Mission

Sabita is recognised as the centre of excellence for bituminous products through technological advancement and the promotion of cost-effective and sustainable use of these products.

Vision

Sabita will:

• Identify the need for and develop and advance best available technology and practice in bituminous materials in South Africa;

• Engage stakeholders to promote the social and economic value of road provision and preservation, and the efficient delivery thereof;

• Develop and promote the use of environmentally sound products and practices in the bituminous products industry;

• Advance best practice in southern Africa with regards to worker health and safety;

• Provide education and training schemes to develop skills and competencies that are sustainable and aligned to industry needs;

• Assist members in meeting the demands of clients by disseminating information on bitumen supply and consumption that it may legally do.
Manuals published by Sabita

Manual 1  Technical guidelines: Construction of bitumen rubber seals
Manual 2  Bituminous products for road construction and maintenance (to be revised) (CD)
Manual 3*  Test methods for bitumen rubber
Manual 4*  Specifications for rubber in binders
Manual 5  Guidelines for the manufacture and construction of hot mix asphalt
Manual 6*  Interim specifications for bitumen rubber
Manual 7  SuperSurf: Economic warrants for surfacing unpaved roads
Manual 8  Guideline for the safe and responsible handling of bituminous products (CD)
Manual 9**** Bituminous surfacings for low volume roads and temporary deviations (CD)
Manual 10  Bituminous surfacings for temporary deviations
Manual 11  Labour enhanced construction for bituminous surfacings
Manual 12  Methods and procedures - Labour enhanced construction for bituminous surfacings (CD)
Manual 13  LAMBS - The design and use of large aggregate mixes for bases
Manual 14*** GEMS - The design and use of granular emulsion mixes
Manual 15*  Technical guidelines for seals using homogeneous modified binders
Manual 16** REACT - Economic analysis of short-term rehabilitation actions
Manual 17  The design and use of porous asphalt mixes (CD)
Manual 18  Appropriate standards for the use of sand asphalt
Manual 19  Guidelines for the design, manufacture and construction of bitumen-rubber asphalt wearing courses
Manual 20  Sealing of active cracks in road pavements
Manual 21*** ETB: The design and use of emulsion treated bases
Manual 22  Hot mix paving in adverse weather
Manual 23  Code of Practice: Loading bitumen at refineries (CD)
Manual 24  User guide for the design of hot mix asphalt
Manual 26  Interim guidelines for primes and stone precoating fluids (under review)
Manual 27  Guideline for thin layer hot mix asphalt wearing courses on residential streets
Manual 28  Best practice for the design and construction of slurry seals (CD)
Manual 29  Guide to the safe use of solvents in a bituminous products laboratory (CD)
Manual 30  A guide to the selection of bituminous binders for road construction (CD)
Manual 31  Guidelines for calibrating a binder distributor to ensure satisfactory performance (CD)
Manual 32  Best practice guideline and specification for warm mix asphalt (CD)

* These manuals have been withdrawn and their contents have been incorporated in a manual entitled: The use of modified binders in road construction published as Technical Guidance 1 by the Asphalt Academy.
** This manual has been withdrawn and its software programme incorporated in TRH12: Flexible pavement rehabilitation investigation and design.
*** These manuals have been withdrawn and their contents have been incorporated in a manual entitled: Bitumen stabilised materials published as Technical Guidance 2 by the Asphalt Academy.
**** This manual has been withdrawn and its contents have been consolidated with the second edition of Manual 10.

Technical guidelines

TG1  The use of modified binders in road construction
TG2  Bitumen stabilised materials
TG3  Asphalt reinforcement for road construction
Sabita DVD Series

DVD100 Testing of bituminous products
  • Penetration bitumen tests
  • Bitumen emulsion tests
  • Hot mix asphalt tests
  • Bitumen rubber tests

DVD200 Repair of blacktop roads
  • Training guide for the construction and repair of bituminous surfacings by hand

DVD300 Hot mix asphalt
  • Manufacture, paving and compaction of HMA

DVD410 The safe handling of bitumen

DVD420 Treatment of bitumen burns

DVD430 Working safely with bitumen

DVD440 Firefighting in the bituminous products industry
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GB5: Innovative design of high-performance asphalt mixes for long life and cost-effective pavements by optimising aggregates and using SBS modified bitumens: Olard

Transfer of high modulus asphalt technology to South Africa: Denneman et al

Development of human resources, systems and procedures for optimal preservation of road assets

Tendering for professional services: both sides of the coin: Liebenberg and Wilson

Overview of a pavement management system in a toll road context: Judd, Tolmie and Jooste

Speciality session – Bitumen technology
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Laboratory practice  
Performance grading of bitumen  
Extending the window of sealing operations  
Human resources  
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Reduced impact on the environment and consumption of non-renewable resources

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Revision of the SA national specifications on asphalt  
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The implications of the Air Quality Act for the asphalt industry: Ferreira

High Modulus Asphalt technology transfer successfully completed: Denneman

Milestones in the introduction and use of warm mix asphalt in South Africa: Lewis and Naidoo
Readers should note that graphics in this publication are numbered as they appear in their papers of origin, and the numbering is therefore not sequential.
Foreword

CAPSA’11, held at the Champagne Sports Resort in KwaZulu-Natal in September 2011, had the primary objective of advancing sustainable practice in southern Africa’s bituminous products sector. The conference theme, *Roads of the future - living within the carrying capacity of our planet*, expressed the burgeoning commitment of our industry to achieve best practice while ensuring human well-being and conserving our environment and resources.

This commitment was reflected in the record attendance of 492 delegates representing 22 countries – one of the highest attendances of any previous CAPSA. A further record of note was the shift of delegate age to younger practitioners, with an increase in the number of delegates on both the 20 - 29 and 30 – 39 yr. age groups since 2004. Both the attendance and age breakdown figures are evidence of the new ethos of concern for the preservation of our world that dominates modern thinking.

The conference was structured for maximum interaction between delegates to create a mentoring environment in which younger delegates could learn from more experienced practitioners. As such, the programme featured two plenary sessions focussed on reducing the impact of road building on the environment, and on limiting energy consumption in the construction of bituminous layers. Other technical sessions were held in parallel, based on diverse interests of delegates. Also, all papers accepted for the conference were presented, either in plenary sessions, parallel sessions or workshops.

Positive response

The programme and presentations drew highly positive responses from both local and international delegates, establishing yet again that CAPSA remains one of the world’s most prestigious flexible pavement conferences.

As with previous CAPSAs, a comprehensive entertainment programme began with an ice-breaker cocktail party, guided tours to sites of local interest near the conference venue, an exhibitors’ function, all culminating in a Gala Dinner featuring music, dancing and entertainment.

It is important to note that CAPSA’11 was a direct development and continuation from CAPSA’07, which was regarded as a particularly successful conference in its focus on realism and practicality dictated by its theme of consolidating best practice.

An additional feature of that conference was its challenge to organisations such as Sabita, the Asphalt Academy, the Society for Asphalt Technology and the Road Pavements Forum to ensure that particular issues are examined to promote the on-going implementation of best practice.
While the main body of this Digest contains an abstract of the outputs of CAPSA’11, it also includes a section containing invited contributions on themes underpinning these outputs. The Digest may be read in conjunction with the CAPSA’11 CD, which contains the full proceedings of the conference and is available from Sabita.

Sabita offers grateful thanks to the CAPSA’11 executive committee (shown below) for their contribution in organising the conference, to Piet Myburgh who selected and edited the material, and to those authors whose papers are featured.
1

CAPSA’11: The Conference
The background, underlying environment and selection of a theme for CAPSA 11

A framework for developing a theme and objectives

“The balance of evidence suggests a discernible human influence on global climate”. Intergovernmental Panel on Climate Change¹

In September 2009, the Steering Committee of CAPSA affirmed that in 2011 CAPSA would advance sustainable practice within the flexible pavement sector through a programme based on three pillars:

- Industry commitment;
- Environmental stewardship;
- Human well-being.

It was noted that since the turn of the century, prompted by a rapid growth in global awareness of the threat posed by the human-induced enhanced greenhouse effect (largely arising from forest clearing and the burning of fossil fuels), more specific and detailed initiatives have led to widespread understanding and awareness of the importance of sustainability.

Sustainability is defined by the IUCN², UNEP³ and WWF⁴ as:

*Improving the quality of human life while living within the carrying capacity of supporting eco-systems.*

This definition lead to the adoption of the theme for CAPSA 11: *Roads of the future - living within the carrying capacity of our planet.*

**Industry commitment**

It was argued that industry should view CAPSA 11 as an opportunity to demonstrate its willingness to set the achievement of economic goals and profitability side by side with sound practice in which quality is pursued within a framework that will not compromise human well-being nor do damage to the environment.

Consequently CAPSA should offer opportunities to:

- Establish contact and interaction with international experience, policy and legislation to ensure that local practice is aligned to best available global technology;
- Explore means whereby the use and application of bituminous products (including beneficiation components) can be exploited as being conducive to sustainable practice through long-life and durable products;
- Foster an awareness of the need to be legally compliant and a duty of care towards employees, society and the environment; and
- Develop and support sustainable human capacity building programmes in the roads industry.

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¹ Jointly supported by the World Meteorological Organisation and the United Nations Environmental Programme;
² International Union for Conservation of Nature;
³ United Nations Environmental Programme;
⁴ World Wide Fund for Nature.
Environmental stewardship

Four aspects of environmental conservation that impinge on the operations and activities of the roads industry in general and the bituminous product industry in particular are:

- Reduced reliance on non-renewable resources;
- The release of harmful emissions into the atmosphere; and
- Contamination of water resources; and
- Noise.

Topic areas identified to be explored under each of these fields are:

1. Reduced reliance on non-renewable resources.
   1.1 Compilation and analysis of comparative life cycle assessment of road building materials, from source to application;
   1.2 Development and adoption of appropriate criteria (inclusive of sociological aspects) for the surfacing of gravel roads;
   1.3 Promotion of lower temperatures in the manufacture and application of bituminous products;
   1.4 Advancing the utilisation of hydrocarbon and mineral assets in roads through the re-use and recycling of asphalt;
   1.5 Effecting reduced whole life road pavement costs and congestion costs through improved durability of pavement layers and longer life pavements;
   1.6 Use of alternative materials (e.g. industrial waste products, building rubble) in the construction of road pavements;
   1.7 Adoption of technologies that have the potential to reduce heat island effects in urban environments; and
   1.8 Asphalt surfaces for reduced rolling resistance and hence improved fuel consumption of (especially) heavy vehicles.

2. Diminished emissions into the atmosphere.
   2.1 Developing an improved understanding of the adverse health effects associated with the discharge of particulate matter (e.g. respirable silica) during quarrying, manufacture, processing, application and milling operations and use of gravel roads and adopting measures to limit exposure levels;
   2.2 Defining the nature and extent of greenhouse gasses – notably CO₂ – and promoting measures to mitigate their adverse effects on employees and society; and
   2.3 Defining and, if necessary, promoting methods and procedures for reduced discharge of PAH’s associated with (modified) bituminous binders.

3. Contamination of water resources.
   3.1 Water conservation and improved land use through run-off management and cleansing by means of the application of porous reservoir asphalt pavements;
   3.2 Disposal of waste to permitted landfill sites; and
   3.3 Discontinuation of the use of coal tar (this has largely been achieved).

4. Noise: Review asphalt technology to combat traffic/surface noise generation (e.g. porous asphalt and UTFC’s).
Human wellbeing

Human well-being covers those persons employed in the industry and those sections of the community that are affected by the operations of the roads industry i.e. society that depends on transport infrastructure and those sections residing in close proximity to operations conducted by the bituminous product industry.

Employees

The potential for cooperation between client bodies and contractors and suppliers should be explored to mitigate exposure of workers to hazards during road works and manufacturing and application of bituminous products. These initiatives could cover:

1.1 Methods and procedures that would reduce risk of injury or loss at road works sites;
1.2 A critical review and appraisal of hazards associated with various manufacturing, processing and application activities; and
1.3 Advancing the use of safe substances and procedures in testing laboratories.

Affected society

In addition to the issues affecting society covered in the section Environmental stewardship above, the following areas should be considered:

2.1 Noise and nuisance to communities in close proximity of industrial set-ups and establishments;
2.2 The safety of road users both during temporary works entailing the application of bituminous products and the exposure to travel on finished surfaces; and
2.3 Sustainable employment creation through innovative technology and management approaches.

Mitigation and adaptation

The above relate mainly to mitigation i.e. to prevent undesirable consequences or to lessen their impact of industry products and services on the environment and climate change.

In addition, however, road engineers need to assess the vulnerability of their road networks in terms of climate change and, in the medium term, develop adaptation strategies and design codes that will ensure their long-term viability. Issues that come to the fore are:

1. Increased run-off and moisture and its effect on pavement strength and capacity;
2. Increased ambient temperatures and its adverse effect on thermoplastic bituminous pavement layers; and
3. Increased solar radiation and its effect on the durability of asphalt layers.
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Role and function of CAPSA

The primary purpose of CAPSA since its inception in 1969 has been to advance technology associated with flexible pavement engineering and material science in general and, more specifically, technology associated with the bituminous products and asphalt industries.

CAPSA has achieved notable success in these arenas, and has been acknowledged as having played a major role in various fields that have become entrenched in southern African practice, notably:

- Analytical flexible pavement design methods and performance modelling;
- Pavement management and inventory systems;
- Testing accuracy and rational quality management procedures;
- Maintenance management covering:
  - Surveillance procedures; and
  - Diagnostic descriptions of pavement conditions; and
- Noise reduction and safe surfaces.

There are therefore sufficiently encouraging incentives for CAPSA to continue on this road of continually assessing the areas in need of development, both in the light of international trends and specific regional needs. The challenge for the organisers of each conference remains to develop conference programmes that tackle the needs of southern Africa within the context of prevailing global or regional socio-economic circumstances. In doing so CAPSA will once again take pavement technology and material science to a new level that will ultimately benefit the region.

Given this motivation, and taking into account pressing issues such as the need to advance sustainable practice as described above, the organisers were in a sound position to present CAPSA'11.

Impetus provided by CAPSA'07

CAPSA'07, by its very nature, provided the impetus for developing the technical content for this conference. It was regarded as a particularly successful conference, this success deriving mainly from the realism and practicality dictated by its theme of consolidating best practice.

It was clear from the various reports of the conference that many advances were made in consolidating best practice and in generating the knowledge and tools needed to address current and future problems. Although many challenges remain, it was shown that problem solving in an open system (such as the roads building industry), is seldom convergent, and problems in such a system tend to persist in a cyclical manner. However, by generating awareness, knowledge and tools related to these problems, progress can be made towards addressing problems with what is available at the time.

Notwithstanding the significant progress stimulated by CAPSA since 1969, it was evident that implementation of available knowledge and tools is the domain in which
most challenges remain, and in which the least progress has been made. A key cause of this was deemed to be the lack of appropriate growth in human resources, and the associated loss of experienced practitioners for various reasons. Consequently a clear conclusion of CAPSA’07 was that progress made with respect to asphalt pavements for southern Africa was critically dependent on human resource development, and on the development of design tools and technology transfer mechanisms suited to the current human resource realities.

This then was the challenge put to CAPSA’11. The need to provide structured continuity to the energy generated at conferences was noted, and practitioners and organisations in southern Africa - such as Sabita, the Asphalt Academy (AsAc), and the Society for Asphalt Technology (SAT) were challenged to examine how the proceedings of the existing forums, e.g. the Road Pavements Forum (RPF) and technical seminars, can be reinforced so that particular issues could be examined in detail and implementation of best practice can be advanced.

Specific areas that posed ongoing challenges to the flexible pavement practice were:

- Variability and risk issues related to quality assurance and pavement design;
- Health, safety and the environment;
- Design of hot mix asphalt;
- Structural pavement design;
- Problems related to surface seals.

**Formulation of conference programme in terms of the themes**

**Focus areas descriptions**

A distillation of the conference framework described above yielded the following focus area descriptors, which formed the basis of developing the conference programme:

**Focus area 1:** *Reduced energy consumption in the construction of bituminous layers.*
Coordinator: Krishna Naidoo (eThekwini Municipality)

**Topics:**
1. Lower temperatures in the mixing and laying of durable asphalt and bitumen stabilised materials;
2. Re-use and recycling of asphalt;
3. Potential for the use of industrial and demolition waste in road layers.

**Focus area 2:** *Reducing the impact of road building activities on the environment.*
Coordinator: Saied Solomons (Sabita)

**Topics:**
1. The development and use of life cycle inventories and life cycle assessments for bituminous pavement layers;
2. Reduction and management of harmful emissions associated with bituminous products;
3. Pavement material selection to lessen the depletion of natural resources;
4. Proper disposal of bituminous waste;
5. Asphalt surfaces for improved fuel economy and mitigation of road noise.

**Focus area 3:** *Designing for extended performance of bituminous layers*  
Coordinators: H Marais (Much Asphalt), K Louw (Colas)

**Topics:**
1. The introduction of mix design procedures for improved durability and performance characteristics of asphalt and bitumen stabilised materials;
2. Ultra-thin asphalt layers, spray seals and microsurfacing for high performance areas;
3. Designing wearing courses to meet road user needs in terms of comfort and safety.

**Focus area 4:** *Flexible pavement systems for extended life*  
Coordinator: B Verhaeghe (CSIR Built Environment)

**Topics:**
1. Balanced structural pavement design procedures for a broad range of operating conditions;
2. Optimal design or rehabilitation strategies and total whole life cost assessments for roads in both urban and rural locations;
3. Methods and procedures for assessing the costs of periodic interventions;
4. Impact of climate change on road pavements and evolving adaptation strategies;
5. Long life asphalt pavements to minimise frequent interventions and disruptions to traffic flow.

**Focus area 5:** *Asset management*  
Coordinator: A Taute (VelaVKE)

**Topics:**
1. Exploiting bituminous product technology to provide sustainable employment, to improve access and mobility and to optimise whole life costs;
2. Economic sustainability through the procurement and management of bituminous roads;
3. Meeting the needs for capacity and skills development in the bituminous products industry;
4. Bituminous roads and pathways as a means to advance equity in the production and sale of goods and services;
5. Ensuring the safety of road users and employees during road works.
The conference
Venue and attendance

The 10th Conference on Asphalt Pavements for Southern Africa was held from 11 – 14 September 2011 at the Champagne Sports Resort in the Drakensberg KwaZulu-Natal in South Africa. The duration of the conference was curtailed to three full days, and the compact programme allowed for:

- Four plenary sessions (Keynote, two technical, Closing plenary);
- Eight parallel technical sessions (two at a time);
- 23 parallel workshop sessions (up to five at a time).

Delegate profile - the need to attract African delegates

CAPSA’11 drew one of the highest attendances of any previous CAPSA. The 492 delegates represented 22 different countries, with South African representation predictably the highest at 87%. Only 3% of delegates representing Africa (nine countries) and drawing delegates from elsewhere in Africa remains a challenge. This should serve as an incentive to future steering committees to take up this challenge and canvass actively for an appropriate level of African participation. Delegates representing countries such as Australia, New Zealand, France, Germany, the UK and USA, and China, among others, made up 10% of the delegates to CAPSA’11. The delegate profile is shown in Figure 1.

In terms of delegate sector profile the consultant sector was, as in the past, the dominant sector, followed by public sector employees. Suppliers of products and services were also well represented. Not unexpectedly, the consultancy and academia sectors submitted most papers. The sector profile is shown in Figure 2.
What was also very encouraging was the shift of delegate age to the younger grouping. As pointed out by CAPSA Chairman Phil Hendricks, there was an increase in the number of delegates on both the 20 - 29 and 30 – 39 yr. age groups since 2004, as shown in Figure 3.
Opportunities for interaction

Mindful of the need for contact between young and more seasoned professionals, the programme provided ample opportunity for interaction and information exchange in workshops and parallel technical sessions.

The CAPSA’11 programme structure provided for two plenary technical sessions with focus areas closely related to the overall conference theme. Other technical sessions were held in parallel, based on diverse interests of delegates. Also, all papers accepted for the conference were presented, either in plenary sessions, parallel sessions or workshops, and are available on the website www.capsa11.co.za.

In view of their close correspondence to the theme of the conference the following sessions were held in plenary format:

- Reduced impact of road building activities on the environment;
- Limiting energy consumption in the construction of bituminous layers.

The focus of the other technical sessions acknowledged the increasing importance of developing longer lasting (i.e. more durable) products and pavement layers that underpin sustainable practice. Subsequent conference sessions included parallel speciality sessions to cater for diverse interests, and parallel workshops to offer all delegates the opportunity to participate in the proceedings of CAPSA’11.

In addition, six parallel specialty sessions addressed the following topics:

- Pavement design systems;
- Thin surfacings – surface texture and safety;
- Materials characterisation;
- Airport pavements;
- Asphalt mixtures;
- Bitumen stabilised materials;
- Development of human resources, systems and procedures for optimal preservation of road assets;
- Bituminous binders.

The total of 23 parallel workshop sessions, with up to five running simultaneously at any time, were designed to supplement the content of plenary and speciality sessions and to encourage delegate interaction – particularly between seasoned professionals and novices - while promoting the theme of sustainability, covered, inter alia, topics such as:

- Recyclable materials;
- Reconstituting bitumen rubber and the use of industrial waste;
- Warm mix asphalt;
- Accreditation/certification of cold mix asphalt and other bituminous products;
- Delivery;
- Appropriate standards for low volume sealed roads;
- Measurement of energy savings and reduced emissions;
- Pavement design approaches;
- Design of hot mix asphalt;
- Slurry seal design (launch of Sabita Manual 28);
- Performance grading of bitumen.
**Inputs-outputs, highlights per focus area**

In covering the content of these focus areas, not all papers are dealt with in this publication, for practical reasons. Consequently, papers deemed to define milestones of progress in the topic area and/or giving firm indications or direction to future practice in flexible pavement engineering, have been singled out. Practitioners who did not attend the CAPSA’11 can obtain copies of all the papers accepted for the conference from www.capsa11.co.za.
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Keynote Session:

Guest speakers

Jonathan Hanks
and Steve Muench
Keynote session

Two guest speakers were invited to give presentations that were central to the theme of the conference and which, it was anticipated, would give impetus to the move towards more sustainable practice in the pavement engineering sector in roads and airport provision and preservation.

The keynote speakers were:

- Jonathon Hanks, cofounder of Incite Sustainability, an organisation championing sustainability as a driver for fundamental change in the world of business. Hanks is a senior lecturer at the UCT Graduate School of Business, and regular contributor to executive and practitioner courses run by the University of Cambridge’s Programme for Sustainability Leadership; and
- Stephen Muench, Associate Professor Construction Engineering, University of Washington and member of the board of Greenroads™.

The commercial imperative for environmental practice – doing business in the context of turbulence: Jonathan Hanks

Opening his address, Hanks said there was a need to change the way that business understands sustainability and the way that people who wish to advance sustainability understand business.

His presentation dealt with three issues:

- An underlying assumption: we have a problem, but are in denial;
- Facing up to the changing context: doing business in turbulence;
- The commercial rationale: understanding value creation, followed by some concluding remarks.

In denial

Boardrooms and civil society appeared to be in denial regarding the extent of the challenges facing us. Hanks asserted that “sustainable development” was a dirty word in many boardrooms and business leaders were not driving the innovation we need to see. He added that sustainability was:

- Marginalised into gestures such as “giving back” through corporate social investment programmes;
- Standardised into compliance checklists (e.g. EIA);
- Popularised as being about the “triple bottom line”.

"We are staring into a deep abyss. We need to do more than comply with standardised checklists and it would be naïve to deny that there is only one bottom line in business," he said.
In 2008 the global economy hit the wall – was this situation more fundamental than a deep recession? One also had to question whether the growth model developed 50 years ago was sustainable. It seemed as if we had hit a wall when *Mother Nature* and the market said – “no more”.

Business had an outdated approach to value creation. “It was optimising short term financial performance in a bubble” according to Michael E. Parker - while sustainable practice was popularised through expressions like “triple bottom line”.

**Increasing turbulence**

Global economy and populations are growing, the former being five times what is was a half century ago, and world population having grown to seven billion. This growth was enabled through access to cheap energy and readily available raw materials. A change of direction is need – from “north” to “south”. It seems as if business is merely going “south more slowly”.

Commodity prices, having declined in real terms at an average rate of 1.2% pa between 1990 and 2002, have since seen a dramatic increase, probably through increased demand from developing countries such as China and India.

We are in a critical position, facing:

- Decreasing resources;
- Increased consumption;
- Increased social turbulence (due to increasing wealth inequalities).

Like many civilisations before us, we may face a collapse, unless we fundamentally change the way we do business.
Understanding value creation

Sustainability is an approach which seeks to create value (profit, economic growth) that sustains the systems and resources (capital stocks) on which this value depends. In the finite and closed environment offered by the planet, our capacity to generate financial capital is dependent on human and social capital - which relies on natural capital seated in the environment. As an example Hanks indicated that during the period 1955 - 1998 the Chinese construction industry was raiding forests leading to a loss of ecosystem services (e.g. flood damage and lost nutrients) that amounted to $12.2 billion annually – almost double the value of timber harvested per year. Our accounting systems fail to factor in these losses.

Instead of regarding environmental issues as peripheral, these should be internalised. The figure below is a simple illustration on how climate change may impact on and drive business.

This leads to challenges over and above those generated by macro-economic indicators:

- Availability and costs of commodities like energy, water and transportation;
- Availability of skilled labour;
- Exposure to volatility in weather.
Key drivers that will influence business performance are:

- Increased demand for new infrastructure;
- Shift in demand for building materials;
- Project delays due to extreme weather conditions;
- Increased costs associated with carbon-intensive raw materials, products and raw materials;
- Shift in investments depending on project exposure and more/less carbon-intensive products/processes.

The future

We are facing a number of challenges and indications are that smart business is facing up to these challenges. Hanks concluded his presentation on a sombre note. There is a concern that government, business and civil society as a whole are failing to learn from history - that we cannot sustain our current way of life. We are threatened by a “dark force” which is our way of life.

His presentation should serve as a reminder to us that, within our sector, we should pursue with vigour designs, methods and procedures that do not unduly consume our human, social and environmental capital stocks, thereby underpinning collective impetus to save the planet.
Greenroads South Africa: 
Stephen T Muench

Greenroads is an independent 3rd party sustainability rating system for roadway design and construction. It awards points for more sustainable practices and can help quantify and communicate the sustainable attributes of a roadway project, the overall goal being to improve sustainability. The review and certification process for sustainable projects is managed by the Greenroads Foundation, an independent non-profit US corporation. Greenroads is a project oriented system which focuses on design and construction on all types and sizes of projects. While the important contribution of operations and maintenance are acknowledged, the Greenroads process is directed primarily at the design and construction phases. “Greenroads is a system that supports opportunities that roads offer to support natural laws and human values”, said Muench.

Muench stated that what we demand of the earth seems to exceed its capacity. We have not succeeded in in achieving more advanced levels of human and economic development within the carrying capacity of the planet, as illustrated in the figure below.

Muench defines sustainability as “a system characteristic that reflects the system’s capacity to support natural laws and human values.” Its application requires compliance with five simple sustainability rules:

What we demand of the earth exceeds its capacity.

Human Development Index vs. Ecological Footprint
From the WWF Living Planet Report 2006
• Don’t take stuff from the earth faster than it will go back in;
• Don’t produce stuff faster than it can be broken down;
• Don’t alter ecosystems;
• Seek quality of life for all;
• Manage resources wisely.

The rating system is based on 11 minimum project requirements which represent sustainability best practices. It also provides for voluntary credits providing the potential for 108 additional credits. The project requirements are listed below.

It was interesting that Muench singled out Quality Control Plans to assure quality construction as a significant contributing factor to sustainability.

The voluntary credit credits are closely aligned to CAPSA focus areas and topics, for instance:

• Materials and resources;
  o Re-use;
  o Recycling;
  o Energy efficiency;
• Pavement technology;
  o Long life;
  o Warm mix asphalt;
  o Cool pavements;
  o Quiet pavements.

Four levels of accreditation have been established, based on the extent of the voluntary credits allocated.
According to Muench there are several compelling reasons for adopting a Green Roads rating system. These include:

- Significant savings (ROI);
- Make money (single bottom line);
- Quantify contributions to sustainability.

Examples of savings achieved through “doing sustainability” include:

- Savings:
  - Through the use of 20% of recycled materials (RA) in asphalt 10% savings were achieved;
  - The premium on long life pavements were recouped over 20 years;
  - Investments in warm mix asphalt technology yielded paybacks in 10 000 – 145 000 tons of asphalt.

- Making money - major US construction company claimed that “green buildings” account for:
  - 30% of its 2008 revenue;
  - 40% of its backlog;
  - 50% of new sales.

- Quantified contributions to sustainability:
  - Asphalt is a major contributor to roadway sustainability – it can account for 74 of the total 108 points (69%) for a green roads rating.

Muench said that the intention was to introduce “Greenroads South Africa” by end of 2012 - the first Greenroads rating system outside of the USA. In conclusion he stated that “we can build roads better than we currently do. South Africa has the talent, desire and technology to do so. Roads present an opportunity – they are what we make of them.”
3

Plenary Session 1:  

Reduced impact of road building activities on the environment
Reduced impact of road building activities on the environment

Outline

Most papers in this session dealt with issues, whereby either the impact of the industry on human and environmental well-being is diminished, or whereby the accumulation of industrial “waste” can be reduced through the useful exploitation of such materials in quality road pavements. They give valuable guidance on a way forward in the interests of responsible practice.

Bitumen emulsions: beyond pavement preservation:
Étienne le Bouteiller

Being well established as a road building material offering long term durable solutions to road provision and maintenance, emulsions contribute to sustainable development by reducing energy consumption and greenhouse gas emissions. Models have been developed to assess the positive impact of the use of bitumen emulsions on these parameters, fully in line with the Declaration on Environment and Climate Change adopted by the Group of 8 (G8) in June 2008.

The author points out that energy is a major part of the costs borne by the road industry, and therefore by the community. Most of this energy consists in hydrocarbons (fuel, gas) used by trucks for the transportation of materials, as well as by the diverse plant and equipment such as asphalt plants and installation machines (pavers, compactors).

Limiting the consumption of energy as well as the production of CO₂ goes well beyond the single pavement preservation concept, and towards a global sustainable development scheme.

For the road industry, saving energy therefore means costs savings that will be transferred to the owners and to the global community. Another positive consequence is that fuel or gas savings will automatically result in a reduction in CO₂ emissions.

Environmental issues are often perceived as constraints. However, in the field of road construction, the opposite is true: an environmental constraint that would lead to energy savings and CO₂ reduction would result in costs savings. In this way, limiting the consumption of energy as well as the production of CO₂ goes beyond the single pavement preservation concept, and towards a global sustainable development scheme.

In Europe, HSE concerns have driven policy to implement the REACH regulation for the Registration, Evaluation, Authorisation and Restriction of Chemicals. REACH (which was reported at CAPSA’07), came into force on June 1st 2007 and places greater responsibility on the industry to evaluate and manage the risks that chemical substances may pose to health and the environment.

REACH applies to all chemical substances and, thus, to bitumen and emulsifiers. First in line are the producers and importers of the substances, who have to do the actual registration followed by the emulsion producers and users. Some emulsifiers and additives currently in use may, indeed, disappear from the market. Moreover, emulsion...
producers and downstream users will have to contribute to the assessment of risk by estimating and measuring the exposure to substances in relation to emulsion formulations and application.

The incentives to develop energy saving, safe and environmentally friendly techniques are higher than ever, and the author contends that bituminous emulsions are still in a leading position.

**Towards more sustainable practice in bituminous products laboratories:**
O’Connell, Mturi and Myburgh

This paper examined methods to improve the working environment in bituminous products testing laboratories, whereby harmful substances currently in general use as solvents in standard test methods as well as cleaning procedures would be replaced. In pursuance of this goal, the accuracy of adapted test methods should not be compromised. Improved practices should also be associated with improved solvent recycling procedures with zero emission requirements.

Findings of a review of current South African practices are used as a basis for the formulation of recommendations for achieving enhanced safety of test procedures that are also less harmful to the environment.

The use of benzene and chlorinated solvents should be phased out in South Africa.

Following an extensive study, the authors make the following recommendations:

- Eliminate a solvent if it is practical to do so. The ignition oven should be become the standard test method for routine determination of binder content of asphalt mixes;
- For improved repeatability, only one specific solvent should be prescribed in South Africa. It is the authors’ recommendation that toluene/ethanol should be evaluated for South African conditions, based on:
  - The acceptable technical performance of this solvent combination;
  - The lower health and safety risks associated with this solvent.
- A single recovery/distillation procedure should be prescribed for South Africa. Possible candidate standards are AASHTO T319, or alternatively, ASTM D5404 (rotary evaporator method), but amended to include a two-flask system for lower binder hardening;
- Safe handling of a hazardous solvent that is not practical to replace;
- The use of benzene and chlorinated solvents should be phased out in South Africa. This recommendation is justifiable in terms of:
  - Health and safety considerations (benzene and the chlorinated solvents are all carcinogens);
  - Environmental considerations.

The findings of the investigation is incorporated in Sabita Manual 29: *Guide to the safe handling of solvents in a bituminous products laboratory.*
Construction of a high quality asphalt wearing course with more than 90% reclaimed asphalt pavement (RA); a case study:
Nöltling, Riebesehl and Denck

The paper describes bold initiatives in Germany to manufacture high quality wearing course layers composed almost exclusively of reclaimed asphalt (RA) while meeting the relevant German specifications. This is in sharp contrast to general European practice where RA addition rates very rarely exceed 50% by mass in the final mix. Since at these levels of re-use the RA is no longer simply a “black aggregate”, rejuvenation of the binder with additional binder and other agents requires the addition of aggregate to create the required voids. Consequently the proportion of RA is limited to about 90%. The primary motivation for such relatively high levels of re-use of reclaimed is to lower input cost.

After the bituminous binder, the second most expensive component material of RA is coarse aggregate, especially in wearing courses where high quality aggregates are used. Present practices can be improved by the better exploitation of these high value materials.

The authors note, in passing, that properly processed, stockpiled and analysed RA is a non-negotiable prerequisite for the use of very high proportions of RA.

While most existing asphalt mixing plants can accommodate RA without special modifications, RA levels are generally limited to 30% to avoid impairment of asphalt quality or the creation of emissions beyond legal limits. However, special plants such as twin dryer drums or double barrel drum mixing plants specially designed to accommodate high levels of RA and can push the possible addition of RA to hot mix beyond the 50% level.

The next challenge was to produce new high quality hot mix asphalt exclusively from RA and a rejuvenator system.

The authors regarded conventional technology in Germany based on Ring and Ball softening point criteria to be limiting to the RA content and not conducive to waste avoidance legislation. To overcome these limitations and improve the sustainability of asphalt pavements it was necessary to explore new technologies.

Following successful trials for the Hamburg city authority where RA contents of 25 – 50% was used in conjunction with highly specified “flux oils”, the next challenge was to produce new high quality hot mix asphalt exclusively from RA and a rejuvenator system.

Within the commercial area of the port of Hamburg, a trial where the rejuvenator was blended with a Fischer Tropsch (FT) wax was launched in 2010. The authors record that the wearing course material that was recycled was “significantly aged”.

The purpose of the FT wax was not only to improve the asphalt quality beyond what could be achieved by using the flux oil only, but also to achieve lower mix temperatures to limit environmental problems associated with emissions from the mixing plant. Heating mixes composed exclusively of RA can produce numerous problems, invariably associated with excessive carbon based emissions and further damage to the already
aged binder. Also, at high temperatures bituminous vapours and aerosols are generated that can cause irreversible clogging of the bag house filters.

Mixing at warm mix temperatures solves both problems in most plants. The combination of wax and flux oil also produces an extremely workable mix, even at reduced temperatures.

In the trial that was paved in September 2010, some fine tuning of the mix proportions required the addition of RA from another site and small amounts of virgin aggregate.

The authors conclude that all compliance and performance testing on the trial incorporating both flux oils and FT wax gave rise to optimism that this new development has the potential to produce asphalt from almost 100% RA while meeting the current performance criteria for asphalt mixes, even in the high load categories. They caution, however, that the selection of flux oils should be carried out with care as there are "dubious substances" in the market that are inappropriate.

"Bitumen can be completely rejuvenated. Combined with all other necessary processes like selective milling, proper stockpile management, constant analysis and monitoring of RA components and properties this technology opens the way to use RA on the highest possible level of value generation."

Steel slag conversion of an industrial waste material into a value adding asphalt ingredient:
Winkelmann and Schaller

For each ton of steel produced in modern steel plants using electric arc furnaces (EAF) about 130 - 180kg of a very particular electric oven slag (EOS) is generated as a waste product. This slag, produced in large quantities each year, has few uses and it makes sense to integrate such products into the volume streams for construction materials. By doing so the volumes of materials being disposed of into landfill sites is reduced as are the utilisation of non-renewable quarried resources.

In Germany there is also the need to comply with legislation enforcing waste avoidance and requiring that only materials with no alternative use can be disposed of. If such alternative uses exist, they must have preference over the use of new materials.

Legislation requires that only material with no alternative use can be disposed of.

Before crushing and screening, the slag is either slowly cooled down in beds and weathered for some time to reduce the reactive potential of unbound calcium carbonate, or quartz sand or oxygen are introduced to the molten slag to bind the calcium carbonate so that the weathering is not possible.

Experience has proved that asphalt containing EOS performs well under difficult North European conditions of freeze-thaw cycles, frequent rains and high asphalt surface temperatures - well above 60°C in summer.

Steel slag is highly esteemed in the building industry as a valuable raw material because of a number of inherent qualities:
• High stability: Steel slag is an artificial stone with very high maximum specific gravity and very high stability. Due to a high compressive strength they are ideal for use in high deformation-resistant asphalt designs;
• Skid resistance: Chippings made from steel slag have a very rough surface texture and will deliver good skid resistance. This can be further increased by use of crushed sand made from steel slag (0/2) mm;
• Polished-Stone-Value: EOS chippings have a PSV-value < 55;
• Cubical shape: The cubical shape of the aggregates not only adds stability to mix designs, but also has a positive impact on tyre noise;
• Affinity to bitumen: Steel slag has excellent adhesion to bituminous binders.

In 2002 an independent study on the skid resistance of stone mastic asphalt (SMA), which can display a significant decline in skid resistance over time, showed that all asphalt mixes with EOS have either good or very good performance. Asphalt mixes composed of aggregates with low PSV can be significantly improved with addition of EOS. The addition of crushed sand made from EOS also significantly improves skid resistance.

Samples were also subjected to the Hamburg wheel tester to determine their deformation resistance, using the Hamburg wheel tracking test. Once again the use of EOS proved to be measurably beneficial. Visual inspection of the test specimen also revealed that that samples with EOS displayed significantly less stripping.
Plenary Session 2:

Reduced energy consumption in the construction of bituminous layers
Reduced energy consumption in the construction of bituminous layers

Outline

Papers covered in this session explicitly demonstrated how measurable reduction in energy consumption can be achieved, while not compromising the performance expectations of pavement layers.

Combining LCC and energy consumption for enhancing decision making regarding rehabilitation options:

Jenkins and Collings

Increasing emphasis on the environmental impact of road construction and rehabilitation has led to sufficient data becoming available for use in the analysis of road building/rehabilitation options and decision making. In this paper, energy consumption figures have been used in combination with whole-of-life costs for four realistic rehabilitation options in general use globally in road pavements. This new insight into project selection leads the authors to conclude that:

While whole-of-life analysis using PWOC provides a measure of financing requirements for pavement upkeep over the entire analysis period, environmental considerations in pavement engineering can now be used in combination with pure economic considerations for improved decisions.

Environmental considerations in pavement engineering can now be used in combination with pure economic considerations for improved decisions.

In the case study presented in their paper, the authors demonstrate that the benefits of bitumen stabilisation with foam or emulsion as cold recycling technology offer significant benefits - both in terms of economic and energy considerations. In addition to the life-cycle costs shown in Figure 9 of the paper, the energy consumption provides deeper insights into the greater impact of road interventions. It highlights the benefits of cold recycling using BSMs both from a cost and an energy perspective.

Table 3: Combined life-cycle costs and energy costs

<table>
<thead>
<tr>
<th>Options</th>
<th>Initial constr. costs (US$/km)</th>
<th>PWOC (δ = 6%) (US$/km)</th>
<th>Total energy (GJ/km)</th>
<th>Energy costs (US$/km)</th>
<th>LCC + energy costs (US$/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>233 506</td>
<td>515 142</td>
<td>976</td>
<td>162 475</td>
<td>677 617</td>
</tr>
<tr>
<td>Option 2</td>
<td>356 500</td>
<td>512 803</td>
<td>809</td>
<td>134 793</td>
<td>647 597</td>
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<tr>
<td>Option 3</td>
<td>331 875</td>
<td>509 924</td>
<td>1 048</td>
<td>174 534</td>
<td>684 458</td>
</tr>
<tr>
<td>Option 4</td>
<td>191 825</td>
<td>323 322</td>
<td>574</td>
<td>95 856</td>
<td>418 908</td>
</tr>
</tbody>
</table>
Energy and related carbon emission reduction technologies for hot mix asphalt plants:
Stotko

This paper discusses various carbon reduction measures that can be implemented on asphalt manufacturing plants, considering a baseline 100 ton per hour co-current flow drum plant. The measures, all considered to be technically sound, include:

- Stockpiling aggregates under roof on sloped concrete floors;
- Counter-current flow design of burner gas and aggregate flow direction in single drum plants;
- Frequent replacement of worn flights in the drier;
- Effective lagging of all vessels and pipelines containing heated materials;
- Tighter control of feed air for combustion and reduction of flue gas heat loss;
- Asphalt product storage in closed silos;
- Conversion of hot mix asphalt operation to warm mix asphalt operation;
- Burner fuel switch from HFO to natural gas.

It was noted that this paper provided an outline of generalised potential savings from implementing energy efficiency measures on a hot mix asphalt plant. Energy audits of plants would be required to define which of the outlined measures are applicable to specific operations and to optimise measures.

The total potential HFO savings and carbon dioxide reductions from implemented measures amount to 19 880 GJ/year and 2 280 tons CO₂/year respectively. These values represent a 30% HFO energy use reduction and a corresponding 35% reduction in GHG emissions.
Warm mix asphalt – The South African experience:
Naidoo et al

This paper demonstrates the successful full scale implementation of WMA in South Africa following an intensive trial period over two years. The process was expedited through the cooperation of eThekwini Municipality, asphalt producers and WMA technology product suppliers.

The most significant finding was that a variety of technologies can be successfully used by South African asphalt producers at temperatures 30°C less than those generally used in HMA. Also, the compatibility of recycling and WMA was confirmed and mixes with up to 40% of RA were successfully manufactured and paved.

While almost all the indications from the trials are that WMA has performance characteristics at least on a par with HMA, indications are that WMA mixes can be sensitive with regards to moisture and it is recommended that attention be given to this during the mix design phase.

Asphalt plants, currently designed to operate most effectively within the temperature range associated with HMA may require adjustments e.g. to burner fuel flow and/or production or mixing rates to lower the temperature. As was demonstrated during the presentation of the paper, WMA is now a viable option and best practice associated with it is captured in Sabita Manual 32: Best practice guideline for warm mix asphalt.
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Fax: (+27) 12 665 2028
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16 Charles de Gaulle Crescent, Highveld, Centurion, 0169

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Driven to Care for the Environment
5

Speciality Session

Pavement design systems
Speciality session – Pavement design systems

Outline

Throughout the conference considerable attention was paid to the importance of durable, long-life pavement layers and systems to underpin sustainable practice. Systematic surveillance and intervention programmes are required to optimise the investment in road infrastructure and to provide an adequate level of service to society in terms of safety and efficiency.

Information systems on pavement performance also enable calibration of models through systematic presentation of performance data of pavements categorised in terms of a relatively simple Pavement Number (PN) system. Both these concepts complement the substantial project on developing a rational, analytical pavement design system under the auspices of SANRAL.

Evaluation of effects of road maintenance actions on applied tyre loads: Steyn

This paper focuses on the fact that real traffic imparts dynamic tyre loads to pavements. Various vehicular and pavement parameters influence the precise values of the moving dynamic tyre load population. These include:

- The actual pavement profile;
- The speed of the vehicles;
- The dimensions of the vehicles;
- The suspension of the vehicle; and
- The load on the vehicle.

While equivalent static load concepts are still widely in use in the structural dosing of road pavements, attempts are currently underway to incorporate the effects of moving dynamic tyre loads on pavements in pavement design procedures.

Previous studies of the effect of potholes on a smooth road excluded the effect of the actual riding quality of the road prior to filling of potholes, as well as the effect that the filled potholes have on the generated tyre loads. This paper evaluates the effect of potholes that had formed (on actual measured pavement profiles) and had been filled, on the generated tyre loads and the effect of excess loads on the expected pavement life of the pavement.

Using a simulation package the effects of a rigid truck (2 axles) travelling at a constant speed and load were investigated over two different road sections (1 km long) with varying riding qualities. The paper covers an evaluation of the tyre loads generated as the vehicle travels over three pavements with varying profiles. These analyses are shown for the pavement in a good (no pothole) condition, a condition with potholes (50 mm deep) at intervals of 50 m to 500 m, and the case where these potholes are filled to a height of 5 mm higher than the surrounding surface. It also provides a brief indication of the effects on expected vehicle maintenance costs and goods damage.
In Figure 5 of the paper the percentage increase in E80s between the no-pothole scenario and both the pothole and the filled-pothole scenarios are shown. Initial inspection of the graph appears to be counterintuitive, as it indicates that the presence of potholes on the IRI 1.8 m/km road cause a higher increase in E80s than the rougher IRI 3.7 m/km road.

However, the data should be seen in conjunction with the actual number of E80s. This number is 13,674 E80s for the no pothole scenario on the IRI 1.8 m/km road while it is 14,705 E80s for the same scenario on the IRI 3.7 m/km road. The higher increase due to potholes for the smoother road is the fact that the rougher road already contains a higher level of unevenness than the smoother road, and therefore the effect of the occurrence of both the potholes and the filled potholes on the smoother road will appear to be more severe.

When comparing the actual E80s on each of the scenarios (Figure 6) it is clear that on the IRI 1.8 m/km road, open potholes with an interval of between 50 m and 100 m can be allowed before the same number of E80s will be generated on this road than on the IRI 3.7 m/km road. The benefit of ensuring that the road is as even as possible during its life is thus clear.

The author draws the following conclusions in the light of the findings in this paper:

- The presence of potholes in a road causes a deterioration in road roughness as well as an increase in the dynamic loads and excessive overloads; and
- Although filling of potholes diminishes the extent of overloads associated with a road with open potholes, good maintenance practices whereby the formation of potholes is avoided is beneficial in that the best riding quality and lowest excessive overloads are experienced on a road without any additional unevenness caused by filled potholes.
Development of a pavement performance information system (PPIS): Hefer, Jooste and Long

Performance trends corroborate the validity of the approach.

The authors reported that they had incorporated the performance of a total of 61 LTPP and HVS field sections into a PPIS database which now forms part of the revision of the South African Pavement Design Method (SAPDM) currently underway under the auspices of SANRAL.

The sections represent different pavement types, namely: full-depth granular pavements, granular base with cemented subbase pavements, cemented base pavements, asphalt base pavements and bitumen stabilised pavements. The framework for collection and storage of performance data is dictated by available data types as shown in Table 1.

Table 1: Data types and typical data fields

<table>
<thead>
<tr>
<th>Data tables/Sheets</th>
<th>Data Fields/Columns (Illustrative, selected fields shown)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>Data, Station No., Lanes, AADT, AADTT, E80 factor</td>
</tr>
<tr>
<td>Materials</td>
<td>Data, position, start depth, end depth, sieve size, GM, PI, CBR</td>
</tr>
<tr>
<td>DCP</td>
<td>Data, start depth, end depth, thickness, layer DN</td>
</tr>
<tr>
<td>Visuals</td>
<td>Date, section start, section end, defect-degree, defect-extent,</td>
</tr>
<tr>
<td>Ride and rut</td>
<td>Date, section start, section end, lane, IRI-L, IRI-R, rut-R</td>
</tr>
<tr>
<td>Deflection</td>
<td>Date, position, load, DO, D200, D300, D450, D600, D900, D1500</td>
</tr>
</tbody>
</table>
A user-friendly web-based database system was developed to make this information available to the industry. The data can be viewed and downloaded from the SANRAL PPIS website at www.sapdm.co.za.

The paper demonstrates the potential use of the performance data by investigating some of the trends observed. Performance trends corroborate the validity of the approach and highlight the value of utilizing historical data from available systems.

Figure 5 shows two windows that are used to display performance data. The left hand window presents the performance data graphically in an X-Y plot. In this plot, each point represents a performance section or structure. The graph is interactive and if the cursor is moved to one of these points, a short name for the section pops up as shown, i.e. N3-4 HVS in this illustration. If selected, details of the section under consideration are displayed in the window on the right hand side.

The Pavement Number (PN) represents the geometric and materials make-up of a structure with a single number representing the overall structural capacity of a
pavement. It is noted that, specifically, the method ensures that lower PN values are assigned where unbound layers are supported by weaker materials. The authors suggest that best practice can benefit from the PPIS in the following ways:

- Key trends in the performance data can be used to validate the basic behaviour models assumed for the development of the updated mechanistic-empirical design method;
- Through internet access to the PPIS, practitioners are able to test planned designs against the information in the performance database;
- The PPIS also provides road owners with more confidence regarding the suitability and reliability of a proposed design; and
- The outputs from this study may also provide a platform from which the deterioration models for Pavement Management Systems can be developed and calibrated.

**Interim revision of the SAMDM for flexible pavements:**

Theyse et al

A framework for the revision of the South African pavement design method for flexible and rigid pavements - initiated by the South African National Roads Agency Limited (SANRAL) was presented at CAPSA'07; this paper focuses on the interim revision of the models for unbound, granular layers. In particular the paper demonstrates that:

- The internationally accepted vertical subgrade strain design model was inadequate and replaced with a model based on the total subgrade deflection;
- The factor of safety model for unbound granular base and subbase layers was replaced with a stress ratio model with the distinction that the stress ratio is calculated from effective stress conditions, which includes the vertical overburden pressure, residual compaction stress, suction pressure in addition to the stress resulting from the external wheel-load;
- The revised method shows considerably less sensitivity to changes in the resilient response parameters of pavement layers compared to models developed in 1996, but with appropriate responsiveness.

**Subgrade damage models**

The authors point out that as the models for unbound granular layers were not sufficiently sensitive to changes in loading conditions, revised permanent deformation damage models for unbound granular pavement layers were needed.

Similar to the 1996 version, SAMDM2011 makes provision for two levels of subgrade permanent deformation, namely 10 mm and 20 mm. The subgrade deflection is the preferred critical parameter for subgrade permanent deformation. The authors note, however, that the integration of the subgrade vertical elastic and plastic strain over the full depth of the subgrade results in the subgrade deflection and subgrade permanent deformation respectively. Such an approach, however, requires information that is rarely available - the exact subgrade stiffness (and hence vertical strain) profile. In calibrating a range of $S-N^5$ type subgrade permanent deformation models as part of the SANRAL SAPDM project, it was found that one should differentiate between the models for deep sand subgrades (typical of KwaZulu-Natal and the Western Cape) and...
gravel subgrades. The S-N models for 10 mm and 20 mm subgrade permanent deformation included in SAMDM2011 are illustrated in Figure 5 of the paper.

The authors acknowledge that the scatter in the data plotted in Figure 5 is wide, but consider such variation to be an inherent characteristic of pavement performance. The distinction between sandy and gravel subgrades as well as subgrade capacities of a particular subgrade type at different levels of subgrade deflection are, however, clear for a given level of subgrade permanent deformation. Although there is significant overlap in the data ranges for 10 mm and 20 mm permanent deformation, the risk profiles are different for the two levels of permanent deformation for a given traffic demand.

**Plastic strain damage models for unbound granular layers**

For unbound, granular base and subbase layers the factor-of-safety model was replaced with a stress ratio model with the distinction that the stress ratio is calculated from effective stress states, not merely the stress associated with the external wheel-load. The effective stress includes the:

- Vertical overburden pressure;
- Residual compaction stress;
- Suction pressure; and
- Stress resulting from the external wheel-load.

The revised method shows considerably less sensitivity to changes in the resilient response parameters of pavement layers compared to 1996 models, while
retaining appropriate responsiveness to changes in input variables such as wheel-load, density, saturation levels and material shear strength. Using the revised models, it was possible to simulate the development of the permanent deformation of a full-depth granular pavement with reasonable accuracy.

Plastic strain data from repeated load tri-axial tests were used for the development of a series of S-N type plastic strain damage models. It was found the volumetric density and degree of saturation of the material had to be incorporated in the formulation of the critical parameter in addition to the stress ratio.

A better correlation was found between the plastic strain laboratory results and the stress ratio formulated in terms of major principal stresses rather than deviator stress. Implementation of the stress ratio in a pavement system requires that the stress ratio be calculated from the effective vertical and horizontal stress under the wheel instead of the major and minor principal stress.

The reason for this is that the overburden pressure and residual compaction stress are uniform stress fields that affect the major and minor principal stress but do not contribute to the vertical permanent deformation of the pavement layer, only the vertical stress component of the external wheel-load does.

It is strongly recommended that shear strength tests be performed for unbound granular base and subbase.

Recommended Mohr-Coulomb shear strength parameters for unbound granular base and subbase materials are summarised in Table 4 of the paper for preliminary design. It is strongly recommended that shear strength tests be performed on the materials selected and that the design should be finalised using project specific material properties.
Performance summary reports were produced from synthesised information available for each performance section. The short - 5 to 10 page - summaries contain the following information:

**Table 4: Recommended shear strength properties for unbound granular material to be used during preliminary design**

<table>
<thead>
<tr>
<th>Application</th>
<th>Material</th>
<th>Saturation level</th>
<th>Recommended shear strength parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohesion (kPa) Friction angle (°)</td>
</tr>
<tr>
<td>Base</td>
<td>G1</td>
<td>20% (dry)</td>
<td>90 - 130 53 - 57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50% (moderate)</td>
<td>75 - 100 51 - 55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80% (wet)</td>
<td>50 - 75 50 - 53</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>20% (dry)</td>
<td>100 - 125 54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50% (moderate)</td>
<td>50 52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80% (wet)</td>
<td>45 50</td>
</tr>
<tr>
<td></td>
<td>G3</td>
<td>20% (dry)</td>
<td>75 51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50% (moderate)</td>
<td>40 51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80% (wet)</td>
<td>20 50</td>
</tr>
<tr>
<td></td>
<td>G4</td>
<td>20% dry</td>
<td>75 51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50% (moderate)</td>
<td>40 47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80% (wet)</td>
<td>20 45</td>
</tr>
<tr>
<td>Subbase - coarse</td>
<td>G5/6</td>
<td>20% (dry)</td>
<td>100 - 125 45 - 49</td>
</tr>
<tr>
<td>material</td>
<td>(BLS X P425 &lt; 170)</td>
<td>50% (moderate)</td>
<td>50 - 100 41 - 45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80% (wet)</td>
<td>10 - 50 39 - 42</td>
</tr>
<tr>
<td></td>
<td>G5/6</td>
<td>20% (dry)</td>
<td>225 - 275 45 - 49</td>
</tr>
<tr>
<td></td>
<td>(BLS X P425 &gt; 170)</td>
<td>50% (moderate)</td>
<td>50 - 100 41 - 44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80% (wet)</td>
<td>25 - 35 31 - 33</td>
</tr>
<tr>
<td>Subbase - fine</td>
<td>G5/6</td>
<td>20% (dry)</td>
<td>125 - 250 43 - 45</td>
</tr>
<tr>
<td>material</td>
<td>(BLS X P425 &lt; 100)</td>
<td>50% (moderate)</td>
<td>40 - 50 43 - 45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80% (wet)</td>
<td>10 - 25 40 - 43</td>
</tr>
</tbody>
</table>

Notes: Coarse material - grading modulus (GM) 1.7 - 2.3; maximum particle size 26.5 mm - 37.5 mm; Fine material - grading modulus (GM) 1.5 - 1.6; maximum particle size < 13.2 mm; BLS - Bar Linear Shrinkage; P425 - Percentage passing 0.425 mm sieve.

*Figure 6: Plastic strain damage model for 19% plastic strain of unbound base and subbase layers*
The damage models for unbound base and subbase layers makes provision for different levels of plastic strain ranging from 1 to 19%, with the appropriate level depending on the terminal deformation level selected by the designer. Figure 6 in the paper illustrates the S-N damage model for 19% plastic strain as a function of the Stress Ratio (SR), saturation level (S) and volumetric density (VD) of the material.

**Sensitivity to input variation**

A critical review of SAMDM1996 in 2004 by Jooste pointed out the sensitivity of the models for unbound materials to changes in the resilient response parameters adopted for unbound layers and their supporting layers. In the 2004 review a base case was established for analysis consisting of the pavement structure summarised in Table 5.

**Table 5: Pavement structure used by Jooste (2004) to perform a sensitivity analysis of SAMDM1996**

<table>
<thead>
<tr>
<th>Layer thickness</th>
<th>Material description</th>
<th>Base case</th>
<th>Variation 1</th>
<th>Variation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>Resilient modulus (MPa)</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td></td>
<td>Poisson’s ratio</td>
<td>0,40</td>
<td>0,40</td>
<td>0,40</td>
</tr>
<tr>
<td>40 mm</td>
<td>Asphalt overlay</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td>150 mm</td>
<td>G1 overlay</td>
<td>650</td>
<td>650</td>
<td>650</td>
</tr>
<tr>
<td></td>
<td>Old cemented layer</td>
<td>450</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>250 mm</td>
<td>Selected subgrade</td>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>150 mm</td>
<td>Sandy subgrade</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Semi-infinite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Four variations of the base case were presented of which two were related to variation in the resilient properties of the pavement layers and two were related to changes in the shear strength properties of the G1 base layer. The modified resilient response parameters are highlighted in Table 5 for the first two variations analysed.

Table 6 summarises the base layer capacity reported by Jooste and the results from the revised models. The revised method is far less sensitive to variation in the resilient input parameters than the 1996 method for the particular case investigated.

**Table 6: Comparison of the G1 base layer capacity according to SAMDM1996 and SAMDM2011**

<table>
<thead>
<tr>
<th>Method</th>
<th>Parameter</th>
<th>Base case</th>
<th>Variation 1</th>
<th>Variation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMDM1996 (from Jooste 2004)</td>
<td>Base capacity</td>
<td>10.7 x 10^4</td>
<td>4.2 x 10^4</td>
<td>54.5 x 10^4</td>
</tr>
<tr>
<td></td>
<td>Deviation from base</td>
<td>0%</td>
<td>-25%</td>
<td>+168%</td>
</tr>
<tr>
<td>SAMDM2011 (—PADS³—)</td>
<td>Base capacity</td>
<td>26 x 10^4</td>
<td>25 x 10^4</td>
<td>27 x 10^4</td>
</tr>
<tr>
<td></td>
<td>Deviation from base</td>
<td>0%</td>
<td>-3%</td>
<td>+5%</td>
</tr>
</tbody>
</table>

**The long-term behaviour of Bitumen Stabilised Materials (BSMs): Collings and Jenkins**

The response of three different pavement structures incorporating either BSM-foam or BSM-emulsion base layers, on three different continents, has been evaluated over periods that range between seven months and four years during which time all of the
pavements were exposed to medium to heavy trafficking. Based on this study the authors draw the following conclusions:

- The moisture in one of the BSM-emulsion layers was shown to reduce asymptotically with time due to curing. This concurs with findings with regard to curing effects on BSM-foam;
- All of the BSM base layers showed a non-linear increase in the stiffness of the layer with time, tending towards a plateau after one year of service;
- A gradual increase in the stiffness of all BSM layers suggests that the effects of curing within a BSM overshadow the detrimental effects of trafficking for at least a year after construction.

The authors especially note that, as all three examples show that the effective stiffness of the BSM layer increased with time (and accumulated traffic load) within at least the first year, BSMs are characteristically different to continuously bound materials that are prone to fatigue degradation - a reduction in effective stiffness with time.

They consider that such a trend would appear to confirm the theoretical postulation that non-continuously bound BSMs are not prone to a decline in integrity due to fatigue distress. They do, however, state that at the time of writing, insufficient reliable data is available to analyse the trends of effective stiffness of BSMs beyond four years of service. Significantly more LTPP data is required.

**Fracture mechanisms**

At the outset the authors stress that the fracture mechanisms as defined by Paris’ Law, while applicable to materials like asphalt, do not apply to BSM. Unlike asphalt, BSMs do not have a continuum of bitumen and are seldom homogeneous, especially when recycled material is stabilised.

This is shown conceptually in Figure 3 of the paper. Discrete distribution of bitumen splinters in BSM-foam does not allow classical fatigue and fracture mechanics to apply. If shear deformation between individual particles ruptures a “spot weld” of bitumen, there is no continuity of bound material that will allow a crack to develop, so “crack development” becomes meaningless. Stated differently, there is neither opportunity for a crack “head” nor stress intensity at the tip to develop. A broken spot weld will result in particles re-orientating (micro-shearing), resulting in permanent deformation, as with granular material.

**Discrete distribution of bitumen splinters does not allow classical fatigue and fracture mechanics to apply.**

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In addition, the relatively low effective stiffness of BSM’s needs to be taken into consideration - often less than 50% of HMA stiffness. The horizontal strains experienced by a BSM are commonly in the order of 10 to 70 με and very seldom exceed 90 με. By comparison, strain-at-break (εb) tests from monotonic flexural beam tests on BSMs yielded results of 1000 to 3000 με and it has been reported that four-point beam fatigue results can yield between one and several million load repetitions at 200 με constant strain loading. The non-continuously bound nature of BSMs, coupled with their relatively low effective stiffness regime, does therefore not create conditions conducive to fatigue failure.

Material behaviour and strain-at-break

The authors note that extensive investigations have been undertaken to find a relationship between strain-at-break (εb) and fatigue for BSMs or, at least, to provide a performance indicator. However, given the “visco-elasto-plastic” behaviour of BSM’s it became abundantly clear that strain-at-break does not provide a reliable correlation with the fatigue relations that have been tested. Not only does the influence of the particular bitumen stabilising agent need to be considered, but also the non-linear nature of the log strain versus log load repetitions relationship.

The authors consider that “linear elastic behavioural modelling will not suffice due to plastic behavioural influences, and strain-at-break can therefore not provide a reliable performance indicator.”
6

Speciality Session 2

Thin surfacings, surface texture and safety
Thin surfacings, surface texture and safety

Outline

The papers singled out for this publication cover three distinct facets of the technology associated with thin surfacings. Areas covered are diverse and deal with innovative practice to exploit natural resources, a review of the performance of ultra-thin asphalt surfacings and a novel analysis of the factors that contribute to seal performance.

Improving the durability of seal aggregate by precoating: Thothele, Robertson and Jenkins

The authors point out that there has been a general increase in cases where a local source of adequate quality seal aggregate is overlooked, or rejected, on the grounds that it is not satisfying conventional durability specification requirements. Alternative sources would then have to be exploited at great economic and environmental cost.

By conducting a series of 10% FACT and ACV laboratory tests on pre-coated seal aggregates, it can be shown that the pre-coat is capable of increasing the crushing strength of aggregates as well as limiting the water absorption of aggregates. It is suggested that this measured effect of pre-coating an aggregate should be considered during the aggregate selection process.

Testing was carried out on four different types of commonly used seal aggregates from five different quarries as shown below:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>Material type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Malmesbury, Western Cape</td>
<td>Granite</td>
</tr>
<tr>
<td>A2</td>
<td>Durbanville, Western Cape</td>
<td>Greywacke Hornfels</td>
</tr>
<tr>
<td>A3</td>
<td>Worcester, Western Cape</td>
<td>Eucrite</td>
</tr>
<tr>
<td>A4</td>
<td>Kimberley, Northern Cape</td>
<td>Dolerite</td>
</tr>
<tr>
<td>A5</td>
<td>De Aar, Northern Cape</td>
<td>Dolerite</td>
</tr>
</tbody>
</table>

The pre-coating fluid that was used in the study was a bitumen based cutback blended from selected petroleum derivatives and a chemical adhesion agent, and is one of the most commonly used pre-coats for seal aggregate. It can be used with all local seal aggregates, including aggregates which are known to have poor affinity for bitumen.

The pre-coating of aggregates was done with minimal amount of fluid and were left to dry for four to five days until completely dry in order to eliminate the possibility of generated fines being bound together by bitumen. The wet test samples were soaked for 24 hours before testing. The number of tests completed for each sample was 36; eighteen tests for the uncoated and eighteen for the pre-coated aggregates.

Test results

The 10% FACT and ACV average results are summarised in Tables 2 and 3, and illustrated in Figures 1 and 2 of the paper.
Table 2: Summary of 10% FACT results

<table>
<thead>
<tr>
<th>Aggregate tests</th>
<th>Source quarry</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not pre-coated</td>
<td>Dry - 10% FACT(kN)</td>
<td>416</td>
<td>387</td>
<td>364</td>
<td>342</td>
<td>301</td>
</tr>
<tr>
<td></td>
<td>Wet - 10% FACT(kN)</td>
<td>305</td>
<td>333</td>
<td>323</td>
<td>324</td>
<td>297</td>
</tr>
<tr>
<td></td>
<td>Wet/dry ratio (%)</td>
<td>73%</td>
<td>86%</td>
<td>89%</td>
<td>95%</td>
<td>99%</td>
</tr>
<tr>
<td></td>
<td>Water absorption (%)</td>
<td>0.26</td>
<td>0.34</td>
<td>0.31</td>
<td>0.07</td>
<td>0.16</td>
</tr>
<tr>
<td>Pre-coated</td>
<td>Dry - 10% FACT(kN)</td>
<td>396</td>
<td>396</td>
<td>354</td>
<td>367</td>
<td>359</td>
</tr>
<tr>
<td></td>
<td>Wet - 10% FACT(kN)</td>
<td>379</td>
<td>368</td>
<td>424</td>
<td>380</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td>Wet/dry ratio (%)</td>
<td>98%</td>
<td>95%</td>
<td>120%</td>
<td>103%</td>
<td>103%</td>
</tr>
<tr>
<td></td>
<td>Water absorption (%)</td>
<td>0.17</td>
<td>0.21</td>
<td>0.16</td>
<td>0.04</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Table 3: Summary of ACV test results

<table>
<thead>
<tr>
<th>Aggregate tests</th>
<th>Source quarry</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not pre-coated</td>
<td>Dry ACV (%)</td>
<td>9.6</td>
<td>10.4</td>
<td>11.9</td>
<td>12.2</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td>Wet ACV (%)</td>
<td>12.9</td>
<td>12.4</td>
<td>14.1</td>
<td>12.8</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>Water absorption (%)</td>
<td>0.26</td>
<td>0.34</td>
<td>0.31</td>
<td>0.07</td>
<td>0.16</td>
</tr>
<tr>
<td>Pre-coated</td>
<td>Dry ACV (%)</td>
<td>10.5</td>
<td>10.7</td>
<td>11.6</td>
<td>11.1</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td>Wet ACV (%)</td>
<td>10.6</td>
<td>11.1</td>
<td>9.1</td>
<td>10.7</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td>Water absorption (%)</td>
<td>0.17</td>
<td>0.21</td>
<td>0.16</td>
<td>0.04</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Figure 1: Graphical representation of 10% FACT results

Figure 2: Graphical representation of ACV test results
It is clear that pre-coating does limit the water absorption of aggregates. The water absorption reduction ranges from 30% for the dolerite (sample A5) to 47% on the eucrite.

The results of the wet 10% FACT clearly show that pre-coating of aggregates plays a significant role in the wet crushing strength of aggregates. The strength improvement of wet-coated aggregates to wet-uncoated aggregates ranges between 11% for sample A2 and 31% for sample A3, with an overall average of 22%. The associated wet/dry ratio is improved by an average of 18% and, surprisingly, the wet crushing strength of samples A3, A4 and A5 surpass that of the dry samples, thus showing wet/dry ratios of more than 100%. All the samples show a similar pattern of strength gain from the wet-uncoated aggregates to the wet-pre-coated aggregates. The likelihood that this improvement in strength is attributed to the pre-coat is high.

Observed trends between dry and soaked ACV results, is that the ACV of pre-coated aggregates is improved by an average of 20%, ranging from 10% to 35%

While the authors deem that the beneficial effect of precoating has been demonstrated, they are of the opinion that the challenge lies with the roads industry to take the option of pre coating into consideration when designing seals and preparing project specifications for seal aggregates in the interests of cost-effectiveness.

**Critical review of performance of UTFC in South Africa:**
Roux, Rossmann and Kannemeyer

Following on from a presentation at CAPSA’04 in which the performance of ultra-thin friction course (UTFC) was evaluated for the first five years after its introduction into South Africa, an opportunity arose to evaluate its performance over an period stretching up to 12 years. The paper critically reviews the performance of UTFC layers from a functional perspective i.e. in terms of texture and riding quality, and in terms of its integrity over time, under different support conditions. The originally predicted “end of life” signs, i.e. ravelling, are also examined.

The performance of UTFC on structurally sound pavements has been proven.

Additionally, given its application on high trafficked roads, with expected increased night work, the suitability of the current application methods is appraised.

Given the proprietary nature of UTFCs, their performance is linked to guarantees and measurable performance indicators such as riding quality, texture depth and visual condition.

The authors conclude that the performance of UTFC on structurally sound pavements has been proven and, on a stiff pavement structure, UTFC has generally performed well with ravelling confirmed as the predominant end of life distress as was suggested in 2004.

Its use as a rut filler in combination with the surface layer has been successful, and improvements in average IRI values of between 0.45 to 1.1 have been achieved where utilised as an overlay on existing pavements.
No marked decrease in surface macro-texture has been observed, with average in-service values of 1.1 to 1.5 being obtained. UTFC was found not to be the ideal product for use in a holding action on cracked pavements or pavements with poor support. On pavements with lesser support, UTFC layers have shown signs of fatigue type cracking, with the onset of failure dependant on magnitude of deflection and traffic loading.

The authors consider that the effectiveness of UTFC as a waterproofing layer is compromised by the current tack coat application rates. These are lower than required and its use on moisture sensitive layers should therefore be discouraged. They also suggest that the influence of binder type and other mix properties as well as method of tack application, on the long term performance of UTFC, should be further investigated.

Towards improved understanding of seal performance: van Zyl and van der Gryp

Studies on seal performance, based on annual visual assessments (1996 – 2009) of approximately five hundred road segments, showed some definite trends in terms of binder hardening and fatigue crack development. These findings indicate that, in line with international experience, bituminous surfacings should not be allowed to age beyond ten years. In this regard, information obtained from three major road authorities in southern Africa, reveals a huge backlog in reseal work in the region.

The authors consider a mechanism different from the one proposed in TMH9.

Considering the impact of oxidative hardening of bituminous binders on the performance of the seal and in particular its impact on fatigue crack development the authors consider a mechanism, different from the one proposed in TMH9 and one currently enjoying more support, as follows:

- Oxidation and hardening of the bituminous binder does occur;
- Vertical moisture ingress through a more permeable seal, could result in softening of any granular base;
- The bituminous surfacings stiffen with time, to such an extent that they become sensitive to even slight deflections;
- Hardening of the binder in the wheel tracks is slower as a result of the kneading action of tyres; and
- Fatigue of this stiff layer occurs, resulting in a typical fatigue crack pattern.

Evaluation of data of the Provincial Government of the Western Cape (PGWC) indicated that even on roads which are considered to be structurally sound and without rut deformation, crocodile pattern cracking is typically observed on the road surface within a year after the binder condition is rated as a Degree 3 as illustrated in Figure 5.
Even though the sample size is small, the trend results tie in with the experience of the PGWC Roads Branch staff and, to a large extent, with performance models already incorporated into their pavement management system.

Based on the average life of bituminous seals from experience in South Africa, Australia and recently reported in New Zealand, being in the order of nine to ten years, a huge backlog in reseal work has developed in southern Africa.

Information has been obtained from three road authorities in southern Africa indicate that the percentage of each sealed surfaced road network with seals older than ten years is:

- Road Authority A = 61%
- Road Authority B = 43%
- Road Authority C = 80%

The authors indicate that the study will continue through sampling of different seal types from different age groups and climatic environments, testing of permeability, stiffness development and fatigue characteristics to provide information that could be used for component modelling.

Figure 5: Fatigue crack development as a function of binder ageing
Asphalt mixtures

Outline

Two papers demonstrate how the analysis of packing characteristics of mixes designed for heavy traffic applications contribute to the performance characteristics of asphalt mixes. While binder rheology is also noted as a contributing factor, especially to the rutting resistance of the mixes investigated, packing characteristics that lead to gradings that are by no means continuous in the classical sense, were found to be prime factors. The paper on HiMA also cautions against the adherence to nominal grading curves for design.

Another issue covered is the growing need for the evolution of asphalt mix design procedures to target the attainment of performance characteristics, rather than empirical parameters, particularly in heavy traffic situations.

Innovations on the asphalt mix design for the rehabilitation of National Route 3 between Mariannhill and Key Ridge:
Liebenberg, Rossmann and Joubert

A feature of this paper, which presents a comprehensive asphalt mix design process aimed at the achievement of key mix performance characteristics, is the use of the Bailey method to optimise aggregate packing, while using the conventional continuous COLTO grading envelopes as a guide only.

Three trial sections of varying binder contents were constructed for each binder type, and extensive performance tests, which included Model Mobile Load Simulator (MMLS) tracking, Hamburg wheel tracking and flexural beam fatigue testing were performed on cores and beams extracted from the trial sections.

COLTO grading envelopes used as an initial guideline followed by establishing the optimum grading using the Bailey method.

National Route 3 between Durban and Gauteng in South Africa is a very good example of a high traffic volume road subjected to extreme operating conditions with respect to loading, topography and environmental conditions. The structural design of these pavements requires a high degree of care, and has to be done in conjunction with the mix design of individual structural layers to ensure that structural design targets are met.

Mechanistic-empirical models at the time indicated that the required stiffness of the asphalt base should be around 4 000 MPa to meet a 15 year design life. It was however noted that the mechanistic-empirical models available at the time only considered the fatigue of asphalt and not rutting, which is more common in pavements with very high traffic loadings.

To satisfy the pavement design requirements a mix design process, more intensive than the processes commonly adopted, was employed. The mix design included the parallel design of two mixes with two binder types, followed by the construction of trial sections of both binders and detailed performance tests on cores extracted from the trial sections.
Distinct features of the mix design process followed were

- Pre-selection of binders to be used in the mix design process, in this case an AP1 binder (using EVA) and an A-E2 binder (using SBS);
- Determination of the mix grading by using the COLTO grading envelopes as an initial guideline followed by establishing the optimum grading using the Bailey method. It was also noted at this stage that the optimum grading may fall outside the COLTO grading;
- Determination of the mix volumetrics and optimum binder content on both the A-P1 and A-E2 binders;
- Evaluating the consistency of plant trial mixes with laboratory prepared mixes for each binder at optimum binder content;
- Construction of six trial sections; three for each binder at various binder contents. The trial sections were constructed at the optimum binder content and 0.3 % above and 0.3 % below the optimum; and
- Extraction of cores and beams from trial sections and evaluation for:
  - Resistance to stripping using modified Lottman and wet MMLS tests;
  - Rutting resistance using the MMLS and Hamburg wheel tracking tests;
  - Fatigue resistance using bending beam fatigue tests.

Asphalt mix designs

The main objective of using the Baily method was to create an optimum grading matrix with good interlock. Figure 2 presents the adopted grading as determined by the Bailey method in relation to the COLTO grading envelope.

Table 2: Bailey design parameters

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>%CA LUW</td>
<td>74</td>
</tr>
<tr>
<td>Primary Control Sieve (PCS)</td>
<td>4.75</td>
</tr>
<tr>
<td>CA</td>
<td>0.68</td>
</tr>
<tr>
<td>FA_c</td>
<td>0.55</td>
</tr>
<tr>
<td>FA_f</td>
<td>0.47</td>
</tr>
<tr>
<td>Nominal Maximum Particle Size (NMPS)</td>
<td>13.2 mm</td>
</tr>
</tbody>
</table>

Figure 2: Adopted mix grading vs standard COLTO continuous grading
Resistance to deformation or rutting

Dry MMLS tests at 60°C and 7 200 repetitions per hour (standard speed) were performed on both the A-P1 and A-E2 mixes. To determine the performance of the mixes under slow loading conditions, further MMLS tests were done at 2 400 repetitions per hour on the 4,2% A-P1 and 4,3% A-E2 mixes. Wet MMLS tests at standard speed were performed on the 4,2% A-P1 and 4,3% A-E2 mixes to determine moisture susceptibility and potential for stripping of the mixes.

Figure 3 presents the results of the MMLS tests at standard speed dry, 33% speed dry and standard speed wet.

On all three the MMLS tests, the A-P1 binder exhibit better rut resistance than the AE2 mix, and on all three tests the A-P1 binder was below the maximum threshold of 2,5 mm after 100 000 load repetitions.

Also, the A-P1 mix exhibited no visible signs of stripping after the wet MMLS test at 7 200 repetitions per hour whereas for the A-E2 mix early signs of stripping were observed.

A significant increase in rut resistance of both mixes when compared to other "standard" mixes.

Hamburg wheel tracking tests on the 4,2 % and 4,5 % A-P1 mix as well as the 4,3 % and 4,5 % A-E2 mix were also performed to gain further confidence in the potential rut resistance of the mixes.
Results from the Hamburg wheel tracking tests, presented in Figure 4, indicate a significantly higher rut rate for the A-E2 binder and generally confirms the trend observed in the MMLS tests, that the A-E2 binder mixes are more rut susceptible than the A-P1 binder mixes.

A comparison (figure 5) of the results from this project with other mixes tested under the Hamburg wheel tracking device, however, showed a significant increased rut resistance of both mixes when compared to other “standard” mixes.

![Figure 5: Comparison of Hamburg wheel tracking tests with other tested asphalt mixes](image)

**Fatigue resistance**

While noting that the fatigue results were based on a limited number of tests and that some scatter in the data was observed, the authors considered the fatigue properties of both mixes to be acceptable.

The final mix selected for this project was an A-P1 mix with a target binder content of 4.3% and target Marshall void content of 4.8%.

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**GB5: Innovative design of high-performance asphalt mixes for long life & cost-effective pavements by optimising aggregates and using SBS modified bitumens:**

Olard

Aggregate packing concepts developed in the field of high-performance cement concretes, initially by Caquot (1937), were adapted to the field of asphalt concretes. These concepts, associated with the use of the gyratory compactor on aggregates only, enabled the development of a new laboratory design procedure for dense high-modulus asphalt concretes.
These mixes are characterised by pronounced coarse aggregate interlock, thereby doing away with the need for low penetration grade bitumens to attain 14,000MPa stiffness modulus value at 15°C.

While aggregate packing is mainly influenced by five parameters (gradation, surface micro-texture, type and amount of compaction effort, and layer thickness), the paper focuses on gradation by optimising the combination of fine and coarse fractions to maximise mixture strength and, in particular, stiffness modulus.

**Basic notions associated with binary gradings**

As a prelude to the study of multi-component systems, an understanding of the factors involved in the relationship between aggregate proportions and porosity in 2-component systems is presented. The system hinges on two types of inter-particle interaction on the void ratio $e$, i.e. the ratio of volume of voids/volume of solids:

- the so-called “wall effect”; and
- the “interference effect” – also called “loosening effect”.

The “wall” effect relates to the interaction between particles and any type of wall (e.g. pipe, container) in contact with the granular mass. In a uniform, two-aggregate mix with the two component fractions differing only by their average particle dimension, the void ratio of the blend reduces when coarse particles are added to an infinite volume of fines. However, there is local porosity due to the wall effect on the void ratio of a granular combination. The left hand side of Figure 1 illustrates this phenomenon.

The “interference” (or “loosening”) concept can be illustrated by focusing on the effect induced by introducing a few fine particles into an infinite volume of coarse particles. As the amount of fines increases, at some point coarse particles are forced apart by loosening, thus modifying their spatial configuration (Figure 1, right hand side).

If the average particle dimension of fines ($d_{\text{FINE}}$) is small enough compared to the coarse particles ($d_{\text{COARSE}}$) i.e. $d_{\text{FINE}}/d_{\text{COARSE}} < 0.2$, the wall effect is linear; otherwise, the interference/loosening effect is never linear and therefore difficult to determine easily.
In the study presented an iterative process was followed to optimise aggregate packing of a quaternary blend consisting of 10/14 mm, 0/4 mm, 0/2 mm and filler, by using gyratory compactor (GC) on aggregates only i.e. without any bitumen. This packing optimisation consists of three sets of GC measurements at 20 gyrations only, as after 20 gyrations without any bitumen abrasion or attrition was observed. The sets of measurement determine:

- The optimal 10/14-0/4 binary blend;
- The optimal 10/14-0/4-0/2 tertiary blend, considered as a binary blend with the previous 10/14 - 0/4 blend being considered as the "coarse fraction", while the 0/2 fraction is considered as the "fine fraction"; and
- The optimal 10/14-0/4-0/2-filler quaternary blend.

Figure 6 shows the gradation curves of each tested asphalt mix dealt with in the paper and indicates the deviation from continuously graded mixes (GB2) and SMA.
Other properties evaluated were:

- Compactibility evaluated by GC. Improvements were noted; densities increased by 2.3% up to 4.0%. This excellent compactibility of the GB5 was confirmed on site during many experimental road works in France and Spain;
- Compressive strength & moisture resistance assessed by the Duriez test;
- Rutting resistance assessed through the French Wheel Tracking test. GB5 mixes exhibit huge resistance to rutting for two main reasons:
  - the well-interlocked and dense mixtures obtained from the optimisation of aggregate packing;
  - semi-blown and polymer modified bitumens used.

The authors note that, for a fixed bitumen type and content, complex stiffness modulus of such well-interlocked and dense mixtures, measured at 15°C -10Hz, is increased by approximately 17%. Hence the proposed aggregate packing optimisation procedure could be used in the framework of high modulus asphalt mix design with slightly softer grades of bitumen than generally used for EME (enrobé à module élevé), thereby enhancing both the potential for reclamation and fatigue resistance of asphalts mixes.

Up to the time of writing, several full scale road works have been successfully completed in France and Spain at either hot (170°C) or warm (125°C) or even half-warm (90°C) mixing temperatures.

The authors conclude that reductions achieved in both binder content and base course thickness (due to enhanced stiffness and fatigue properties) lead to a cost-effective and eco-friendly perpetual pavement design.
COMMITTED TO PLAYING A CONTRIBUTING ROLE IN IMPROVING THE ROADS OF THE WESTERN CAPE

Tel. 021 975 0784
Fax. 021 975 0792
email: info@moreash.co.za
web: www.moreasphalt.co.za

By using the best available technology to produce asphalt in an environmentally responsible manner, we are helping to provide a better life for all our citizens.
In this paper the authors present the development of an interim guideline for the design of High Modulus Asphalt (HiMA) for bases. The procedure covers the selection criteria for aggregates and binder and the choice of a grading curve.

Like the original French method, the HiMA design guideline is performance orientated. Trial mixes are assessed in terms of workability, durability, elastic modulus, resistance to permanent deformation and fatigue performance. Local criteria for these performance indicators were set by comparing the performance of a mix design against European and South African test methods.

The HiMA, or Enrobés à Module Élevé (EME), technology, developed in France in the early 1990’s is currently used extensively on main routes, airports as well as urban roads. HiMA combines superior permanent deformation resistance with high structural stiffness and good fatigue performance. The key to achieving these often conflicting aims of design are a high binder content, consisting of hard bitumen with a penetration value of between 10 and 25 combined with good quality, fully crushed aggregate.

**Aggregate selection**

In the selection of an aggregate source, both angularity and surface texture are important. High aggregate angularity and sufficient surface texture assist in the creation of adequate voids in the mineral aggregate (VMA) to accommodate a fairly high binder content. The aggregate selection guidelines proposed in the interim design guide are proposed in Table 1.

The particle index test provides a measure of aggregate angularity and surface texture. Tentative values for this property are proposed. Generally aggregates with a high particle index result in a higher VMA. It is suggested that the flakiness index for HiMA aggregate should lie between 10 and 15.

<table>
<thead>
<tr>
<th>Property</th>
<th>Test</th>
<th>Method</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>Fines aggregate crushing test: 10% FACT</td>
<td>TMH1, B1</td>
<td>&gt; 160 kN</td>
</tr>
<tr>
<td></td>
<td>Aggregate crushing value ACV</td>
<td>TMH1, B1</td>
<td>≤ 25%</td>
</tr>
<tr>
<td>Particle shape and</td>
<td>Flakiness index test SANS 3001</td>
<td></td>
<td>≤ 25</td>
</tr>
<tr>
<td>texture</td>
<td>Particle index test ASTM D 3398</td>
<td></td>
<td>&gt; 15</td>
</tr>
<tr>
<td>Water absorption</td>
<td>Water absorption coarse aggregate (&gt;4,75 mm)</td>
<td>TMH1, B14</td>
<td>≤ 1,0%</td>
</tr>
<tr>
<td></td>
<td>Water absorption fine aggregate</td>
<td>TMH1, B14</td>
<td>≤ 1,5%</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>Sand equivalency test</td>
<td>TMH1, B19</td>
<td>≥ 50</td>
</tr>
</tbody>
</table>

**Aggregate grading**

The LPC bituminous mixtures design guide provides target grading curves and envelopes for HiMA mixes. These only provide a point of departure for the mix design...
process and that they should not be used to impose restrictions on the grading in the fashion of the current South African COLTO specifications. Until more experience is gained in South Africa, it is recommended that the envelopes published in the LPC guideline be used.

Binder selection and the richness factor

In Europe, either a 10/20 or a 15/25 Pen grade binder is typically used in HiMA mixes. However, at the time of writing, the only binder available locally for use in the technology transfer project to date was a 20/30 Pen grade conforming to EN 12591. It is expected that 15/25 penetration grade bitumen will become available in South Africa in the near future.

A key parameter in arriving at a suitable binder content for HiMA is the richness modulus $K$ - a proportional value related to the thickness of the binder film coating the aggregate and the aggregate relative density.

$K$ is obtained from:

$$TL_\text{est} = K \cdot a \sum$$

Where:

- $TL_\text{est}$: is the binder content by mass of total aggregate. $TL_\text{est}$ can be converted to the binder content by mass of total mix ($P_b$) generally used in South Africa using equation 2:
  $$TL_\text{est} = \frac{100P_b}{(100 - P_b)}$$
- $a$: is a correction coefficient for the relative density of the aggregate (RDA)
  $$a = 2.65$$
- $\sum$: is the specific surface area calculated from:
  $$100\sum = 0.25G + 2.3S + 12s + 150f$$

Where:

- $G$: is the proportion of aggregate retained on and above the 6.3 mm sieve;
- $S$: is the proportion of aggregate retained between the 0.26 mm and 6.3 mm sieves;
- $s$: is the proportion of aggregate retained between the 0.063 mm and 0.25 mm sieves;
- $f$: is the percentage passing the 0.063 mm sieve.

Performance testing

An extensive laboratory study was conducted to translate the French performance specifications for HiMA to South African equivalents. To achieve this mixes were replicated in South Africa and France and subjected to the relevant French performance tests and evaluated using local test methods for the various performance parameters.

The set of performance tests used in the French mix design procedure and the selected locally available equivalents are shown in Table 5.
Table 5: French performance tests and selected South African equivalents

<table>
<thead>
<tr>
<th>Parameter</th>
<th>French test method</th>
<th>Selected South African equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>EN 12697 - 31: Gyratory compactor</td>
<td>ASTM D6926: SUPERPAVE gyratory compactor</td>
</tr>
<tr>
<td>Durability</td>
<td>EN 12697 - 12: Duriez test</td>
<td>ASTM D4867: Modified Lottmann test</td>
</tr>
<tr>
<td>Permanent</td>
<td>EN 12697 - 22: Wheel tracker</td>
<td>AASHTO 320-03 SUPERPAVE Shear Tester</td>
</tr>
<tr>
<td>Deformation</td>
<td>EN 12697 - 26: Flexural beam</td>
<td>AASHTO TP 62: Dynamic modulus</td>
</tr>
<tr>
<td>Dynamic modulus</td>
<td>EN 12697 - 31: Gyratory compactor</td>
<td>AASHTO T 321: Beam fatigue</td>
</tr>
</tbody>
</table>

Workability (gyratory compactor study)

Since the configuration of the gyratory compactors available in South Africa – the US SUPERPAVE (ASTM D6926) - differs from the EN-12697-1 standard used in France in terms of the angle of gyration, a comparative study was conducted to convert the French workability criteria to equivalent criteria using the SUPERPAVE gyratory compactor. The gyratory compactor in the CSIR laboratory, having an adjustable angle of gyration, facilitated this process.

Compaction trials, using both compaction angles, were carried out. Figure 3 shows the average compaction curves obtained for the two mixes studied. A compactive effort of 100 cycles using the European gyration angle corresponds to approximately 45 cycles in a compactor set to SUPERPAVE specifications. Based on the results of the investigation, it is proposed to set an indicative maximum air void criteria at a compactive effort of 45 SUPERPAVE gyrations for South African HiMA mixes, compared to the 100 gyrations specified in France.

Figure 3: Gyratory compaction curves for two mixes using European and SUPERPAVE configurations
Durability
While the durability of HiMA is assessed in France using an unconfined compressive test (EN12697-12) on moisture conditioned specimens (Duriez test), it was deemed unnecessary to develop separate durability criteria for HiMA; instead, the modified Lottman test is retained with criteria being the same as for asphalt in general.

Permanent deformation
The Repeated Simple Shear Test at Constant Height (RSST-CH) was selected as a locally available test method, because it is the standard test used in the revision of the South African Pavement Design Method, currently underway. The test is performed in accordance with the AASHTO 320-03 procedure with certain alterations. It is stated that the intention is to develop an additional set of deformation criteria for wheel tracker type tests at a later stage.

Dynamic Modulus
The French performance criteria of 14 GPa at 10 Hz and 15°C were maintained in the South African interim design guideline.

Fatigue
Based on the comparison of the relative performance of the French mix design subjected to trapezoidal and the Four Point Beam (FPB) testing, minimum specifications were set for the performance of HiMA in FPB tests.

The criteria require validation through accelerated pavement testing (APT).

Tentative performance specifications for HiMA
The tentative performance specifications developed based on the experimental work are shown in Table 8. The authors state that the criteria require validation through accelerated pavement testing (APT), and indicated that an APT programme is planned for the next phase of the HiMA T2 project.

Table 8: Tentative performance criteria for HiMA bases

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Description</th>
<th>Method</th>
<th>Performance requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Class 1</td>
<td>Class 2</td>
</tr>
<tr>
<td>Workability</td>
<td>Gyratory compactor, air voids after 45 gyrations</td>
<td>ASTM D6926</td>
<td>≤ 10%</td>
</tr>
<tr>
<td>Moisture sensitivity</td>
<td>Modified Lottmann</td>
<td>ASTM D 4867</td>
<td>Refer Table 7</td>
</tr>
<tr>
<td>Permanent deformation</td>
<td>RSST-CH, 55°C, 5000 repetitions</td>
<td>AASHTO T 320</td>
<td>≤ 1,1% strain</td>
</tr>
<tr>
<td>Dynamic modulus</td>
<td>Dynamic modulus test at 10 Hz, 15°C</td>
<td>AASHTO TP 62</td>
<td>≥ 14 GPa</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Beam fatigue test at 10 Hz, 100C, to 70% stiffness reduction</td>
<td>AASHTO T 321</td>
<td>≥ 310 με for 10 E6 repetitions</td>
</tr>
</tbody>
</table>

In conclusion the authors indicate that damage models for the prediction of rutting and fatigue of HiMA material are in progress as part of the revision of the South African pavement design method.
Speciality Session 3

Development of human resources, systems and procedures for optimal preservation of road assets
Pavement courses offered by SARF

- Practical Road Pavement Engineering - Presenters D Wright and T Lewis
- Traffic Calming - Presenter K Labuschagne
- Compaction of Road Building Materials - Presenters M White, Prof P Savage and D Pagel
- Introduction to Road Materials Engineering - Presenters A Lewis and D Wright
- Road Pavement Rehabilitation - Presenter G Jordaan
- Design and Construction of Surfaced Low Volume Roads - Presenters R Burrell, Dr P Paige-Green and G van Zyl
- Pavement Rehabilitation by Recycling/Bitumen Stabilisation - Presenters Prof K Jenkins, D Collings and K Louw
- Riding Quality and its effect on Road Transport - Presenter Prof W Steyn

Courses offered in association with the Sabita Asphalt Academy

- Bituminous Binders for Roads - Presenter B Pearce
- Design, Construction and Application of Surfaced Seals - Presenter G van Zyl
- Design of Hot Mix Asphalt (HMA) - Presenter Dr J Anochie-Boateng
- Latest Developments in Asphalt Technology - Presenter H Marais
- Overview of HMA - Presenter D Pagel
- Flexible Pavement Design - Presenter Dr F Long
- Analysis and Assessment of Test Data - Presenter B Pearce

Contact us:
South African Road Federation
Tel: 011 403 5003/4
Fax: 011 403 7736
Fax2mail: 086 576-7952
Email: administrator@sarf.org.za
Website: www.sarf.org.za

South African Road Federation
Development of human resources, systems and procedures for optimal preservation of road assets

Outline

The papers presented here cover divergent elements of the scope of this focus area. Concerns have been raised that a system for procurement of consultancy services through a tendering process may well compromise the quality of service and is probably counterproductive. One paper analyses the situation and makes suggestions on how to improve the system in the interests of fair, equitable, transparent, competitive and cost effective practice.

The other paper deals with the significant challenge to a toll concessionaire of balancing the objectives of operating profitably, on the one hand, and meeting contract requirements of functionality and safety for a heavily trafficked network, on the other.

Tendering for professional services: both sides of the coin:

Liebenberg1 and Wilson

This paper analyses SANRAL's data as well as information elicited from surveys among consultants, contractors and SANRAL staff as a means towards understanding the impact that competitive tendering has had on this unique sector over the last five years.

Since 2006, more than 200 projects were procured by SANRAL using its competitive tender system. A total of 131 of these projects, were included in this study which comprised:

- 60 periodic maintenance projects;
- 44 rehabilitation and pavement strengthening projects; and
- 25 improvement projects.

The total value of the professional services included in this study was approximately R1-billion.

On average, SANRAL tenders made up more than 50% of the total tenders in the road and pavement sector submitted by consultants in South Africa between 2008 and 2010. SANRAL was chosen as the subject of this study for the following reasons:

- It maintains good records on past and present projects;
- The tendering system was implemented over a very short period of time, making it possible to determine a change in trends of some indicators over a short period of time; and
- SANRAL provided the largest market share for roads and pavement related professional services to consulting engineers in southern Africa.

It is recorded that in 2005, two important publications were issued by the Department of Public Works. The first was the Standard for Uniformity in Construction Procurement (CIDB, 2005a), and the other a best practice guideline for the procurement of
professional services (CIDB, 2005b). Both became compulsory activities for organs of state and SANRAL began to apply them for engineering services.

While the authors are in favour of change, they advocate that such change should be well-considered and guided by the law. They quote a judgement of the KwaZulu-Natal High Court which made it clear that an award has to be made on price and preference, and that the price component cannot be diluted in any way. In other words, the SANRAL (and CIDB published) method of merging technical criteria points with financial points has been declared unacceptable because the Preferential Procurement Policy Framework Act regulations were drafted beyond the legal capacity of the act. This gives a hierarchical order to legislation drafting and creates a nightmare for client bodies doing their utmost to abide by the various statutes that regulate their systems.

The ruling has caused SANRAL to revise its system to become more compliant. But suffice it to say that the changes do not impact on the study generated by this paper. Rather, what the ruling says about the procurement system is that in the South African context of developing the previously disadvantaged, change can be expected.

In addition to the projects referred to above, surveys were conducted among professionals in the consulting engineering and contracting sectors as well as SANRAL project engineers over a period of six weeks in early 2011. The anonymous surveys were collected with the assistance of Consulting Engineers South Africa (CESA) and contained more than 100 questions in total. Four different surveys were conducted among the following:

- Consulting engineering companies that generally provide professional services to SANRAL (19 responses);
- Engineering professionals in the consulting environment (25 responses);
- Contractors (7 responses); and
- SANRAL project engineers (17 responses).

The pricing system provides little incentive to engage in value engineering solutions.

All the consulting firms that participated indicated a reduction in project profitability and turnover in the transport sector of their business as a result of the tendering process, while 86% reported a reduction in total company turnover. Opinions on whether the tendering system for professional services has been beneficial to the consulting engineering industry are presented in Table 9.

Table 9: Opinion on whether the tendering system has been beneficial for the consulting industry

<table>
<thead>
<tr>
<th></th>
<th>Consultants</th>
<th>Contractors</th>
<th>SANRAL Project Engineers</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beneficial</td>
<td>19.0%</td>
<td>66.0%</td>
<td>18.8%</td>
<td>22.5%</td>
</tr>
<tr>
<td>Not beneficial</td>
<td>81.0%</td>
<td>34.0%</td>
<td>81.2%</td>
<td>77.5%</td>
</tr>
</tbody>
</table>

Most consultants (67%) did not regard the current tendering system as sustainable and that some changes to the system are required. Table 10 presents an opinion whether the tendering system for professional services should be abolished.
Table 10: Opinion on whether tendering system should be abolished

<table>
<thead>
<tr>
<th>Abolish tendering</th>
<th>Consultants</th>
<th>Contractors</th>
<th>SANRAL Project Engineers</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>63.0%</td>
<td>0.0%</td>
<td>23.5%</td>
<td>39.0%</td>
</tr>
<tr>
<td>No</td>
<td>37.0%</td>
<td>100.0%</td>
<td>76.5%</td>
<td>61.0%</td>
</tr>
</tbody>
</table>

The authors regard most of the information collected as painting a gloomy picture of the impact of the tendering process on the road and pavement sector of the consulting industry. They consider that this outcome could be due for several reasons:

- Incomplete adjustment to the new system;
- There may be a need for consolidation in the industry;
- It appears that individuals and companies that participated may have negative sentiments toward the tender process and their views may therefore be biased.

The authors conclude that that a variation on the existing pricing structure is required to avoid adverse effects on the quality of deliverables and a possible reduction in the quality of work delivered since the implementation of the tendering system.

Also, the pricing system provides little incentive to engage in value engineering solutions, with consultants only willing to provide what has been specified and priced for.

A further concern raised by the industry, and reported in this paper, is the time and cost to submit tenders. The authors recommend that a mechanism, such as pre-qualification to reduce the number of tenderers per tender, should be considered, as they question the ability of the industry, particularly smaller entities, to sustain the cost of tendering over the medium and long term.

Competitive tendering for professional services is common practice internationally, and has been introduced as the norm in Southern Africa. SANRAL is currently leading this process, which is considered to be transparent and fair to a large extent. However, a number of issues, some of which have been identified in this paper, can be addressed to improve the system to achieve the objectives of the Constitution of South Africa, which is that it should be fair, equitable, transparent, competitive and cost effective.

Overview of a pavement management system in a toll road context: Judd, Tolmie & Jooste

This paper summarises the key features of the pavement management activities of a South African toll concessionaire’s process for deriving a reliable long term pavement management strategy.

The N3TC Concession Contract contains certain compliance requirements with respect to functional and structural parameters - primarily to maintain the road pavement network with sufficient structural capacity to accommodate traffic safely and comfortably during the concession period with a residual structural pavement life.

Balancing the two objectives of operating profitably and meeting contract requirements of functionality and safety is regarded as a significant challenge for a heavily trafficked network such as the N3TC, demanding a consistent and rigorous approach to network management.
In this case there are two annual milestones with respect to managing the pavement network. These entail the presentation of:

- An updated financial model to demonstrate to the senior lenders, the shareholders and SANRAL that the project is financially secure;
- Operating reports on condition and traffic together with a three year capital rehabilitation program for submission to SANRAL and the Independent Engineer for consideration and approval.

As shown in Figure 2, to meet these annual milestones, two key processes need to be executed:

- Assessment of the network condition and compliance to the contract requirements; and
- The development of a pavement engineering strategy using a deterioration model under a given financial plan.

**Figure 2: N3TC annual pavement management system activities**

**Condition Data**

Annual surveys include the following:

- Surface profile measurements;
- Rut, IRI every 10 m;
- IRI is averaged over 100 m for compliance analysis.

Additionally, FWD measurements are carried out annually for structural analysis purposes.

Typical functional requirements are indicated in Tables 1 and 2.
Table 1: Concession contract requirements for rutting

<table>
<thead>
<tr>
<th>Limiting rut depth (mm)</th>
<th>Maximum length of each 1km segment with rut depth above limiting value</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>10% (i.e. the 90th% rut depth should be below this value)</td>
</tr>
<tr>
<td>20</td>
<td>5% (i.e. the 95th% rut depth should be below this value)</td>
</tr>
<tr>
<td>25</td>
<td>0% (i.e. the maximum rut depth should be below this value)</td>
</tr>
</tbody>
</table>

Table 2: Concession contract requirements for roughness

<table>
<thead>
<tr>
<th>Limiting IRI for road category</th>
<th>Maximum length of each 1km segment with IRI above limiting value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>3.5 (i.e. the 80th% IRI should be below this value)</td>
</tr>
<tr>
<td>3.5</td>
<td>3.8 (i.e. the 95th% IRI should be below this value)</td>
</tr>
<tr>
<td>4.5</td>
<td>4.9 (i.e. the maximum IRI should be below this value)</td>
</tr>
</tbody>
</table>

Key outputs of the condition surveys is a network condition report reflecting:

- Analysis of compliance to concession requirements;
- Summary of current network condition;
- Analysis of network performance trends.

A novel feature is the use of rule-based models for the estimation of deterioration rates.

Deterioration modelling

Deterioration modelling, which plays a critical role in developing engineering strategy and validating the financial model, aims to:

- Model the likely deterioration of the network;
- Select and apply the most appropriate treatments at the most appropriate times; and
- Assess the combined effects of network deterioration and improvement on network condition over time.

A novel feature of the N3TC deterioration model is the use of rule-based models for the estimation of deterioration rates and the selection of work sections to apply work in a realistic manner. The rule based model allows the user to establish deterioration models based on general, observed and known patterns (i.e. “rules”) of road deterioration. It has been previously reported that the rule-based models as implemented on the N3TC network are robust and – compared to regression equation based approaches – relatively easy to calibrate.

Table 3 summarises some of the key aspects included in the N3TC models.
Table 3: Key aspects of the rule-based N3TC model (after Jooste et al 2010)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rules taken into account</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial structural capacity (determined only in first modelling year)</td>
<td>FWD deflection bowl parameters; Rut depth; Roughness (IRI).</td>
<td>Actual observed values are used. Rut depth and IRI have low weights and are used to temper the prediction obtained from FWD parameters. After the initial prediction, structural capacity is reduced each year using the predicted number of standard axles in that year.</td>
</tr>
<tr>
<td>Crack initiation (years)</td>
<td>Structural capacity; Traffic loading; Surfacing thickness.</td>
<td>The membership function for crack initiation varies from 4 - 12 years. Typical predicted crack initiation time is 8 years.</td>
</tr>
<tr>
<td>Crack area (%)</td>
<td>Time elapsed since crack initiation (TACI); Traffic loading; Structural capacity.</td>
<td>Rules were set to mimic a typical S-shape development in which the time to reach &quot;high&quot; cracking is governed by the TRCI membership rules.</td>
</tr>
<tr>
<td>Crack increment (mm/year)</td>
<td>Structural capacity; Traffic loading; Crack area; Rut depth.</td>
<td>After the first modelling year predicted values are used for all variables.</td>
</tr>
<tr>
<td>Roughness increment (IRI/year)</td>
<td>Structural capacity; Traffic loading; Crack area; Rut depth.</td>
<td>After the first modelling year predicted values are used for all variables.</td>
</tr>
<tr>
<td>Intervention trigger rules</td>
<td>Structural capacity; Traffic loading; Crack area; Rut depth.</td>
<td>Several exclusion rules are used to ensure specific treatments are selected where extreme situations apply (e.g. low structural capacity). In all other cases the treatment with the highest possibility score is selected.</td>
</tr>
</tbody>
</table>

The use of work sections

A second novel feature of the N3TC deterioration model is the use of Work Sections to group and maintain parts of the network in the same years. Features of this method are:

- It ensures treatments are grouped in a practical and realistic manner;
- Work sections are user-defined and easily changed;
- Within work sections, treatments are varied based on condition situation; and
- Rule-based models selects the most appropriate treatment.

Special consideration had to be made to take this situation into account during the development of the N3TC deterioration model. This meant that the model had to provide the facility to group network segments (typically 1 km long) into a "work section", and that the model needed to treat all segments within a work section at the same time. Furthermore, the model needed to apply the most appropriate intervention to each modelling segment within the same work section.

The work section concept is depicted in Figure 5 which illustrates how work sections can be of any length and can cover all lanes of both directions of a dual carriageway, or a single direction, depending on the needs and approach of the network engineer.
Conclusions

In conclusion the authors state that a reliable long term pavement management strategy had been developed and the N3TC Contract - now in its 12th year of operation - provides a valuable learning platform for the management of a concession contract.

They single out some lessons learnt; these pertain to functional data measurements, the need to study concession requirements carefully and model calibration and validation.
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8

Speciality Session 4

Bitumen technology
Bitumen technology

Outline

Papers selected for this focus area all deal with rheological aspects of bitumen. Areas covered are the use of the Dynamic Shear Rheometer for rapid estimation of penetration values, the uncertainty of the Rolling Thin Film Oven Test to emulate short term ageing for a range of asphalt applications, and using this apparatus to gauge the long term ageing characteristics of bitumen in both asphalt and spray seals.

The use of the dynamic shear rheometer (DSR) to predict the penetration of bitumen: van Heerden et al

The authors note that while the penetration value of bitumen is the most commonly used method for measuring the consistency of bitumen, it is also used to monitor bitumen quality during its production process. The study presented in the paper was conducted to develop a method of analysis in a short space of time during production, so as to enable speedy adjustments without having to wait for the time consuming penetration test.

Consequently the study aimed at affirming previously published relationships between penetration properties and the dynamic shear rheometer test results using the test procedures developed in the SHRP.

The incentive for using the DSR for quality assessment is that the complex modulus results can be available in as little as 20 minutes.

The authors note that most refineries use the penetration and viscosity properties of bitumen as quality control parameters during the production of penetration grade bitumen. However, the penetration test (using the ASTM D5 procedure) requires a time consuming conditioning step before a sample can be analysed.

The incentive for using the DSR for quality assessment is that the complex modulus results can be available in as little as 20 minutes. Hence the objective of this study was to find a correlation between the complex modulus of 80/100 penetration grade bitumen using the conditions prescribed by the SHRP PG system and the penetration test results, both tests being carried out at 25°C.

DSR testing was carried out according to ASTM D7175 - Standard test method for determining the rheological properties of asphalt binder using a dynamic shear rheometer; the penetration value was determined according to ASTM D5.

Figure 4 in the paper presents the plot of log (Penetration) versus log (G*) at 25°C for the more than 100 bitumen samples mentioned above. Clearly a good correlation coefficient (R²=0.99) and strong linear relationship of the entities was observed.
The relationship based on the sample represented in Figure is given by:

\[
\log (\text{Pen}) = 2.971 - 0.381 \log (G^*)
\]

The authors compared the predicted penetration values with the actual penetration values for the same samples as determined by ASTM D5. A plot of these penetration values is presented in Figure 5. Not surprisingly the high \( R^2 \) (0.9898) is a further indication that the derived equation was appropriate.
A new set of samples was collected from different refineries and the process repeated. Figure 7 shows the correspondence of predicted and determined penetration values (with the reproducibility limits) and illustrates that the model that was developed is applicable to most bitumen crude slates that are processed by South African refineries and that the model is also not particularly sensitive to the process by which the bitumen is produced.

The predicted values all fall within the reproducibility limits for the ASTM D5 test method for penetration. It is suggested that, by using the above-mentioned relationship between $G^*$ and penetration, the DSR result can be converted into an equivalent penetration value relatively quickly.

The authors conclude that the calculation of a penetration value which provides a result in the equivalent time that it takes to determine the viscosity in a Brookfield Viscometer will expedite decisions both during crude slate changeovers and product quality assurance. By the selection of appropriate complex modulus limits, one could, with high degree of confidence, predict whether compliance limits for penetration will be met. They suggest that the model presented in this paper can, with further work, be extended to include other penetration grades as well as homogeneous modified binders.
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Fax: +27 (0)11 493 6349
Email: dickkinglabs@iafrica.com
Unit 6, Selby 515, Prop Street,
Selby, Johannesburg, Gauteng
Email: lanserac@iafrica.com
**Adjusting the standard rolling thin film oven procedure to improve the prediction of short term ageing:**

**O’Connell, Mturi and Maina**

The authors demonstrate that the standard RTFOT that is generally used to simulate the short-term ageing (STA) that a binder undergoes during hot mix asphalt (HMA) manufacture, transport, laying and compaction, cannot accommodate the wide range of mixing and compaction temperatures of various HMA mixtures used today. There is poor correlation between RTFOT aged values and those obtained from binder recovered from cores after construction. They suggest that the RTFOT can be modified to predict short term ageing of binders more accurately.

The mechanistic-empirical framework for pavement design published by the National Cooperative Highway Research Program (Report No. 1-37A: *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures* - NCHRP, 2004) has attracted international interest and, in South Africa, is being used in the review of the South African Pavement Design Method (SAPDM), currently underway. This framework (hereafter referred to as the MEPDG – Mechanistic-Empirical Pavement Design Guide) has a hierarchical approach with regards to the input requirements for the mechanistic-empirical design method.

**The RTFOT can be modified to more accurately predict the short-term ageing of binders.**

This paper focuses on the level 2 and level 3 predictive equations to obtain dynamic modulus values, and specifically on the binder viscosity required as input into the predictive equation.

**Level 2** requires limited laboratory testing for binder properties that are used in predictive equations for dynamic modulus.

**Level 3** requires minimal laboratory testing and estimated material properties, such as dynamic modulus (\(E^*\)), are obtained from predictive equations applied to typical (historical) binder properties values.

The MEPG stipulates that the binder viscosity value after RTFOT is used for the Witczak equation. The authors maintain, however, that a fixed short term ageing procedure cannot make provision for the wide range of e.g. mixing and compaction temperatures and construction delays. They found that the Witczak model over-predicted \(E^*\) for mixes with high mixing/compaction temperatures because RTFOT binder viscosity is lower than in-situ value (see figure below).
Five widely used South African HMA mixes were evaluated based on the MEPDG. Each binder was evaluated and characterised for the following conditions of sample history:

- Binder subjected to the RTFOT to simulate ageing that occurs during manufacture, transport, laying and compaction of the mix;
- Binder recovered from HMA samples manufactured in the laboratory and subjected to short-term ageing (STA). The purpose of short-term ageing is to simulate field ageing – four hours in an oven at compaction temperature prior to sample compaction;
- Binders recovered from cores that have been sampled from the pavement after construction.

Results for three of the five binders investigated are presented in this paper as shown in Table 1. The binder properties used for comparison are presented in Table 1.

**Table 1: Summary of binders presented in this paper**

<table>
<thead>
<tr>
<th>Binders presented in this paper</th>
<th>Mix type</th>
<th>Binder content (m/m%)</th>
<th>Design voids (v/v%)</th>
<th>Compaction temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60/70 penetration grade bitumen</td>
<td>Medium continuous grading as designated by COLTO (COLTO, 1998), Designated as Mix 5 (Anochie-Boateng et al., 2011a)</td>
<td>5.0</td>
<td>4.9</td>
<td>135</td>
</tr>
<tr>
<td>40/50 penetration grade bitumen</td>
<td>BTB (Asphalt Base, 26.5 mm max) as designated by COLTO (COLTO 1998), Designated as Mix 1 (Anochie-Boateng et al., 2011b)</td>
<td>4.4</td>
<td>4.5</td>
<td>140</td>
</tr>
<tr>
<td>SBS modified binder conforming to A-E2 (TG1, 2007) classification</td>
<td>Coarse continuous grading as designated by COLTO (COLTO, 1998), Designated as Mix 2 (Anochie-Boateng et al., 2011c)</td>
<td>4.3</td>
<td>4.8</td>
<td>145</td>
</tr>
</tbody>
</table>

Binder properties tested were Softening Point (ASTM D36-06), Penetration (ASTM D5-06) and Apparent Viscosity @110°C (ASTM D4402-06).
An example of the results softening point for 60/70 penetration-grade bitumen, 40/50 penetration-grade bitumen and SBS-modified binder is illustrated in Figure 1a.

**Figure 1a: Softening point vs sample history**

All the results demonstrate that there was poor correlation between the values obtained from binders with different sample histories, even though those sample histories are traditionally thought to present comparable short term ageing of the binders.

These findings have implications for the use of any predictive equation that depends on binder stiffness. The relationships for the RTFOT, STA and Core binders are illustrated in Figure 2.

**Figure 2: Viscosity - temperature relationship**
Using the viscosities generated by the viscosity-temperature relationship, the dynamic moduli were generated for 10 Hz at 0°C and 50°C by the Witczak model. Results are presented in Table 4.

**Table 4: Dynamic Modulus generated at 10 Hz**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>RTFOT</th>
<th>STA</th>
<th>Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°C</td>
<td>15 090</td>
<td>19 655</td>
<td>22 965</td>
</tr>
<tr>
<td>50°C</td>
<td>740</td>
<td>1 080</td>
<td>1 512</td>
</tr>
</tbody>
</table>

These results indicate that at low a temperature (0°C), the predicted value of dynamic modulus can vary up to 50% above that predicted by the viscosity after RTFOT. At a high temperature (50°C), the predicted value of dynamic modulus can vary up to 100% above that predicted by the viscosity after RTFOT.

The authors argue that, if any predictive equation is to be successful, the RTFOT procedure should be adjusted so that RTFOT viscosity equates to in-situ values. This can be achieved by:

- Adjusted RTFOT procedure for each binder class (or mix type);
- Refinement of the RTFOT result to make provision for:
  - binder film thickness;
  - travelling time / site delays.

From experimental work conducted indications are that the extension time requirements to simulate STA samples are as follows:

- 160 ± 5 minutes for the 40/50 penetration-grade bitumen;
- 258 ± 5 minutes for the 60/70 penetration-grade bitumen;
- 200 ± 5 minutes for SBS-modified binder.

**Conclusion**

The authors are of the opinion that if any modelling which depends on binder stiffness is to be used in the SAPDM, an adjusted or revised short-term ageing method should be established. This can be achieved by extending the RTFOT time using the current method. However, additional data generation and collation is required to ensure that the extended RTFOT times are statistically representative for each binder class.

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**The use of an extended rolling thin film ageing method as an alternative to the pressurised ageing vessel method in the determination of bitumen durability:**

**Muller & Jenkins**

Since it is considered that the South African bitumen specification framework in its current form does not adequately address long term durability aspects of bitumen, the authors identified the necessity for the development of an accelerated ageing procedure for use in South Africa. While the Pressure Ageing Vessel (PAV) is an internationally accepted method for the simulation of long-term binder ageing, the equipment is not readily available in South Africa. The paper presents an alternative test procedure to determine the long term ageing characteristics of bitumen which meets (amongst others) the following criteria:
Following extensive investigations the authors, in essence, propose an approach that they described as being a “hybrid” one, using readily available RTFOT equipment. By modifying the RTFOT test condition, the Extended RTFOT at 163°C is shown to age bitumen residues to the PAV stiffness levels. Also, when reducing the temperature to 100°C and with the use of steel rods to present continuously fresh binder surface areas, conditions are created that resemble those in the Rolling Cylinder Ageing Test, albeit on a much smaller scale. The authors maintain that the extended duration and the reduced temperature approach addresses the concerns related to relevance of the accelerated ageing test for binders used in spray seals.

Bitumens from five sources were used and the 60/70 penetration grade was selected as it is a popular grade used in asphalt manufacture in South Africa.

**The reduced temperature approach addresses the concerns related to the relevance of the accelerated ageing test for binders used in spray seals.**

**Rheological evaluation**

The dynamic shear rheometer was used for evaluating binder properties of PAV aged specimens. The rheological properties were evaluated over a temperature range between 10°C and 40°C.

Comparing the fatigue component of the complex modulus, $G^*\sin \delta$, for the virgin binder and aged binder residues over the temperature range between 10°C and 40°C for the different ageing regimens (Figure 7), it is clear that the extent of ageing at 100°C and 163°C vs. the PAV aged binder residues are similar. The objective to reach the bench-mark stiffness (PAV value) was achieved with both the extended RTFOT at 163°C after 325 minutes and at 100°C at approximately 48 hours.

*Figure 7: Comparison of the Complex Modulus ($G^*$) between 10°C and 40°C*
This trend is evident across the whole temperature range but is more pronounced at the lower temperatures range 10°C to 25°C, where the binder’s elastic modulus will dominate. Two options were considered to gauge the relative rate of ageing between the ERTFOT163 and ERTFOT100 procedures.

Figure 8 illustrates the trends for the fatigue component of the complex modulus at 10°C and 25°C with the magnitude of stiffness the differentiating factor.

At both 10°C or 25°C the rate of ageing at 163°C and 100°C show similar trends. Any one of these two measurement points can therefore be selected to obtain a relative rate of ageing with the two extended RTFOT ageing procedures.

When the fatigue failure or distress criterion (5000kPa) is used, the temperature gradually increases from 17°C for virgin bitumen to 23°C at PAV stiffness (Figure 7). This presents another method of comparative measurement while maintaining the distress value criteria.

Conclusion

The authors conclude that it is possible to achieve similar levels of stiffness as those deriving from the PAV test using the extended RTFOT procedure at 163°C. The ageing during the extended RTFOT at 100°C (steel rod assisted) shows a reduced ageing rate relative to the extended RTFOT at 163°C. The authors believe their paper provides sufficient evidence for the proposed “Extended” RTFOT ageing method to be considered as an alternative to the use of the Pressurised Ageing Vessel to assess long term durability of bitumen.
9

Workshop Sessions

Value and outputs
**Workshop value and outputs**

To stimulate wider, individual participation in the technical programmes of the conference, provision was made for four workshop sessions, each session providing for five topic areas in parallel with each session considering three main questions. Overall 60 themes were debated over 40 hours by an average of 45 delegates per session. These workshops were designed to supplement the content of plenary and specialty sessions and to encourage delegate interaction – particularly between seasoned professionals and novices, thereby providing an opportunity for mentorship, all the while promoting the theme of sustainability.

Issues of a general nature, identified during these workshops are given below.

**Low volume sealed roads**

As there are compelling reasons for providing low volume or lightly trafficked roads with a permanent surfacing, the technology attached to this area needs major attention to ensure that every opportunity is exploited to provide this facility in sub-Saharan Africa.

**Design of asphalt**

The so-called Marshall design procedure may be appropriate for low risk situations, e.g. low traffic volumes; however, the move to more performance-related procedures, clearly linked to structural design inputs, was required. Techniques to optimise aggregate packing, with conventional gradings providing initial guidance only, should be pursued.

**Laboratory practice**

While SANAS accreditation sets the correct management procedures in relation to laboratory quality assurance activities, it should be supplemented by a national laboratory proficiency scheme – a role that could devolve to the RPF for oversight. Also, the SANAS system should extend to site laboratories through accreditation via the parent laboratories.

**Performance grading of bitumen**

As a first step to attaining this grading system the dynamic shear rheometer (DSR) apparatus should be entrenched in practice – including refinery laboratories. Production laboratories would also benefit from the use of the DSR through expediting the estimates of penetration values used as a key quality assurance parameter during production runs.

The measurement of the complex modulus of bitumen by means of the DSR is likely to become a routine function to determine bitumen properties as inputs to mix- and pavement design procedures.
Extending the window of sealing operations

A risk based approach should be adopted to extend the season for applying spray seals. Such an approach would lessen the peak demands in situations where local demand frequently exceeds average refinery capacity.

Human resources

During discussions on topic areas such as pavement design and materials characterisation the issue of capacity building was raised. While the need was identified as an urgent one, it was not clear who should take responsibility for the education and training of current and future generations.
10

Conference conclusions

Forward momentum
Conclusions and forward momentum

The terms of reference of CAPSA 11 was set by:

- The challenges identified at CAPSA'07;
- The need to orientate the roads industry towards more sustainable practice.

In the closing plenary an assessment was made of how well these aims were met, i.e. how well technical issues have been addressed – all within the context of sustainable practice. The outcomes of questions posed and responses are listed below.

**Reduced impact on the environment and consumption of non-renewable resources**

Bituminous products are considered to be conducive to effecting energy savings, notably the reductions in energy consumption in the offing with warm mix asphalt technology gaining a foothold. In southern Africa the initiatives of eThekwini Municipality has yielded an up-to-date WMA best practice guideline for SA, published by Sabita. Delegates from Australia indicated that similar moves were afoot in Australia, with Brisbane municipality playing a leading role. Delegates at the conference expressed the hope that other road authorities would be encouraged to adopt warm mix technology in their road building and rehabilitation programmes.

A topic debated during the workshop session was the need for the classification of RA. No resolution was reached, except that it the following recommendations were made:

- Selected milling and stockpiling should take place – the material should be utilised in the same layer from which they were obtained;
- Aggregates should not be crushed. If this is not feasible the material should be screened and oversize material lightly crushed;
- While TRH 21 gives sound guidance, it was noted that someone should take ownership of the document to ensure that it is kept up-to-date and relevant to changing needs.

With confidence gained in achieving temperature reductions of the order of 30°C, it seems feasible that greater temperature reductions should be pursued and achieved. Officials from eThekwini Municipality indicated that they intend to face this challenge through a programme of stepwise reductions.

It was generally accepted that the innovative stance of eThekwini will facilitate the wider application of warm mix asphalt in SA. It was likely that other municipalities - notably the COCT - will soon commence with trial sections within the framework of their IDP.

The introduction of Green Roads or an LCA system would have to operate on an equitable basis and therefore should become mandatory. For this to come about, road authorities should embrace the principle and drive it. Sabita would have a role to play in assisting authorities to measure, manage and innovate for the advancement of such a system.
Design of asphalt

The question was posed: what initiatives are being taken to update asphalt mix design procedures to cover:

- Warm mix technology;
- High modulus asphalt;
- Thin layer conventional asphalt;
- Complementing analytical structural design procedures.

It was stated that Sabita had embarked on a substantial project, to be carried out by the CSIR whereby the current *Interim Guidelines for the design of hot mix asphalt*, published in 2001 would be transformed into an up-to-date design method – not a “guideline”. A benchmark for moving forward had already been established whereby multi-level mix design methods will be developed. The CSIR is in a position to ensure that conformity with the SAPDM, currently being developed, will be achieved.

Current mix design procedures are not necessarily conducive to the production of optimal mixes, given a range of application environments. Clearly a new mix design method aimed at producing model mixes needs to inform national specifications, which is due for a make-over.

Revision of the SA national specifications on asphalt

Current design procedures, on which asphalt specifications are based, are not conducive to the production of optimal mixes. Clearly, a revision of the design procedures – in all probability incorporating a multi-level approach based on risk – should indeed drive and inform any revisions of current specifications. Formal communication structures for meeting this need to be put in place.

Design of spray seals

To exploit the experience and knowledge of researchers and practitioners engaged in the design and construction of spray seals a web-based discussion forum - Southern Hemisphere Spray Seal Alliance - was proposed. Participants envisaged were:

- Sabita, SAT, CSIR, and academia;
- AAPA, ARRB and academia.

Pavement design systems

Variability and randomness were being introduced to the fullest extent within the bounds of reasonableness. The South African Pavement Design Method (SAPDM), currently being developed, is founded on and driven by statistics. Data inputs are based on probability-density functions and will seek to make predictions on likely performance attributes. It is acknowledged that variability translates into risk – therefore the SAPDM can be regarded as a risk management system, while it remains underpinned by sound engineering modelling.

The rules based Pavement Number Method will be incorporated into the SAPDM for both lower risk applications and preliminary investigations of pavement type options.

Preservation of pavement assets

Pressure on road authorities to spend budgets exerts undue pressure on consultants to deliver designs within short period (e.g. two months). Clearly, more time is required to
gain intimate knowledge of road conditions and external inputs, to optimise designs and
to avert changes in the scope of current contracts, and thereby to pre-empt premature
failure. Term contracts should be considered.

Low volume sealed roads

This topic, closely related to the needs of the African continent in terms of mobility and
access, should be considered for a full session at the next CAPSA. Issues that should
be looked at are the more efficient exploitation of materials such as laterites, calcretes
and sand (in general use in southern Africa region), the adoption of appropriate
(non-conventional) standards and the translation of experience into standards and
design methods.

Role of CAPSA on the African continent

As was pointed out by CAPSA Chairman Phil Hendricks during the opening session,
regional challenges and opportunities abound, especially in low volume surfaced roads.
The exponential growth of Chinese and French contractor activity in Africa from 2000 to
2005 should provide a stimulus to develop knowledge and resources on the continent
(see Figure 4). He quoted estimates which indicate that annually infrastructure
investment of the order of $93-billion is required. An investment of $32-billion on roads
alone will increase trade on the continent by $250-billion over the next 15 years.

Currently only 10 000 km of roads connect countries in Africa, while it is estimated that
60 000 – 100 000 km are required to integrate the region. These issues – the growth
potential and infrastructure needs – together with the huge appetite in Africa for the
tools developed through CAPSA will guide the steering committees of future CAPSA’s
to appreciate the regional role of CAPSA. To hold the next conference outside of South
Africa would require a concerted effort to ensure that regional needs are fed into the
conference programme.
Venue and programme

It is recommended that when selecting a venue for future conferences, ready access to airports should be a serious consideration. The venue for 2011, the Champagne Sports Resort in the Drakensberg of KwaZulu-Natal offered multitude of venue options. The hotel layout was conducive to flexibility of accommodation of sessions while catering for a range of delegate numbers and also enabling concurrent sessions to be held with ease – a prerequisite for a compressed conference programme.

The 2011 conference was held over three days. This is considered to be the lower limit – for future conferences a minimum duration of 3 ½ days should be considered.

South African practice is not currently exploiting to its full extent the knowledge and experience in the field of low volume surfaced roads to entrench sound practice. Consideration should be given to give prominent exposure to this topic at the next conference.

The programme, especially the workshops, should be structured to provide increased scope for interaction between young and seasoned professionals.

The continuum

Being a four year periodic event, flexible pavement technology needs to rely on other, satellite organisations to provide the necessary impetus for ongoing development and advancement. Such organisations are readily identifiable - Sabita, RPF, SAT, AsAc and SARF. It would therefore seem appropriate for CAPSA to charge these bodies with the responsibilities of advancing the positive outcomes of this conference, on the one hand, and to seek solutions to closing the gaps identified on the other.
Recommendations to the RPF

The RPF is a key agent in establishing a continuum between successive CAPSA’s, and thus seems appropriate that the outcomes of the conference, especially those requiring action, should be embodied in recommendations to the RPF. The more pertinent recommendations, presented to the RPF meeting in November 2011, are listed below.

- In its programmes the RPF should provide for ongoing structured feedback sessions on progress against milestones identified by CAPSA;
- The RPF should support independent third-party rating systems of sustainability in road design and construction;
- The RPF should assist in the establishment and function of the envisaged Southern Hemisphere Spray Seal Alliance;
- RPF programmes should cater for innovative practice for low volume surfaced roads;
- The RPF should reconvene the bitumen specification task group to consider the introduction of the DSR as a measure of bitumen properties;
- The RPF should encourage and offer opportunities for mentorship via its programmes and delegate profile.
11

Invited contributions
Behaviour of bitumen stabilised materials (BSMs) – do we really understand it?
Kim Jenkins

Introduction

Since 1995, bitumen stabilised materials (BSMs) have been used worldwide to construct the base layer of many thousands of kilometres of road pavements, mainly for rehabilitation projects by recycling the material in the existing pavement. This is illustrated by the global distribution of road recyclers between the continents and sub-continents, see Figure 1. Over this 16 year period, one model of recyclers from one manufacturer alone steadily grew to more than 750 by 2011. The split between machine capacity to execute in place soil stabilisation versus bitumen stabilisation is currently approximately 50:50 based on the global averages.

Despite the fact that the majority of pavements incorporating BSMs have performed well, there remains a general lack of understanding of BSMs, particularly about the nature of the material, its failure mechanisms and associated design approach.

What is a BSM and what is it not?

BSMs are non-continuously bound materials that fall into a class of their own. They are granular materials (and sometimes reclaimed asphalt) treated with small amounts of bitumen emulsion or foamed bitumen (usually 3% residual bitumen, by mass) that significantly increases the cohesion of the material whilst having little effect on the internal angle of friction. Unlike asphalt, where a continuum of bitumen binds all the aggregate particles together, the bitumen in a BSM is dispersed selectively amongst only the finer particles, regardless of whether bitumen emulsion or foamed bitumen is used as the stabilising agent. When compacted, the isolated bitumen-rich fines are mechanically forced against their neighbouring aggregate particles, regardless of size, resulting in localised bonds which are not continuous (i.e. not joined to each other).

To illustrate non-continuously bound materials, Figure 2 (Collings et al, 2011) shows a compacted slice of aeolian dune sand treated with 4% foamed bitumen, magnified 40 times, courtesy of the Geology Department at the University of KZN. Since the dune sand is white and bitumen black, this picture clearly shows the bitumen is dispersed throughout the matrix of the dune sand as tiny splinters. The coarser particles (maximum size is 0.425mm) are not

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Figure 1: Global distribution of road recyclers

Figure 2: Dispersed bitumen splinters
coated with bitumen. When such a material is compacted, the individual bitumen splinters are mechanically forced against their neighbouring particles and, being sticky in nature, the bitumen splinter adheres to its neighbour, setting up an isolated bond. With the bitumen dispersed as millions of such splinters, the result is millions of localised bonds that are isolated; hence the term “non-continuously bound” material.

The addition of a similar amount of residual bitumen in the form of an emulsion will produce a similar result with a slightly different dispersion mechanism. The charged bitumen droplets in an emulsion are initially attracted to the finest particles with the highest surface area, progressively coating larger particles as more emulsion is added until, ultimately “cold-mix asphalt” is achieved. Thus, by limiting the amount of emulsion added, a non-continuously bound material is produced.

In addition, BSMs are produced at ambient temperatures, typically between 15°C and 30°C. A BSM behaves more like an unbound granular material than one that is continuously bound, as would be achieved had cement been used as the stabilising agent. As a result, the failure mechanism for a BSM is more akin to that of granular materials than for a cement stabilised material (or hot mix asphalt that is also a continuously bound material).

In contrast, the question of “what is a BSM not?” should also be addressed, as it would define materials that should be excluded from the focus of this article. A BSM is not a continuously bound material such as a cemented or asphalt material. Features of what a BSM is not, therefore, include materials with:

- High percentages of bitumen binder i.e. 3.5%;
- High cement contents i.e. 1.5% cement;
- High percentage of RA i.e. 75% and either rejuvenating agent or largely unaged original binder in the RA.

It is possible to prepare such continuously bound materials but their behaviour differs fundamentally from BSMs and they should be designed accordingly.

**General behaviour of BSMs**

In a manner that is consistent with granular-type materials, the failure condition used for modelling BSMs is permanent deformation, rather than fatigue cracking. The applicable failure condition does not imply that BSMs cannot crack. Like granular materials, they are prone to shearing when the material is stressed under repeated loads. Overstressing can manifest as a shear failure in a BSM, similar to granular material. These conditions, however, bear no relation to the fatigue cracking phenomenon that affects bound materials. Such fatigue cracks develop as a consequence of repeated loads that cause relative low levels of tensile strain in the material.

The lack of fatigue behaviour does not, however, imply that BSMs do not experience a change in Resilient Modulus over time. This is discussed later. But first, it is important to understand the nature of the material behaviour. A BSM is elasto-plastic, as illustrated by its granular-type, stress-dependent behaviour shown in Figure 3.
However, a BSM is also visco-elastic, as shown by its loading time and temperature dependency, due to the presence of bitumen in the mix, as shown in Figure 4. Combining these types of material behaviour yields visco-elasto-plastic material behaviour for BSMs. It is evident that even when BSMs incorporate 1% cement, they do not behave in a purely elastic manner.

**Figure 3: Dynamic triaxial tests on BSM-foam (Jenkins et al, 2002)**

**Figure 4: Master curves of BSM-emulsion and BSM-foam (Jenkins et al, 2006)**

\[
\text{Resilient modulus } M_r (\text{MPa}) = k_1 \theta ^2 k_2 \\
k_1 = 81.77 \\
k_2 = 0.409 \\
R^2 = 0.88
\]
**Flexibility of BSMs**

The composition of BSMs dictate their behaviour. Higher cement contents and lower bitumen contents generally lead to mixtures with higher strength or stiffness and lower flexibility. In fact, adding bitumen to a cemented material in order to produce a BSM decreases the strength in most cases! Is this disadvantageous? No! Sufficient strength and stiffness is required to resist deformation and to enable load spreading. But, pavement balance is achieved with lower modular ratios, so moderate strength and stiffness should be aimed for, tempered with flexibility.

Remembering that both UCS and ITS tests are strength tests (compressive and tensile respectively), it is easy to be encouraged to increase the cement content of a BSM mix in order to meet mix design requirements. For this reason, flexibility considerations were brought into TG2 (2009) by restricting practitioners to reasonable levels of cement application i.e. < 1%. This guideline does not preclude the experienced practitioner the opportunity to add a little more cement e.g. 1.5% if so desired. But the consequences need to be clearly understood.

**Measuring flexibility**

Recognising that flexibility is important is only part of the solution; measuring it is another matter entirely. Research at Stellenbosch University has shown that, if displacement measurements are made during UCS, ITS or triaxial testing of BSMs as part of the mix design, the “ductility” of the material can be measured at the point where the ultimate load is reached.
As can be seen from the results provided in Figures 6 and 7, the trend of decreasing "flexibility" with increasing cement content is evident, which is intuitive; however, significant variability is evident. Even the introduction of additional variables e.g. confinement stress in the case of $\sigma_{1\text{max}}$, does not reduce the Coefficient of Variation CoV to acceptable levels. This renders flexibility an unreliable and impractical measure to be included as a requirement in a mix design. Even though limits cannot be set, experienced practitioners should monitor and be guided by displacement values measured during mix design testing.

To facilitate the investigation of alternate measures of flexibility, extensive investigations have been undertaken to find a relationship between strain-at-break ($\epsilon_b$) and fatigue for BSMs or, at least, to provide a performance indicator (Twagira et al., 2006). One concern with $\epsilon_b$ is the extent of the visco-plastic component’s influence on the behaviour of BSMs. By combining the results of "high-cycle" versus "low-cycle" fatigue, the linearity of the fatigue relationship was tested (Collings et al., 2011). In the case of BSMs this can be tested by combining fatigue (dynamic) results and "strain-at-break" $\epsilon_b$ (monotonic) results from beam specimens prepared in the same manner and tested in a Beam Fatigue Apparatus. This research was carried out with meticulous attention to detail in compacting slabs of representative mixes, curing and sawing the slabs to provide beams for testing at Stellenbosch University. The fatigue functions were extrapolated to the measured strain-at-break values in order to test the linearity of the material behaviour. One example provided in Figure 8 shows little correlation between monotonic strain-at-break tests and fatigue relations.
It is abundantly clear that strain-at-break does not provide a reliable correlation with the fatigue relations that have been tested. Not only does the influence of the particular bitumen stabilising agent need to be considered, but also the non-linearity of the log strain versus log load repetitions relationship. Linear elastic behavioural modelling will not suffice due to plastic behavioural influences, and strain-at-break can therefore not provide a reliable performance indicator (which should be expected since BSMs are visco-elastic-plastic materials).

**Damage models using Fracture Mechanics**

To investigate the applicable damage models for BSMs, fatigue is assessed using the principles of fracture mechanics. This approach has proven to be a very useful tool for modelling materials that suffer fatigue cracking under repeated loading conditions. The principles of fracture mechanics have been successfully applied in pavement engineering to the design of asphalt overlays where reflective cracking requires analysis. Paris’ Law, shown in Equation 1, is used to describe crack growth in a material.

\[
\frac{dc}{dN} = A.K^n 
\]

Where: 
- \( \frac{dc}{dN} \) = increase in crack length per load cycle
- \( K \) = stress intensity factor at the tip of the crack, due to bending or shear
- \( A, n \) = material constants

It is understandable that Paris’ Law can be applied to asphalt, which incorporates bitumen that is distributed in a continuum and the asphalt layer can be treated as a beam since it is a continuously bound material. Besides other factors, the crack intensity factor is dependent on the ratio of crack length to beam thickness, c/d shown in Figure 9. In addition, methods are available to determine each of the Paris Law.
parameters (Lytton, 1989) and asphalt is sufficiently homogeneous to enable such analyses to be undertaken.

Figure 9: Beam approach to crack-growth analysis

Figure 10: Non-continuous bound BSM-foam

Unlike asphalt, BSMs do not have a continuum of bitumen and are seldom homogeneous, especially when recycled material is stabilised. This is shown conceptually in Figure 10. Discrete distribution of bitumen splinters in BSM-foam does not allow classical fatigue and fracture mechanics to apply. If shear deformation between individual particles ruptures a “spot weld” of bitumen, there is no continuity of bound material that will allow a crack to develop, so c/d becomes meaningless. Stated differently, there is neither opportunity for a “crack tip” nor stress intensity at the tip to develop. A broken spot weld will cause particles to re-orientate (micro-shearing), resulting in permanent deformation, as with granular material. The rupture of spot welds can influence the effective stiffness, as is discussed later.

In addition, the relatively low effective stiffness of BSM’s needs to be taken into consideration (often less than 50% of HMA stiffness, depending on temperature and loading time). The horizontal strains experienced by a BSM are commonly in the order of 10 to 70 $\mu$e and very seldom exceed 90 $\mu$e. By comparison, strain-at-break ($\varepsilon_{b}$) tests from monotonic flexural beam tests on BSMs yielded results of 1000 to 3000 $\mu$e and four-point beam fatigue results can yield between one and several million load repetitions at 200 $\mu$e constant strain loading (Mathianiya et al, 2006). The non-continuously bound nature of BSMs, coupled with their relatively low effective stiffness regime, does therefore not create conditions conducive to fatigue failure.

Long term effective modulus of BSMs

To determine conclusively whether or not BSM layers suffer from fatigue failure, the behaviour of a pavement carrying heavy traffic, was investigated. A section of the N7 highway near Cape Town was considered, part of which was rehabilitated by recycling with BSM-foam (2.3% bitumen and 1% cement) on the southbound carriageway in 2002. The northbound carriageway was rehabilitated by recycling with BSM-emulsion in 2007 (2% residual bitumen and 1% cement). Both carriageways were recycled in situ.
and stabilised to a depth of 250mm. In addition to physical moisture measurements of the BSM-emulsion base layer (Moloto, 2010), Portable Seismic Pavement Analyser (PSPA) measurements were taken on the BSM base with time in order to evaluate the change in modulus of the base with time. At a later stage, FWD analyses were carried out to back analyse the effective modulus of the BSM base. Figure 11 shows that the resilient modulus increased over the first seven month evaluation period of the BSM-emulsion during the “curing” phase after construction.

The examples of in situ measurements of BSM bases in in-service pavements, within the first year of construction, consistently show an increase in effective modulus (Collings et al., 2011). After the first year, deflection measurements indicate reduction in back-calculated modulus, as shown in Figure 12 based on the analyses at Stellenbosch University.

Figure 11: Modulus of BSM-emulsion base measured with PSPA (Malubila, 2005)

Figure 12: Back-calculated Modulus of BSM-foam base on N7 for 90th percentile deflections
The effective stiffness reduction could probably be attributed to rupturing of bitumen “spot welds” due to excessive shear stresses rather than fatigue failure resulting from trafficking. It should be noted that the modulus begins to stabilise at about 750 kPa, which is well above the expected modulus of the equivalent granular material.

Conclusions

Laboratory testing and the response of pavement structures incorporating either BSM-foam or BSM-emulsion base layers, with periods of evaluation ranging between seven months and four years while exposed to medium to heavy trafficking, yielded the following conclusions:

- BSM base layers show non-linear increase in the stiffness of the layer versus time, reaching a plateau within a year. This indicates that the effects of curing within a BSM overshadow the detrimental effects of trafficking for at least a year after construction;
- Using the theory of fracture mechanics, the non-continuous nature of the bonds within a BSM render such materials immune to the formation and propagation of conventional fatigue cracks; tensile stress concentration at a crack-tip can simply not develop within a material that is not continuously bound;
- Flexibility is an important BSM property to be considered in mix and pavement design. Setting requirements for flexibility, using surrogate measures such as “strain-at-break” are impractical due to complex material behaviour and variability of results. Currently flexibility is safeguarded by limiting the cement content of the BSM (TG2, 2009);
- The effective modulus of BSMs shows trends of reduction after 1 year post-construction. At this point, insufficient data is available to reliably analyse the trends effective stiffness of BSMs from 1 to 15 years in-service. Significantly more LTPP data is required for this purpose, incorporating the variables of traffic, pavement structure and support, BSM mix design as well as climate.

References


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The Implications of the Air Quality Act for the asphalt Industry
Anton Ferreira

This article is not intended to be a comprehensive discussion of the implications of ALL the provisions of the Air Quality Act. Rather, its aim is to provide a brief and informative overview of the most immediate challenges facing asphalt producers that must comply with the Atmospheric Emissions License requirements. Readers are encouraged to do further reading and in particular the Air Quality Act which is freely available as a download on the website of the DEA.

1. Background

The Atmospheric Pollution Prevention Act (45 of 1965) has been repealed and replaced by the National Environmental Management: Air Quality Act (NEM: AQA) Act 39 of 2004.

Although the AQA came into effect on 11 September 2005, a number of significant requirements were only due to commence at a later date. One significant section that was postponed for implementation is Section 21, which provides for the "listing of activities resulting in atmospheric emissions". Other important provisions were those in

Objectives of the Air Quality Act:

(a) To protect the environment by providing reasonable measures for:
   (i) the protection and enhancement of the quality of air in the Republic;
   (ii) to prevent air pollution and ecological degradation; and
   (iii) to secure ecologically sustainable development while promoting justifiable economic and social development; and

(b) Generally to give effect to section 24(b) of the Constitution in order to enhance the quality of ambient air for the sake of securing an environment that is not harmful to the health and well-being of people.

Definition:

Air pollution is defined as any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances.
Chapter 5 (Sections 36 to 49) providing for a "new set" of requirements for the "licensing of listed activities".

On 24 December 2009 the NEM: AQA National Ambient Air Quality Standards (NAAQS) were established by proclamation in a Government Gazette. These standards identify the substances, concentration limits and reference methods to be used to measure atmospheric emissions. Compliance dates were also set for each substance. The NAAQS are the minimum standards that must be complied with, and specific standards have also been set for "Listed Activities". The NEM: AQA finally came into full effect on 1 April 2010.

2. Effects of the NEM: AQA

2.1 Listing of activities resulting in atmospheric emissions

In accordance with Section 21 (1) (a) of Act - "The Minister must, or the MEC may, by notice in the Gazette, publish a list of activities which result in atmospheric emissions and which the Minister or MEC reasonably believes have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage."

The minister has published a list of activities and associated minimum emission standards identified in terms of section 21 (effective 1 April 2010). In terms of this publication an asphalt plant is a listed activity under Subcategory 5.8: Macadam preparation: The production mixtures of aggregate and tar or bitumen to produce road surfacing in permanent facilities and mobile plants.

The minimum emission standards for asphalt plants are as given in the table below:

<table>
<thead>
<tr>
<th>Description</th>
<th>The production mixes of aggregate and bitumen to produce road surfacing in permanent facilities or mobile plants</th>
<th>mg/Nm³ under normal conditions of 273 Jelvin and 101.3kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>All plants</td>
<td></td>
</tr>
<tr>
<td>Substance or mixture of substances</td>
<td>Plant status</td>
<td>Subcategory</td>
</tr>
<tr>
<td>Particulate matter</td>
<td>N/A</td>
<td>50</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>SO₂</td>
<td>120</td>
</tr>
<tr>
<td>Total volatile organic compounds from vapour recovery/destruction units (Thermal treatment)</td>
<td>N/A</td>
<td>150</td>
</tr>
</tbody>
</table>

The requirements of Section 21 could have a significant impact on the Asphalt Industry and in particular on the operation of mobile asphalt plants.

2.2 Consequences of listing

In terms of Section 22 of the Act "No person may, without a provisional atmospheric emission licence or an atmospheric emission licence conduct an activity -

(a) listed on the national list anywhere in the Republic; or
(b) listed on the list applicable in a province anywhere in that province."

A Listed Activity therefore triggers the requirement for an Atmospheric Emissions License (AEL), which requires that an "operator" report on all its air pollution sources. Initially a "provisional AEL" is issued and an AEL is granted once the operator can
prove that they can comply with the requirements as set out in the Act. Asphalt producers are therefore compelled to compile comprehensive emission inventories for the entire site where a Listed Activity is carried out. In order to facilitate implementation of and compliance with the Act, the Act provides for government to turn down license applications from applicants who have a bad record of air quality management practices. It also provides for government to demand that "problem" operators appoint qualified air quality management practitioners.

2.3 Controlled fuels, and control of dust, noise and offensive odours

The AQA does not only provide for fumes, particle or gaseous air emissions produced by asphalt plants. Other "pollutants" such as dust, noise and offensive odours are also addressed. Another significant feature is that the Act also aims to control the use of heating fuels used in the production of asphalt.

2.3.1 Use and prohibition of controlled fuels

Section 27 of the Act provides that: A notice contemplated in Section 26 (1) may

(a) Establish standards for the use of the controlled fuel in combustion processes;
(b) Establish standards for the manufacture or sale of the controlled fuel;
(c) Establish specifications, including maximum or minimum levels or concentrations of the constituents of substances or mixtures of substances, for the composition of controlled fuels;
(d) Prohibit the manufacture, sale or use of the controlled fuel.

2.3.2 Consequences of declaration (of a substance as a controlled fuel)

Section 28 of the Act provides that:

(1) No person may manufacture, sell or use a controlled fuel unless that manufacture, sale or use complies with the standards established in terms of section 27;
(2) No person may manufacture, sell or use a prohibited controlled fuel unless that manufacture, sale or use complies with any conditions of manufacture, sale or use established in terms of section 27.
2.3.3 Control of dust, noise and offensive odours

Sections 32, 34 and 35 of the Act provides that the Minister or MEC may prescribe measures for the control of dust and offensive odours and, in the case of noise, may also prescribe essential national control standards.

While the Noise Induced Hearing Loss Regulations of the Occupational Health and Safety Act deal comprehensively with the impact of noise in the workplace, here the intention of the legislator is clearly to control noise emanating from production activities which may impact on the external environment.

3. The implications for the asphalt industry

It is probably fair to say that very little attention was given to atmospheric pollution regulations in the past as the enforcement of the legislation was lacking. The authorities aim to correct this with the much more detailed and robust provisions of the NEM: AQA.

In order to fully assess the implications of complying with the "new" requirements, one has to have a detailed understanding of both the "old" and the "new". This requires a very comprehensive analysis of a range of very complex, interrelated items of legislation.

It is not the intention to provide an in-depth analysis here, and therefore only the most significant potential issues that may impact on asphalt plants will be discussed.

3.1 Process for Environmental Authorisation (EA)

In the past, via a Department of Environmental Affairs (DEA) directive, the Basic Assessment (BAR) process, instead of the full Scoping and Environmental Impact Assessment (S&EIA) process, would suffice when seeking EA. Under the new dispensation the applicant must apply for permission to apply the BAR instead of the S&EIA process.

This will have the effect of additional delays in a process that currently can take as much as 12 months to complete, and has significant implications for operators wishing to apply for authorisation of mobile asphalt plants.

3.2 Atmospheric Emissions Licence (AEL)

The requirement for an AEL is not new; however the administrative process and compliance criteria have changed significantly in terms of the NEM: AQA. The new process for obtaining an AEL for a listed activity includes, amongst others, providing detailed information on the following:

- Energy sources used;
- Sources of atmospheric emission (including all tiers of greenhouse gas);
- Emission monitoring and reporting;
- Appliances and measures implemented to prevent air pollution for the entire operation at the plant;
- A list of potential start up, maintenance, shut down, upset conditions and associated responses related to the operations at the plant, highlighting possible releases and responses for the proposed listed activity or activities in respect of the application.

Under certain circumstances, section 48 of the Act also provides) for the designation of an emission control officer who is charged with specific duties with regard to the
requirements and conditions of an AEL. Such an emission control officer must have requisite air quality management competence in respect of the listed activity in question. In practice this means that the applicant has formal processes in place, as part of an environmental management plan/system that will assure demonstration of compliance to the authorities. Failure to do so will result in an AEL application being declined or, worse, the imposition of heavy fines and closure of existing plants.

3.3 Compliance timeframes

The NEM: AQA came into effect on 11 September 2005 but implementation of the provisions in connection with Listed Activities and Atmospheric Emission Licenses was postponed until 1 April 2010. Compliance with the minimum emission standards for Listed Activities, provided for in Section 21, is effective as follows:

- New plants: Immediately, i.e. 1 April 2010 (by definition this includes mobile asphalt plants);
- Existing plants:
  - Must comply with minimum emission standards for existing plant within five years; i.e. before 1 April 2015;
  - Must comply with minimum emission standards for NEW plant within 10 years; i.e. before 1 April 2020;

The reason for the five year transition period from old to new is not clear, but is probably intended to allow enough time for competent authorities at provincial and local government levels to establish the infrastructure and capacity to administer and enforce the requirements of AQA effectively.

4. Impact on the industry

4.1 Consequences of non-compliance (offences and penalties)

Section 51 of the Act defines the conditions under which a person may be found guilty of an offence for non-compliance with, or a contravention of, a provision of the AQA. Section 52 establishes the penalties if found guilty of an offence as contemplated in section 51. Section 52 (1) provides as follows:

“A person convicted of an offence referred to in section 51 is liable to a fine not exceeding five million rand, or to imprisonment for a period not exceeding five years and in the case of a second or subsequent conviction, to a fine not exceeding R10 million or imprisonment for a period not exceeding 10 years or in both instances to both a fine and such imprisonment.”

Note

The grace period of almost five years was also necessary to allow those responsible for emissions to plan and prepare for full compliance with the provisions. Sadly, industry responded very poorly and failed to take full advantage of the opportunity.

A significant implication of these provisions is that the “person” referred to here includes a natural person (an employer or employee) and not only a “juridic person” (the Company or Organisation). A “juridic person” cannot be imprisoned, therefore the intention of the legislator is clearly that accountable managers/employees (e.g. the AEL holder) who fail to ensure compliance with provisions of the Act will be prosecuted and severely punished if found guilty of an offence.

Such fines are surely an incentive for compliance with the requirements of the Act!
4.2 Impact on future operations and contractual obligations

The major impact of the AQA requirements on the asphalt industry is the ability to establish mobile plants to service specific road building projects, especially those in areas remote from metropolitan areas where fixed plants are established. As mentioned, mobile plants are deemed to be new plant and must demonstrate full compliance with the provisions of the Act before an AEL will be granted. If the application is successful, a provisional AEL is issued and an AEL will only be issued if the holder of the provisional AEL can demonstrate full compliance with the conditions and requirements of the provisional AEL for a period of at least six months.

In practice the implications of these requirements are as follows:

- The applicant will have to provide credible baseline information on emissions at a similar plant to support the granting of a provisional AEL;
- If successful, the holder of the provisional AEL will have to monitor and report actual emissions at the plant for at least the first six months of operation. This will enable the holder to demonstrate full compliance and thereby be entitled to an AEL for continued operation of the plant;
- The activity of measuring and reporting emissions is a specialised function that requires the services of a person with the requisite air quality management competence, as well as specialised equipment to perform this activity effectively. This requirement has a significant cost implication to industry;
- Given the current timeframe for completion of the authorisation processes, lengthy delays to establish the mobile plant could have a major impact on fulfilling contractual obligations.

5. Industry responses

Although somewhat belated, there has been a positive response from the asphalt industry to manage and reduce the potential impact of the provisions of AQA.

5.1 Cooperation with the Department of Environmental Affairs (DEA)

Concerned Sabita members realised that the asphalt industry would have to make a concerted effort to engage with the DEA in order to explain the potential adverse effects that the AQA requirements could have not only on the industry, but more so on the road infrastructure development programmes and, ultimately, the national economy. This process of engagement was initiated via the Sabita environmental workgroup which held a number of workshops and meetings to prepare for discussions with the DEA. In summary the outcomes of the process were as follows:

- It is clear that there are misconceptions with regard to the asphalt industry's contribution to air pollution, especially since the use of coal tar products in asphalt production has ceased. Globally and particularly in the USA, UK and Europe, industry has managed to convince authorities that asphalt production utilising bitumen instead of tar is not a significant contributor to air pollution. The stringent requirements of Section 21 of AQA are therefore perceived to be unjustified;
- Members accept that, notwithstanding the sentiments above, asphalt production does contribute to air pollution, albeit in a minor way in the overall context. Therefore industry must take ownership of the matter and clearly demonstrate willingness to self-regulate and strive towards continuous improvement of effective management of air emissions resulting from asphalt producing activities. To this end Sabita has produced a code of practice entitled Management of potential environmental impact at temporary asphalt plants.
A meeting was held with high level officials of the DEA Chief Directorate: Air Quality Management, at which a three-man delegation from Sabita discussed pressing issues and proposed a way forward. The main thrust of the Sabita presentation was to agree on a process that will expedite applications for Environmental Authorisation and Atmospheric Emission Licenses. The DEA delegation demonstrated willingness to listen to the industry, and the outcome of the engagement was extremely positive and promising. The latest response from the directorate is:

- The Notice for de-listing mobile asphalt plants from S.21 list of activities has been prepared and will be communicated with Sabita in due course;
- Best practice guidelines, to be published separately from the regulation, are compiled (using the Sabita submission as a reference) and will also be discussed with the sector.

The implied condition is therefore that mobile plants will be de-listed provided best practice guidelines are followed to manage the facility and associated activities.

- Sabita will continue to foster and maintain constructive relationships with the DEA and continue the process of engagement to find ways to streamline and reduce the impact of the AQA requirements on the activities of asphalt producers.

6. Conclusion

The general consensus is that the NEM: AQA is a significant improvement on past legislation, and long overdue to ensure that our fragile environment is adequately protected. Although somewhat daunting, the provisions of the AQA can be successfully implemented, provided a systematic approach or management system is in place and supported by competent human resources.

Going forward

The de-listing of mobile asphalt plants must not be taken for granted or viewed as a general relaxation of requirements. The authorities are however demonstrating good faith in the ability of industry to self-regulate to achieve common goals. This trust should be revered at all times. Asphalt producers, and in particular Sabita members, have a duty to ensure compliance with the provisions of the AQA, and also to demonstrate commitment by supporting the initiatives taken by Sabita in the best interest of all role players.

**High Modulus Asphalt technology transfer successfully completed**

**Erik Denneman**

**Introduction**

The past decades have seen significant increases in the volumes of heavy vehicles on South Africa’s road network. At the same time, sustainable material use in road construction and low maintenance solutions minimising road user delay cost, are becoming increasingly important. Asphalt mix design technology has to keep pace with the ever-rising demands placed on pavement materials, and one of the initiatives aimed at increasing the options available for the design of heavy trafficked sections is Sabita’s High Modulus Asphalt (HiMA) Technology Transfer (T2) project.
HiMA is the South African name for asphalt technology originating in France in the early 1990s, where it is known as Enrobés à Module Elevé (EME), and is used extensively on main routes, airports as well as urban roads. HiMA technology combines superior permanent deformation resistance with high structural stiffness and good fatigue performance. The improvement in permanent deformation resistance of HiMA compared to conventional bituminous base materials at various temperatures is shown in Figure 1. The key characteristic of HiMA is a high binder content of hard bitumen with a penetration value of between 10 and 25.

The T² project began with a study tour to Europe in 2008 and ended with the successful implementation of a HiMA trial section on an access road to Durban harbour in 2011. The performance of HiMA under local conditions will be monitored for some time to come, but the results to date are positive. This article presents the process followed in the transfer of the HiMA technology to South Africa and identifies possibilities for its wider use.

**Figure 1: Permanent deformation of HiMA compared to conventional BTB (results from Sabita T² study)**

**HiMA T²: Study tour findings**

To gain a better understanding of the HiMA concept and to assess its viability for implementation in South Africa, a European study tour was undertaken as a first phase of the HiMA T² project. Visits were made to the French companies Colas, Total and Shell, as well as the Transport Research Laboratory (TRL) in the United Kingdom. TRL was appointed by the British Highway Authority to transfer and implement EME technology in the United Kingdom after the unsuccessful attempts by local practitioners.

The members of the study tour identified a number of challenges to the successful transfer and implementation of HiMA in South Africa:

- The ability to manufacture harder grades of binder in South Africa;
- The need to integrate HiMA in the South African pavement design philosophy;
- The ability to translate French mix design parameters into South African ones;
- The ability of asphalt contractors to manufacture and pave the material; and
- The ability to market HiMA technology to major decision makers.
To address the first challenge, harder grades of bitumen produced by two local refineries were sent over to France for testing. The feedback was positive: both binders had properties which satisfied the 15/25 penetration grade specifications. Hence, at least two refineries seemed to be able to produce binders that would meet the specifications for HiMA. If some of the refineries were to be unable to produce 15/25 penetration grade bitumen, they could modify 40/50 penetration grade bitumen by the addition of organic additives, or consider polymer modification of the base bitumen. 

With regards to the integration of HiMA in the South African design philosophy, it was found that although the structural design approaches of France and the UK are distinctly different from those used in South Africa (e.g. deep strength asphalt versus high-quality crushed stone base course layers), the integration of HiMA in the South African flexible pavement design method did not seem to be insurmountable. Even though there are no off-the-shelf transfer functions available for HiMA that could be incorporated in the South African mechanistic design method, fatigue of HiMA should not be a design concern on account of its higher binder content, particularly if the tensile strains at the bottom of the layer can be kept under control. Preliminary structural analyses performed on typical South African pavements had shown that an average thickness reduction of the bituminous base layer by 30% should be possible using HiMA.

An average thickness reduction of the bituminous base layer by 30% should be possible using HiMA.

The translation of French mix specifications, intrinsically linked to their particular testing procedures, to South African equivalents was viewed as a mayor challenge. One available avenue was to learn from the experience of TRL. Another avenue, which was preferred, was to conduct parallel testing between South Africa and France. Two French companies, were requested to design HiMA mixes using South African binders and aggregates based on French standards. Upon completion, duplicate testing would be done in South Africa using South African mix design procedures. The intention would be to derive equivalent South African specifications from this exercise.

With respect to the ability of the local industry to produce HiMA, the following observations were made. The manufacturing process of HiMA is not different from that of normal asphalt with the exception that HiMA is mixed at higher temperatures to ensure proper coating of the aggregate with the viscous binder. Dedicated bitumen tanks will be required as the binder will have to be heated to higher temperatures prior to mixing (similar to polymer-modified binder and bitumen-rubber). The paving temperature of the asphalt should not be less than 145°C when the asphalt exits the paver to ensure that the required compaction is achieved. When the technology was initially transferred to the United Kingdom, they expected to struggle with achieving the required compaction and were told that very heavy (45 tons) pneumatic tired rollers would be required. Subsequently, it has been found that normal compaction equipment can be used as long as rolling techniques and compaction temperatures are carefully controlled. Care should be taken when compacting the layer to ensure that longitudinal cracks do not appear. The target field voids should be between 4% and 6%, which relates to a density of 94 - 96% of maximum theoretical relative density (MTRD). Due to the high binder content and fine grading of EME Classes 1 and 2, the surface finish
after construction is very smooth and shiny. It is therefore not ideal to have traffic on the layer as it could pose a safety risk due to poor skid resistance. Where traffic accommodation is expected to be a problem, the application of the surfacing layer shortly after construction of the HiMA layer is recommended.

The study tour team considered cost effectiveness the key to HiMA technology becoming an accepted practice in South Africa. It was felt that while the Europeans portray the reduction in layer thicknesses vis-à-vis conventional HMA as one of the main benefits of HiMA, the philosophy in SA should rather be that it is a material able to render longer pavement life with improved performance compared to conventional crushed stone bases with asphalt wearing courses. The key benefit of a longer life pavement is that, inter alia it can ensure improved whole life cycle costing with reduced user delays on our heavily trafficked roads. To demonstrate this benefit it would be necessary to construct a trial section with HiMA as a base layer, surfaced with a thin asphalt wearing course, and subject it to accelerated pavement testing (APT). The results obtained from the performance of this pavement structure and materials could then be compared with historical data of conventional pavement materials and structures. This information would then become the premise on which to substantiate the stated philosophy and be used as a credible source to convince clients and their engineers that HiMA should be the premium material of first choice for the construction and rehabilitation of heavily trafficked pavements for freeways and airports into the future.

**HiMA should be the premium material of first choice.**

The study tour members were of the opinion that HiMA had great potential for implementation in South Africa, provided the above constraints could be addressed effectively, and that it would be able to compete with concrete pavements to render a long-life pavement for heavily trafficked roads and airports. To this end, a fast-tracked technology transfer and implementation plan was prepared.

**HiMA T²: Development of South African mix design guidelines**

The intention of the second phase of the project was to translate French design methods and criteria into their South African equivalents, and to draft provisional guidelines on mix design based on the outcomes of the laboratory study. When this task was planned, it was (erroneously) assumed that the French mix designs would be completed by September 2008 so that testing in South Africa could be initiated in October 2008.

Unfortunately, the French mix design process took far longer than expected, and the first mix design report received from the French laboratories was only completed in July 2009. It indicated that the proposed mix met all EME2 requirements with the exception of fatigue. A mix design requested from the other company was never received.

The mix design produced by the French company served as the “reference mix” used in the development of South African design criteria for HiMA base courses. The mix was subjected to an extensive laboratory test program, which also linked in with the work on the development of the new South African Pavement Design Method (SAPDM ) for SANRAL with 20/30 penetration grade binder as the reference mix. In 2011 a local 10/20 penetration grade binder became available, and a subsequent laboratory study
was performed using the reference mix design, but replacing the 20/30 pen grade binder with the 10/20 binder. The results from the tests on the reference mix were used in the development of an interim guide for the design of HiMA mixes and the structural design of HiMA pavements, which is available to Sabita members.

The HiMA mix design guidelines developed for South Africa are based on the French methodology for the design of bituminous mixtures. Since the reference mix design was developed in France using South African mix components and French tests, the performance of the mix in terms of the French criteria for HiMA was known. This mix design was then used to produce test specimens at the CSIR laboratories in Pretoria. The specimens were tested using South African test methods, allowing a comparison to be made between the French and South African performance parameters.

The French method for HiMA design involves the use of so called performance specifications, the aim of which is to evaluate mix properties in relation to the loading and environmental conditions to which the material will be subjected in the field. The intention of these specifications is to prescribe the performance of the final product, without necessarily putting limitations on the composition of the material. An advantage of this approach is that it reduces barriers to innovation and promotes the efficient use of natural resources, without sacrificing performance. The proposed performance related design process for HiMA mixes is shown in Figure 2.

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**Figure 2: Performance related design process for HiMA**
The first step is to select appropriate mix components in terms of aggregate and binder. A suitable grading is developed from the different aggregate fractions, and the binder content is set based on a minimum richness factor, similar to the film thickness used in South Africa. Using this trial mix design gyratory specimens are compacted. In the test a maximum air void content after a set number of gyrations has to be achieved - the first of the required performance criteria, aimed at creating a workable mix. If the workability criteria are met, specimens are subjected to a durability test. The remaining performance criteria relate to a minimum dynamic modulus requirement, a minimum level of resistance to permanent deformation, and finally a minimum fatigue life.

The interim guide on the design of HiMA contains details of the aggregate selection, development of trial grading curves, binder selection, minimum binder content and binder richness factor. HiMA is typically produced using fully crushed fractured aggregate, and both angularity and surface texture are important in the selection of an aggregate source. The interim HiMA design guide provides target aggregate grading curves and envelopes for HiMA mixes. It should be noted that these only provide a point of departure for the mix design process and that they should not be used to impose restrictions on the grading in the fashion of the current COLTO specifications. In Europe, either a 10/20 or a 15/25 Pen grade binder, conforming to EN 13924, is typically used in HiMA mixes. These penetration grade bitumen types are expected to become more readily available in South Africa in the near future.

An extensive laboratory study was conducted to translate the French performance specifications for HiMA to South African equivalents. The set of performance tests used in the French mix design procedure and the selected locally available equivalents are shown in Table 1.

### Table 1: French performance tests and selected South African equivalents

<table>
<thead>
<tr>
<th>Parameter</th>
<th>French test method</th>
<th>Selected South African equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>EN 12697 - 31: Gyratory compactor</td>
<td>ASTM D6926: SUPERPAVE gyratory compactor</td>
</tr>
<tr>
<td>Durability</td>
<td>EN 12697 - 12: Duriez test</td>
<td>ASTM D4867: Modified Lottmann test</td>
</tr>
<tr>
<td>Permanent deformation</td>
<td>EN 12697 - 22: Wheel tracker</td>
<td>AASHTO 320-03 SUPERPAVE shear tester</td>
</tr>
<tr>
<td>Dynamic modulus</td>
<td>EN 12697 - 26: Flexural beam</td>
<td>AASHTO TP 62 dynamic modulus</td>
</tr>
<tr>
<td>Fatigue test</td>
<td>EN 12697 - 24: Prism</td>
<td>AASHTO T 321 Beam fatigue</td>
</tr>
</tbody>
</table>

The results of the comparative testing were presented in a paper at CAPSA’11. The tentative performance specifications developed based on the experimental work are shown in Table 2. The criteria require validation through accelerated pavement testing (APT) and Long Term Pavement Performance (LTPP) trials. This type of testing was planned as part of the following phase of the HiMA T+ project.

### Table 2: Tentative performance criteria for HiMA bases

<table>
<thead>
<tr>
<th>Property</th>
<th>Test</th>
<th>Performance requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Method</td>
<td>Class 1</td>
</tr>
<tr>
<td>Workability</td>
<td>Gyratory compactor, air voids after 45 gyrations</td>
<td>ASTM D6926</td>
</tr>
<tr>
<td>Moisture sensitivity</td>
<td>Modified Lottman</td>
<td>ASTM D4867</td>
</tr>
<tr>
<td>Permanent deformation</td>
<td>RSST-CH, 55°C, 5 000 repetitions</td>
<td>AASHTO T 320</td>
</tr>
<tr>
<td>Dynamic modulus</td>
<td>Dynamic modulus test at 10 Hz, 15°C</td>
<td>AASHTO TP 62</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Beam fatigue test at 10 Hz, 10°C, to 70% stiffness reduction</td>
<td>AASHTO T 321</td>
</tr>
</tbody>
</table>
HiMA T²: Development of structural design guidelines

As mentioned earlier, the laboratory study on the HiMA reference mix was designed to feed into SANRAL project to revise the SAPDM. Resilient response and damage models for HiMA will form an integral part of the new SAPDM once this is released. In the interim, the design of pavements containing HiMA will have to rely on existing models available to practitioners. The interim HiMA design guide provides a guideline on the design of pavements with HiMA layers using available methods.

Asphalt is a visco-elastic material and the modulus of asphalt is therefore sensitive to changes in temperature and loading speed. The revised SAPDM will include methods to develop dynamic modulus ($E^*$) master curves for the material and predict the stiffness of an asphalt material at any combination of loading speed and temperature. The influence of aging of the binder on the modulus of the material will also be taken into consideration in the SAPDM models. Although the aging models are not yet available, it is already possible to use master curves in HiMA pavement design. Master curves are generated using time-temperature superposition principle. This principle allows for test data collected at different temperatures and frequencies to be shifted along the frequency axis relative to a reference temperature to form a single characteristic master curve. Master curves can be developed based on dynamic modulus laboratory tests on cylindrical or, where less reliability is required using a predictive equation. A detailed description of master curve development as part of the SAPDM project was presented in a paper at CAPSA 2011. Figure 3 shows master curves for HiMA and a number of mixes tested as part of the SANRAL SAPDM project. The results indicate that the HiMA mix has a significantly higher stiffness at high temperatures or low loading speeds.

![Figure 3: Dynamic modulus master curves for different mixes](image)

New fatigue prediction models are being developed under the SANRAL revision of SAPDM, which is planned to become available end 2013. It is proposed that in the interim the existing TRH4-1995 models for fatigue in thick asphalt bases be used for HiMA. These models are deemed conservative for HiMA base materials, because of
the higher binder content used in HiMA mixes. The TRH4-1995 design method does not contain damage models for permanent deformation in asphalt layers.

Models for permanent deformation are being developed as part of the new SAPDM. To get an estimate of the permanent deformation in HiMA base layers use can be made of the models in the Mechanistic Empirical Design Guide (MEPDG) recently introduced in the USA. These models have not been validated for South Africa, but provisional results from the SAPDM development project suggest they may be reasonably accurate.

**HiMA T²: Implementation**

After the completion of the interim HiMA guidelines a number of mix designs were performed for different asphalt producers. The first full implementation of a HiMA base designed in accordance with the newly developed mix and structural design guidelines in the rehabilitation of a heavily trafficked road section owned by eThekwini municipality. The trial section comprises the North bound lanes of South Coast road at the intersection with Bayhead road.

The existing asphalt surfacing at the section had deformed significantly due to high volumes of trucks en route to the harbour as shown in Figure 4. Estimates based on limited traffic count information available for the section indicate that the section carries in the order of 8000 standard axles (E80s) per day. The road section was considered an ideal setting for the validation of the HiMA technology.

![Figure 4: (a) Severe deformation of section prior to rehabilitation](image)

![Figure 4: (b) Traffic situation at the intersection](image)

The existing bituminous base and subbase layers had densified to such an extent that it was considered unstable. It was decided to mill out 190 mm of existing base, subbase and surfacing and replace it with two 80 mm HiMA base layers, surfaced with 30 mm SMA. The structure after rehabilitation is shown in Figure 5.

![Figure 5: Rehabilitated pavement structure](image)
Construction of the HiMA base layers took place in August 2011, while the SMA surfacing was placed several weeks later. The performance of the section with time will be monitored, and Falling Weight Deflectometer (FWD) measurements, rut measurements and visual assessments will be performed every six months. The first assessment was performed in February 2012, and showed some minor distress to the SMA surfacing layer, but no permanent deformation of the base layers.

Figure 6: Construction of the HiMA layers

In summary

South Africa has gained an asphalt technology that is suitable for application on the most heavily trafficked roads. An interim design method for HiMA mixes and structures containing HiMA layers was developed, the performance related methodology has been completed, and covers all aspects of the mix design using South African test methods. The interim performance criteria were set based on a small number of mix designs, and while the design method requires further validation through accelerated pavement testing and field trials, the initial results are encouraging. The new South African pavement design method will contain damage models for the prediction of rutting and fatigue in HiMA pavements.

Milestones in the introduction and use of WMA in South Africa

Tony Lewis and Krishna Naidoo

Introduction

Warm mix asphalt (WMA) is a process that is taking a firm hold of the asphalt industry worldwide, and it seems likely that the manufacturing and paving temperatures of the majority of asphalt mixes will be reduced by at least 20°C below those of hot mixed asphalt (HMA) within the next ten years.

WMA is already quite well known to the asphalt industry in South Africa, after being workshopped at various SAT seminars and RPF events, as well as at Capsa’11.
The intention of this report is to synthesise the most important milestones in the introduction and use of WMA in South Africa, from its inception in 2008 to its present status in early 2012. This includes a summary of the experience that was gained by way of three full-scale national trials, the successful outcome of which paved the way for the compilation of a comprehensive guideline, Sabita’s Manual 32: Best practice guideline for warm mix asphalt, which was published in September 2011.

The use of WMA is starting to snowball in South Africa, with new asphalt suppliers and new WMA Technologies coming on board, and this report concludes with a glimpse of the latest developments in this field.

The development of WMA worldwide

WMA is described as the manufacturing and paving of asphalt mixes at significantly lower temperatures compared to those of convention HMA, while maintaining or even exceeding the quality of equivalent HMA mixes.

The international road construction industry is rapidly adopting this idea, and by the end of 2010 an estimated 50 million tons of WMA had been successfully manufactured and paved in the United States. NAPA reports that by 2016 it is likely that 50% of the asphalt used in the USA will consist of WMA. Large quantities are also being paved in some countries in the European Union, notably in France, Holland and Germany, as well as in the Far East.

By 2016 it is likely that 50% of the asphalt used in the USA will consist of WMA.

What is driving the global shift towards WMA?

Lower overall emissions

Lower mixing temperatures to manufacture WMA means less energy is required for heating, consumption of burner fuel is reduced, conserving non-renewable fossil fuels and reducing greenhouse gas emissions.

Improved working environment

Reducing fuel burned reduces emissions of aerosols and fumes, both at the mixing plant and the paving site, improving conditions for both the workers and the neighbouring communities. Lower asphalt temperatures improve general worker safety and reduces the risk of heat related injuries.

Engineering benefits

WMA offers a host of engineering benefits, some of which are:

- Improved workability and compactability, which is beneficial for hand work at intersections, widenings, around manholes or for patching;
- The longer “compaction window” provides significant advantages over HMA when transporting and paving asphalt at night and in cold weather. It allows for longer haulage distances or times. WMA can be produced at normal HMA temperatures to enable substantially longer haulage distances or times to be achieved;
- The reduced temperatures of WMA can be expected to reduce binder ageing during production and paving, and result in improved durability, flexibility and
resistance to fatigue and age cracking. This should therefore result in reduced lifecycle costs;

- There is close synergy between WMA and asphalt recycling, for instance the softer binder resulting from the lower temperatures used in the manufacture of WMA may assist in improving the properties of the aged binder in the reclaimed asphalt (RA), thereby enhancing the mix’s fatigue properties. WMA technology also improves the compactibility of stiffer mixes that may result from the incorporation of high proportions of RA.

Getting started with WMA in South Africa

At a Society for Asphalt Technology (SAT) seminar on WMA held in Pretoria on 9 July 2008 it was proposed that a task team be formed to conduct trial sections to assess the benefits of the various WMA technologies.

Subsequently a meeting was held at the eThekwini Municipality in Durban on 5 September 2008 to plan the construction and evaluation of WMA trials sections. This decision can be taken as the first important milestone in the introduction of WMA into South Africa.

The first WMA trial in South Africa was undertaken on Brackenhill Road, Waterfall, a suburb situated approximately 30 km inland of Durban, during November 2008. The road traverses fairly steep grades, and it was felt that this would enable the mixes to be evaluated over hilly terrain that is typical of that found in the eThekwini Municipal Area. Besides residential traffic, the road serves the Brackenhill light industrial area, which includes a readymix concrete plant, and therefore carries a fair number of heavy vehicles.

It was agreed that full advantage should be taken of the trials, and to include:

- Warm asphalt mixes, with and without the addition of reclaimed asphalt (RA);
- Mixes containing high RA contents;
- A “control” mix. It was decided that this mix should conform to eThekwini Municipality’s “Mix D”, which has been much used as a surfacing mix in the Durban area over many years, and is close to the COLTO “medium” continuous graded asphalt surfacing mix.

National Asphalt’s asphalt mixing plant near Shongweni was used to manufacture the asphalt mixes for the trials which were carried out over the 2.2 km length of Brackenhill Road from 3 to 5 November 2008.

These trials, which took only two months from concept to implementation, heralded the introduction of WMA in South Africa and the feasibility of paving and compacting mixes at significantly lower temperatures than conventional mixes was proven. They also confirmed that a worthwhile saving in burner fuel can be expected from WMA. The outcome of this work gave the group managing the trials, the Warm Mix Asphalt Interest Group (WMAIG), confidence to press on with further trials, utilising important lessons learnt, some of which were to:

- Select trial sites which did not include hilly topography that would have made it difficult to pave, and could therefore prejudice the performance of certain of the trial sections;
- Carry out only one trial mix per day;
- Specify full-scale plant mix trials;
Apply more effort into recording roller patterns and passes, as well as measuring and recording the rate of density gain as compaction progressed.

A second decision, which turned out to be an important milestone, was to compile a comprehensive template, which would form the basis for all future trials. The template, which was used as a checklist during the two subsequent trials, proved invaluable and ensured that the same high standards were applied throughout the trials.

A further milestone was the second trial, which was carried out on Leicester Road, located in Durban’s industrial area of Mobeni, in May and June 2009. The section between Grimsby Road and Pendlebury Road was selected as it offered the following features:

- It is situated on a very gentle grade;
- The section carries a fair amount of heavy traffic;
- It offers just over 1 km of dual carriageway;
- Traffic accesses between the two carriageways mean that some handwork was required. This was an opportunity to assess the use of WMA in handwork.

Furthermore the site is quite close to Much Asphalt’s Coedmore plant, from which it was decided to resource the asphalt. The opportunity was taken to use a batch-type plant to manufacture the mixes, whereas the first WMA trials were manufactured in National Asphalt’s continuous drum mixer type plant. It was decided to limit the variables at the paving site by using as far as possible the same team and equipment that National Asphalt had used on the first trials.

It was decided that the trials would include both carriageways, a total area of approximately 20 000 m², using three different mixes:

- Mix D with 10% RA (control section manufactured and paved at HMA temperatures);
- Mix D with 10% RA + Rediset (WMA manufactured and paved at reduced temperatures);
- Mix D with 10% RA + SASOBIT® (WMA manufactured and paved at reduced temperatures).

It was decided to use 10% reclaimed asphalt in all the 40 mm thick surfacing trial mixes. Advantages of carrying out sections using the same mixes on each of the carriageways included the opportunity to compare the performance of the mixes in the respective carriageways under slightly different traffic loadings, as well as the chance to assess the mixes during different days of production.

The trials commenced on 25 May and were completed on 4 June 2009; the main outcomes are summarised below:

- A great deal of effort was put into applying the lessons learnt during the first WMA trials on Brackenhill Road;
- The WMA template was rigorously applied throughout the trials and proved invaluable as a comprehensive checklist;
- The core aim of the WMA Interest Group’s work in producing WMA at the target temperatures with a resulting pavement that is at least as good as the control HMA was successfully achieved. In fact two of the WMA mixes were slightly superior to the control HMA with regard to deformation resistance under MMLS accelerated trafficking;
• All six trial sections were successfully compacted to achieve the required minimum 92% MTRD level of compaction;
• The trials have confirmed that the period available to compact the asphalt layer after it has been paved, commonly known as the “compaction window”, is significantly extended in the case of WMA.

The WMA trial work culminated in the completion of the third and most extensive WMA trials on Durban’s Higginson Highway, which were carried out over a period of nine months during 2010. Preparation work began with the initial laboratory mix designs in April, full-scale plant mix trials in May, June and July, with the main trials on Higginson Highway being undertaken from 25 October to 8 December 2010.

The trials, which covered a 3,4 km length of the outbound carriageway and include ten base and eight surfacing mixes, are most likely the largest asphalt trials ever carried out in South Africa. They included mixes containing various proportions of reclaimed asphalt (RA), up to 40%, combined with the use of conventional and polymer modified binders.

With both the previous trials having shown that WMA can be successfully manufactured and paved at temperatures at least 20°C below those of conventional asphalt, the intention of the Higginson Highway trials was to push the boundaries, with further reductions in temperatures, as well as increased proportions of reclaimed asphalt (RA) and the use of polymer modified binders.

As with the previous trials, the primary consideration was that the quality and performance characteristics of the warm mixes should be at least the same as those of asphalt manufactured and paved at conventional temperatures. In the same way as in the previous trials, decisions regarding the scope of the trials, as well as the management of the work throughout the trials, were directed by the Warm Mix Asphalt Interest Group.

The main findings of these trials are summarised below:

• All the WMA mixes included in these trials performed well against the fundamental requirement of being at least as good as conventional HMA;
• A variety of asphalt mixes could be manufactured and paved at significantly lower temperatures, with potential burner fuel savings, as well as reduced emissions, fumes and odours, resulting in healthier working conditions;
• Warm technologies can be combined with asphalt mixes containing reclaimed asphalt contents of up to 40%. This not only results in the environmentally-friendly practice of reusing old asphalt, but also in real savings as significantly less new bitumen needs to be used in the recycled mixes;
• Combining WMA technologies with conventional polymers and reclaimed asphalt works well;
• There was convincing evidence that WMA could be considered as a standard specified option for all pavement classes.

Following this trial it was the WMAIG’s opinion that sufficient experience had been gained to compile a national guideline and specification for WMA.

WMA best practice guideline

The technical and practical experience gained from the three trials, as well as that gathered by members of the WMAIG who undertook a study tour of some EU countries, was used in the compilation of the guideline. The document was drafted by a
team of WMAIG members and was subjected to both local and international peer review.

Sabita’s Manual 32: *Best practice guideline for warm mix asphalt*, which was published by Sabita in September 2011 after its launch at CAPSA’11, can be seen as the final milestone in the introduction phase of WMA into South Africa.

This manual covers all the usual aspects of WMA, which are presented in 14 Chapters. It also contains an interim specification for WMA for base and surfacing mixes, and has been prepared as a stand-alone specification along the lines of the COLTO document.

Present status

The relatively quick introduction of this new technology into South Africa - it took just over three years - has surprised the asphalt industry in some other countries, where it is taking much longer. This quick response no doubt hinges to a large extent on the excellent cooperation and teamwork between all parties involved in our local asphalt industry and in particular those involved in the WMAIG. The eThekwini Municipality’s Road Rehabilitation Branch must be acknowledged for their initiative and boldness in using new technologies on their roads, and their drive to implement environmentally-friendly processes. The valuable contribution of the WMA Technology suppliers, both with their specialised knowledge as well as their products, should also be mentioned.

Two of the country’s leading asphalt suppliers, National Asphalt, and Much Asphalt, are currently producing warm mixes on a routine basis. Besides using rheological modifiers and polymer-rheology modified hybrid WMA technologies, both suppliers are using foamed bitumen water technologies in their mixes. Indeed, the use of WMA has already become a routine way of manufacturing and paving asphalt in parts of the country, such as the eThekwini Municipality.

WMA technologies have been especially useful in extending the haulage distances. The mixes are manufactured with the WMA technology at conventional HMA temperatures. The long “compaction window” that is produced in this way enables the mix to be hauled for several hours without the risk lowered paving and compaction temperatures causing compaction problems.

Future developments

The movement towards more widespread application of WMA is gathering size and momentum, with Aqua Transport’s asphalt division readying themselves for full-scale WMA implementation during the next two months, under the WMAIG’s guidance.

Preparations for a WMA trial on National Route 3 in the Free State are currently underway, spearheaded by concessionaires N3TC, consultants WSP, and contractors Aveng Grinaker-LTA, all with the support of the WMAIG.
The well-known international asphalt plant manufacturer, Ammann, has expressed interest in WMA trials. They have patented a foamed bitumen system which is fitted to their batch-type mixers or can be retro-fitted to other asphalt plants. The WMAIG looks forward to supporting Ammann in this work.

Another interesting development is that, with the support of the WMAIG, PQ Corporation, a leading global manufacturer of silicates and zeolites, is contributing to a full-scale trial of their WMA technology. Both base and surfacing, as well as polymer modified mixes, will be included in these trials, which National Asphalt aims to manufacture and pave within the next three months. These trials should add another string to South Africa’s bow, with a zeolite water-type technology being added to our list of proven WMA technologies.
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The Southern African Bitumen Association (Sabita)
5 Lonsdale Building, Lonsdale Way, Pinelands 7405
Postnet Suite 56, Private Bag X21, Howard Place 7450
Tel +27 21 531 2718  Fax +27 21 521 2606
email: info@sabita.co.za  www.sabita.co.za