide a more durable surfacing than one produced with Olexobit 100.
The future of the original PA laid 50 mm thick may be a matter for debate but it is clear that it was the forerunner to the adoption of quieter road surfacings. In this sense, the developments carried out in the UK have benefited from the experience of using 20 mm PA. It is worthy of note that improvements in binder technology and in asphalt production techniques have resulted in a PA that, under the right conditions, will exceed a 10 year life, confirming unpublished conclusions drawn by TRL Ltd back in 1993 but only published in 1997.

Conclusions

From the results obtained on recovered Olexobit 100 binder from the 1994 M4 contract (it is assumed that results from the 1993 contract also apply), and comparing with previously reported results, the following conclusions may be drawn, bearing in mind the imprecision associated with the binder recovery process.

- The PA in both contracts has reached the “limiting” values of penetration and softening point that would indicate that the material is near the end of its useful life. These have occurred after at least 10 years in service (10 years for the 1994 contract and 11 years for the 1993 contract) and both materials are still extant (excluding relatively minor remedial maintenance treatments understood to have been principally required because of accident damage), and serviceable.

- The hardening model, developed by TRL Ltd, appears valid but only in the sense that it signals to highway authorities that the material is near the end of its useful life. It is believed that much depends on the severity of the winter months as to whether sudden failure will occur.

- The use of more fundamental tests, excepting the low temperature stiffness, has not really added more precise information as to when the material may be nearing the end of its useful life.

- It is noted that the older 1993 contract was subject to trial lane revisions in early 2004 and, although it was deemed necessary to replace the existing surface course, it was considered best to await the outcome of the trial lane markings. This trial has proved successful and the section (Junction 34/33) will be resurfaced in 2005.

- Olexobit 100 has proved to be a good performer in PA materials and it confirms earlier thinking that to achieve a long-life PA, a soft PMB and a thick initial binder film are prerequisites. The use of a slightly softer grade within the Olexobit universal range, ie. Olexobit 150 grade, could now be recommended for heavily-trafficked roads, which should extend the life expectancy of PA by approximately a further 2-3 years.

- The future of PA, in the form used in the M4 contracts, may be under threat but the experience gained from using such materials has spearheaded research and development on a whole range of porous type surfacings that can meet the traffic and environmental demands of today's society.

Acknowledgements

BP Bitumen wishes to gratefully acknowledge the cooperation of TRL Ltd in making available the PA planings from the M4 road site to complete the evaluation. BP Bitumen also gratefully acknowledges the input provided by Hanson plc and the Welsh Assembly Government in compiling this paper.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pen (25°C) (0.1mm)</strong></td>
<td>98**</td>
<td>68¹</td>
<td>44¹</td>
<td>26</td>
<td>23</td>
<td>22</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td><strong>Pen (5°C) (0.1mm)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>18</td>
<td>17</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td><strong>Softening Point (°C)</strong></td>
<td>52.4¹</td>
<td>54.6²</td>
<td>63.2</td>
<td>65.0</td>
<td>57.0</td>
<td>70.2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Ductility (5°C) (mm)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>32</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pen (25°C) (0.1mm)</strong></td>
<td>103**</td>
<td>97¹</td>
<td>53¹</td>
<td>33</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td><strong>Pen (5°C) (0.1mm)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>23</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td><strong>Softening Point (°C)</strong></td>
<td>48.2¹</td>
<td>51.2²</td>
<td>57.0</td>
<td>59.6</td>
<td>62.2</td>
<td>63.8</td>
</tr>
<tr>
<td><strong>Ductility (5°C) (mm)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>32</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

¹ = 200 g, 60 secs, ² = TRL results, ** = avg, pen obtained on supplies to the contract

Table 1. Binders as supplied to, and recovered from, the M4 PA Contracts (Junction 32/33 and 33/34)
References


6 Daines M E. Trials of porous asphalt and rolled asphalt on the A38 at Burton, Department of Transport TRRL Report RR 323, 1992. Transport and Road Research Laboratory, Crowthorne.

FUEL-RESISTANT MASTIC ASPHALT

Vicky Ablitt,
Industrial and Emulsions Engineer, Shell Bitumen

Introduction

Crude oil is made up of a mixture of hydrocarbons that differ in molecular weight and boiling range. Before crude oil can be used it must be separated, purified, blended and, sometimes chemically or physically changed through a fractional distillation process producing various products such as lubricants, diesels, gas oil, gas and long and short residues. The long and short residues are distilled further to produce various grades of bitumen.

Bitumen is the heaviest component available from the fractionating process. However it can be softened when mixed with lighter petroleum-based products that are chemically compatible with bitumen. The damaging materials to bitumen can include motor gasoline, diesel fuel, lubricating oils, brake fluids and other distillate products. Such oils are required by motor vehicles and hence can be and are spilled onto asphalt surfaces. In areas of slow moving channelised traffic or parking areas, the accumulation of spillages can be sufficient to damage the integrity of the asphalt layer and can lead to significant distress.

Traditionally, protection against the light petroleum-based products has been given by coal tar. Tar-based materials have been used for many years as seals over asphalt layers as a protective coat against spills of lighter petroleum residues. Tar is a viscous condensate from the high temperature carbonisation of coal during coke production; the solvency effect of light petroleum residues on tar is significantly less than conventional bitumen. However, due to the health and safety concerns raised about the carcinogenic effects of coal tar, the use of tar based products has since been in decline. As a result, it was recognised that a replacement for coal tar as a fuel resistant solution was required by the asphalt industry. With this in mind, Shell Bitumen developed a fuel-resisting product Mexphalte Fuelsafe in the mid 1990s and progressed further with the new and improved fuel-resisting product Cariphalte Fuelsafe. Having experience and proven technology in the field with the use of these products, Shell Bitumen decided to expand their fuel-resisting portfolio and provide a solution for mastic asphalt applications.

Mastic asphalt

Mastic asphalt consists of ingredients that comprise bitumen and additions of coarse and fine aggregates to form a cohesive voidless, impermeable mass that when heated to a suitable temperature can be spread by means of a hand float without compaction. Mastic asphalt is extremely versatile and at application temperatures it is workable on various complex detail and configurations providing a seamless and durable finish.

Mastic asphalt is considered to be the ultimate protection for a wide range of construction applications and offers total waterproofing integrity for roofing, elevated car and lorry decks and other applications such as tanking, flooring, paving and bridge deck surfacing. The types of mastic asphalts that are available today are numerous. These speciality mastic asphalts are being designed for applications such as acid resistance, coloured and decorative surfacings, hydraulic asphalts for riverbank protection and sea defence. Today’s modern market for mastic asphalt is unique and is ideal for the use in domestic and industrial applications. It was from this diversity of products that Shell Bitumen worked with Pure Asphalt in the development of a fuel-resistant mastic asphalt. Pure Asphalt had already been approached by local authorities for supplying fuel resistant mastic asphalt for the re-surfacing of bus cage areas, car parking areas and bunding areas.

Significant damage has been caused in these areas by spillages of diesel from buses, cars and other sources. The aim for Pure Asphalt is to resurface these areas with mastic asphalt with fuel-resistant properties that will help prolong the life of the surfacing.

In the UK, mastic asphalt is usually manufactured with a hard grade bitumen. As Cariphalte Fuelsafe is considerably softer than this, it was decided to transfer the same fuel resistant technology but with a penetration of less than 25 dmm for both footpath and pavement applications.

Footpath and paving grade mastic asphalt: BS 6925: 1447

Mastic asphalt has exceptional waterproofing and durability characteristics. Their uses range from the resurfacing of multi-storey car parks, bus stop areas, roads and footways offering a durable working surface resistant to rutting. Pure Asphalt has developed mastic asphalt formulations for both footpath and general paving applications. The footpath mastic asphalt has been designed specifically for pedestrian traffic whilst the paving grade was formulated to meet the requirements of general traffic conditions in areas such as car parks, bus lanes etc. Mastic asphalt paving in the areas mentioned above provide specifiers with design flexibility in that smaller contracts can be supplied with block mastic...
asphalt for re-melting to the size and area required to resurface the site. Due to the flexibility of the mastic asphalt application, this can help to provide ease of application without the need for large on-site laying plants. All standards can be enhanced by the addition of fuel-resisting binders that can be made into mastic asphalt blocks to help prolong the surface resistance to fuel such as petrol and diesel spillages.

**Experimental**

As stated previously, a hard grade of bitumen normally less than 25 dmm is traditionally used for mastic asphalt. Therefore, 15/25-penetration bitumen was used as a control and compared with the experimental candidate fuel resisting binders that were being evaluated. Table 1 gives details of the initial properties of the binders and control binders being used. It can be seen from table 1 that the conventional 15-25 penetration grade bitumen has a similar penetration, but lower softening point and lower viscosity profile compared to experimental binders 1 and 2.

<table>
<thead>
<tr>
<th>Binders</th>
<th>Penetration @ 25°C (dmm)</th>
<th>Softening Point (°C)</th>
<th>Brookfield Viscosity (Pa.s) @:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control 15/25 pen</td>
<td>17</td>
<td>67.8</td>
<td>120°C: 17.5</td>
</tr>
<tr>
<td>Experimental 1</td>
<td>14</td>
<td>86.0</td>
<td>140°C: 70.5</td>
</tr>
<tr>
<td>Experimental 2</td>
<td>15</td>
<td>94.5</td>
<td>160°C: 29.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>180°C: 9.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200°C: 4.3</td>
</tr>
</tbody>
</table>

**BS 598-107:1990:** Mixing and compaction of Marshall blocks

**Mixing**

All the equipment used in this method had to be heated prior to the manufacture of the specimens. The aggregates used were heated in an oven prior to adding to the mixing bowl. The aggregates were then stirred thoroughly and a crater was formed to receive the binder. The heated binder was stirred and weighed to the nearest gram and then added to the mix bowl with the aggregates. The mixture was whisked until the binder was evenly coated around the aggregates.

**Compaction**

The mixture of bitumen and aggregates was placed into a steel mould cylinder, which had been heated 6 hrs before the mixing process and stirred using a spatula to prevent bridging of the aggregate. The heated hammer foot was lowered onto the steel block for 5 ± 1 minutes before the start of compaction. The mould was transferred to the compaction pedestal and located in the mould holder. Fifty blows with the compaction hammer at a rate of 60 ± 5 blows per minute are required to produce a consistent and reproducible block. Three specimens were mixed and compacted for each binder content and grading used. The specimens were then ready for immersion into diesel.

**Diesel Immersion Test – Shell Bitumen in house test method**

The specimens were placed into containers and filled with diesel ensuring that the block was fully immersed. Vertical wires attached to a number of framed units were labelled for reference. Each specimen was placed onto the framed units and hung vertically underneath the balance so that the block was completely immersed in fuel. The specimens were weighed each day up to 28 days. This can be seen in fig 1 and 2:

**Figure 1 & 2**

**Table 1. Rheological properties of 15/25 bitumen and two experimental fuel resistant bitumens**

**Diesel Immersion Test results**

Pure Asphalt provided Shell Bitumen with two mixture design specifications for mastic asphalt, these being footpath and pavement grade mastic. The fuel-resistant mastic asphalt binders were compacted as detailed above using each mixture design. A control binder mixture of 15/25 penetration was also used with both mixture designs and compacted using the same method. All compacted specimens were then submerged into diesel for 28 days and the mass loss was recorded. Figures 3 and 4 show the

**Figure 3. Graph to show the resistance to diesel after 28 days for Experimental binder 1 and compared to 15/25 penetration bitumen**
outcome of the fuel resisting binder when compared to 15/25-penetration grade bitumen.

Photographs were taken of the fuel resistant mastic asphalt Marshall samples to show the resistance to diesel after 28 days immersion and compared with the control 15/25-penetration grade bitumen. This is shown in fig 5, 6 and 7:

**Fuel-resistant mastic asphalt mixtures**

Figures 5 and 6 show that the fuel-resisting binders were significantly better at resisting the effects of diesel fuel when compared to 15/25-penetration grade bitumen (fig 7). This can be seen for both of the candidate binders and using both mixture designs.

**Conclusions**

It can be concluded that Experimental binders 1 and 2 show excellent fuel-resistant properties to diesel fuel compared to the control 15/25-penetration grade bitumen. Figure 7 shows that 15/25-penetration grade bitumen deteriorates dramatically when immersed into diesel. This occurred for both mixture designs (footpath and pavement grades) using the control binder.

The development of the fuel-resisting binders delivers a performance that can help minimise the risk of deterioration of footpath and pavement grade surfacing’s. By taking account of its fuel-resisting nature it could be perceived as a cost-effective alternative to other “non-fuel-resisting” products as less maintenance would be required. This increased resistance to fuel spillages therefore prolongs the life expectancy of the asphalt surface.

**References**


**Bibliography**


4) Sampling and examination of bituminous mixtures for roads and other paved areas – Part 107: Method of test for the determination of the composition of design wearing course rolled asphalt – BS 598-107: 1990

5) Fuel Immersion test method: Shell Bitumen In-house test method.
TEN YEARS OF DYNAMIC SHEAR RHEOMETER RESEARCH AT NOTTINGHAM

Dr Gordon D Airey MIAT,
Senior Lecturer, Nottingham Centre for Pavement Engineering, The University of Nottingham

Abstract

The Dynamic Shear Rheometer (DSR) is one of the most complex and powerful instruments currently used to characterise the flow properties of bitumen. This Paper describes the successful utilisation of DSR testing on a selection of research projects undertaken within the Nottingham Centre for Pavement Engineering (NCPE) at The University of Nottingham over the last ten years. It addresses, in addition to standard DSR testing of bitumen, the issues associated with DSR sample preparation, testing geometry and measurement precision. In terms of material characterisation, the Paper provides a rheological assessment of the effect of bitumen polymer modification, DSR data linearity and the aging susceptibility of low penetration grade bitumens.

Introduction

In May 1994, the Pavements and Geotechnics Research Division within the School of Civil Engineering at The University of Nottingham took delivery of a Bohlin DSR50. Although this machine was subsequently replaced with more advanced rheometers, it provided the initial opportunity to undertake detailed, fundamental bitumen rheology research at Nottingham.

Over the last ten years, various rheological studies have been undertaken within the School of Civil Engineering and NCPE using these DSRs. These investigations have concentrated primarily on standard rheological testing of bitumen using the DSR but have also included tests undertaken on aggregate plates and bitumen emulsions using modified testing configurations. This paper gives an overview of a selection of different research projects investigating issues associated with DSR testing methodology as well as the rheological characterisation of different asphalts.

Testing methodology

Various techniques exist to measure the rheological properties of bituminous binders, including transient (creep) shear test methods using sliding plate rheometers, capillary forced flow rheometers, and cone and plate viscometers. However, these methods are often conducted in the non-linear flow region and are therefore difficult to characterise in the laboratory or to model in practical engineering applications. Conversely, dynamic shear rheometry provides a robust means of measuring the rheological, viscoelastic properties of bituminous binders within their region of linear response. The principle used with the DSR is to apply sinusoidal, oscillatory stresses and strains to a thin disc of bitumen, which is sandwiched between the two parallel plates of the DSR (fig 1). The viscoelastic parameters that are measured are the ratio of maximum (shear) stress to maximum strain, known as the complex “shear” modulus, G*, and the phase (time) lag between the applied shear stress and shear strain responses, known as the phase angle, δ.

In terms of the repeatability and reproducibility of DSR testing, temperature control, plate geometry selection (compliance), data linearity and machine type tend to have the greatest impact. In terms of temperature control, most modern rheometers are capable of maintaining a temperature to within ± 0.1°C, as recommended by Petersen et al., thereby ensuring accurate and consistent results. Unfortunately, some of the other factors affecting DSR testing have tended, at times, to be overlooked.

Machine Compliance

In general, two parallel plate geometries are commonly used with the DSR comprising 8 mm diameter plates with a 2 mm testing gap and 25 mm diameter plates with a 1 mm testing gap. The selection of the testing geometry is based on the operational conditions with the 8 mm plate geometry generally being used at low temperatures (-5°C to 20°C) and the 25 mm geometry at intermediate to high temperatures (20°C to 80°C).

To investigate the influence of testing geometry on the rheological properties measured with the DSR, tests were performed at different temperatures and frequencies (0.01 to 15 Hz) using different plate diameters and gap widths (8 mm...
diameter with 2 mm gap between 10 to 35°C and 25 mm diameter with 1 mm gap between 25 to 75°C). The $G'$ and $\delta$ results for a conventional 40/60 paving grade bitumen are presented in the form of an isochronal plot at a frequency of 10 Hz in fig 2. At the relatively high frequency of 10 Hz, there are considerable differences in the values of $G'$ and at both 25°C and 35°C. In terms of the testing geometry, the 25 mm geometry underestimates the stiffness of the bitumen while overestimating the relative proportion of elastic to viscous response compared to the 8 mm geometry. However, the isochronal plot does not provide a convenient and robust means of deciding which geometry produces a true measure of the rheological characteristics of the binder.

The values of $G'$ and $\delta$ measured with the different sample geometries, have also been plotted in the form of a Black diagram in fig 3. The Black diagram shows a separation (divergence) of the rheological data from the two plate geometries at $G'$ values greater than 5 x 10^5 Pa (temperatures below 35°C and high frequencies). In addition, the Black diagram provides a reliable means of evaluating the suitability of the DSR testing configurations. Extrapolating lines to the y-axis indicate different values of limiting stiffness for the 25 mm and 8 mm geometries. The 25 mm configuration indicates a limiting stiffness of approximately 5 x 10^6 Pa, which is considerably lower than the traditionally recognised value of 2 x 10^9 Pa (glassy modulus) indicated by the 8 mm configuration.

The DSR experiments with the 25 mm and 8 mm geometries show that, with wide frequency sweeps at different temperatures, it is necessary to use both spindle configurations when performing dynamic shear testing within the transitional stiffness region of between 10^7 Pa and 10^9 Pa. This overlapping allows the differences in $G'$ and $\delta$, as measured by the two configurations, to be identified and the appropriate values to be selected for the rheological characterisation of the bitumen.

Sample preparation

In addition to ensuring accurate temperature control and appropriate sample geometry, sample preparation can also significantly affect the accuracy and repeatability of the measured rheological parameters. Although various sample preparation methods and procedures exist, these can, in general, be reduced to three main types, which may be described as:

- the hot pour method,
- the silicone mould method; and
- the weighing (mass) method.

The hot pour method consists of setting the gap between the upper and lower plates to a height of 50 mm plus the required testing gap, either at the proposed testing temperature or at the mid-point of an expected testing temperature range. Once the gap has been set, a sufficient quantity of hot bitumen (typically at 100°C to 150°C) is poured onto the bottom (lower) plate of the DSR to ensure a slight excess of material appropriate to the chosen testing geometry. The upper plate of the DSR is then gradually lowered to the required nominal testing gap plus 50 mm. The bitumen that has been squeezed out between the plates is then trimmed flush to the edge of the plates using a hot spatula or blade. After trimming, the gap is closed by a further 50 mm to achieve the required testing gap as well as a slight bulge around the circumference of the testing geometry (periphery of the test specimen).

The silicone mould method consists of pouring hot bitumen (typically at 100°C to 150°C) into either a 8 mm or 25 mm diameter silicone mould of height approximately 1.5 times the recommended testing gap for the two geometries, namely 3 mm and 1.5 mm for the 8 mm and 25 mm diameter geometries respectively. As with the hot pour method, the testing gap is set at a height of 1 mm or 2 mm plus 50 mm. Once the bitumen has cooled, either by means of short-term refrigeration or natural cooling, the bitumen disc (typically at ambient temperatures) is removed from the mould and centred on the lower plate of the DSR. The upper plate is then lowered to the required gap plus 50 mm, the excess bitumen trimmed with a hot spatula and the gap further closed to its final testing height. No trimming of the specimens is required if the specimens are either moulded to the required testing gap or cut to size before being mounted in the DSR. However, this inevitably increases the
variability associated with this method resulting from inaccurate centring of the specimen and possible lack of adhesion between the plates and the bitumen.

For the weighing method, the testing gap is set at exactly 1 mm or 2 mm for the 25 mm and 8 mm diameter plates respectively. A pre-calculated mass of hot bitumen (typically at 100°C to 150°C) is then poured directly onto the upper plate of the rheometer, which has been removed from the DSR and placed in a supporting assembly on an electronic balance with a resolution of 1 mg. The mass of bitumen is calculated from knowledge of the volume required and the specific gravity of the binder (taken to be approximately 1). The upper plate is then replaced in the DSR and the plates closed to their final testing gap. Because the exact sample volume is placed between the plates, no trimming of the sample is required and no bulge is evident. This method relies on the operator positioning the bitumen sample centrally on the upper plate. Any eccentricity will ultimately result in an overflow of bitumen on one side and a shortfall on the opposing side with the consequential loss of repeatability and generation of erroneous results.

To determine the repeatability of the three sample preparation methods, a number of both conventional (unmodified) as well as polymer modified bitumens (PMBs) were prepared and tested in the DSR over a range of temperatures and testing geometries. Ten repeats were undertaken at each combination with the repeatability being assessed in terms of the resulting rheological properties of the prepared bitumen sample at 20 logarithmic intervals between 0.1 to 10 Hz within the linear viscoelastic response of the binder17.

Tabular and graphical methods were used to assess the repeatability of each sample preparation method. For the tabular method, the coefficient of variation, CoV, (standard deviation / average value) of the DSR parameters for each of the testing combinations were calculated at frequencies of 0.1, 1.13 and 10 Hz. The hot pour method was found to be the most repeatable method (lowest CoV values) for all frequencies, temperatures, plate configurations and bituminous binders.

For the graphical method, the rheological data obtained for the ten bitumen samples were plotted on a logarithmic complex modulus versus logarithmic frequency scale and trend lines fitted to the data. The coefficient of determination (R²), used as an indicator of the accuracy of the fit, was determined for each of the trend lines and included in the plots. A plot of G* versus frequency for the hot pour method is shown in Fig. 4. In general, the repeatability of the hot pour method was found to be highest, although the repeatability of the silicone mould and weighing methods was only marginally lower.

In addition to assessing the repeatability of the three preparation methods, the values of G* for each sample preparation method were also compared in. The results show that, compared to the hot pour method, the silicone mould and weighing methods give slightly higher and slightly lower values of G* respectively. The hot pour and silicone mould methods are very similar in that both supply excess bitumen to the DSR testing geometry and require subsequent trimming of the bitumen before producing a bulge around the specimen periphery by lowering the upper plate a further 50 mm. However, whilst the bitumen is above its softening point (predominantly viscous in nature) when it is poured in the hot pour method (typically greater than 100°C), in the case of the silicone mould method, the bitumen sample is at ambient temperature when it is mounted in the DSR (below its softening point and therefore more elastic in nature). This reduced temperature results in the generation of internal stresses in the sample when it is squeezed between the plates, which are not necessarily dissipated prior to testing this phenomenon would explain the slightly higher values of G* of the binder, particularly evident for the more elastic PMBs.

The lower G* values for the weighing method are inevitable due, firstly, to the lack of a bitumen bulge around the periphery of the sample and, secondly, to a possible lack of adhesion between the plates and binder, resulting in a slight reduction in the torque required to achieve the same strains as that achieved with the hot pour method.

Precision of measurements

As mentioned previously, the factors affecting the precision and accuracy (repeatability and reproducibility) of measurements made with the DSR can be grouped into equipment, binder handling and sample preparation, and finally, temperature control issues. Various studies have looked at these factors in terms of defining the repeatability and reproducibility of DSR rheological parameters15. The results of these reproducibility studies showed that the percentage variations ranged from 23% to 39% in the determination of complex modulus and 1% to 12% for phase angle. As part of these studies, the precision of the rheometers at Nottingham, with regard to their repeatability, was determined by testing five samples each of a penetration grade bitumen and three PMBs at a combination of 12 frequencies and 7 temperatures.

The CoV values for complex modulus of all four binders are
shown in the form of a histogram in Fig. 5. The histogram shows that 80% of the CoV values are less than 10%, with a maximum CoV value of 26%, which compares favourably with that found for the inter-laboratory reproducibility study. Histograms for $\delta$ were also produced and showed, as expected, a lower degree of variation for the phase angle measurements with 80% of the CoV values being less than 2% with a maximum of 7%.

Figure 5. - Repeatability of complex modulus using the hot pour method

MATERIAL CHARACTERISATION

Polymer modification of bitumen

The use of synthetic polymers to modify the performance of conventional bituminous binders dates back to the early 1970s, with these binders subsequently having decreased temperature susceptibility, increased cohesion and modified rheological characteristics. As part of an extensive European research project, the rheological characteristics of a range of elastomeric, styrene butadiene styrene (SBS) and plastomeric, ethylene vinyl acetate (EVA) PMBs were quantified using the DSR. The SBS and EVA PMBs were produced by blending the SBS and EVA copolymers with three base bitumens at three polymer contents of 3, 5 and 7%.

Figure 6. - Isochronal plots of complex modulus at 0.02 Hz for EVA PMBs

Figure 7. - Isochronal plots of phase angle at 0.02 Hz for EVA PMBs

Figure 8. - Isochronal plots of complex modulus at 0.02 Hz for SBS PMBs

Isochronal plots of $G^*$ and $\delta$ at 0.02 Hz for a group of EVA PMBs are shown in figs 6 and 7. The EVA PMBs show a pronounced increase in $G^*$ and improved temperature susceptibility (decrease in the slope of the complex modulus isochrones) with increasing polymer content up to a temperature of 55°C. In addition, the higher polymer content PMBs exhibit a plateau region indicative of a dominant polymer network within the modified binder. At approximately 55°C, the crystalline melting of the semi-crystalline EVA polymers results in a sharp increase in the slope of the complex modulus isochrones and, therefore, a reduced increase in $G^*$.

With the phase angle being generally considered to be more sensitive to the chemical structure and, therefore, the modification of bitumen than complex modulus, the $\delta$ isochrones in fig 7 clearly illustrate the temperature dependence of the modified binders and the effectiveness of the EVA polymer. As the temperature increases, the phase angles for the base bitumen approaches 90° C and, therefore, predominantly viscous behaviour, while the polymer begins to significantly improve the elastic response of the modified binders. This increase in elastic response at high temperatures can be attributed to the viscosity of the base bitumens being low enough to allow the elastic network of the polymer to influence the mechanical properties of the modified binders. The presence of this polymer network can
be identified as a plateau region situated between the points where the phase angle passes through a maximum and then a minimum with increasing temperature. As temperature increases further, the polymer melts and there is a sharp increase towards a more viscous behaviour.

Isochronal plots of complex modulus and phase angle at 0.02 Hz for one of the SBS PMB groups are shown in Figures 8 and 9. Although there are only minor increases in $G'$ at low temperatures due to SBS modification, there is considerable evidence of extreme polymeric modification at high temperatures with the establishment of a plateau region indicative of a dominant polymer network. The phase angle isochrones in Figure 9 clearly illustrate the improved elastic response (reduced phase angles) of the modified binders compared to their respective base bitumen. Whereas the phase angles of the base bitumen approaches $90^\circ$ and, therefore, predominantly viscous behaviour with increasing temperatures, the SBS polymer significantly improves the elastic response of the modified binders.

Linear response of binders

In order for the rheological response of a binder to be contained within its linear region, DSR tests are normally conducted over a range of temperatures and loading frequencies using relatively small strains. However, the actual values of these strains are not always clear, particularly if “special” binders such as process modified and PMBs are being tested. A detailed research project was, therefore, undertaken to assess the linearity limits of a range of conventional as well as modified binders.

The linear behaviour was determined by performing stress sweeps (strain sweeps) at selected temperatures (10°C to 70°C) and frequencies (0.1 to 10 Hz). The stress sweeps at each temperature/frequency combination were performed from the minimum torque value of the DSR to either the maximum torque value or a 30% reduction in complex modulus. The LVE limit was defined as the point where complex modulus has decreased to 95% of its initial value as prescribed during the SHRP study. A typical complex modulus and phase angle isochrone for a traditional multigrade bitumen at $30^\circ$C and 10 Hz is shown in Figure 10. The linear viscoelastic strain limits as a function of complex modulus (Figure 11) and phase angle (Figure 12) are key factors in assessing the linear response of binders. A comprehensive approach to determining these limits is crucial for ensuring the consistent performance of asphalt pavements.
modulus versus strain plot is shown in fig 10 for a multigrade bitumen.

The LVE strain and stress limits were then plotted as functions of complex modulus and phase angle in figs 11 to 13. As a function of complex modulus, the strain limits for the binders in fig 11 are all very similar, although the LVE strain limits for the multigrade bitumen tend to be slightly lower than that of the other binders. In addition, the elastomeric PMBs appear to have a maximum strain limit of approximately 100%. As would be expected, there is a general increase in the strain limit with a decrease in stiffness for the binders.

In terms of the LVE stress limit as a function of complex modulus in fig 12, once again the linearity performance of the binders is similar with the multigrade bitumen having a slightly lower stress limit. In addition, there appears to be a divergence in the linearity behaviour of the elastomeric PMBs compared to the other binders at low G* values. The strain limits as functions of phase angle in Fig 13 provide a clearer indication of the difference in the linearity behaviour of the two SBS PMBs and the other binders. Whereas the unmodified, process modified and plastomeric modified bitumens show a general increase in strain limit with increasing phase angle, the two block copolymer modified bitumens show a distinctive elastomeric behaviour. This behaviour is indicative of the presence of an elastomeric polymer which becomes increasingly more dominant at high temperatures and/or low frequencies. This increased elastic response at high temperatures (low frequencies) has a considerably effect on the linearity behaviour of the SBS PMBs compared to the other binders.

In addition to the linearity data, the SHRP LVE strain and stress functions have been included in Figs 11 and 12 to compare the SHRP findings to those obtained in this study. Strain and stress dependent LVE criteria have also been included, such as. The strain dependent LVE criterion between 2% and 6% at high G* (> 1 MPa) and intermediate to low d (< 55∞) values as well as a stress dependent LVE criterion between 1.5 and 7 kPa at low stiffness (< 10 kPa) values for the non-elastomeric PMB binders. For the elastomeric PMBs, there is no high temperature stress dependent LVE criterion and, in addition to the strain criterion at low temperatures, there is a second strain criterion between 50% and 200% due to the presence of the dominant polymer matrix at high temperatures, as shown by the bifurcation of the data in Figures 11 and 13. The only indication that the LVE limits for modified bitumens may be lower than that of conventional binders can be seen for the multigrade bitumen and for the two SBS PMBs at high temperatures due to their increase elastic response.

![Figure 14. Changes in complex modulus as a function of ageing for 15B and 50C](image14)

![Figure 15. Changes in viscoelastic response as a function of ageing for 15B and 50C](image15)

![Figure 16. Changes in complex modulus as a function of ageing for 15E and 50C](image16)

![Figure 17. Changes in viscoelastic response as a function of ageing for 15E and 50C](image17)
Ageing susceptibility of hard bitumen

In parallel with the introduction of the concept of “long life” pavements, has been the increasing trend to use progressively stiffer base materials incorporating low penetration grade bitumen. These “hard grade” bitumens with penetrations of 25 dmm and lower have been used to produce a higher stiffness modulus asphalt in order to reduce the transmission of stresses to the subgrade and produce a “long life” pavement. However, the manner in which these low penetration grade bitumens age, particularly as a function of their different production methods, is unclear.

To investigate the influence of production method and the ageing susceptibility of low penetration grade bitumens, four bituminous binders including a control 40/60 paving grade bitumen and three 10/20 paving grade bitumens were subjected to DSR testing. The binders were evaluated in their unaged (virgin) condition as well as after being subjected to short-term RTFOT ageing and long-term HiPAT pressure ageing.

The effect of short-term and long-term ageing on the rheological characteristics of a semi-blown 10/20 pen bitumen (15B) as well as a straight-run (direct distillation) 10/20 pen bitumen (15E) as compared to that obtained for the control (50C) bitumen are shown in figs 14 and 17. The results show a standard increase in G* with ageing (figs 14 and 16) and a reduction in phase angle (figs 15 and 17), although the relative changes tend to be considerably lower for the straight-run 10/20 bitumen (15E) compared to the semi-blown (15B) binder. This larger increase in stiffness and elastic response for the aged 15B binder compared to the aged 15E binder means that the semi-blown binder might be more susceptible to “brittle type” damage and failure due to its reduced ability to dissipate “crack propagation” energy.

Summary

This paper has described a number of successful rheological projects that have been undertaken using the DSR over the last ten years. The DSR experiments with the 25 mm and 8 mm disk configurations have shown that, with wide frequency sweeps at different temperatures, it is necessary to overlap the dynamic shear testing, using the two configurations. This overlapping allows the differences in G* and δ, as measured by the two configurations, to be identified and the appropriate values to be selected for the rheological characterisation of the bitumen.

In terms of materials, the rheological characterisation of both EVA and SBS PMBs has allowed their enhanced properties (increased stiffness and high temperature elastic response) to be accurately quantified compared to what was possible using conventional binder testing techniques, such as penetration and softening point. Similarly, the use of DSR rheological data has provided a clear indication of the differences between the ageing susceptibility of semi-blown and straight-run 10/20 pen binders. In terms of LVE behaviour, the results have shown that, in general, there is no significant narrowing of the linearity range for polymer and process modified bitumens.

Other projects, not presented in this paper, have included an investigation of the influence of crude source and bitumen grade (binder viscosity) on the interaction between crumb rubber and bitumen that occurs during the crumb rubber modified (CRM) dry process. In addition to standard DSR testing, a modified testing arrangement has been used to measure the rheological properties of bitumen before and after accelerated ageing while in contact with mineral aggregate. Finally, an improved understanding of the role of Ordinary Portland Cement (OPC) in enhancing the mechanical properties of bitumen emulsion mixtures for structural layers in roads has been assessed through the rheological properties of the residual emulsion.

References


THE SCORE PROJECT: SUPERIOR COLD RECYCLING


Introduction

Cold in-situ recycling of old pavements is an example of environmentally friendly technology (Environmentally Friendly Construction Technology, EFCT). Indeed, this technique generates savings in:

- transportation since new materials transfer are limited
- energy associated with the use of cold materials
- natural resources by making maximum use of in-place materials and reducing waste of materials coming from the old pavement.

Use of cold techniques also improves safety on site and impact on the environment.

Although it may sound surprising, considering the social and economic pressure toward EFCT, cold in-place recycling is not developed in most European countries. Indeed, this technology suffers today from a lack of general understanding of the system that would allow for a common rational approach to mix design. Furthermore, the advantages and limitations of the process remain unclear. Consequently, engineers in charge of pavement management do not consider cold in-situ recycling as a standard solution for pavement maintenance and rehabilitation.

Considering this situation, eight partners have decided to put their research capabilities together to improve existing technologies: Probisa (Spain), in charge of the project co-ordination, Nynas (UK), Eurovia (France), SSZ (Czech Republic), Produktion (Sweden), LCPC (France), Cedex (Spain) and Université Joseph Fourier (France). The project is called SCORE “Superior Cold Recycling based on benefits of bituminous microemulsions and foamed bitumen. A EFCT system for the rehabilitation and maintenance of roads”.

The programme started in June 2002 for a period of three years within the 5th Framework Programme of Research and Development of the European Commission in the area of research, technology development and validation. The Project represents a workload of 281 man months with a budget of 3 million. Three objectives have been assigned to this Project.

- Investigate the possibility of making better use of the aged bitumen through a detailed analysis of the interaction between the old bitumen and rejuvenators.
- Improve the technique through use of foamed bitumen and microemulsions, or an association of both.

In order to define a realistic work programme, it has been decided to focus the project on cold in-situ recycling of asphalt. First results are being processed and analysed, which will take a large amount of work. This Paper describes the project organisation and provides preliminary results illustrating the selected method.

Project organisation

Project co-ordination is provided by J. J, Potti from Probisa. The programme is divided in nine tasks, each addressing a specific aspect of cold in-situ recycling as detailed below. Each task is lead by one of the partners (table 1). A key element in the management of the project has been the creation of an Orientation Committee gathering experts from different countries (Germany, Spain, France, Portugal, Czech Republic, UK) as well as managers of road networks: the manager of road structures for a urban community of a large city in France, members of the Roads Directorate for Andalusia, consultants involved in the road maintenance schemes for UK and the Czech Republic. The Orientation Committee underlines the critical points to be studied or to be improved to make cold in-situ recycling a more attractive maintenance solution. Suggestions from the Orientation Committee are then translated into research programmes by the Technical Committee that discusses the details of the testing programme.

History

The project started on 1 June 2002 for a period of three years. During the first year, four tasks have been covered (fig 1). Task 9 has also been started and will continue until the end of the project. A detailed description of each task is presented below.

1 Probisa-Spain, 2 Nynas-UK, 3 Eurovia-France, 4 Staby Silnic a Zelenic-Czech Republic, 5 Vagverket Produktion-Sweden 6 LCPC, France, 7 CEDEX-Spain, 8 Université J Fourier, Grenoble, France.
Technical Programme

The general objective of the project is to optimise the existing technologies in order to produce the best materials possible. This naturally implies the development of mixture design and evaluation methods, as well as a better characterisation of the materials to be recycled and a follow-up of construction sites. Within these objectives, it is necessary to start with a review of current knowledge, which includes in particular the work carried out by PIARC under the leadership of J-F Corté. From the review of current practices and thanks to the input from the Orientation Committee, a detailed programme has been defined to address the important issues to be improved at each stage of the programme. Each task is an autonomous investigation. In summary, tasks 1 to 4 inclusive are focussing on the individual components which comprise the final mixture. Task 5 is a validation of task 4, dedicated to the manufacturing process of microemulsions. Results and materials from earlier tasks are then used in the mixture design work of task 6, followed by an in-depth analysis of mechanical characterisation in task 7. Results are then validated through trial sections in task 8. Task 9 has a particular role in the sense that it addresses no specific technical issue but the exploitation and diffusion of the project’s results.

Task 1: Selection and characterisation of representative aggregate

The purpose of this task is to gather and characterise materials representative of the various European sources. Aside from geographical variations, this task also addresses the effect of mixture formulation and milling parameters on the properties of the RAP (Reclaimed Asphalt Pavement) aggregate. A possible outcome from this Task could be a list of recommendations for milling conditions adapted to the pavement to be recycled as well as a list of relevant tests to characterise the RAP aggregate. This work was carried out on several sites throughout Europe where samples were collected from different milling conditions before characterisation.

As an example, fig 3 presents the particle size distribution of materials collected on the Zdár site in the Czech Republic using a Wirtgen WR 2500. The different parameters investigated include high and low milling drum rotation speeds (130 and 200 rpm), milling depth of 60 and 100 mcm as well as two machine translation speeds (2 and 6 m/min). Some key elements from such sites have then been confirmed by an experiment by the Rouen road study centre (CETE) on a section built specifically for this project.

Another aspect of this task concerns the implementation of a characterisation methodology for the aggregate. Methods available in each country have been collected before selecting those that are most appropriate.

Task 2: Interaction between old and new bitumen

The purpose of this task is to address the following two questions: up to what point can an old bitumen be rejuvenated? How much time does it take to reach equilibrium? This work should lead to rational criteria for the selection of the new binder: “normal” bitumen or a rejuvenator.

The study was carried out at a fundamental level where the kinetics of diffusion between an old bitumen and a soft base or a rejuvenating oil have been analysed. Rheological tools, as described in fig 4, have been used for that purpose: thin layers of hard and soft bitumen are positioned between the plates of a rheometer and the viscous modulus of the system followed through time. Based on this approach, analysis allows the establishment of key parameters on diffusion. In parallel, diffusion kinetics are evaluated directly on mixtures to determine the extent to which fundamental elements can
explain the behaviour of a finalised mixture.

On the practical side, the SCORE task 2 team has developed an oil-based cold rejuvenating emulsion active at a very low treat rate (0.1 to 0.2% by weight of dry aggregate) and capable of rejuvenating about 1% of the old bitumen given a maturation time of 7 to 10 days. This emulsion has been formulated from environmental friendly components and is therefore not labelled; this is quite important, as most rejuvenating agents used in the past would be too toxic to be acceptable today.

The suggested injection point of this emulsion is in the milling machine cooling water flow where it presents the added advantage of behaving as a cutting oil, reducing milling teeth wear. This emulsion therefore exhibit the following advantages.

• Reduction of teeth wear, the extent of this reduction is under investigation at an industrial scale as part of task 8.

• Rejuvenation of up to 1% of aged bitumen, leading to a reduction in demand for new binder.

• Lubricating effect on the mixture leading to a substantial decrease in void content.

While investigating the effect of ambient temperature on diffusion speed, a collateral finding is that RAP aggregate compactability is affected by temperature even in the range of temperatures that can be expected on site. Figure 5 shows the void reduction associated with the combined use of rejuvenating emulsion and temperature within a range that can be encountered on site. Substantial reduction in void content can be achieved by slightly raising the temperature of the rejuvenated RAP aggregate at the time of compaction to 40/50°C. The practical implications of this finding are under investigation.

**Task 3: Optimisation of foamed bitumen**

The purpose of this Task is to improve and provide a means of better controlling bitumen foaming properties at laboratory scale in order to produce recommendations for use by the industry. The scientific approach is based on a detailed understanding of the phenomena involved in the development of a laboratory-scale apparatus providing good control on the formulation and manufacturing parameters. Results are then compared to those achieved on a commercial foam rig using different types of nozzles (fig 6). Finally, the influence of foam quality on the final mixture is also investigated.

**Task 4: Manufacturing microemulsions**

This task is dedicated to the development of a laboratory-scale prototype to manufacture bitumen emulsions with particle sizes below 1 micron.

As a first step, small quantities of emulsions with a median diameter of 0.6 µm have been produced (fig 7). The objective is to find out which formulation and manufacturing parameters control the emulsification process of such emulsions.
Task 5: Evaluation of the potential of micronised emulsions

This task is directed related to the previous one: the purpose is to highlight the advantages and limitations of micronised emulsions. Investigation will concentrate on the potential of such emulsions in cold recycling and possible improvements of the mixture performances.

Task 6: Mixture design - Optimisation of recycled materials

The purpose is to determine optimum formulations using materials selected in task 1. It is also intended, at the end of this exercise, to propose recommendations which will be a selection of the most appropriate technique (emulsion, micro-emulsions, foamed bitumen) for a given type of RAP. It is, therefore, a formulation study where different means at laboratory scale are used to investigate compactability, workability, water sensitivity and mix cohesion build-up. Results from the OPTEL programme as well as from more recent work on workability will be implemented in this study.

The main tests envisaged are presented on Table 2. Tests will be carried out on materials selected from the previous tasks: RAP from task 1, rejuvenator or new bitumen following the conclusions from task 2, improved foamed bitumen from Task 3 and micronised emulsion (provided task 5 demonstrates that this is advantageous) based on formulations developed within tasks 4 and 5. Furthermore, attractive options will be investigated, such as the addition of a small amount of cement according to some Spanish experience, i.e. at lower treatment rates than recommended in the German guide.

Effect of mixture parameters on mixture performances will then be used to publish recommendations for each technique (emulsions, micro-emulsion and foamed bitumen).

Task 7: Mechanical performance of optimised mixtures

This task follows naturally from the previous one, since the objective is to evaluate the mechanical performance of optimised formulations from task 6. This will allow for an estimation of the impact of the different techniques investigated on the mixture structural performances and life expectancy, as well as compare them on a cost versus benefit basis. Different testing methods to determine stiffness modulus will be investigated and appropriate fatigue tests will be eventually developed.

The objective of task 7 is, therefore, a complete mechanical characterisation of the mixture formulations optimised in task 6. This will provide a rational comparison based on performance and behaviour in situ.

Task 8: Full-scale validation trials

The objective of this final technical task is to demonstrate at the industrial scale the different results gathered through the project. It is scheduled to evaluate on site, the relevance of the different tests carried out in the laboratory as part of tasks 6 and 7. This will, in particular, allow the confirmation or otherwise of the predictions in terms of workability and compactability (task 6) and structural behaviour (task 7). Trials will take place in as many countries as possible in order to test the conclusions of this project in various environments (climate, traffic, type of pavement). A list of trial sites is under development as well as the follow-up testing methods. This will most likely be dependent upon the geographical location of the sections and the technical choices to be validated. As a minimum, the volumetric characteristics (voids and densities) and mechanical performances will be evaluated as a function of curing. It is hoped that follow-up will be carried out after the end of this Project, particularly if the results justify such additional effort.
Task 9: Dissemination and exploitation of the results

Finally, a specific task is dedicated to the dissemination and exploitation of the results of this project. It is within this task that, through responses from outside the SCORE team, we will be able to redirect the project. For this purpose, a trilingual Internet site has been set-up specifically for SCORE (fig 8). A literature review, carried out at the beginning of the project, was part of this task which is the only one covering the entire project duration.

![Figure 9. The HomeWelcome page of the SCORE web site](http://www.score-project.org/)

Conclusion

The methodology followed to achieve the aims of this project is an improved understanding of each step of the technology. As a result of this approach, the SCORE team is convinced that it will be possible to derive a better understanding of cold in-situ recycling and develop techniques which result in a more widely-accepted solution for pavement maintenance and rehabilitation.

References

6. POTTI J J, D LESUEUR and, B ECKMANN, , Vers une méthode rationnelle de formulation des enrobés à froid: les apports du projet OPTEL. RGRA nr† 805, April 2002, pp 38-4
7. DELFOSSE F, M-L PIERRE, C QUINTON and B ECKMANN, Bituminous emulsions for cold mixes: the Nynas workability test, Proc. 3rd World Congress on Emulsions, Lyon, 4-E218, September 2002
8. POTTI J J, M MARTINEZ and, J MANCEBO, Diseño y sistemática de Probisa en el desarrollo de obras de reciclado en frío con emulsión en situ Boletín técnico de Probisa n° 44, 2002
11. WALTER J. Factors controlling RAP cold mix modulus Proc. 3rd World Congress on Emulsions, Lyon, 4-E057, September 2002
12. http://www.score-project.org/
ROUTES TO MEMBERSHIP

* All members must demonstrate a commitment to Continued Professional Development (CPD)

FELLOW (FIA T)
Member for the previous five years, with approved relevant M.Eng., C.Eng, or Level 5 'Vocational Qualification' and who is at least 35 years of age, having over 10 years experience with Asphalt; in a position of relevant authority.

Or member for the previous five years, who is at least 40 years of age having over 15 years of experience with Asphalt; in a position of relevant authority. This route requires an asphalt-specific CV, or 1,000 words written technical paper, which will receive a professional peer-group review.

MEMBER (MIA T)
Associate Member with, relevant B.Eng (Hons), I.Eng. or approved relevant Level 4 'Vocational Qualification' and who is at least 25 years of age, having over 5 years of experience with Asphalt; in a position of relevant authority.

Or technician or Affiliate, who is at least 30 years of age, having over 10 years of experience with Asphalt; in a position of relevant authority. This route requires an asphalt-specific CV, or 500 words written technical paper, which will receive a professional desktop review. [Applications for membership as (MIA T) from non-members are welcome, via the Affiliate (AIA T) route].

ASSOCIATE MEMBER (AMIA T)
Student who has passed the IAT Professional Exam or other relevant HNC/D or Eng.Tech, approved by Council.

Or technician or Affiliate with, approved relevant Level 3 'Vocational Qualification'.

TECHNICIAN (Tech. IAT)
Person over 18 years of age, who is unqualified but employed in a position, involving Asphalt Technology, and/or the Management thereof and enrolled on an approved relevant Level 1 or 2 Vocational Qualification.

AFFILIATE (AIA T)
Person over 18 years of age, who is employed in the supply of plant, materials or services in support of Asphalt Technologies and/or the Management thereof.

STUDENT
Person over 16 years of age, who is enrolled on DAPS or Full-time HNC/D course on relevant subject matter, approved by Council and having the required 4 GCSE Examination passes, at level (A-C) (Students over 25 years of age, must transfer to Affiliate).
Introduction

Before the arrival of thin surfacing systems in the early 1990s, hot rolled asphalt was used on almost all trunk roads. The increasing demands made on surface courses from higher traffic levels, higher performance vehicles and more restricted periods for construction have required increasing performance from the surface course. As a result, modified binders were used in hot rolled asphalt on a limited basis prior to the introduction of performance-related design mixtures for hot rolled asphalt surface course in the Specification for Highway Works as Clause 943. To identify the benefits of modified binders more clearly, TRL organised a road trial in 1987 on behalf of the Department of Transport and supported by the British Aggregate Construction Materials Industries (now the Quarry Products Association) and the Refined Bitumen Association. The trial of hot rolled asphalts was located on the southbound carriageway of the A38 Burton Bypass between trial sections of porous asphalts. At this location, the A38 carried about 3,600 commercial vehicles per lane per day on the nearside lane and 500 cv/l/d on the offside lane in 1990. When the site was scheduled to be resurfaced in 2003, by which time the surface courses had been in service for 16 years, a final inspection was carried out.

Trial sections

Three aggregate skeletons were used in the trial, designed with 50 pen bitumen to have stabilities in the ranges (3.5 ± 2) kN (low stability, LS), (6 ± 2) kN (medium stability, MS) and (8 ± 2) kN (high stability, HS). In all cases, the coarse aggregate was 30% of 14 mm Rowley basalt and the filler was Caldon Low limestone with Dorrington sand in the LS grading, 2:1 Bayston gritstone dust to Dorrington sand in the MS grading and 6:4 Stourport sand to Croxden fine sand in the HS grading. The skeletons were mixed with unmodified (70 pen for the LS grading and 50 pen for the MS and HS gradings) and modified binders. The details of the aggregate skeletons are given in table 1 and the aggregate/binder combinations in table 2.

<table>
<thead>
<tr>
<th>Property</th>
<th>Grading 4</th>
<th>Grading 5</th>
<th>Grading 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Marshall Stability</td>
<td>3.5 ± 2 kN</td>
<td>5 ± 2 kN</td>
<td>8 ± 2 kN</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>14 mm Rowley basalt Dorrington sand</td>
<td>14 mm Rowley basalt Stourport sand (60%) Croxden fine sand (40%)</td>
<td>14 mm Rowley basalt Bayston gritstone dust (60%) Dorrington sand (33%) Caldon Low limestone</td>
</tr>
<tr>
<td>Filter</td>
<td>Caldon Low limestone Caldon Low limestone Caldon Low limestone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grading 20 mm</td>
<td>130%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>14 mm</td>
<td>98.7%</td>
<td>98.0%</td>
<td>98.8%</td>
</tr>
<tr>
<td>10 mm</td>
<td>91.6%</td>
<td>79.5%</td>
<td>82.5%</td>
</tr>
<tr>
<td>6.3 mm</td>
<td>57.4%</td>
<td>69.9%</td>
<td>70.1%</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>56.5%</td>
<td>60.0%</td>
<td>65.9%</td>
</tr>
<tr>
<td>600 μm</td>
<td>54.3%</td>
<td>59.4%</td>
<td>42.9%</td>
</tr>
<tr>
<td>212 μm</td>
<td>37.3%</td>
<td>24.6%</td>
<td>24.2%</td>
</tr>
<tr>
<td>75 μm</td>
<td>19.0%</td>
<td>10.0%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Binder Content</td>
<td>8.1%</td>
<td>7.2%</td>
<td>6.9%</td>
</tr>
<tr>
<td>Binder Grade 70 pen bitumen</td>
<td>70 pen bitumen 50 pen bitumen 50 pen bitumen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marshall Stability *</td>
<td>4.9 kN</td>
<td>7.4 kN</td>
<td>8.0 kN</td>
</tr>
<tr>
<td>Marshall Flow °</td>
<td>3.9 mm</td>
<td>3.5 mm</td>
<td>4.3 mm</td>
</tr>
<tr>
<td>Void (by volume)</td>
<td>3.7%</td>
<td>2.9%</td>
<td>2.8%</td>
</tr>
</tbody>
</table>

* For the unmodified control mixture

Table 1. Design of mixtures by aggregate gradings
The trial sections, each between 94 m and 121 m in length, were laid in December 1987. 20 mm pre-coated chippings of Bayston Hill gritstone were applied to all the sections at an average rate of 13.6 kg/m², equivalent to 70% coverage.

Sets of four cores from each section were taken shortly after laying and tested for specific gravity and wheel-tracking rate at 45°C. The mean results are given in table 2.

Performance

3.1 Skid resistance

The skid resistance of each section was measured using the Sideway-force Coefficient Routine Investigation Machine (SCRIM) at 50 km/h, generally three times each year, until 1996. The Mean Summer SCRIM Coefficients (MSSC) were determined and have been reported by Nicholls. These data suggest that stable conditions were reached by 1991.

There were differences between the MSSC on the nearside and offside lanes of each carriageway but there was very little difference between the different sections. The similarity results from the same aggregate being used for the pre-coated chippings on each section, each of which was subjected to the same traffic and weather conditions.

3.2 Surface texture

Surface texture was measured using both sand-patch and sensor-measured methods on this site during a period of developing technology.

3.2.1 Sand-patch texture depth

Sand-patch texture depth is a measure of the average distance that the surface is below a plane defined by the highest points of the surface. The sand-patch texture depths were measured initially biennially, then annually up to 1996. The texture depth of some sections was measured in 2003 by Shell Bitumen when they examined their sections. Albeit that only a limited number of sand-patch tests were carried out, the results show little change in texture since the previous measurements in 1996. The tests were performed to BS 598-105:1990 or its predecessor. The average annual results are given in Table 3 for measurements on locations with pre-coated chippings.

The sand-patch texture depths show little change between sections, although there are differences for particular years, with the mean texture depth dropping over the first year, then rising with occasional drops, as from 1991 to 1992 and from 1995 to 1996. However, this could be partially explained by measurement variation as the means were all within the range (1.95 ± 0.2) mm. With regard to the difference between sections, the nearside lanes of LS 70 pen and MS 50 pen and the offside lane of HS 50 pen were below the mean in 1996 while the offside lanes of LS 70 Chem and MS Multi were above the mean. The tendency for the lower textures

Table 2. Trial mixtures

<table>
<thead>
<tr>
<th>Aggregate Grading</th>
<th>Binder Acronym</th>
<th>Section No.</th>
<th>Specific Gravity</th>
<th>W/T Rate @ 45°C (mm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>70 pen bitumen (Control)</td>
<td>17</td>
<td>2.326</td>
<td>11</td>
</tr>
<tr>
<td>100 pen bitumen plus 2% U143</td>
<td>100 Chem</td>
<td>0</td>
<td>2.354</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>50 pen bitumen (Control)</td>
<td>11</td>
<td>2.354</td>
<td>4.5</td>
</tr>
<tr>
<td>50 pen bitumen plus 5% UL1501</td>
<td>50 SR</td>
<td>2</td>
<td>2.333</td>
<td>3.1</td>
</tr>
<tr>
<td>50 pen bitumen plus Synthetic Rubber</td>
<td>Car S</td>
<td>12</td>
<td>2.309</td>
<td>6.1</td>
</tr>
<tr>
<td>Medium Pi bitumen (Multishale)</td>
<td>Car DM</td>
<td>12</td>
<td>2.337</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 3. Mean sand-patch texture depths in (mm) with pre-coated chippings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LS</td>
<td>70</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>2.00</td>
<td>2.05</td>
<td>2.10</td>
<td>2.15</td>
<td>2.20</td>
<td>2.25</td>
</tr>
<tr>
<td>70 pen</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>2.00</td>
<td>2.05</td>
<td>2.10</td>
<td>2.15</td>
<td>2.20</td>
<td>2.25</td>
<td>2.30</td>
<td>2.35</td>
</tr>
<tr>
<td>HS</td>
<td>70</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>1.90</td>
<td>1.85</td>
<td>1.80</td>
<td>1.75</td>
</tr>
<tr>
<td>70 pen</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>1.90</td>
<td>1.85</td>
<td>1.80</td>
<td>1.75</td>
<td>1.70</td>
<td>1.65</td>
</tr>
<tr>
<td>MS</td>
<td>50</td>
<td>2.30</td>
<td>2.25</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>1.90</td>
<td>1.85</td>
</tr>
<tr>
<td>50 pen</td>
<td>2.25</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>1.90</td>
<td>1.85</td>
<td>1.80</td>
<td>1.75</td>
</tr>
<tr>
<td>MS Multi</td>
<td>50</td>
<td>2.35</td>
<td>2.30</td>
<td>2.25</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>1.90</td>
</tr>
<tr>
<td>50 pen</td>
<td>2.30</td>
<td>2.25</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>1.90</td>
<td>1.85</td>
<td>1.80</td>
</tr>
<tr>
<td>MS</td>
<td>50</td>
<td>2.40</td>
<td>2.35</td>
<td>2.30</td>
<td>2.25</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
</tr>
<tr>
<td>50 pen</td>
<td>2.35</td>
<td>2.30</td>
<td>2.25</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>1.90</td>
<td>1.85</td>
</tr>
<tr>
<td>HS</td>
<td>50</td>
<td>2.45</td>
<td>2.40</td>
<td>2.35</td>
<td>2.30</td>
<td>2.25</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
</tr>
<tr>
<td>50 pen</td>
<td>2.40</td>
<td>2.35</td>
<td>2.30</td>
<td>2.25</td>
<td>2.20</td>
<td>2.15</td>
<td>2.10</td>
<td>2.05</td>
<td>2.00</td>
<td>1.95</td>
<td>1.90</td>
</tr>
</tbody>
</table>

Table 3. Mean sand-patch texture depths in (mm) with pre-coated chippings
generally to occur on the nearside, heavier loaded lane and the higher textures on the offside is not unexpected, neither is the fact that the "extremes" did not occur on the sections with polymer-modified or chemically-modified binders.

3.2.2 Sensor measured texture depth

Sensor-measured texture depth was ascertained by laser-based devices which calculate the root mean square of the variation in texture depth. Measurements were made using both the mini-texture meter and meters travelling at traffic speeds until 1996. The results have been reported and show a significant and generally consistent difference between the nearside and offside lanes, unlike those obtained with the sand-patch texture depths.

3.3 Deformation

Deformation was measured on the trials annually up to 1996 using a 2.0 m straight-edge beam and calibrated wedge at two transverse locations, bridging the nearside wheel-path in the nearside lane and the offside wheel-path in the offside lane. Measurements were taken at 6 equidistant points along the beam at 10 locations at approximately 10 m centres along each section. From these data, the mean and standard deviation peak-to-valley height for each section was calculated. The mean value from the first set of measurements carried out on a section provides a baseline for subsequent determinations of the deformation. The subsequent value may be influenced by some bedding-in, although this may have been underestimated because the initial readings were not taken until after one summer. In this case, bedding-in was unlikely to have been significant because no significant rutting occurred in that lane through the following eight years of monitoring. The cumulative deformations determined for each section are given in table 4. The deformation on all of the sections was also measured by Shell Bitumen in 2003 using the same technique, and these results have been included in table 4. It was noted that, along this section of the A38, the different trial sections have different levels of Table 4. Total deformation (mm)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>3.8</td>
<td>5.9</td>
<td>6.3</td>
<td>6.7</td>
<td>7.6</td>
<td>8.7</td>
<td>9.2</td>
<td>10.3</td>
<td>16.5</td>
</tr>
<tr>
<td>70 Pen</td>
<td>o/s</td>
<td>9/85</td>
<td>&lt;0.1</td>
<td>-0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>-0.2</td>
<td>-0.3</td>
<td>-0.1</td>
<td>0.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>LS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>3.2</td>
<td>5.3</td>
<td>5.5</td>
<td>5.5</td>
<td>6.3</td>
<td>6.9</td>
<td>6.5</td>
<td>8.0</td>
<td>12.2</td>
</tr>
<tr>
<td>100 Chem</td>
<td>o/s</td>
<td>9/85</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>LS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>2.2</td>
<td>2.5</td>
<td>2.9</td>
<td>3.0</td>
<td>3.4</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>6.3</td>
</tr>
<tr>
<td>70 Chem</td>
<td>o/s</td>
<td>9/85</td>
<td>0.4</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>LS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>0.8</td>
<td>1.1</td>
<td>1.3</td>
<td>1.0</td>
<td>1.1</td>
<td>1.3</td>
<td>1.4</td>
<td>1.2</td>
<td>3.9</td>
</tr>
<tr>
<td>70 Eva</td>
<td>o/s</td>
<td>9/85</td>
<td>0.0</td>
<td>0.3</td>
<td>0.6</td>
<td>-0.6</td>
<td>0.7</td>
<td>-0.8</td>
<td>-0.8</td>
<td>-0.9</td>
<td>-0.7</td>
<td>--</td>
</tr>
<tr>
<td>MS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>1.6</td>
<td>2.4</td>
<td>2.2</td>
<td>2.3</td>
<td>2.5</td>
<td>2.9</td>
<td>2.9</td>
<td>3.3</td>
<td>7.0</td>
</tr>
<tr>
<td>50 Pen</td>
<td>o/s</td>
<td>9/85</td>
<td>&lt;0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.0</td>
<td>0.3</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>n/s</td>
<td>5/88</td>
<td>&lt;0.1</td>
<td>0.4</td>
<td>0.0</td>
<td>0.4</td>
<td>0.5</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Multi</td>
<td>o/s</td>
<td>9/85</td>
<td>&lt;0.1</td>
<td>-0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>-0.1</td>
<td>-0.1</td>
<td>-0.3</td>
<td>0.1</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>1.2</td>
<td>1.5</td>
<td>1.5</td>
<td>1.6</td>
<td>1.9</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>4.9</td>
</tr>
<tr>
<td>50 SR</td>
<td>o/s</td>
<td>9/85</td>
<td>&lt;0.1</td>
<td>1.3</td>
<td>0.0</td>
<td>-0.7</td>
<td>-0.6</td>
<td>-0.7</td>
<td>-0.7</td>
<td>-0.7</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>1.2</td>
<td>1.5</td>
<td>1.2</td>
<td>1.3</td>
<td>1.7</td>
<td>1.7</td>
<td>2.0</td>
<td>1.6</td>
<td>3.9</td>
</tr>
<tr>
<td>SBS</td>
<td>o/s</td>
<td>9/85</td>
<td>0.0</td>
<td>0.3</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>--</td>
</tr>
<tr>
<td>HS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>1.0</td>
<td>1.4</td>
<td>1.5</td>
<td>1.7</td>
<td>1.5</td>
<td>2.0</td>
<td>1.9</td>
<td>2.4</td>
<td>7.7</td>
</tr>
<tr>
<td>50 Pen</td>
<td>o/s</td>
<td>9/85</td>
<td>&lt;0.1</td>
<td>-0.2</td>
<td>-0.1</td>
<td>-0.3</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.4</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>HS</td>
<td>n/s</td>
<td>5/88</td>
<td>0.0</td>
<td>0.4</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
<td>1.2</td>
<td>1.1</td>
<td>1.0</td>
<td>1.0</td>
<td>3.6</td>
</tr>
<tr>
<td>SBS</td>
<td>o/s</td>
<td>9/88</td>
<td>&lt;0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Total deformation (mm)
exposure to direct sunlight. It was very noticeable that the deformation was more than halved where the surfacing was shaded from direct sunlight, usually by trees. Conversely, the deformation increased by about 50% where the surfacing was over a bridge.

3.4 Visual appearance

Visual inspections were carried out annually until 1997 and then in 2003 by a Panel drawn from the industry (including the Highways Agency, Contractors, Materials Suppliers and TRL), with each section being rated on a scale running from "Excellent" (E) through "Good" (G), "Moderate" (M), "Acceptable" (A), "Suspect" (S) and "Poor" (P) to "Bad" (B); suffixes are applied when particular features are observed, these being loss of aggregate "–", variable "v" or variability with traffic intensity (that is, a unusual difference between the wheel-tracks and other areas) "i", and cracking "c".

4. Conclusions

The main conclusions from the results of monitoring the trial of various modified and unmodified hot rolled asphalts are:

1. The durability of the low-stability mixtures was inferior to that of the medium-stability and high-stability mixtures, whose performances were similar. The exception was the low-stability mixture with 70 pen bitumen plus 5% UL15019 EVA.

2. The durability of the unmodified control sections occurred in the medium-stability and high-stability mixtures.

3. The deformation measured on all three aggregate skeletons in 2003 was substantially lower where modified binders have been used. For the medium-stability and high-stability mixtures, the deformation on the asphalt containing modified binder was about half of that using conventional 50 pen bitumen. The reduction was even more significant in the low-stability mixture.

4. For the three mixtures tested, the laboratory wheel-tracking results at 45°C produced the same ranking as the deformation measured after 16 years’ service.

5. The durability of these hot rolled asphalt mixtures is better overall than that of average thin surface course systems. The exceptions are that the durability of the thin asphalt concrete and thin stone mastic asphalt systems are superior to that of low stability hot rolled asphalts.

5. Acknowledgements

Copyright TRL Limited. All rights reserved.
The author would like to thank the Highways Agency (HA) and the Refined Bitumen Association (RBA) for jointly funding the 2003 road closure, the members of the Inspection Panel who took part in the inspections and to Shell Bitumen for supplying additional texture depth and deformation data. The information contained herein, other than that provided by Shell Bitumen, is the property of TRL Limited and does not necessarily reflect the views or policies of the HA, the RBA or Shell Bitumen. While every effort has been made to ensure that the matter presented in this report is relevant, accurate and up-to-date at the time of publication, TRL Limited cannot accept any liability for any error or omission.

Table 5. Inspection Panel results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LS 70 pen</td>
<td>E/G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G/M</td>
<td>M</td>
<td>M/A</td>
<td>M</td>
<td>M/L</td>
<td>S/P</td>
<td></td>
</tr>
<tr>
<td>LS 100 Chem</td>
<td>E</td>
<td>E/G</td>
<td>G</td>
<td>G</td>
<td>G/M</td>
<td>M/A</td>
<td>M</td>
<td>M/L</td>
<td>A</td>
<td>M/A</td>
<td>S/L</td>
</tr>
<tr>
<td>LS 70 Chem</td>
<td>E</td>
<td>E</td>
<td>E/G</td>
<td>G</td>
<td>G</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>G/M</td>
<td>M</td>
<td>A/S</td>
</tr>
<tr>
<td>LS 70 EVA</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G/M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>MS 50 pen</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>G</td>
<td>E/G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>MS Multi</td>
<td>E/G</td>
<td>E/G</td>
<td>E</td>
<td>G</td>
<td>G</td>
<td>G/M</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>M</td>
<td>M/A</td>
</tr>
<tr>
<td>MS 50 SR</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E/G</td>
<td>G</td>
<td>G</td>
<td>E/G</td>
<td>G/M</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>MS SBS</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E/G</td>
<td>E</td>
<td>G</td>
<td>G</td>
<td>E/G</td>
<td>G/M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>HS 50 pen</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E/G</td>
<td>E/G</td>
<td>G</td>
<td>G</td>
<td>G/M</td>
<td>G</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>HS SBS</td>
<td>E/G</td>
<td>E/G</td>
<td>E/G</td>
<td>G</td>
<td>E/G</td>
<td>G/M</td>
<td>G/M</td>
<td>G</td>
<td>M</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Inspection Panel results
6. References


4 DAINES M E. Trials of porous asphalt and rolled asphalt on the A38 at Burton, Department of Transport TRRL Report RR 323, 1992. Transport and Road Research Laboratory, Crowthorne.

5 BRITISH STANDARDS INSTITUTION. Sampling and examination of bituminous mixtures for roads and other paved areas: Method of test for the determination of the composition of design wearing course rolled asphalt, BS 598:107-1990. BSI, London.


7 BRITISH STANDARDS INSTITUTION. Sampling and Examination of Bituminous Mixtures for Roads and Other Paved Areas: Methods of Test for the Determination of Texture Depth, BS 598:105-1990. BSI, London.


Introduction

Many of the properties of thin surfacings including their resistance to permanent deformation and durability have been confirmed beyond any reasonable doubt. Nevertheless, a number of issues about these mixtures remain unresolved. These include problems associated with skid resistance, surface texture, mixture design and binder drainage.

This Paper describes part of a research programme undertaken at University College in Dublin to assess the performance of thin surfacings. This test programme included the design of two thin surface courses, one designed using 40/60 pen binder and cellulose fibres and one designed using a polymer modified binder. Binder drainage, wheel-tracking, stiffness, water sensitivity and fatigue tests were carried out on both of these mixtures and the comparative performance of both analysed against all the test results. The results of these tests are summarised.

Background

The Germans developed stone mastic asphalt (splitumastixsphalt) in the 1960s to counter the effects of studded tyres which, at that time, were commonly used during winter. Although the use of studded tyres was banned in 1975, these stone mastic asphalts continued to be used as they demonstrated enhanced performance over asphalt concrete. Stone mastic asphalts exhibited reduced susceptibility to permanent deformation, premature ageing and cracking. After many gradual improvements to the technology, these materials were incorporated into a German Standard in 1984.

Around the same time, the French were developing their use of thin layer surface courses. It was the combination of the German and French technologies which produced the range of thin surfacings adopted in the United Kingdom from the early 1990s.

Towards the end of the 1990s, a limited number of thin surfacings were introduced to Ireland. However, due to the discovery that surface texture reduced faster than was the case with traditional mixtures with the consequent effect that would have on the future skid resistance performance of the road surface, the National Roads Authority (NRA) instructed Local Authorities in Ireland to confine usage of thin surfacing to areas where the speed limit did not exceed 30 mph. Thin surfacings are high stone content, gap-graded materials with a high binder content. They are designed to maximize contact between coarse aggregate in the mixture thus increasing stone-to-stone interaction. As a thin surfacing mixture characteristically contains a high percentage of coarse aggregate, there is a high volume of voids between the coarse particles, filled to a large extent with a mortar composed of fine aggregate, sand, filler, bitumen and, sometimes, fibres. To avoid segregation and binder drainage, fibres are usually added to mixtures using penetration grade bitumens. However, when a polymer modified binder is used there is no need for fibres. The United Kingdom has moved away from fibre-based mixtures preferring polymer modified binders.

A well-designed thin surfacing has many advantages over traditional surface courses. These include good resistance to rutting and high durability. Many of the properties of thin surfacings including their resistance to permanent deformation and durability have been confirmed beyond any reasonable doubt. However, a number of issues about these mixtures remain unresolved. These include problems associated with skid resistance, surface texture, mixture design and binder drainage.

The main objective of this research programme was to design two thin surfacings that comply with the relevant specifications using:
a) a penetration grade bitumen with cellulose fibres; and
b) a polymer modified binder.

These surface courses must possess adequate levels of resistance to rutting and fatigue cracking. In addition, the stiffness and water sensitivity of these mixtures were to be evaluated. This Paper details the design of the mixtures outlining the problems encountered and the actions taken to alleviate these. It also discusses the tests undertaken with specimens of these surface courses and analyses the results obtained.

**Thin surfacing specifications**

The bulk of surface courses laid in the UK today are thin surfacings. Thin surfacings are more properly described as “thin surface course systems” (TSCS) and are asphalts laid as surface courses on road pavements. They are usually laid at a maximum thickness of 40 mm. These variations of stone mastic asphalts have been made available over the past twelve years or so in the UK. However, problems arose when these materials first became available in the UK because the standard UK specification at the time did not readily permit their usage.

Since the advantages of thin surfacings were evident, the Highway Authorities Product Approval System (HAPAS) sometimes described as “BA/HAPAS”) was devised to allow them to be included within the UK specification. The HAPAS system was set up by the Highways Agency (HA) in conjunction with the County Surveyors Society (CSS) and the British Board of Agrément (BBA). The BBA is a government body that undertakes the assessment of construction projects. The role of the BBA, in this instance, is to oversee the approval system. Successful applicants are awarded a HAPAS Certificate. As indicated above, thin surfacings are now the default choice for surface courses in the UK and the HAPAS system played a significant role in this becoming so.

Thin surfacings were slow to gain a foothold in Ireland and were first laid on Irish roads in the late 1990s. The first thin surfacings were obtained from Shell Bitumen. This Specification gives the target composition of 10 mm and 14 mm mixtures. These grading requirements were used to design the 14 mm thin surfacing with 40/60 pen binder and cellulose fibres.

The Irish IAT SMA Draft Specification states that polymer modified bitumen may be used in thin surfacing mixtures but should be used in accordance with the manufacturer’s instructions. A Cariphalte TS Specification for thin surfacings was obtained from Shell Bitumen. This Specification gives the target composition for 6, 10, 14 and 20 mm thin surfacings. These grading requirements were used to design the 14 mm thin surfacing with Shell Cariphalte TS.

When a comparison is made between the Irish IAT SMA Draft Specification and the Shell Cariphalte TS Specification for a 14 mm mixture, the main differences are that the Shell Bitumen specification allows a higher percentage to pass the 2.36 mm sieve and a lower percentage to pass the 75µm sieve. Thus, in the Cariphalte TS mixture, there is a lower percentage of 14 mm and a higher fine aggregate content, the latter resulting in a larger surface area which has, of course, to be coated with binder. By allowing a lower percentage to pass the 75µm sieve, there is a lower filler content, which increases the workability of a mixture. In a mixture employing 40/60 pen binder with cellulose fibres, the fibres increase the surface area to be coated with bitumen and reduce the risk of segregation of the mixture. Overall, a comparison of these specifications shows that they give similar gradings.

**Thin surfacing mixtures and tests**

Two surface course mixtures were designed and examined in the laboratory:-

1. 14 mm with 40/60 pen binder and cellulose fibres
2. 14 mm with a polymer modified binder (Cariphalte TS)

These are described in this paper as the 40/60 pen/fibres and Cariphalte TS mixtures respectively.

As two different surface courses were to be designed in this project, it was important to select tests that would accurately rank the different mixtures. A review was carried out of the tests recommended in the HAPAS guidelines, the Irish IAT SMA Draft Specification, UK specification for SMA binder course in the Manual of Contract Documents for Highway Works (MCDHW) and the final draft of the European
Standard for SMA. Following the review, a number of tests were chosen: binder drainage, wheel-tracking, stiffness, sensitivity to water and fatigue.

**Mixture design**

*14 mm thin surfacing with 40/60 pen and fibres*

The 14 mm thin surfacing with 40/60 pen binder and cellulose fibres was designed using table 1 of the Irish IAT SMA Draft Specification for 14 mm Stone Mastic Asphalt. Guidance was also taken from the grading used by SIAC Construction for their 14 mm thin surfacing with 40/60 pen bitumen and fibres. An anti-stripping agent, Wetfix, was added to the 40/60 pen bitumen to ensure good adhesion to the aggregate.

It was recommended by SIAC Construction that the percentage passing the 2.36 mm sieve would be ~21% and that the percentage passing the 75µm sieve should not exceed 10%. The material passing the 2.36 mm sieve provides a significant surface area for the binder to coat, helping to avoid binder drainage. Alternatively, the material passing the 75µm sieve mixes with the binder and, in effect, increases the binder volume in the mixture which will tend to increase the risk of binder drainage.

SIAC Construction currently use 0.4% fibres in their 14 mm thin surface course with a binder content of 6%. Binder drainage tests must be carried out as part of the mixture design for thin surfacing mixtures. The factors that influence the binder drainage properties of a mixture include: aggregate grading, aggregate type, aggregate shape, aggregate porosity and aggregate/bitumen chemistry. Other relevant factors are the binder content, fibre content, moisture content and temperature. As all of these factors influence binder drainage, every time a change is made to a mixture, a check must be carried out to ensure that the bitumen content is correct and that binder drainage will not occur. Basket binder drainage tests were carried out on the 14 mm thin surfacing with 40/60 pen in accordance with BS DD 232:1996. In this test the quantity of binder lost through drainage after 3 hours at the test temperature is measured in duplicate for mixtures with the same relative aggregate properties but with different binder contents. The maximum binder content is determined as the mixed binder content 0.3% less than that at which 0.3% of the binder drains.

The binder drainage test was first carried out at a temperature of 160°C, with a fibre content of 0.4% and binder contents of 5.0% to 7.0%, increasing in increments of 0.5%. The expected maximum binder content of the mixture was 6%. No binder drainage was recorded. Advice was taken from Shell Bitumen and due to the fact that no binder drainage was recorded, the fibre content was reduced to 0.3% and the test was repeated at a temperature of 170°C, with binder contents of 6.0% to 7.8%, increasing in increments of 0.3%. Once again, no binder drainage was recorded.

As the binder content used by SIAC Construction was 6% with 0.4% cellulose fibres, it was decided that a 6% binder content would be used for the 14 mm thin surfacing, with 0.4% cellulose fibres.

**14 mm thin surfacing with Carphalite TS**

The Carphalite TS mixture was designed using the Shell Carphalite TS specification. The Irish IAT Sub-Committee’s SMA Draft Specification was also consulted in regard to this design. The particle size distribution results for the four aggregate materials were again used to determine the grading. A Schellenberg binder drainage test was carried out on the mixture design for thin surfacing mixtures.
Carphalte TS mixture in accordance with prEN 12697-45:2002. The principle of this test method is that the quantity of material lost by drainage, after 1 hour at the maximum mixing temperature expected at the mixing plant, is measured by the residue left after inverting the beaker containing the specific mixture.

This binder drainage test was carried out at 170°C for binder contents of 6% to 7.8%, increasing in increments of 0.3%. The specification for this test states that if more than 0.5% of the mass of the original mixture remains after the beaker has been inverted and held upside down for 10±1 seconds, the remaining mixture must be washed with solvent over a 1 mm sieve. An average of 28% of the original mass of the mixtures remained in the beaker when the test was carried out. Washing the material through the sieve using white spirit was attempted but was unsuccessful. It was recommended that methylene chloride be used to wash the remaining material through the sieve, however, methylene chloride is carcinogenic and couldn’t be used in our laboratory.

It was recommended by Shell Bitumen that a binder content of 5.3% be used. This is the minimum target binder content specified in the Irish IAT SMA Draft Specification. Due to problems experienced when test specimens were made using the Carphalte TS thin surfacing, this mixture was redesigned. These problems included the mixture having low workability when being manually mixed for the Schellenberg binder drainage test, a very glossy-looking surface on wheel-tracking slabs made in the roller compactor and an inconsistency throughout the height of the specimen in specimens that were made in the gyratory compactor. The lower halves of the material appeared to have a higher density than the upper halves. There appeared to be more binder mortar in the lower halves of the specimens, the bottom faces of which were totally smooth, while there were surface voids on the top surfaces, although there was also evidence of a high quantity of bitumen on the surface.

There were a number of possible reasons why these problems occurred and several changes were made to the mixture in order to try to resolve these difficulties. One possibility was that the binder content in the mixture may have been too high, although the minimum allowed for a polymer modified binder in the Irish IAT SMA Draft Specification was being used, and that binder drainage was occurring. Another possibility was that the proportion of filler in the mixture was too high which, when mixed with the bitumen, made the mortar content too high. A further possibility was that the high filler content caused the mixture to have low workability.

The sand in the fine aggregate fraction of the mixture was replaced by crushed rock fines. A number of UK asphalt suppliers consider that the use of sand rather than crushed rock fines means the mixture is likely to require a reduced binder content, making the mixture less resistant to texture loss with time and more likely to rut. However, using sand improves workability of the mixture, apparent during both the laying and compaction phases.

In order to reduce the amount of aggregate passing the 75µm and the 300 mm sieve, the percentage of filler in the mixture was cut. The percentages passing the 2.36 mm, 6.3 mm, 10 mm and 14 mm sieves were raised by increasing the overall fine aggregate amount and decreasing the overall coarse aggregate content. Following advice from Shell Bitumen and SIAC Construction, the percentage passing the 75µm sieve was decreased to ~7%, and the percentage passing the 2.36 mm sieve was increased to ~29%.

This redesigned mixture with Carphalte TS (0% sand) solved the problems of low workability, glossy surface on slab specimens and the inconsistency through the gyratory specimens. Results are presented in this Paper for both Carphalte TS mixtures. However, the recommended mixture is one in which the fine aggregate proportion consists solely of crushed rock fines.

Wheel-Tracking

The component materials for a wheel-tracking test specimen were mixed and compacted in the laboratory according to the procedure developed at UCD for preparation of slab specimens. Wheel-tracking tests were undertaken, on these laboratory-compacted slabs, in accordance with BS 598-11:1998/95.
Results

The Irish IAT SMA Draft Specification gives limiting wheel-tracking requirements for different site classifications. Wheel-tracking was carried out at 60°C in this Project as the mixtures that were tested are being considered for use on very heavily-stressed sites requiring high rut resistance. Therefore, the limits of interest are a maximum wheel-tracking rate of 5.0 mm/hr and a maximum rut depth of 7.0 mm.

The HAPAS guideline document has a value of 5.0 mm/hr as the maximum value of wheel-tracking rate and 7.0 mm as the maximum rut depth for mean results of 6 consecutive results. It gives 7.5 mm/hr as the maximum wheel-tracking rate and 10.5 mm as the maximum rut depth for values measured on a single core. These results are for layers which are at least 30 mm thick. The test method outlined in the HAPAS guideline document is for specimens cored from a road.

Table 4 shows the results obtained for rut depth and rut rate for each of the sets of wheel-tracking results and the mean results for rut depth and rut rate for each set. Fig. 4 shows a comparison of the average deformation results over 45 minutes for the three different mixtures. For each mixture, four specimens were compacted and tested.

Analysis

The rut depths and the wheel-tracking rates for all mixtures are very low. Although two of the Coefficients of Variation for the mean rut rate are high, the actual values are all relatively low. All the results are significantly below the maximum limits set in the Irish IAT SMA Draft Specification. It is expected that thin surfacing mixtures will possess good wheel-tracking characteristics as a result of the coarse aggregate content. The coarse aggregate plays the dominant role and provides good shear resistance. Good shear resistance, coupled with good compaction, gives significant levels of rut resistance.

It can be seen from the results that there was a slightly higher average rut depth at 45 minutes for the Cariphalte TS slabs than that found in the 40/60 pen/fibres slabs. The surfaces of the Cariphalte TS slabs had a very glossy appearance. The wheel-tracking rates for the first Cariphalte TS and the 40/60 pen/fibres mixtures were almost equal, with the former having a slightly lower mean rut rate. When changes were made to the Cariphalte TS mixture, the mean wheel-tracking rate increased slightly.

Wheel-tracking results presented by Read for 14 mm thin surfacing compare favourably with the results shown in Table 4. Results published by Gibney et al for a 10 mm thin surfacing with both 40/60 pen binder and Cariphalte 4M show higher rut depths and rut rates for both mixtures compared to the results that were found in this Project for both the mixtures.

Stiffness modulus

The indirect tensile stiffness modulus test was carried out on specimens that were manufactured in the laboratory, in accordance with BS DD 213:1993. A voids content of 6.5% was used in the design of these specimens. These

Table 4. Wheel-tracking results

<table>
<thead>
<tr>
<th>Mix</th>
<th>Rut Depth (mm)</th>
<th>Rut Rate (mm/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40/60 pen + fibres</td>
<td>1.44</td>
<td>1.48</td>
</tr>
<tr>
<td>Cariphalte TS</td>
<td>1.42</td>
<td>1.40</td>
</tr>
<tr>
<td>Cariphalte TS (0% sand)</td>
<td>1.40</td>
<td>1.42</td>
</tr>
</tbody>
</table>

Table 5. 14 mm surface course stiffness modulus results

<table>
<thead>
<tr>
<th>Mix</th>
<th>40/60 pen + fibres</th>
<th>Cariphalte TS</th>
<th>Cariphalte TS (0% sand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4244</td>
<td>3234</td>
<td>3155</td>
</tr>
<tr>
<td>2</td>
<td>4087</td>
<td>2880</td>
<td>2919</td>
</tr>
<tr>
<td>3</td>
<td>4873</td>
<td>3302</td>
<td>2959</td>
</tr>
<tr>
<td>4</td>
<td>4496</td>
<td>2745</td>
<td>3001</td>
</tr>
<tr>
<td>5</td>
<td>4162</td>
<td>2486</td>
<td>3027</td>
</tr>
<tr>
<td>6</td>
<td>3945</td>
<td>2590</td>
<td>3480</td>
</tr>
<tr>
<td>Ave.</td>
<td>4306</td>
<td>2874</td>
<td>3137</td>
</tr>
</tbody>
</table>

Table 4. Wheel-tracking results

Figure 4. Comparison of average deformation
specimens were compacted in a gyratory compactor to a specified density which was achieved for all specimens.

Results

The results obtained for a series of six specimens for each mix are shown in Table 5.

Analysis

In a thin surfacing mixture, high stiffness is achieved by using a moderately hard binder in conjunction with a low voids content. A low voids content results from using a high bitumen content and a high filler content relative to other asphalts.

The surface course results show that the 40/60 pen/fibres mixture has a higher stiffness modulus than that found in the Cariphalte TS mixture when stiffness is measured at 20°C. This is consistent with stiffness modulus results for mixtures using a polymer modified binder.

The Cariphalte TS Product Information Sheet states that Cariphalte TS has a high viscosity at high pavement temperatures and possess an increased elasticity at lower temperatures.

Water sensitivity

Water sensitivity tests were carried out in accordance with the HAPAS guideline document test procedure. Table 6 shows the conditioning cycles used.

Results

A comparison of the average stiffness results and stiffness ratios for the thin surfacings over the three water sensitivity cycles is shown in Table 7. The unconditioned stiffness results (ITSMu) are the average stiffness values from Table 5.

Note: The stiffness ratio, ITSM Ratio, ci, for the specimens for each conditioning cycle is calculated from the equation ITSM Ratio, ci = ITSMci/ITSMu, where U = unconditioned, ci = conditioning cycle, i = 1,2,3, ITSMu = unconditioned stiffness and ITSMci = conditioned stiffness after conditioning cycle ci.

<table>
<thead>
<tr>
<th>Mixtures</th>
<th>40/60 pen + fibres</th>
<th>Cariphalte TS</th>
<th>Cariphalte TS (0% sand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITSMu (MPa)</td>
<td>4330</td>
<td>2674</td>
<td>3117</td>
</tr>
<tr>
<td>ITSM1 (MPa)</td>
<td>4473</td>
<td>2754</td>
<td>2000</td>
</tr>
<tr>
<td>ITSMratio1</td>
<td>1.03</td>
<td>1.27</td>
<td>1.17</td>
</tr>
<tr>
<td>ITSM2 (MPa)</td>
<td>4434</td>
<td>4190</td>
<td>3020</td>
</tr>
<tr>
<td>ITSMratio2</td>
<td>1.02</td>
<td>1.41</td>
<td>1.19</td>
</tr>
<tr>
<td>ITSM3 (MPa)</td>
<td>4296</td>
<td>3370</td>
<td>2922</td>
</tr>
<tr>
<td>ITSMratio3</td>
<td>0.98</td>
<td>1.14</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Note: The stiffness ratio, ITSM Ratio, ci, for the specimens for each conditioning cycle is calculated from the equation ITSM Ratio, ci = ITSMci/ITSMu, where U = unconditioned, ci = conditioning cycle, i = 1,2,3, ITSMu = unconditioned stiffness and ITSMci = conditioned stiffness after conditioning cycle ci.

Table 7. Comparison of average stiffness and water sensitivity results of thin surfacing mixtures

Analysis

The stiffness of the 40/60 pen/fibres mixture increases from its initial value to that for the first cycle, drops very slightly over the second cycle and decreases again over the third cycle. The stiffness of the Cariphalte TS (0% sand) mixture increases more significantly from its initial value to that for the first cycle, and then decreases slightly over the next two cycles.

The average stiffness for the Cariphalte TS mixture shows a large increase for the second cycle. This was not encountered with any of the other sets of specimens and the possibility that these may have been slightly below the test temperature of 20°C when tested has been considered as the reason for this phenomenon. During the water sensitivity tests on these specimens, problems were encountered with the 20°C water bath. There was a difficulty in maintaining the temperature at 20°C in the water bath due to very warm weather. The water bath may have been set at too low a temperature to cope with this situation. The test was not repeated as the Cariphalte TS (0% sand) mixture was selected as the recommended surface course.

Table 6. The 4-day conditioning cycles

<table>
<thead>
<tr>
<th>DAY 1</th>
<th>Specimens brought to test temperature (20°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unconditioned stiffness test ITSMu</td>
</tr>
<tr>
<td>00 GD 210:1993 (Section 5.1.5)</td>
<td></td>
</tr>
<tr>
<td>Partial vacuum</td>
<td>50 mm Hg / 250 mm Hg</td>
</tr>
<tr>
<td>20°C +/- 1°C</td>
<td>30 mins +/- 1 min</td>
</tr>
<tr>
<td>Hot water bath</td>
<td>60°C +/- 1°C</td>
</tr>
<tr>
<td>Cooled water bath</td>
<td>5°C +/- 1°C</td>
</tr>
<tr>
<td>DAYS 2, 3 &amp; 4</td>
<td>Test temperature 20°C +/- 1°C</td>
</tr>
<tr>
<td>Minimum</td>
<td></td>
</tr>
<tr>
<td>Unconditioned stiffness test ITSMu (day 2), ITSMu (day 1) and ITSMu (days)</td>
<td></td>
</tr>
<tr>
<td>00 GD 210:1993 (Section 5.1.5)</td>
<td></td>
</tr>
<tr>
<td>Hot water bath</td>
<td>60°C +/- 1°C</td>
</tr>
<tr>
<td>Cooled water bath</td>
<td>5°C +/- 1°C</td>
</tr>
</tbody>
</table>

Note: It is acknowledged that the water temperature in the 5°C water bath will rise when the specimens at 60°C are placed into the bath.
Shell Bitumen expect a ratio of 0.5 to 1.00 for a 40/60 pen/fibres mixture depending on how well the mixtures are designed and how good the adhesion is between the binder and the aggregate. A minimum ratio of 1.0 is expected with the Cariphalte TS mixture. This higher ratio with Cariphalte TS occurs because the adhesion is so much greater and because the bitumen film thickness is increased even though the overall binder content is reduced compared to the 40/60 pen mixture. Read\textsuperscript{16} states that a ratio of greater than 0.70 is a good result and the stiffness ratios that he presents for a thin surfacing mixture are similar to those obtained during this Project. For any single set of Read’s water sensitivity test results, trends similar to those were observed in this Project. The results tend to peak for either the second or third cycle for particular specimens. When average stiffness results are viewed over the three cycles, the peak occurs for the second cycle.

High ratios have been achieved for both the thin surfacing with 40/60 pen/fibres and the Cariphalte TS mixture. The high ratio for the former may be due to the use of the anti-stripping agent.

**Fatigue**

The indirect tensile fatigue test was carried out on specimens that were manufactured in the laboratory. The test specimens were compacted in 100 mm diameter steel moulds, in a gyratory compactor to a specified density giving a voids content of 6.5%. It is recommended in the NU-10 User Manual that specimens should be 40 mm thick to achieve a good spread of stress levels. With a small specimen thickness, relatively high stresses can be generated. In the NU-10, horizontal tensile stresses exceeding 800 kPa are possible with 40 mm thick specimens, with a supply pressure of about 7 bar. The fatigue tests were carried out in accordance with BS DD ABF:1997\textsuperscript{20}.

Twelve thin surfacing specimens with 40/60 pen/fibres (six specimens compacted to 83 mm in height and then cut to 40 mm each) were made in the laboratory and tested. Twelve thin surfacing specimens using Cariphalte TS (six specimens compacted to 83 mm in height and then cut to 40 mm each) were then made in the laboratory and tested. The Cariphalte TS specimens appeared to have a higher density in the lower half than in the upper half. The surface faces of the specimens had a high binder content or binder mortar, especially on the bottom faces. In addition, the upper halves of the Cariphalte TS specimens appeared to fail at fewer pulses than the lower halves. A further twelve Cariphalte TS specimens were made and tested. It was attempted to compact these specimens to 40 mm by specifying the density. However, it was not possible to achieve the required densities in the gyratory compactor for this reduced height due to specimen height restrictions, even with the addition of a special steel mould insert. These specimens were again found to have a high binder or binder mortar content on their surface faces and in particular their bottom faces. Twelve Cariphalte TS (0% sand) specimens were compacted to 50 mm in height and tested. These specimens were made using the new mixture design with 0% sand.

**Results**

The fatigue results for the mixtures are compared graphically in figs 5 and 6.

![Figure 5. Comparison of thin surfacings stress fatigue results](image-url)

![Figure 6. Comparison of thin surfacings strain fatigue results](image-url)

**Figure 5. Comparison of thin surfacings stress fatigue results**

**Figure 6. Comparison of thin surfacings strain fatigue results**

**Analysis**

Fig 5 shows a comparison of the stress results for the various mixtures. In this stress fatigue relationship, the Cariphalte TS (0% sand) mixture outperforms the two other sets of Cariphalte TS and 40/60 pen/fibres mixtures. The Cariphalte TS (0% sand) mixture is the recommended Cariphalte TS surface course mixture and clearly outperforms the 40/60 pen/fibres mixture.

Fig 6 shows a comparison of the strain results for the mixtures. The three Cariphalte TS mixtures have strain fatigue lines that are close to each other. All of the 14 mm thin surfacing with Cariphalte TS mixtures significantly outperform the 14 mm with 40/60 pen and fibres mixture.
The Shell Cariphalte TS Product Information Sheet\textsuperscript{14} states that mixtures made with Cariphalte TS have a resistance to fatigue cracking at least 5 times higher than that found in mixtures made with conventional bitumens.

**Discussion**

Thin surfacings are asphalts for which a recipe approach does not work; the same grading, the same binder content are not appropriate for all mixtures\textsuperscript{3}. Optimum mixture design can be difficult to achieve with a thin surfacing, in particular when a polymer modified binder is used. Small changes in aggregate grading, aggregate type or marginal increases in binder content cause the behaviour of the mixture to vary significantly. This was made very clear when dealing with the Cariphalte TS mixtures during the design stage of this Project, although the same is true for 40/60 pen/fibres mixtures. A complete mixture design is required in order to properly design a thin surfacing. As a result of the binder drainage tests giving inconclusive results, binder contents were based on advice from industry and on the appearance of specimens after compaction. A more scientific approach is needed to ascertain the optimum binder content for a particular mixture.

Problems were initially experienced with the Cariphalte TS mixture. These included low workability when being manually mixed, a very glossy looking surface on wheel-tracking slabs and an inconsistency throughout the height of the material in specimens that were made in the gyratory compactor. These problems were eliminated by using crushed rock fines as the fine aggregate proportion of the mixture. In addition, the filler content was reduced.

A brief economic evaluation suggested that there was very little difference in the costs of mixtures made with Cariphalte TS and those made with 40/60 pen/fibres. Although Cariphalte TS is more expensive than 40/60 pen bitumen, the Shell Cariphalte TS specification requires a less coarse mixture which reduces the cost of the mixture since high PSV 14 mm aggregate is more expensive than the fine aggregate. A further factor is that Cariphalte TS mixtures require a lower binder content.

All the wheel-tracking rates and rut depths recorded were well within the limits defined in both the Irish IAT SMA Draft Specification and the HAPAS guidelines. These results provide evidence of a well-designed mixture with no rutting problems. The lowest rut depth was recorded for the Cariphalte TS (0% sand) mixture, although this was only very slightly less than the 40/60 pen/fibres mixture.

The 40/60 pen/fibres mixtures have higher stiffness moduli than those made with Cariphalte TS when stiffness is measured at 20\textdegree{}C. Cariphalte TS is less temperature susceptible than penetration grade bitumens and would retain a higher stiffness at higher temperatures than a penetration grade bitumen. Over the three cycles of the water sensitivity tests, after an initial increase in stiffness, the stiffness results dropped over the second and third cycles for all mixtures. High stiffness ratios were obtained for all mixtures over the three cycles.

The Cariphalte TS mixtures outperformed the 40/60 pen/fibres mixture in relation to fatigue.

**Further work**

The binder drainage tests carried out during this project were inconclusive and could not be used to determine the optimum binder content for a given mixture. Binder contents were instead based on advice from industry. A more scientific approach is needed to find the optimum binder content for a particular mixture design if binder drainage tests do not yield conclusive results.

When problems were encountered after specimens were compacted, the grading was changed to better accommodate the binder. These changes generally involved adapting the grading to make it less coarse, increasing the fraction passing the 2.36 mm sieve to provide more surface area to be coated by the binder and to reduce the filler content.

Towards the end of the 1990s, the NRA introduced thin surfacings to 1\% of the Irish road network. However, due to the discovery that surface texture reduced faster than was the case with traditional mixtures with the effect that would have on the future skid resistance performance of the road surface, the NRA instructed local authorities in Ireland to confine usage of thin surfacing to areas where the speed limit did not exceed 30 mph\textsuperscript{1}.

Further use of the material is restricted until, through further development and testing, surface texture performance of thin surfacings can be guaranteed over an acceptable life cycle. It is obvious that the skid resistance and texture depth problems associated with thin surfacings need to be addressed in an Irish context. A road trial will be laid over the coming months in order to carry out skid resistance and texture depth testing on an Irish site, using the mixture design information from this Project. Initial skid resistance and texture depth readings will be taken and a visual assessment will be made of the laid material. At predetermined intervals after the trial surface has been laid, skid resistance, retained texture depth and the rate of decline of texture depth will be determined and visual assessments will be undertaken.
Acknowledgments

This paper is published with the permission of Shell Bitumen and SIAC Construction, whose input is gratefully acknowledged. In addition, the authors acknowledge the advice and guidance received from David Strickland and Andy Self of Shell Bitumen.

This work would not have been possible without the financial support received from Enterprise Ireland which is also gratefully acknowledged.

References


8 British Board of Agrément. Guidelines Document for the Assessment and Certification of Thin Surfacing Systems for Highways, Draft 6, 2002. BBA.


11 Strickland D. RE: Stone Mastic Asphalt Project (Binder Drainage), e-mail to C. Butler, June 2003. Available e-mail: Caroline.Butler@ucd.ie


PERFORMANCE CHARACTERISTICS OF
POLYMER-MODIFIED MASTIC ASPHALT
FOR BRIDGE SURFACING

Iswandaru Widyatmoko 1 Richard Elliott 1 and John Read 1

Abstract

Mastic asphalt surfacing is a widely used and specified material for bridge surfacing and has been traditionally known as a durable and deformation resistant surfacing. Trinidad Lake Asphalt (TLA), which comprises naturally-weathered bitumen and filler, is often used for modifying the mastic binder properties in order to obtain improved performance of a particular mastic asphalt mixture (such as stiffness and deformation resistance). Increased traffic loading and severe environmental conditions often demand more stringent requirements for the mixture performance; in these cases, further modification of the mastic binder by polymer addition may be required.

Rheological analysis showed that the “stiffening” effect caused by addition of TLA into mastic binder, which is normally anticipated in the case of conventional mastic asphalt (incorporating unmodified bitumen), took place in a different way if a polymer modifier was also used. Changes in rheological properties of different mastic binders were also reflected by changes in performance (such as low temperature strength, stiffness and deformation resistance) of their respective mastic asphalt mixtures.

Introduction

Natural rock asphalt (limestone impregnated with 5 - 15% bitumen) was discovered in France and Switzerland in the 18th century, and was found to provide a durable and waterproof layer after mining, grinding and heating to form a paste or epuré. In the 19th century it was discovered that a naturally-occurring asphalt located in a “lake” in Trinidad, West Indies (Trinidad Lake Asphalt, TLA) could be added to (and eventually replace) the rock asphalt, while enhancing the durability of the mixture. During this period, the refinement of adding stone to the epuré was found to provide greater stability to the resulting mastic asphalt mixture. Pavement-quality mastic asphalt of this type has a long pedigree of successful use on bridge decks, including across the Nile in 1929, the Forth in Scotland in 1964, the Bosphorus in Turkey in 1973, the Humber in England in 1980, and the Tsing Ma Bridge in Hong Kong in 1997.

Modern pavement-quality mastic asphalt commonly comprises a blend of TLA and penetration-grade bitumen (termed “asphaltic cement”) that is mixed with limestone fine aggregate to form a mastic “epure”. The addition of coarse aggregate completes the composition of the mastic asphalt.

Trinidad Lake Asphalt consists of a mixture of bitumen and minerals of the following composition: soluble bitumen (53 - 55%), mineral matter (36 - 37%) and other (9 - 10%). The bitumen component is made up of maltenes (63 - 66%) and asphaltenes (34 - 37%). Typical properties of refined TLA, as specified in BS 3690-3, are summarised in table 1.

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration at 25°C (mm)</td>
<td>BS 3900-41</td>
<td>2 - 5</td>
</tr>
<tr>
<td>Softening point (°C)</td>
<td>BS 3900-8 (BS 6271)</td>
<td>85 - 90</td>
</tr>
<tr>
<td>Cold in Nastเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกมเกม</td>
<td>BS 3900-8 (BS 6271)</td>
<td>115 - 130</td>
</tr>
<tr>
<td>Viscosity at 85°C (Poise)</td>
<td>BS 3900-12</td>
<td>20 - 50</td>
</tr>
<tr>
<td>Viscosity at 18°C (Poise)</td>
<td>BS 3900-2</td>
<td>15 - 45</td>
</tr>
<tr>
<td>Ash content (% O)</td>
<td>BS 3900-23</td>
<td>1 - 1.5</td>
</tr>
<tr>
<td>Sulfur</td>
<td>BS 3900-24</td>
<td>0.001 - 0.002</td>
</tr>
</tbody>
</table>

Note: *The methods shown in parentheses are the new BS EN specifications, which have now superseded the BS test methods quoted in BS 3690-3.

Table 1 – Properties of refined TLA

Mastic asphalt surfacing is a widely used and specified material for bridge surfacing. This material has been traditionally known as a durable and deformation-resistant surfacing; however, significant increases in traffic loading and requirements for application under more severe environmental conditions warrant improved performance. Surfacing systems for bridge decks, including those in the UK, are generally selected using an empirical recipe type approach, and evaluated using index tests rather than tests which measure the fundamental mechanical properties.

However, it is well known that asphalts complying with the same recipe specification can be radically different in terms of their engineering properties. In this study, a range of constituent materials for the various components of the surfacing system was evaluated and specifically, this paper focuses upon the benefits from using polymer-modified binders in the mastic asphalt surfacing system.

A programme of performance testing using a Dynamic Shear Rheometer (DSR) and the Nottingham Asphalt Tester (NAT) was carried out by Scott Wilson Pavement Engineering (SWPE), to assess the fundamental properties of the mastic asphalt (binders and mixtures respectively), and to optimise its constituents within the specified limits. In addition, performance in the laboratory wheel-tracking test was also measured.
Composition and properties of mastic binder

Altogether 18 mastic binders were assessed, using a controlled-stress DSR, which measures fundamental properties across a range of temperatures and frequencies, and using viscosity, penetration and softening point tests. A range of elastomeric bitumens, pre-blended by the suppliers both with and without TLA, was investigated, together with a control binder replicating the control “asphalt cement” used for conventional mastic asphalt surfaced.

A list of all the elastomer polymer-modified binders (PMBs) and the control binder used in this study, and their empirical properties, is presented in table 2, while the viscosity/temperature relationships of selected binders are presented in fig 1.

Table 2 shows that the reduction in penetration value by the addition of TLA to PMBs was typically not followed by a corresponding increase in softening point value. For example, the addition of 50% TLA to binder Elastomeric B resulted in a reduction in both penetration and softening point values. It should be noted here that the correlation between softening point and the respective mixture performance for PMBs is not as clear as that between unmodified binders and their respective mixture performance 5. On the other hand, binder rheology is considered to offer better correlation with mixture performance 6. Consequently, a detailed assessment of binder rheology was carried out.

Fig 1 shows that the addition of TLA into the mastic binders also did not always result in increased high-temperature viscosity (eg, the viscosity of sample R was actually reduced by the addition of TLA), when tested using a rotary viscometer to ASTM D4402. For those situations where it applied, the higher viscosity of the polymer-modified mastic asphalt (than that of the unmodified one) may imply reduced workability. However, observations made during the laboratory manufacturing of some polymer modified mastic asphalt (eg, sample S) indicated that the reduced workability could be offset by using an additional additive, such as that used in sample T.

The rheological testing was carried out in accordance with Clause 928 of the Manual of Contract Documents for Highway Works4, which is currently an assessment requirement for PMBs for use in UK trunk roads. The testing involved determination of complex shear modulus ($G^*$) and phase angle ($\delta$) of the studied PMB materials over a range of test temperatures and frequencies. From the rheological testing, the following parameters were shown to have a significant influence on the stiffness and visco-elastic response of the studied mastic binders: (i) whether TLA was added into the unmodified bitumen or PMB, and (ii) the type of PMB used. Fig 2 shows the visco-elastic response of selected mastic binders, before and after the addition of TLA.

Table 2 – Composition and properties of mastic binders

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Base Binder</th>
<th>Added TLA</th>
<th>Extra Additives</th>
<th>Pen (°C)</th>
<th>RSP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Elastomeric A</td>
<td>-</td>
<td>-</td>
<td>17</td>
<td>119.1</td>
</tr>
<tr>
<td>B</td>
<td>Elastomeric B</td>
<td>-</td>
<td>-</td>
<td>13</td>
<td>111.1</td>
</tr>
<tr>
<td>C</td>
<td>Elastomeric C</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>94.5</td>
</tr>
<tr>
<td>D</td>
<td>Elastomeric D</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>86.0</td>
</tr>
<tr>
<td>E</td>
<td>60/70 pen (°C)</td>
<td>25%</td>
<td>-</td>
<td>71</td>
<td>71/0</td>
</tr>
<tr>
<td>F</td>
<td>Elastomeric F</td>
<td>-</td>
<td>Yes</td>
<td>20</td>
<td>81.0</td>
</tr>
<tr>
<td>G</td>
<td>Elastomeric G</td>
<td>-</td>
<td>-</td>
<td>23</td>
<td>123.1</td>
</tr>
<tr>
<td>H</td>
<td>Elastomeric H</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>128.4</td>
</tr>
<tr>
<td>I</td>
<td>Elastomeric I</td>
<td>-</td>
<td>-</td>
<td>90</td>
<td>120.5</td>
</tr>
<tr>
<td>J</td>
<td>Elastomeric J</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>91.0</td>
</tr>
<tr>
<td>K</td>
<td>Elastomeric K</td>
<td>-</td>
<td>-</td>
<td>16</td>
<td>87.4</td>
</tr>
<tr>
<td>L</td>
<td>Elastomeric L</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>100.4</td>
</tr>
<tr>
<td>M</td>
<td>Elastomeric M</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>109.3</td>
</tr>
<tr>
<td>N</td>
<td>Elastomeric N</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>100.3</td>
</tr>
<tr>
<td>O</td>
<td>Elastomeric O</td>
<td>-</td>
<td>Yes</td>
<td>15</td>
<td>102.3</td>
</tr>
<tr>
<td>P</td>
<td>Elastomeric P</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>100</td>
</tr>
</tbody>
</table>

Note: Pen and RBSP denote penetration (BS EN 1426) and ring & ball softening point (BS EN 1427) tests respectively. *The term “mastic binder” denotes bituminous binder used in the mastic asphalt mixture, either with or without TLA, prior to the addition of limestone fine and coarse aggregates. **Used as a control sample.
Fig 2 also shows that for the mastic binder not containing PMB (sample Z), the addition of TLA increased the elastic response as indicated by the reduced phase angle (sample E). However, the reverse is true for the polymer-modified mastic binders, where the addition of TLA increased the phase angle value (which indicates reduced elastic response). Also, samples S and U appeared to have comparable visco-elastic response even though these samples contained different types of polymer modifier (ie, Elastomers K and R used in these polymer-modified mastic binders had different constituents); fig 2 would therefore suggest that different elastomeric binders may require different levels of TLA addition in order to obtain similar visco-elastic properties. Overall, fig 2 shows the potential benefit of using PMB (over unmodified binder), with or without TLA addition, as indicated by the reduced elastic response at low temperature (improved flexibility and healing capacity, hence potentially beneficial for inhibiting cracking) but increased elastic response at high temperature (improved elasticity, which is potentially beneficial for resisting deformation).

The “stiffening” effect due to the addition of TLA into unmodified mastic binder is also different from that for PMB; this effect is illustrated in fig 3. A significant increase in complex modulus ($G^\ast$), specifically at temperatures of 10°C and above, is shown by sample E when 70% TLA was added into the 60/80 pen bitumen Z; however, $G^\ast$ at temperatures of 10°C or lower was not significantly affected. Conversely, whereas a significant increase in $G^\ast$ was observed in the polymer-modified mastic binders, specifically in the low to medium temperature region (eg, 60°C or less), at temperatures higher than (say) 60°C, a “softening” effect was observed.

Composition of mastic asphalt surfacing

Three key performance characteristics were investigated in small element tests; specifically deformation resistance (at high temperature), load-spreading ability (stiffness at service temperature) and resistance to cracking (tensile strength and stiffness at low temperature). The tensile strength, stiffness and deformation resistance data are summarised in table 4.

The stiffness reported is the indirect tensile stiffness modulus (ITSM 7) and the deformation resistance is reported in terms of the cumulative strain at the end of the Repeated Load Axial Test (RLAT, 8). The tensile strength is the indirect tensile strength test (ITST) of dry specimens, using the methodology described in AASHTO T-283 9, but tested at -10°C. The ITST results are presented as “dissipated energy”, which is the area under the load/time curve recorded during the test.

Note: 1 Mean of 6. 2 Mean of 10. 3 Testing carried out at 30°C or 40°C, as appropriate. 4 Permanent strain after 3600 pulses. Mean of 4.

Table 4 – Mechanical test data
20°C is the reference temperature for the determination of stiffness modulus in the UK. At this temperature, it can clearly be seen that mixture stiffness increases as TLA is added to the mixture (eg, note changes in stiffness values between sample B and sample D and between sample R and sample U). The increase in mixture stiffness also correlates well with the increase in binder stiffness, as illustrated in fig 4.

Table 4 suggests that the improvement in deformation resistance, as represented by lower RLA T strains, could not be clearly identified in all of the polymer-modified mastic mixtures, since a number of samples reached 7.5% permanent strain before the 3600 pulses had elapsed. However, for those which showed significant improvement in the deformation resistance (eg, samples A, C, S and T), the improved performance coincided with the lower high-temperature phase angle (increased elastic response) of the respective mastic binders (fig 2) compared with that of the control sample. Improved performance was also observed in stiffness and tensile strength values for the low temperature tests, ie, all of the polymer-modified mixtures showed lower stiffness and higher ITST dissipated energy values, which are desirable for improved low-temperature properties.

Overall, three mixtures (samples R, T, and U) appeared to show the best combination of low and high temperature performance; sample T was essentially similar to sample S but with improved workability. These mixtures, together with the control mixture (sample E), were evaluated further in the laboratory using a simulative upper service temperature test, specifically the wheel-tracking test (WTT), to test rutting resistance at 70°C and an applied stress of 0.7MPa. The WTT data from this programme of testing are summarised in table 5.

The polymer- modified mastic asphalt mixtures (samples R, T and U) show a significant improvement in WTT rut resistance compared with that of sample E. A computer model was used to show that the predicted rut depth of sample E was estimated to be 7 to 10 times higher than the rut depths for samples R, T or U. These findings would suggest that the modified mixtures will provide a significant improvement in the material’s rut resistance, consistent with the indications from binder rheology (ie, the increase in both high-temperature elastic response and complex modulus, as shown in figs 2 and 3).

Concluding remarks

The mechanical properties of mastic asphalt are highly affected by the rheological properties of the respective mastic binder. Analysis showed that the “stiffening” effect caused by addition of Trinidad Lake Asphalt (TLA) into mastic binder, which is normally anticipated in the case of conventional mastic asphalt (incorporating unmodified bitumen), took place in a different way if a polymer modifier was also used. Specifically, the following observations were made on a total of 18 unmodified and modified binders, the latter incorporating TLA and polymers both in isolation and in combination:-

1) the addition of TLA to unmodified bitumen caused a reduction in penetration, and an increase in softening point and viscosity, as expected;
2) the addition of TLA to polymer-modified bitumen (PMB) caused a reduction in penetration and in softening point; the effect on viscosity was variable;
3) rheological analysis provided some explanation for this behaviour:
   (i) with unmodified bitumen, TLA caused an increase in complex modulus ($G^*$) and a reduction in phase angle (d), indicating an increased elastic response;
   (ii) with PMB, TLA caused an increase in d, indicating a reduced elastic response, and an increase in $G^*$ below around 60°C but a reduction above this temperature; this complex interplay of rheological properties may help to explain the performance of these binders in the empirical tests (penetration, softening point and viscosity);
4) in a mastic asphalt mixture, the effect of the addition of TLA into unmodified and modified binders was to increase mixture stiffness; the effect on deformation resistance, measured in a repeated load creep test, was less clear; again, the explanation for this behaviour may lie in the rheological properties of the binder at elevated temperatures (60 - 70°C);
5) simulative testing, involving wheel-tracking at 70°C, clearly showed the benefits of selected modifiers (with and without TLA) in the corresponding mastic asphalt mixture, compared with an unmodified control.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Mean Rut Rate* (cm/min)</th>
<th>Mean Rut Depth* (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mx E</td>
<td>&lt;0.05</td>
<td>&gt;0.2</td>
</tr>
<tr>
<td>Mx R</td>
<td>5.9</td>
<td>7.7</td>
</tr>
<tr>
<td>Mx T</td>
<td>5.5</td>
<td>5.2</td>
</tr>
<tr>
<td>Mx U</td>
<td>9.5</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Note: *Between 30 and 45 minutes. **Sample failed before 30 minutes had elapsed.

Table 5 – Wheel-tracking at 70°C
The control mixture has a track record of successful use for surfacing steel bridge decks. This research, which adopted a performance-based mixture design, demonstrates the potential use of polymer-modified binders for mastic asphalt application, to enhance mixture performance for use under severe environmental conditions and/or to carry increased traffic loading.

REFERENCES

1 Elliott, R C, Sida, M: Performance testing and laying of mastic asphalt for bridge surfacing, IAT Yearbook 2002, pp 35-41
7 British Standards Institution: Method for determination of the indirect tensile stiffness modulus of bituminous mixtures, BS DD 213, 1993
8 British Standards Institution: Method for determining resistance to permanent deformation of bituminous mixtures subject to unconfined dynamic loading, BS DD 226, 1996
9 AASHTO designation T 283-99: Standard method of test for resistance of compacted bituminous mixture to moisture-induced damage
10 British Standards Institution: Methods of test for the determination of wheel-tracking rate and depth – Sampling and examination of bituminous mixtures for roads and other paved areas, BS 598-110, 1998
WARM ASPHALT MIXTURES USING A SYNTHEtic ZEOLITE

W Barthel
Mitteldeutsche Hartsteinindustrie AG, Hanau, Germany

J-P Marchand
EUROVIA SA, Rueil-Malmaison, France

M von Devivere
EUROVIA GmbH, Bottrop, Germany

1. Introduction

1.1 Environmental aspects

Around the world, various initiatives have been implemented to protect the environment. Currently, the main emphasis is on cutting carbon dioxide emissions in order to reduce the greenhouse effect. Although carbon dioxide is part of our natural environment, as a result of the burning of oil, coal and gas, more than half of the current quantity of this gas is present because of the activities of mankind.

One initiative is the European Union target which seeks to reduce carbon dioxide emissions between 1990 and 2010 by 15%.

The asphalt industry in Germany and in France is trying to play its part in this reduction. In order to do so, the German Asphalt Association (Deutscher Asphaltsverband, DAV) started a programme in 1998 called “low temperature asphalt” which has as its main objective to develop and investigate several production methods in which hot-mix asphalts can be produced at lower temperatures than is conventionally the case.

The German road research association FGSV has adopted the DAV initiative. In France “warm asphalt mixtures” is one of the themes of the Motorway Innovative Chart signed between the Motorway Association (ASFA), the Road Contractors Association (USIRF) and the Road Directorate (SETRA).

2. Experimental

2.1 Warm asphalt mixtures (Niedrigtemperaturasphalt, NTA)

In order for this initiative to be effective, a requirement was that such asphalts should be able to be applied and compacted at the lower temperatures without any loss in workability and quality (fig 1). Since 2001, collaboration between the Mitteldeutsche Hartstein-Industrie AG (MHI) and EUROVIA has been ongoing to develop a method of producing hot-mix asphalts for road construction which can be mixed at lower temperatures than is usual and to introduce such mixtures to the international market.

Fig. 1. Construction site with warm AC 0/11.

Reducing production and application temperatures of hot-mix asphalts will result in a significant environmental contribution by lowering energy consumption. Furthermore, at lower temperatures fume emissions are significantly lower. In France and Germany, production of hot-mix asphalts is undertaken at temperatures between 150 and 250°C. Gussasphalt is normally manufactured at a temperature of around 250°C. Furthermore, occasionally it is necessary to manufacture at even higher temperatures in order to retain heat in the mixture to increase the period during which laying and compaction will be effective. Harder bitumens and some modified binders require higher production temperatures if mixing is to be effective.

2.2 Zeolite

One method of achieving lower temperatures is the addition of zeolite.

This involves adding some 0.3% zeolite to the mixture which has the effect of lowering production and laying temperatures by approximately 30°C.
Zeolites are crystalline hydrated aluminium silicates. Zeolites exist in the natural environment and are also produced artificially.

Synthetic zeolites are characterized by a very homogeneous structure and quality in which the granularity is of prime importance. Natural and synthetic zeolites have the ability to hold different quantities of water. How this water is released varies between different zeolites.

A special zeolite has been developed for use in lowering the temperatures at which asphalts are mixed. It is added to the hot mixture in the temperature range of 100 to 200°C during which it loses its crystalline water. The developed zeolite has been called “aspha-min”.

### 2.3. Production of warm asphalt mixtures

All bitumens normally used in asphalts including polymer modified bitumen can be used in this process. Furthermore, all mineral aggregates and fillers normally used for the production of asphalts can be used in this process. This means that no modifications are required to mixture designs and recipes. Also in the type testing procedures, no modifications are required. This additive increases workability at low temperatures. Depending on the type of asphalt mixing plant (batch plant or drum mixer) mixing temperature of between 130 and 145°C can be used. This means, in general, that a reduction of mixing temperature of approximately 30°C is possible.

The additive is stored at the mixing plant in a big bag or in a special silo (Fig. 2). It is added to the asphalt during mixing via special equipment, similar to that used when adding certain types of fibre. It is important that the addition of zeolite does not prolong the mixing process avoiding any possibility that the performance of the mixing plant is affected.

### 2.4 Characteristics of zeolite and how it works

![Fig. 3. Adding zeolite in a drum mixer.](image)

The structure of aspha-min is such that crystalline water is stored in the pores of the material. By adding it to the pre-heated mixture of sand and stone at the same time as the bitumen is being introduced, a water based vapour is created (fig. 3). This creates a controlled foaming effect which then creates an increased volume of the binder in the mixture. The resultant extremely fine foam creates micro pores which produces a mixture with higher workability. Thus, such asphalts can be more easily compacted.

A successful application results from the homogeneous addition of the aspha-min. It is important that the aspha-min particles lose their water content in several steps and not all at once. It was observed that it was possible to compact the mixtures down to a temperature of approximately 100°C. Thus, the workability of the mixture is increased without changing the temperature. Furthermore, no separation of the binder takes place in the mixing process which means that good adhesion between binder and aggregates is obtained.

![Fig. 4. Construction site with BBSG 0/14 + aspha-min](image)

All test sections constructed so far demonstrate that asphalts produced with aspha-min is not performing or behaving any differently from conventional asphalt mixtures produced without aspha-min (fig. 4).
2.5 Reduction of emissions

As it was important to determine the influence of the lower mixing temperature on emissions and energy consumption, a specific test programme was devised. The evaluation of the measurements indicated that a reduction of mixing temperatures of 30 to 35°C reduced energy consumption by 30% (fig 5).

Lower temperatures in the production process also mean a reduction in the emission of fumes and total particulate matter. Measurements (fig 6) have demonstrated the level of reduction achieved. Bitumen B 65 in Germany at a temperature of 168°C gave an emission of 350.7 mg/m³ of fumes and aerosols. At a production temperature of 142°C where zeolite had been added, the emission levels were found to have fallen to 90.4 mg/m³. Thus, this temperature drop of 26°C produced a reduction in fume emissions of some 75%.

Measurements at the application site have demonstrated even larger reductions (fig 6). In practice, reductions of over 90% were measured as the mixing temperature was reduced from 175°C to 140°C. Thus, a 35°C reduction in mixing temperature resulted in the emission level being 1/10 of what it was at the higher temperature.

Significant changes were also found in odour emission. Measurements have indicated that, in all cases where zeolite had been added and temperatures have been reduced, the number of odour units (GE’s) was reduced significantly. A number of truck drivers and members of the asphalt gang have suggested that when the asphalt was produced at lower temperatures, working conditions improved significantly.

2.6 Workability and performance

In general, all asphalts produced at lower temperatures with the application of zeolite could be handled in the same way as traditional asphalts produced at normal temperatures.

Comparative testing was done by the same asphalt gangs on similar stretches with similar types of asphalt mixtures. The only difference was the reduction in temperature.

In order to show the effectiveness of the aspha-min at a reduced mixing temperature, comparisons were made by laying a common asphalt mixture (French mixture type BBSG 0/10) both without and with (0.3%) aspha-min. The mixtures were placed in a layer of 50 mm thick binder course of BBSG 0/10 with 5.6% of 35/50 pen grade bitumen.

Comparative testing was done by the same asphalt gangs on similar stretches with similar types of asphalt mixtures. The only difference was the reduction in temperature.

In order to show the effectiveness of the aspha-min at a reduced mixing temperature, comparisons were made by laying a common asphalt mixture (French mixture type BBSG 0/10) both without and with (0.3%) aspha-min. The mixtures were placed in a layer of 50 mm thick binder course of BBSG 0/10 with 5.6% of 35/50 pen grade bitumen.

### Table 1. Stiffness modulus and void content for different mixtures.

<table>
<thead>
<tr>
<th>Asphalt type</th>
<th>Type of compaction</th>
<th>Samples</th>
<th>e (cm)</th>
<th>Voids (%)</th>
<th>Voids corrected for 6 cm (%)</th>
<th>Modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70°C w/o zeolite</td>
<td>Immediate</td>
<td>6.1</td>
<td>6.1</td>
<td>6.0</td>
<td>11.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deferred</td>
<td>4.9</td>
<td>8.0</td>
<td>4.4</td>
<td>19.30</td>
<td></td>
</tr>
<tr>
<td>140°C w/ zeolite</td>
<td>Immediate</td>
<td>4.8</td>
<td>5.3</td>
<td>6.6</td>
<td>12.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deferred</td>
<td>4.5</td>
<td>11.3</td>
<td>11.3</td>
<td>9.70</td>
<td></td>
</tr>
<tr>
<td>140°C w/o zeolite</td>
<td>Immediate</td>
<td>6.0</td>
<td>8.5</td>
<td>9.2</td>
<td>10.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deferred</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Production was done at two temperatures (170°C and 140°C) and with two modes of compaction, immediate and deferred.

The following test sections were constructed:-

- BBSG without zeolite at a mixing temperature of 170°C,
- BBSG with zeolite at mixing temperature of 140°C, and
- BBSG without zeolite at mixing temperature of 140°C.

The asphalt were mixed in a batch plant. Various parameters were measured from samples taken in the trucks at the production plant, on arrival at the site (after a transportation time of approximately 1 hour), in the hopper of the paver, in
the paver augur and at screed level after placement. The resultant values are depicted in table 1 and figures 8 and 9.

No problems were encountered in manufacturing BBSG 0/10 with Zeolite. It was noted that the asphalt containing zeolite mixed at 140°C had a void content within the specification of around 5.3% whereas the reference mixture without zeolite had a void content of around 6.7%. Moreover, the relative decline in the temperature of the asphalt from production through to placement was lower than was the case with the traditional mixture. Fig. 9 illustrates that the mechanical characteristics are unchanged as a result of adding zeolite.

2.7 User characteristics

Users expect roads to provide a comfortable and safe surface, regardless of whether the asphalt has been laid hot, warm or cold. Characteristics such as stability, skid resistance and durability must have the necessary values.

It is three years since the first asphalts containing zeolite were laid. Measurements on the stretches laid initially have indicated no significant changes in the surface characteristics and no deformation was found. All test sections were built to facilitate comparison to traditional asphalts. To date, NTA or Warm Asphalt Mixtures are directly comparable with conventional asphalts. Furthermore, the use of less heat in the production process means that there is less oxidation of the bitumen. This should improve the durability of the binder and therefore of the entire mixture and, in turn, the road surface. Cores taken from the laid sections appeared to be identical to those taken in pavements with traditional asphalts.

Evaluation of field test sections continues.

3. Conclusions

The addition of zeolite to asphalt mixtures has had no discernible effect on the mineral composition of the mixtures, the addition of recycled asphalt, the type and amount of binder or the addition of other possible additives in terms of the mixing time or the performance and characteristics. The addition of aspha-min into the mixing process did not create any special problems or limitations from a storage or handling viewpoint. The special purpose-designed equipment for adding the zeolite imposed no limitations and performed well.

The addition of zeolite did not prolong mixing times and the production effort was similar to that encountered with traditional hot-mix asphalts.

By reducing the mixing temperature by approximately 30°C, a lower energy consumption is necessary. This lower energy consumption results in lower CO2 emissions into the atmosphere. This, combined with a lower level of emissions of fumes and odour, makes a significant contribution to a better environmental performance.

Additional advantages are that wear and tear of asphalt mixing plants is reduced at lower temperatures. Lower mixing temperatures reduce the rate at which oxidation occurs improving durability of the mixture and the road in which it is placed.

Since 1998, laboratory and on-site testing has been undertaken. Tests were also performed during a variety of weather conditions, with mixtures containing different types of binder and some manufactured using a proportion of added recycled asphalt.

Materials have been laid ion temperatures as high as 30°C down to near freezing point. In all cases, no significant differences were apparent as compared to traditionally asphalts. Although the addition of zeolite increases the cost of the asphalt, savings can be obtained in energy reduction and wear and tear of the plant. Additional cost benefits, which are more difficult to calculate, are related to fume, odour and CO2 reduction as well as improved the working environment.

All these factors add significantly to the image of the asphalt industry and will contribute to the continued use of asphalts in road construction.

4. Acknowledgements

The authors are grateful to Dr Rühl of Berufsgenossenschaft for his support in executing the emission measurements.
In July 2004 all 73 entries on pages 57-59 of The Asphalt Yearbook 2004 were asked to send in corrections and/or amendments. The list below incorporates the information in the 36 replies received. Those 2004 entries from which we have not heard or for which we have no independent listing of details, are omitted this year, but the editor (cetpmenzies@btinternet.com) would be grateful for amendments and/or additions to the list below.

Note: all overseas telephone and fax numbers are shown as for dialling from the UK; if calling from elsewhere, please omit 00 and dial instead your own international access code, and if dialling UK numbers from outside the country, please use the appropriate international access code, followed by 44, and omit the first 0 of the number.

ARRB Transport Research Ltd: 500 Burwood Highway, Vermont South VIC 3133, Australia, tel 00 61 3 9887 8104, e-mail info@arrb.com.au, website www.arrb.org.au.

Arbit – German Bitumen Industry Association: Steindamm 55, D-20099 Hamburg, tel 00 49 40 2802939, fax 00 49 40 2802125, e-mail arbit@arbit.de, website www.arbit.de

Asfaltindustrien – Danish Asphalt Industries: Storholmen 91, DK-2650 Hvidovre, tel 00 45 3678 0822m fax 00 45 3677 1208, e-mail ai@asfaltindustrien.dk, website www.asfaltindustrien.dk

Asphalt Academy – AsAc: c/o Transportek CSIR, PO Box 395, Pretoria 0001, South Africa, tel 00 27 12-8412436, fax 00 27 12-8412350, e-mail asac@csir.com or patloots@iafrica.com, website http://asac.csir.co.za

Asphalt Recycling & Reclaiming Association – AAPT: #3 Church Circle – PMB 250, Annapolis MD 21401 tel 001 410 267 0023, fax 001 410 267 7546, e-mail krissoff@arra.org, website www.arra.org

Association of Asphalt Paving Technologists – AAPT: 4711 Clark Ave, Suite G, White Bear Lake MN 55110, tel 001 651 293 9188, fax 001 651 293 9193, e-mail AAPT@qwest.net, website www.asphalttechnology.org

Association of Equipment Manufacturers – AEM: 111 East Wisconsin Avenue, Suite 1000, Milwaukee WI 53202, tel 001 414 298 4152, fax 001 414 272 1170, e-mail cima@cimanet.com, website www.cimanet.com

Association of Planning Contractors: PO Box 252, Wallingford, OX10 6ZQ, tel 01491 835786, fax 01491 833332

Australian Asphalt Pavement Association – AAPA: Level 2, 5 Wellington Street, Kew VIC 3101, tel 00 61 3 9853 3595, fax 00 61 3 9853 3484, website www.aapa.asn.au

British Standards Institution – BSI: 389 Chiswick High Road, London W4 4AL, tel 020 8996 9000, fax 020 8996 7400

Building Centre: 26 Store Street, London WC1E 7BT, tel 020 7692 4000, fax 020 7580 9541

Building Research Establishment – BRE: Garston, Watford WD2 7JR, tel 01923 664000, fax 01923 664010

Civil Engineering & Transport Publications: PO Box 31, Bognor Regis PO22 0DX, tel 01243 551199, e-mail cetpmenzies@btinternet.com

Commission of the European Communities – representation in the United Kingdom: 8 Storey’s Gate, London SW1P 3AT, tel 020 7973 1992, fax 020 7973 1900 or 1910, website: www.europe.org.uk

Construction Industry Computing Association: 1 Trust Court, Histon, Cambridge CB4 9PW, tel 01223 236336, fax 01223 236337, e-mail postmaster@cica.org.uk, website www.cica.org.uk

Construction Industry Research and Information Association – CIRIA: Classic House, 174-180 Old Street, London EC1V 9BP, tel 020 7549 3300, fax 020 7253 6523, e-mail enquiries@ciria.org, website www.ciria.org

Construction Industry Training Board – CITB: Bircham Newton, King’s Lynn PE31 6HR, tel 01485 577577

Construction Products Association: 26 Store Street, London WC1E 7BT, tel 020 7323 3770. fax 020 7323 0307, e-mail enquiries@constprod.org.uk, website www.constprod.org.uk

PROFESSIONAL AND TRADE BODIES RELATED TO ASPHALT
Deutscher Asphaltverband / Deutsches Asphaltinstitut – DAV/DAI: Schleiflingweg 6, D-53123 Bonn, tel 00 49 228 979650, fax 00 49 228 9796511, e-mail dav@asphalt.de, website www.asphalt.de

EPIC Training and Consulting Services Ltd – the training and consulting services organisation for the extractive and mineral processing industries: Alban Row, 27-31 Verulam Road, St Albans AL3 4DG, tel 01727 869006, fax 01727 843318, e-mail clivewebb@epicltd.co.uk, website www.epicltd.com

European Asphalt Pavement Association – EAPA: Postbus 175, NL 3620 AD Breukelen, tel 00 31 3462 66868, fax 00 31 3462 63505, e-mail info@eapa.org, website www.eapa.org

European Bitumen Association – Eurobitume: Boulevard du Souverain 165, 4th floor, B-1160 Brussels, tel 00 32 2 566 91 40, fax 00 32 2 566 91 49, website www.eurobitume.org

European Committee for Standardisation – CEN, Central Secretariat: rue de Stassart 36, B-1050, Brussels

Federation of Road Surface Treatment Associations – FORSTA: PO Box 986, Chester CH4 8XD, tel/fax 01244 677648, e-mail secretary.forsta@btconnect.com, website www.forsta.co.uk

Freight Transport Association – FTA: Hermes House, St John’s Road, Tunbridge Wells TN4 9UZ, tel 01892 526171, fax 01892 534989, website www.fta.co.uk

German Road and Transportation Research Association – Forschungsgesellschaft für Strassen- und Verkehrswesen: Konrad-Adenauer-Strasse 13, D-50996 Köln, tel 00 49 221 93583-11, fax 00 49 221 93583-75, e-mail konitzer@fgsv.de, website www.fgsv.de

GESTRATA – Austrian Asphalt Contractors’ Association: Karlsgasse 5, A-1040 Vienna, tel 00 43 1 504 15 61, fax 00 43 1 504 15 62, e-mail gestrata@asphalt.or.at, website www.asphalt.or.at

Health and Safety Executive – HSE: Magdalen House, Trinity Road, Bodelo L2 3QZ, tel (HSE Infoline) 08701 545500, fax 02920 859260, e-mail hseinformationservice@nabrit.co.uk, website www.hse.gov.uk

High Friction Surfacing Association – HFSA: PO Box 986, Chester CH4 8XD, tel/fax 01244 677648, e-mail secretary.hfsa@btconnect.com, website www.hfsa.org.uk

Highways Agency: 123 Buckingham Palace Road London SW1W 9HA, tel 020 7153 4779, fax 020 7153 4786, website www.highways.gsi.gov.uk (G Clarke, Chief Highway Engineer)

Institute of Highway Incorporated Engineers – IHIE: De Morgan House, 58 Russell Square, London WC1B 4HS, tel 020 7436 7487, fax 020 7436 7488, e-mail secretary@ihie.org.uk, website www.ihie.org.uk

Institute of Quarrying – IoQ: 7 Regent Street, Nottingham NG1 5BS, tel 01159 411315, fax 01159 484035, e-mail iq@qmj.co.uk, website www.qmj.co.uk

Institution of Civil Engineers – ICE: One Great George Street, London SW1P 3AA, tel 020 7222 7722, fax 020 7222 7500, e-mail library@ice.org.uk, website www.ice.org.uk

Institution of Highways & Transportation – IHT: 6 Endsleigh Street, London WCH 0DZ, tel 020 7387 2808, e-mail info@iht.org, website www.iht.org

International Road Federation – IRF: 2 Chemin de Blandonnet, CH-1214 Vervier, Geneva, tel 00 41 22 42 306 02 60, fax 00 41 22 306 02 70, e-mail info@irfnet.org

International Society for Asphalt Pavements – ISAP: 4711 Clark Ave Suite G, White Bear Lake MN 55110, e-mail ISAPave@quest.net

Mastic Asphalt Council – MAC: Claridge House, 5 Elwick Road, Ashford, Kent TN23 1PD, tel 01233 634411, fax 01233 634466, e-mail mascalhtcfc@aol.com

National Asphalt Pavement Association – NAPA: Building, 5100 Forbes Boulevard, Lanham, Maryland 20706-4407, tel 00 1 301 731 4748, fax 00 1 301 731 4621, e-mail napa@hotmail.org

National Center for Asphalt Technology – NCAT: 277 Technology Parkway, Auburn AL 36830, tel 00 1 334 844 6202, fax 00 1 334 844 6248, e-mail vinnie@eng.auburn.edu, website www.ncat.us

Northern Ireland Department for Regional Development – Roads Service: Clarence Court, 10-18 Adelaide Street, Belfast BT2 8GB (G W Allister, Director of Engineering)

Quarry Products Association – QPA: Gillingham House, 38-44 Gillingham Street, London SW1V 1HU, tel 020 7963 8000, fax 020 7963 8001, website www.qpa.org

Refined Bitumen Association – RBA: Crowthorne House, Nine Mile Ride, Wokingham RG40 3GA, tel 01344 769059, fax 01344 684773, e-mail tonyh.rba@btconnect.com, website www.bitumenuk.com

Road Surface Dressing Association – RSDA: Westwood Park, London Road, Little Horkesley, Colchester CO6 4BS, tel 01206 274052, fax 01206 274053, e-mail jlxgter@rsda-gb.co.uk, website www.rdsa-gb.co.uk
Road Users' Alliance – RUA: Delegate House, 30A Hart Street, Henley-on-Thames RG9 2AL, tel 01491 578761, fax 01491 579835, e-mail info@rua.org.uk , website www.rua.org.uk

SITEB – Italian Asphalt Road Association: Via G A Guattani No 24, I-00161 Rome, tel/fax 00 39 644 23 32 57, e-mail siteb@siteb.it, website www.siteb.it

Scottish Executive – Chief Road Engineer: Victoria Quay, Edinburgh EH6 6QQ (J Howison, Chief Road Engineer)

Slurry Surfacing Contractors’ Association – SSCA: PO Box 986, Chester CH4 8XD, tel/fax 01244 677648, e-mail secretary.scca@btconnect.com , website www.scca.uk.com

Society for Asphalt Technology – SAT: c/o Transportek CSBR, PO Box 395, Pretoria 0001, South Africa, tel 00 27 12—8412436, fax 00 27 12-8412350, e-mail patloots@iafrica.com , website http://www.socsat.co.za

Society of Chemical Industry – SCI (Construction Materials Group): 14/15 Belgrave Square, London SW1X 8PS, tel 020 7598 1500, fax 020 7245 1279, e-mail Nicole.honeyghan@soci.org, website www.soci.org

Southern African Bitumen Association – Sabita: Postnet Suite 56, P/Bag X21, Howard Place, 7405, South Africa, tel 00 27 21 5312718, fax 00 27 21 5312606, e-mail info@sabita.co.za, website www.sabita.co.za

Transportation Research Board – TRB: National Academy of Sciences, National Research Council, 2101 Constitution Avenue, Washington DC 20418

Union des Syndicats de l’Industrie Routière Française – USIREF: 10 rue Washington, F-75008 Paris, tel 00 33 1 44 13 32 90, fax 00 33 1 42 25 89 99, e-mail usiref@usiref.com, website www.usiref.com

VWB Asfalt – Dutch Asphalt Association: Postbus 68, NL 3620 AB Breukelen, tel 00 31 34626 2644, fax 00 31 34626 3505, website www.vwbasfalt.org/content/english.htm


World Road Association – PIARC Association Mondiale de la Route – AIPCR: La Grande Arche Paroi Nord, Niveau 8, F-92955 Paris La Defense Cedex, tel 00 33 1 4796 8121, fax 00 33 1 4900 0202, e-mail piarc@wanadoo.fr , website www.piarc.kcpc.fr

Other internet sites containing information on bitumen and asphalt topics

Asphalt Emulsion Manufacturers’ Association: www.aema.org

American Association of State Highway and Transportation Officials: www.aashto.org

Belgian Road Research Centre: www.waw.be/brrc

Benelux Bitume: www.beneluxbitume.org

California Advanced Transport Technologies Industries Association: www.calstart.org

Institute of Roofing: www.instituteofroofing.org.uk

International Slurry Surfacing Association: www.history.rochester.edu/SSSA

Ontario Hot Mix Producers Association: www.ohmpa.org

Swedish Asphalt Pavement Association: www.fas.se

Swedish National Road and Transport Research Institute: www.vti.se

The National Highway Institute: www.nhi.fhwa.dot.gov (please note: the “dot” in the site address stands for Department of Transportation and is not a “.”)

Transportation Research Forum: www.utexas.edu/depts/ctr.trf/