Considerable effort has been taken to ensure the accuracy and reliability of the information contained in this publication. However, neither Sabita nor any of its members can accept any responsibility whatever for any loss, damage or injury resulting from the use or implementation of this information.

The views and opinions expressed in this publication are those of the authors, and do not necessarily reflect the views of Sabita or any of its members.
Mission

Sabita’s plans and actions are consistent with good corporate citizenship to underpin its dealings with government, and to assist its members.

Vision

Sabita will:

- advance best practice in southern Africa with due regard to worker health and safety, as well as the conservation of the environment;

- provide education and training schemes to develop skills and competencies that are sustainable and aligned to national goals and frameworks; and

- engage government to promote the social and economic value of road provision and efficient delivery by state road organisations.
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Preface

Published annually by Sabita for the past five years, the Digest is an ongoing overview of technological advance, system changes, and overall progress in Sabita’s drive to develop and upgrade standards of practice in southern Africa’s bituminous products industry. CAPSA, over the years, has been a valuable partner in this process, and in fact the formation of Sabita was announced at CAPSA’79.

Since CAPSA’04 at Sun City coincides with Sabita’s 25th anniversary, we thought it appropriate to feature in this publication papers accepted for the conference — papers which, in our opinion, are noteworthy in offering direction to the industry. As in the past, members’ contributions have also been invited, and these are included.

We gratefully acknowledge the valuable contribution of Professor Kim Jenkins of the SANRAL Chair at the University of Stellenbosch. As chairman of the CAPSA’04 technical committee, he was able and most willing to give his guidance and assistance in the editing process.

Due to space constraints, only a certain number of selected CAPSA’04 papers could be accommodated in this publication, and readers are urged to consult the conference agenda for a comprehensive list of valuable material presented.

Piet Myburgh
Executive Director
Sabita
Engen Ad
The Southern African Bitumen Association (Sabita) celebrates its 25th anniversary in 2004 from a position of unprecedented strength, respect and influence.

The organisation’s achievements since its launch at CAPSA’79 in Durban are the result of a conscious commitment to ongoing analysis, adaptability, and the active participation of its members in formulating and pursuing the association’s strategic objectives.

Sabita has achieved its positive status in the blacktop roads industry — both locally and internationally — through vigilant perception of the volatile socio-economic landscape of southern Africa in general, and of the region’s bituminous products industry in particular. Central to the process of satisfying these needs has been the organisation’s willingness to be flexible, to form partnerships and alliances with road industry stakeholders, and to align itself with the key objectives of government policy makers.

In establishing the Southern African Bitumen and Tar Association (Sabita) in 1979, the blacktop roads industry sought to create a proactive mechanism which would build a framework of opportunity for the structured and unified development of the bitumen market. Closely linked to this was the objective of uniting Sabita members in their common goals, and of promoting efficiency, profitability and best practice.

AREST

In its early years Sabita’s primary focus was on technology development to broaden the market base for its members, and to render their products and services cost-effective and competitive. Much of this effort was channelled through the Sabita-sponsored Asphalt Research Strategy Task Force (AREST), established in 1987.

While these objectives were appropriate to the needs of Sabita members, and to the market, during the years 1979-1987, Sabita’s strategic goals have been radically adapted to perceived needs since then, underlining the
association’s flexibility in the face of rapidly changing social and economic conditions.

Strategic objectives identified by Sabita’s Council at that time envisaged that Sabita would:

- Be an “ongoing CAPSA to bridge the gap between the five-yearly conferences by providing forums for discussion on matters relevant to the blacktop industry;
- Represent the industry on committees that guide the design and construction of roads;
- Access overseas expertise and experience by forging links with international sister organisations; and
- Represent the interests of its members in the public media.

These goals were regarded as “ambitious but attainable”.

Sabita’s activities were funded exclusively by member subscriptions until 1987. In that year the association took a quantum leap forward when the oil companies committed themselves to funding research, a chair of learning (Stellenbosch University) and other activities designed to entrench global standards in South Africa’s blacktop roads industry.

This needs-driven research, as identified by AREST, led to the formalisation of generic technologies such as LAMBS, GEMS, and ETB, and the dissemination of this knowledge in published technical manuals.

Economic guidelines promoting efficient delivery, such as Manual 7: SURF+ Economic warrants for surfacing roads, were also developed and published.

This manual is currently being updated to align its recommendations with current economic imperatives.

In all, Sabita has published 23 technical manuals, three training guides and 21 supportive audio-visual aids, and these publications have become entrenched in university and technikon curricula.

**CAPSA Secretariat**

As part of its service to the industry, Sabita undertook to manage the CAPSA secretariat in 1980, and performed this function between then and CAPSA’99 at Victoria Falls, Zimbabwe. 1989 also saw the appointment of a Technical Manager (later Technical Director) to oversee the direction and development of relevant technologies, publications,
educational material, seminars and workshops, the founding of the Society for Asphalt Technology (SAT) under the auspices of Sabita, and ongoing research projects.

Although technology development remained a major focus for the next several years, attention increasingly shifted towards social development issues, including human capital development to ensure an informed industry staffed by informed practitioners.

**Asphalt Academy**

This new focus led to the evolution of the Asphalt Academy (AsAc), a Sabita-CSIR Transportek joint venture under CEO Les Sampson. Launched in 2001, AsAc was tasked with delivering well-trained and educated practitioners to the asphalt and bituminous products sector in southern Africa. In addition to developing and presenting a comprehensive range of training courses, workshops and seminars, AsAc has developed learnerships in line with the requirements of the Skills Development Act, convened and managed research programmes on modified binders and foamed bitumen treated materials, and published technical guidelines.

Despite its relatively short period of existence, AsAc is currently recognised as the premier centre of learning for the blacktop sector in southern Africa, and is developing strategies to extend its influence into the Southern African Development Community (SADC).

The reformulation of the Bituminous Materials Liaison Committee (BMLC) in 1990 into a more interactive forum, co-sponsored by Sabita and the CSIR Transportek, created a fertile environment for the evolution of relevant strategic directions for the blacktop industry, and ensured lively debate and knowledge sharing amongst the industry’s leading practitioners.

The BMLC later evolved into the Road Pavements Forum (RPF) with expanded sponsorship, which included representatives of the cement and concrete sector, and the quarrying and aggregate supply industry.

In 1993 Sabita instituted the Sabita Chair in Asphalt Pavement Engineering at Stellenbosch University, which established the necessary contact to ensure that civil engineering courses at tertiary institutions gave appropriate emphasis to flexible pavement engineering, and to promote postgraduate studies in
During the late 1980s and early 1990s it also became apparent that if Sabita were to function effectively on behalf of its members, and at the same time exert meaningful influence on the development of both the regional economy and the blacktop industry, it would need to integrate its objectives with those of the broader economy.

This perception was underlined when new directions, identified by RE-AREST in 1991, gave rise to a project entitled Social Development Issues affecting Roads and Road Transportation. This new focus on the value of roads in the development and upliftment of South Africa’s underdeveloped areas increasingly influenced Sabita’s strategic decision making. Challenge analysis in the early 1990s made it clear that, in the face of a rapidly changing political climate as South Africa moved towards a functional democracy, Sabita would achieve greater value for it’s members by fostering an environment of constructive engagement with government and roads authorities. The discovery, by a Sabita funded study, that 220 000 km of roads serving townships and remote rural areas were not on the state’s inventory, refocused the state in their quest for proper asset management.

One initiative driven by the need for more efficient delivery was the Sabita-sponsored Roads Develop People programme [later re-named the Councillor Empowerment Programme (CEP)],
instituted in 1997. More than 1200 local government councillors attended interactive workshops on the assessment of road construction and maintenance needs in their constituencies, and on budgeting, fund allocation processes and other management skills. This highly successful empowerment programme was supported by the SA Department of Transport and the United States Federal Highway Administration.

A natural evolution of this programme was the formation of Sabita’s **Urban Renewal and Rural Development (URRUD)** focal point. This group, led by vice-chairman Daniel Mashatola and representative of the broad bituminous products industry, has reviewed and updated the *Roads Develop People* programme in 2004 to align it with structural changes within the various local and provincial government sectors.

Central to the revised programme will be workshops focussing on the socio-economic benefits of adequate roads, road engineering processes and terminology, the importance of asset management, employment opportunities in road construction and maintenance, rational decision making, and business and implementation planning.

In a significant shift in strategic direction in 1996, Sabita dropped the word “Tar” from its name and became the Southern African Bitumen Association (Sabita), with the primary objective of promoting excellence in the use of bituminous products. Closely linked to this shift was a broadened strategic framework embracing not only core technology development, but also market development, national norms and standards through the national Task Force on Specifications for Bituminous Products, and a re-alignment with concerns for worker safety health, and environmental conservation.

The focus on HSE issues gathered momentum over the next six years, culminating in the launch of Sabita’s **Centre for Health and Safety and Environmental Conservation (COSHEC)** focus group in 2003. COSHEC has undertaken to develop guidelines aimed at protecting worker health and safety, and to develop policies (based on global conventional wisdom) to protect the environment. Focus areas include:

- Delisting by the Department of Water Affairs and Forestry (DWAF) of bitumen as a hazardous waste;
- Safe working practices;

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**John Gregg**  
1994 Excellence Award

**Chris Potgieter**  
1995 Excellence Award

**Benoit Verhaeghe**  
1995 Research Award

**Basie Nothnagel**  
1996 Excellence Award

**Martin van de Ven**  
1997 Excellence Award
• Bitumen safety training;
• Handling of bituminous products in transport and storage;
• Alternative technology to coal tar products.

It is anticipated that COSHEC will become the instrument through which the bituminous products industry will act proactively in a self-regulatory manner to ensure that policies adopted and implemented are up-to-date, relevant and representative of global best practice.

National awareness

However, while Sabita continues to drive technology, education, safety and market development initiatives, its most important overall objective remains to inculcate a national awareness of the crucial link between adequate roads and socio-economic development.

The association’s Public Policy Awareness Campaign, which highlighted relevant issues in print, radio and television media, achieved a major breakthrough in 2000 with the publication of a Sabita-funded academic report on the funding of infrastructure in the public sector.

Drawn up by a team headed by Professor Don Ross of the University of Cape Town, the so-called Ross Report — The

Growth in Sabita membership

<table>
<thead>
<tr>
<th>Year</th>
<th>Membership</th>
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<tbody>
<tr>
<td>1999</td>
<td>10</td>
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<td>2000</td>
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<td>2003</td>
<td>50</td>
</tr>
<tr>
<td>2004</td>
<td>60</td>
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</tbody>
</table>

Trevor Distin 1998 Excellence Award
Dennis Roßmann 2001 Excellence Award
Elżbieta Sadzik 2002 Excellence Award
Les Sampson 2003 Excellence Award
under-provision and under-capitalisation of road maintenance, rehabilitation and upgrading in South Africa—underlined the potential capital appreciation accruing to off-road assets through infrastructure development.

The converse — loss of benefit to off-road assets when road infrastructure is inadequate — was given equal emphasis.

The report also challenged the appropriateness of conventional cost benefit analysis (CBA) in prioritising infrastructure needs in a country with such wealth disparities as South Africa.

The Ross Report has contributed to much more positive cooperation between Sabita and both the public and the authorities, who recognised that Sabita members were above simple self-interest, and were committed to finding viable solutions to the social development problems inherited by the current regime.

A graphic indicator of Sabita’s prominent stature and influence in post millennium South Africa is its membership, which is stronger and more broadly-based than at any time in the association’s 25-year history. This membership growth was fostered by the decision in 1996 to include the consulting engineering sector in the association’s membership, but a powerful influence attracting new members has been the recognition within the broad roads industry, and in the bituminous products sector in particular, that

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**Sabita’s membership is now stronger and more broadly-based than at any time in the association’s 25-year history**

**Ongoing projects**

The publication of the Ross Report led to significant meetings between representatives of the bituminous products sector, the Minister of Transport and the Parliamentary Portfolio Committee on Transport. It also resulted in a cooperative venture by the South African National Roads Agency (SANRA) and Sabita to set up projects for the development of an Opportunity Value Assessment mechanism suitable for use in South Africa.

Opportunity Value Assessment (OVA) measures the costs saved on maintaining a primary non-roads asset by investing in good roads, and the contribution to the value of the primary asset as a result of its being serviced by good roads. These projects are ongoing.

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it is within Sabita’s power to make very positive impacts on the development of the industry, and thereby to promote the interests of Sabita members and of their economic region. Sabita’s 25-year track record, often in the face of severe restraints and difficulties, is a vivid confirmation of the association’s success and achievement in fostering a robust and innovative industry.
With ten industry-defined courses developed by the end of 2002, AsAc’s primary focus in 2003 shifted to the transfer of knowledge through course presentation using CETA-accredited presenters whenever possible.

The schedule of courses developed and presented by Tjeka (see Table 1) related to specific unit standards. A decision was taken at the start of the year to run all the courses outlined on the schedule in order to evaluate the need for the various courses, and the response of the market based on the increased importance being placed on courses forming part of unit standards/qualifications.

A total of 48 courses has been scheduled for presentation nationwide in 2003/04. In addition to these, a very successful three-day advanced bitumen course was also organised in association with the SANRAL Chair.

<table>
<thead>
<tr>
<th>Asphalt Academy courses available for presentation in 2003/2004</th>
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<tbody>
<tr>
<td><strong>Course</strong></td>
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<tr>
<td>Introduction to bitumen</td>
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<tr>
<td>Application of seals</td>
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<tr>
<td>Application of hot-mix asphalt</td>
</tr>
<tr>
<td>Manufacture of hot-mix asphalt</td>
</tr>
<tr>
<td>Pavement repair and maintenance (LIC)</td>
</tr>
<tr>
<td>Bituminous surfacings (including LIC)</td>
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<tr>
<td>Design of surfacing seals/modified binders</td>
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<tr>
<td>Design of hot-mix asphalt</td>
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<tr>
<td>Asphalt testers’ course — Modules A, B, C</td>
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<tr>
<td>Bituminous Materials on Site (BMOS)</td>
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<tr>
<td>Advanced bitumen course</td>
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<tr>
<td>Compaction of HMA (SARF module)</td>
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</table>

*Table 1: AsAc courses available for presentation in 2003/2004*
in Pavement Engineering at the University of Stellenbosch, featuring international guest lecturers from the universities of Wisconsin (Hussain Bahia) and Delft (Professor Martin van de Ven).

A new strategy, based on the successes of 2003/04, will be pursued in 2004/05. This will involve the formation of strategic alliances and partnerships with other industry groupings and client bodies to further streamline and improve the efficient delivery of courses in the future.

**Block course**

AsAc’s role in supporting tertiary institutions in 2003/04 took the form of a comprehensive survey of curricula, courses and resources relevant to the road industry. The results of the survey will be presented in a joint paper with the SANRAL Chair at CAPSA’04.

However, based on the findings of the survey, one of the major initiatives for 2004/05 will be the development of a block course in flexible pavement engineering targeted at newly qualified civil engineers and technicians entering the roads industry. Some of the survey findings included:

- A major problem lies with interpretation of under-graduate and post-graduate courses at Technikons compared with the Universities, and a clearer definition will need to be developed;
- The number of undergraduates exposed to pavement engineering appears to have increased since 1999 (average increase 8%/year to 2002). However, it is of concern that only between 15 and 20% of post graduate civil engineering students are specialising in pavement engineering;
- The number of lecturers at post-graduate level specialising in pavement engineering is a concern;
- Pavement engineering is not specifically offered at B Tech level at Technikons. The industry should consider actively promoting pavement engineering as a B Tech course or AsAc should develop a block course to introduce newly qualified civil engineers, technicians and technologists to flexible pavement engineering;
- Equipment available for specialised research at tertiary institutions is considered to be ad hoc and generally limited. This is seen as an added problem in attracting students to specialise in pavement engineering.

**Major gaps**

A survey of industry training needs, carried out during 2003/04, identified two major gaps in the current portfolio of courses. These were on bitumen stabilisation (either using emulsion or foam) and a specialist course related to health, safety and
environmental issues applicable to the bituminous products sector. It is anticipated that for the next two years, most of the feedback in this area will be presented in ad hoc workshops and seminars to feedback the latest best-practice guidelines as they are developed and published. A course on bitumen stabilisation could be developed for subsequent years once the latest technologies are accepted and refined in practice.

A proposal to develop a course for trainers was also received. This is considered to be priority area and will need further attention in 2004/05.

**Guidelines**

AsAc has also managed work on three new best-practice guideline documents throughout the year. These are related to emulsion-treated materials, thin asphalt surfacings, and a practical guide to hot-mix asphalt design. These guidelines are likely to be published as part of AsAc’s TG series during 2004/05, and will be fed back to industry through regional workshops and seminars.

For the coming year AsAc plans to ensure that courses and curricula offered at institutions of learning are consistent and relevant to industry needs through:

- Regular assessment of course curricula;
- Providing relevant knowledge transfer to lecturers, trainers and learners.

In collaboration with tertiary institutions, AsAc will also ensure that advanced courses and post-graduate studies are properly scheduled, coordinated and aligned with relevant legislation and quality standards.

Teaching will take the form of:

<table>
<thead>
<tr>
<th>The development of a course for trainers is considered to be an AsAc priority area</th>
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<tbody>
<tr>
<td>A proposal to develop a course for trainers was also received. This is considered to be priority area and will need further attention in 2004/05.</td>
</tr>
</tbody>
</table>

- Seminars and workshops to disseminate best practice;
- Publication and distribution of manuals and technical guidelines;
- Management and maintenance of appropriate information systems;
- Support for and participation in CAPSA and RPF activities;
- Support of Sabita and CSIR Transportek courses and initiatives within South Africa and into SADC countries

Other areas identified for AsAc action in 2004-05 include:

- Development of a Flexible Pavement Engineering block course for presentation at Technikons. The initial development will be in association with Vaal Triangle Technikon;
- Optimisation and rationalisation of the course schedule;
- Development of a quality management system for the
ongoing evaluation of courses;
- Development of a strategic alliance with KwaZulu-Natal DoT for better marketing and promotion of courses in that province;
- Development of strategic alliances with institutions of learning/training providers offering learnerships relevant to the roads and bituminous products industry;
- Targeting of specific client authorities to identify specific course and programmes for their areas. The Free State, Limpopo, Mpumalanga and the Eastern Cape are identified as target areas for the next financial year;
- Development of a strategic alliance with SAT to better market ad hoc seminars and workshops for ongoing practitioner development;
- Development of a strategic alliance with SARF;
- Further develop an alliance and operational understanding with T-squared centres as appropriate;
- Obtain CETA recognition/registration for AsAc course material relevant to specific unit standards;
- Develop and incorporate a HSE course into the AsAc portfolio in line with Sabita requirements;
- Present seminars/workshops of the latest technical guidelines related to:
  - Ultra Thin Asphalt;
  - EBTM guidelines;
  - SA HMA practical guidelines;
  - Binder distributors;
- Develop a proposal for presentation of courses in Namibia for submission to the Namibia Road Authority;

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<td>Attendees</td>
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<tr>
<td>Introduction to bitumen</td>
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<td>204</td>
<td>4</td>
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<tr>
<td>Application of surface seals</td>
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<td>Advanced bitumen course</td>
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<td></td>
<td><strong>72</strong></td>
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*Table 2: AsAc courses and attendances*
Develop strategic alliances to open up other SADC markets;

The role and profile of AsAc is now well established and growing in South Africa, and attendance at AsAc courses has shown consistent growth over the past three years (see Tables 2 and 3). Strategically, it is now an ideal time to gather new ideas for subsequent years to ensure that AsAc maintains and improves its services to the industry. With this in mind, attendance at international conferences such as the Eurobitume/Eurashphalt Congress in Vienna in May 2004, and CAPSA’04 At Sun City, is seen as important. Gathering information on new international activities and innovations, especially related to education and training and ongoing practitioner development that could be introduced into South Africa, is a vital element in AsAc’s ongoing ability to satisfy industry needs. Particular attention in the short term will be given to the development of a course based on Health and Safety issues, based on the new Sabita Manual 8: \textit{Guidelines for the safe and responsible handling of bituminous products}.

<table>
<thead>
<tr>
<th>Publications and Workshops</th>
<th>Date of Workshop</th>
<th>Attendees</th>
<th>Publication sales</th>
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<tbody>
<tr>
<td>TG1: Modified Binders Guideline</td>
<td>October 2001</td>
<td>249</td>
<td>889</td>
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<tr>
<td>TG2: Foamed Bitumen</td>
<td>September 2002</td>
<td>256</td>
<td>970</td>
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<td>TRH3 HMA design</td>
<td>June 2001</td>
<td>319</td>
<td></td>
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<tr>
<td>TRH3/HMA design/Modified binders</td>
<td>March 2002</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>Ultra-thin layer asphalt</td>
<td>May 2002</td>
<td>75</td>
<td></td>
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<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td><strong>950</strong></td>
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</tbody>
</table>

\textit{Table 3: AsAc publications and feedback workshops}
Only one change took place in the national council during the past year, and that was the resignation of Benoit Verhaeghe as Honorary Treasurer. This post is now held by Elzbieta Sadzik, who continues to exert firm control over the finances of the Society.

The four regional chairpersons — Gary Swart (East), Renaldo Lorio (South), Basil Jonsson (Central) and Duncan Smith (North) — as well as our Honorary Secretary (Duncan Mason) and two ex-officio members (Piet Myburgh and Les Sampson), remain unchanged and make up the balance of the Council.

Renaldo Lorio has relocated to Port Elizabeth, and Julian Wise has temporarily taken responsibility for the Southern Region until the next local AGM. My sincere thanks go to Renaldo for his valued contributions to the Southern Region. The good news is that, with Renaldo now in the Eastern Cape, he has indicated that he is in a position to set up a new region, a territorial gap which has long been recognised by council. The day to day administration of the Society continues to be managed extremely ably by Pat Loots. How she does it is nothing short of miraculous, as she also works for the Asphalt Academy, and in addition, is the Secretary for the CAPSA’04 conference in September 2004. Nevertheless, she has done amazingly well and my personal thanks go to her for all her hard work in keeping it all together.

Strategic issues

Council has thus been able to devote its attention to such strategic issues as:

- encouraging regional activities;
- propagating the image of SAT (eg the website);
- membership growth;

Sharp upswing in SAT activities in all regions

J Onraët
President
Society for Asphalt Technology
• marketing the aims and objectives of SAT;
• ensuring the correct balance in the relationship with Asphalt Academy;
• financial transparency and stability;
• promotion of SAT in sub-regions.

**Finance**

SAT is a completely self-sustaining organisation, and relies exclusively on the prompt payment of subscriptions, as well as income received from activities of the regions.

The cost of annual subscriptions has only been marginally increased since the inauguration of the Society, the principle being to attract membership from all levels of the asphalt industry, and to make membership affordable to all.

Regrettably, there are still a number of delinquent members who have just not paid timeously, however, still rely on regional activities.

**Regional Activities**

Over the past eighteen months one of the fundamental challenges facing SAT has been that of delivery to its members, and I am very pleased to report that all regions have made significant progress towards this goal — due entirely to the energy inputs of the regional committees.

**Central Region:**

The Central Region Committee, under the leadership of Basil Jonsson, is made up of a healthy cross section of industry sectors:

- Basil Jonsson, bitumen supplier;
- Joe Grobler, consulting engineer;
- Rob Brown, consulting engineer;
- Tom van Rijckeversel, hot mix asphalt supplier;
- Morris de Beer, researcher;
- Hennie Kotze, client body;
- Emile Horak, educational institution;
- Enrico Fletcher, client body;
- Chris de Jager, educational institution;
- Piet Fourie, materials laboratory manager.

The fundamental challenges facing SAT has been to ensure delivery to its members — and some who are even seriously in arrears. Elzbieta will be resolving this issue (hopefully amicably) in the coming months.

The income from subscriptions alone is insufficient to cover the running costs of the Society, and Council therefore proposes to increase subscriptions by 12% from January 2005. The financial viability of the organisation will,
This committee has been busy over the past twelve months or so organising the following:

- Asphalt Enhancement Techniques at the Edge of the Performance Envelope — Discrete Elements (workshop);
- Quality Control of Foamed Bitumen-treated Materials (workshop);
- Site visit to national refineries (Natref);
- Factors Influencing Premature Ageing in Bitumen: The USA Experience (technology exchange session);
- Current challenges in the asphalt industry: Cracking and Rutting of SA Roads (workshop). This successful workshop is scheduled to be repeated in all other regions.

An average of 120 people attended the various functions, and the refinery visit was totally oversubscribed.

This region, being closest to the CAPSA’04 conference venue, has taken responsibility for arranging the SAT Golf Day at Sun City during the conference.

**Eastern Region:** The Eastern Region, under the able chairmanship of Gary Swart, is also made up of a good blend of practitioners representing a wide spectrum of industry sectors:

- Gary Swart, consulting engineer;
- Daryl Jorgensen, hot mix asphalt producer;
- Craig Bradley, consulting engineer;
- Stuart Anderson, consulting engineer;
- Bob Hornsey, bitumen supplier;
- Barry Nothard consulting engineer;
- Keith Paul, educational institution;
- Krishna Naidoo, municipal engineer;
- Veejay Ori, consulting engineer;
- Mark Evans, materials laboratory manager;
- Barry Blunt, binders producer.

Gary Swart reports that a number of seminars and workshops were held in this region, with attendance averaging 55 people per session.

Notable events were:

- Rehabilitation of 19 km of N2 Illovo Road — Mlaas Canal using Novachip (case study);
- Use of Salvicium in the rehabilitation of Umgeni Road/Argle Road intersection (case study);
- Recycling of Recycled Asphalt Pavement (RAP) material to form a paver laid base in the Mobile KMA 200 (report back);
- Safe Handling of Bituminous Products workshop;
- Paving Fabrics and Grids in Asphalt Overlays workshop;
• Ultra-thin surfacing on N1 (case study);
• Blacktop roads for developing communities using appropriate technology;
• Reseal of N2/27 & 28 using SE-2 binder New Guelderland to Munzini Contract (report back);
• Ultra-thin friction course on N7 (case study)

Some activities planned for the near future are:

• Proposed revisions to TRH3;
• Use of manually operated chip spreader for labour based construction of a surface seal;
• Constructability of asphalt surfacing.

Southern Region: Julian Wise, who as mentioned, is acting regional chair, reports that...

"... the dedicated Southern Region Committee, together with our highly supportive presenters, members and visitors, once again produced a very active, stimulating and successful year.

The main emphasis was to provide events that were relevant to our industry in the region, and that would stimulate debate, understanding and be a learning experience. In addition, the social interaction and networking was regarded as equally important.

Highlights of the year starting from April 2003 were:

• Five half day workshops in our highly successful “Understanding” series;
• Hot-mix asphalt — case studies of specific problem projects;
• Seal work — raw materials;
• Seal work — overall design considerations;
• Seal work — specific design of different seals;
• Seal work — construction.

Attendances at these workshops averaged 120 people, and the excellent presenters came from all over the country. We were also very grateful to have generous sponsors from the industry for the refreshments, thus allowing attendance fees to be very modest.

Two more workshops on cold in situ recycling are arranged for August and October (steering well clear of CAPSA’04).

Two “Cocktail Hour” presentations were held. These very enjoyable, shorter, more informal get-togethers attract an average of 30 to 40 people. Discussions included:

• A simple tool for estimating the compaction window time for HMA;
• The asphalt anomalies of some older Cape roads.

An interesting half-day site visit was arranged to the N7 rehabilitation project where the specific focus was on the bitumen rubber
asphalt overlay and ultra-thin friction courses. Financially, the Southern Region remained well in the black. So with this in mind, we decided to produce a booklet as a useful tool for the members. “A Trouble Shooting Guide for HMA Paving” will shortly be published and distributed under the SAT banner, although potential sponsors are still being sought. Many thanks to all those who contributed to and reviewed the booklet.

A feather in the cap of the Southern Region was that, of the ten SAT Fellows that were nominated this year, six were from this region. Congratulations to you all.

Our extremely committed and hard working Chairman, Renaldo Lorio, took up a new position in Port Elizabeth a couple of months ago. His dedication and capacity for work has been an example to us all. We sincerely thank him and wish him well in his new post.

Lastly, many thanks to all the committee members for the teamwork and great spirit. Your efforts have been well recognised.

**We are assured of support from Renaldo Lorio and others in the formation of an Eastern Cape Region of SAT**

The Northern Region: Understandably, and for obvious reasons, the Northern Region (with its base in Harare) has not been as active as Duncan Smith would have liked. Let’s hope that this region can restart activities in the not-too-distant future when a more temperate industry climate prevails.

**Membership**

SAT membership currently stands at 495, of which there 18 are currently fellows. Nominations have been received and approved for the appointment of 12 new fellows. These appointments will be announced at CAPSA’04. (Remember it was at CAPSA’94 that SAT was officially inaugurated, so SAT and CAPSA are inextricably linked).

Official membership cards are currently being produced by Pat and will be sent to members as an accompaniment to the receipt of subscription payments.

There is a list of “untraceable” members, and we are planning to put their names on the website in an attempt to find them.

**The future**

It is my fervent hope that the newly elected regional committees and Council for 2005 will maintain continuity in the activities and deliverables to members. In particular, I would like to see the official formation of an Eastern Cape Region, and I am assured of much support in this ambition from Renaldo Lorio and other industry individuals in that area. It is envisioned that this could be the proto-type for other new regions.
The financial situation of the Society remains a concern, and will be a primary focus for the near future — bearing in mind that the society is registered as a Section 21 company, operating on a non-profit basis.

I am also concerned that not enough use is being made of the SAT website. This is an extremely powerful tool and affords members an opportunity to post news and opinions. A very positive opinion on our site was submitted by Kim Neaylon, an engineer with the South Australian Government, and I encourage all members to do the same.

SAT has made its mark at the CAPSA’04 conference, by arranging the SAT Golf Day. I am confident that we will have a complete sell-out and that the event will be remembered for many years to come.

“Finally, my sincere thanks — to my Council, all of whom have given me their utmost loyalty and support during my two year tenure as President of the Society. I know that together we have laid the groundwork for a stable future for our organisation and to all the loyal members of SAT — please continue to support this worthwhile learned society.”
Tosas ad
Introduction:

CAPSA’04 gives new direction:

In this section we present extracts of selected papers which we believe would be of particular interest to readers. These extracts have been grouped into categories that do not necessarily coincide with the conference session titles. Rather they are grouped in terms of themes that reflect, in our view, key focus areas pertinent to the future direction of the roads industry.

We hasten to add that this section is not intended as an expedient means of coming to terms with the conference proceedings. Of necessity many papers of significant value have not been included in this section, and we should also stress that what appears here are selected sections and diagrams or tables that illustrate the main thrusts only. Readers with an interest in the subject matter are therefore strongly encouraged to read the entire paper.

Readers should also note that tables and diagrams in this publication are not numbered sequentially. To avoid confusion, note that tables and diagrams are numbered as in the original papers.

Professor Kim Jenkins, Chairman, CAPSA’04 Technical Committee and co-editor.
Human and economic resource development
The number of students in civil engineering has declined steadily in South Africa for the past decade. At senior schools Grade 12 figures have not only declined steadily in over the past 5 to 8 years (550 000 in 1998 to 450 000 in 2002), but the proportion of learners with mathematics and science at the higher grade has remained at very low levels.

This paper reports on investigations into these problems, which can be broadly grouped into issues linked to language of tuition, learner specific socio-economical situations and also to issues influenced by the attitude, level of qualification and competence of teachers. Recent outreach activities have confirmed that the most cost-effective way in making an impact on this problem seems to be by concentrating on the teachers. One recent initiative in this direction is the Teachers Mentorship Programme (TMP), which was developed by the University of Pretoria, using senior mentor teachers to give assistance to these teachers in their school during school time.

While indicators such as the language of tuition and the socio-economic situations of learners are important and warrant an in-depth discussion, the most valuable observations are those regarding the influence of mathematics and science teachers on the performance of learners. These teacher related observations are:

- Approximately one in four mathematics teachers were not formally qualified to teach mathematics;
- South African teachers spent excessive time re-teaching topics that should have been covered at lower levels;
- The more time that teachers spent preparing lessons after school, the better the learners scored in mathematics;
- Teachers’ pedagogical beliefs about mathematics were a

The most valuable observations are those relating to the influence of teachers on the performance of the learners.
highly significant predictor of achievement;
• The time spent by teachers in total at school was highly significant in predicting learners’ achievement;
• The poor performance by South African learners may be influenced by the low expectations of teachers.

Even though national government and various forums of role-players are addressing this issue of science and mathematics teaching at schools, the extent of the problem requires all stakeholders to contribute. The engineering profession clearly has too much at stake for it to reason that it is a problem that needs to be sorted out by the minister of education and departments of education.

Mentoring
Increasing awareness that greater effectiveness and efficiency in promoting mathematics and science can be achieved by concentrating on support for the teachers led to the development of the Teachers Mentorship Programme (TMP). The TMP involves mentoring of mathematics and science teachers at disadvantaged schools, in school time, by experienced mentor teachers. Short courses and workshops away from their own work have limited lasting effect, often ignoring the reality of the teachers’ working conditions and problems. Such intervention is designed to take place once a week for at least a three-year period to ensure sustainability.

The TMP concept was conceived late in 2002, and external funding from corporate sponsors was sought from early 2003. The intention from the start was to first run a pilot project in at least four disadvantaged schools in the Greater Pretoria (Tshwane) area, and the basic TMP concept was implemented at the Bokgoni Technical Secondary School in Atteridgeville in Tshwane in the second half of 2003.

Recommendations
The objectives of capacity building were defined as follows:

- Change educators’ mindset: assist them to see mathematics and science as not difficult, just different;
- Help educators to understand

The engineering profession has too much at stake to reason that this problem should be sorted out by the authorities

Although there has been no formal impact assessment to measure
changes in teacher attitudes or abilities for this pre-pilot, there is anecdotal evidence to confirm that the four month TMP at Bokgoni has gone some way to achieving the objectives as stated above.

The Bokgoni experience helped to identify areas that needed attention to make the pilot project a success. The approach described and the lessons learnt clearly give an indication of activities and steps needed to take make TMP a success. The TMP was envisaged as a franchise concept whereby lessons learnt could be packaged like a recipe to be implemented at other schools with a high degree of certainty that it will have a positive effect on learner mathematics and science education.

With research still ongoing, it is encouraging to note after one bridge building exercise, at least five black Grade 11 and 12 girls indicated their enthusiasm to study civil engineering. Such numbers against the background of the demographics of students in engineering is highly significant.
Extract from CAPSA’04 paper:

Sustainable provision of low-volume sealed roads

MI Pinard
InfraAfrica Consultants

PAK Greening
TRL Ltd

Good engineering practice, flexibility in approach and attention to various sustainability factors are fundamental to the development of appropriate and economic designs for low-volume sealed roads (LVR).

Much of road infrastructure investment is currently in relatively low-volume secondary and feeder roads as well as in providing primary access. These types of roads typically comprise more than 75% of the total highway system in most SADC countries and impact on more than 75% of the population that live in rural areas and depend on reliable access for their livelihoods.

Financial/economic issues

- Gravel is a sacrificial, “wasting” layer that is being rapidly depleted;
- The cost of periodic regravelling and routine maintenance of gravel roads can be very high;
- Unpaved roads generate a continuous cycle of deterioration, which requires substantial amounts of replacement gravel;
- A continuous cycle of gravel road deterioration resulting in loss of asset value and the creation of an increasing backlog;

Technology issues

- Imported motorised graders are the traditional equipment for grading and regravelling or regravelling operations. This not only requires considerable financial investment in a high-cost finance environment but also raises very serious problems of ownership and operation of relatively sophisticated equipment. The net result is often operational, support and technical problems, as well as a local financing burden;
- Very often, spot improvement gravelling may be the optimum solution for unpaved road maintenance. However, because selective gravelling in practice is difficult to achieve, this results in wastage of finite resources;
The technology of using graders for regravelling purposes is not sustainable in a number of countries where it would be preferable to employ alternative methods of maintaining unpaved roads involving local communities to a greater extent and utilising local resources and management more extensively.

**Social/environmental issues**

- There is a continuous demand for the use of a non-renewable, natural resource, which is being seriously depleted in many countries. As a result, haul distances and costs are continually increasing while land take is continuing at an alarming rate. Moreover, borrow-pit rehabilitation can be a costly exercise that is often neglected;
- Dust generation in dry weather causes adverse impacts in terms of being a health hazard for communities living adjacent to the road as well as causing pedestrian, animal and vehicle safety problems related to visibility and overtaking movements. In addition, dust emissions cause damage to crops and natural habitats;
- Gravel roads are often slippery and dangerous in wet weather, especially in steep terrain, causing access problems for communities. They are also susceptible to erosion causing siltation of drains and watercourses.

**New approaches**

Examples of appropriate planning techniques include the Integrated Rural Accessibility Planning developed by the International Labour Organisation (ILO, 1997), which integrates the mobility needs of rural households, the siting of essential social and economic services and the provision of appropriate transport infrastructure. In addition, the Sustainable Rural Livelihoods approach is useful in identifying the ways in which any particular investment intervention will impact, benefit or disbenefit the local community.

**In some circumstances bitumen sealing of gravel roads is justified at traffic levels below 100 vehicles per day.**

Most of the older models used in the road appraisal process rely on benefits arising from reduced motorised road user costs. However, many of the benefits arising from the provision of LVRs are of a social rather than economic nature and the beneficiaries also include non-motorised traffic and pedestrians — factors that are typically not captured in conventional cost-benefit analyses models.
This makes traditional methods of economic appraisal generally inappropriate for the appraisal of LVRs. However, developments in technology, research and knowledge have created a new platform for a more rational and up-to-date approach to the economics of rural road provision. Improved appraisal methods are increasingly able to capture the social benefits or disbenefits arising from the provision or absence of adequate road infrastructure which should be included in any economic evaluation of rural road projects.

One of the most important outputs of research of the last few years is that in some circumstances bitumen sealing of gravel roads is economically justified at traffic levels below 100 vehicles per day.

**Design:** Environmental effects tend to determine the performance of LVRs. Such effects are quite complex and almost no pavement design methods in regular use cater adequately for this. From recent research work carried out in the southern Africa region the following issues were found to be the most important for the design of LVRs:

- Selection criteria for roadbase materials;
- Sub-grade strength or design class;
- Crown height above drain level;
- Sealed surface design, including the sealing of road shoulders;
- Geo-climatic zone;
- Traffic.

**Materials:** Materials make up 70% of the cost of a typical rural road. However, until relatively recently many of the design criteria have reflected specifications which often preclude the use of many local materials because such materials do not meet these standards. However, research work carried out in the southern African region has shown that many natural gravels have performed well as pavement materials and considerable use can therefore be made of them once appropriate specifications have been developed from suitable research studies.

**Surfacing:** The challenge is to fit the materials available to an appropriate seal type rather than vice versa in the most cost-effective and sustainable manner. For example, where traditional quality, single sized aggregate with a relatively high crushing is not available for use in a Chip Seal, relatively low strength, graded aggregate can be successfully used in an Otta Seal.

**Geometric Design:** More appropriate standards are required that are more flexible and responsive to local conditions. This includes, for example, using a ‘design by eye’ approach where no formal alignment calculations are made and where engineering judgment and simple surveys can be used to define the alignment and identify where spot improvements are necessary. In this way maximum use can be made of the existing formation thereby reducing the amount of additional earthworks.
Road Safety: Traffic surveys, which form the basis of highway improvement schemes, rarely include counts of slow-moving traffic or pedestrians, leading to large numbers of accidents, typically 30 to 50 times higher per capita than in developed countries.

Construction

Compaction: In many design manuals, the levels of compaction or density to be achieved during construction are defined as a proportion of the maximum dry density that can be obtained in a standard laboratory test. However, with many road-building materials and the use of modern plant, higher densities can be achieved with relatively little additional compaction effort. Thus, ‘compaction to refusal’ with the heaviest plant available will often provide a substantial benefit in terms of increased pavement stiffness and potentially longer pavement life.

In many circumstances considerable long-term benefits can be achieved using these methods for a relatively small additional cost during construction.

Labour-based methods: In many countries in the region there is a trend to devolve the responsibility for rural roads to district councils. As a result, many types of council are now responsible for relatively small networks containing few surfaced roads. In these circumstances, the maintenance of these roads (and the construction of relatively short sections of new road) can be carried out more cost effectively using labour-based methods and appropriate types of plant and equipment that are suited to small-scale contractors (Sabita, 1995).

Unfortunately, a negative perception still persists in some countries that labour-based methods are slow, costly and sub-standard. This is not the case; labour-based technology is a structured method of providing or maintaining infrastructure to a specified standard whilst optimising the use of labour under fair working conditions. The use of labour is supplemented with appropriate equipment where necessary for reasons of quality or cost.

Overload control: Traditional, government-driven, approaches to overload control have generally been ineffective and suffer from a number of short-comings.

New, radically different and promising approaches are emerging in a number of countries which are worthy of consideration (SATCC, 1999). They include: operation which places the onus on overload control on transport.
operators and freight forwarders; decriminalisation of offences for overloading by imposing an economically-based overloading fee, and outsourcing of weighbridge operations to the private sector.

Sustainability

It has now become increasingly apparent in most developing countries that sustainability must become the basis of a more demanding policy for the provision of LVRs. Some of the new paradigms include:

**Approach:** New, approaches must be pursued which satisfy the seven key dimensions, namely - political, social, institutional, technical, economic, financial and environmental.

**Funding**

Alternative financing mechanisms, such as the establishment of dedicated road funds, coupled with institutional reforms designed to bring private sector skills into the road sector, have been underway in many countries during the past few years and considerable progress is being made. Within this changing environment it is apparent that the perceived risk of adopting more innovative solutions in the provision of low-volume roads is considerably less and the climate is more favourable for greater implementation; it is for these reasons that the production of the guideline at this time is opportune.

**Environmental sustainability:**

The environment has often been regarded as the price to be paid for development. This has often resulted in solutions that are environmentally unsustainable. In many countries, it is now abundantly clear that the time has come to provide more sustainable solutions to LVRs by sealing them, where viable, at an affordable cost. This will require a more creative approach than hitherto in the use of local materials.

**Research findings**

The benefits of successful research can be very large indeed. Such research has shown, for example, that a revised approach to economic appraisal, more appropriate geometric and pavement design standards, better use of locally available materials for the road pavement layers and surfacing, innovative construction methods and greater local and private sector participation in maintenance are just some of the areas where large savings in costs and increases in efficiency can be made.

**Technology transfer**

The “local” content in both the consulting and contracting component of road projects...
(especially sealed roads) in some SADC countries is often very small or at such a level that there are virtually no opportunities for local practitioners to influence either the design or the construction methodology. In these circumstances, technology transfer in either direction is stifled and the long-term goal of sustainability through technology transfer, about which so much is spoken, is unlikely to be achieved. It is conservatively estimated that savings of between US$1 - 1.8 billion (authors’ estimate) can be achieved in low-volume road construction in the SADC region over the next 20 years by the implementation of existing knowledge.

**Summary**

The message is for the engineer to be more flexible in his approach to low-volume roads and to move away from the rigidity of design manuals. It can now be shown to be justifiable to provide a sealed (or bituminous surfaced) road rather than a gravel road at traffic levels that are very much lower than hitherto thought.
This paper is a continuation of previous research into the state of tertiary education in pavement engineering in South Africa, with an extension to include not only asphalt technology but pavement education.

The authors stress that it is imperative that a finger remains on the pulse of pavement engineering education in South Africa, so that the quality and supply of engineers, technologists and technicians can be reconciled with the needs of industry.

A survey undertaken in 2001 and 2002 included a review of the following:

- Matriculation intake:
  The percentage of matriculants with a C Symbol or higher (a minimum requirement for university entrants) was 22% for science and 29% for mathematics in 2000 (of the 4% of learners who registered for these subjects), a percentage value that has remained constant for at least 4 years. It is apparent that the trend means that the feeder-group for science and technology is shrinking in South Africa.
  
  The overall decline takes place even before the competition for eligible learners into Civil Engineering begins. This competition takes the form of attractive “high tech” streams such as Information Technology and “high prospect streams” such as Business and Actuarial Sciences, as well as fellow engineering disciplines.

- Students specialising in pavement engineering;
- Lecturer-student contact;
- Time spent in laboratories;
- Lecturer qualifications;
- Physical resources;
- Current trends.

It is imperative that the quality and supply of technicians, engineers and technologists be reconciled with the needs of industry.
civil engineering, however, the actual student records of undergraduate pavement engineering reflect a stable intake. Although not part of the 2002 study, the most recent figures actually obtained show that the 2004 intake into pavement engineering in South Africa experienced an upsurge after a poor 2003 intake.

**Minimal variation**

The percentage of civil engineering students specialising in pavement engineering at post-graduate level is between 15 and 20%, showing that the actual variation in postgraduate student numbers is minimal. And the fact remains that if all of the undergraduate (UG) and post-graduate (PG) students were to remain in South Africa and practise engineering, the student numbers would probably be adequate. However, the HSRC emigration survey (Horak, 2002) shows that an alarming figure of some 24% of civil engineers plan to move abroad. Naturally, the throughputs of universities and technikons cannot keep pace with such demands.

**Lecturer-student contact**

The amount of time available to technikon lecturers to acquaint themselves with the latest developments in the field or to participate in research, is significantly lower than for university lecturers. This is due to the relatively higher student numbers at the technikons. The university responsibilities, by contrast, have more of a focus on lecturer research and publication, and supervision of student research.

Over ten years, one trend that appears to be emerging is the spread of student-lecturer contact hours at different institutions, which has gone from consistent to becoming more erratic. This would apply to both undergraduate and postgraduate levels.

The laboratory hours continue to dominate at the technikons, which is consistent with the philosophy of application of technology taught at these institutions. The use of lecture notes and reference material as a PG teaching medium is 40% higher at universities than technikons, according to the 2002 survey. At the same time, the number of contact hours for postgraduate classes in pavement engineering has increased somewhat at universities over the past 10 years, particularly those with specialist staff who promote this specialisation.

**Lecturer qualifications**

The numbers of suitably qualified lecturing and laboratory staff was found to be adequate. The total lecturing contingent in pavement engineering in South Africa has decreased by one in the universities and one at the technikons, in total. There has not been any dramatic change in the distribution of the lecturers.

In addition to the numbers of lecturing staff, the qualifications of the lecturers has remained acceptable according to the
Physical resources

Libraries: There are two issues that raise concerns. Firstly, the resources in the libraries of technikons are hopelessly inadequate, with more than half of the technikons having access to less than 25 volumes on pavement engineering in their libraries. The second issue is probably of greater concern, and that is the decreasing availability of literature. The number of volumes has definitely declined in the past ten years. It is unclear whether this is a result of inaccurate reporting, poorer library management or loss of resources, but it occurs contrary to an expansion of the extent of the subject resources i.e. from asphalt technology volumes to pavement engineering volumes.

Laboratories: The laboratory facilities that are available to pavement engineering education have not changed much in the past decade. Of the institutions providing pavement engineering education, 86% have facilities for granular, bitumen, asphalt and concrete testing. However, 36% of the institutions do not have access to non-standard testing facilities for research testing. For this reason, some 85% of the institutions indicated that they would like to expand their testing capacity, including tests such as fatigue testing, bitumen rheology and asphalt testing. There is also an interest in bolstering laboratory personnel to carry out the testing.

Figure 15: Lecturer numbers and qualifications for under-graduate pavement engineering
**Critical trends**

The results of the survey indicate that during the past ten years, tertiary education in pavement engineering in South Africa has continued to maintain a steady output of engineers and technicians, with sufficient lecturing staff to provide the education. However, certain critical trends have been noted in the 2002 survey that require special attention, namely:

- The number of tertiary institutions offering a generalised background to pavement engineering at undergraduate level has been rationalised;
- There has been a slight overall decline in the number of specialist pavement engineering staff at tertiary institutions. Within the industry there is a perception of migration of some pavement specialists from academia to positions within industry for financial and work-environment reasons;
- Reduction in library resources in pavement engineering that are available to students;
- Poor quality of specialist laboratory equipment is hindering research initiatives and the attraction of good post-graduate students into pavement engineering.

The “Professor workshops” were implemented by the Sabita Chair at the University of Stellenbosch in 1998 to create an efficient knowledge transfer environment with updates in “state of the art” pavement technology, without lecturers having to attend many international conferences. This enabled the latest technology to be processed into an educational context and integrated into course material. It is now a specific strategic objective of the Asphalt Academy to develop and reconvene a course or workshop of this nature.

**Conclusions**

The survey conducted in 2002 has highlighted some important developments in pavement engineering in South Africa over the past decade. When juxtaposed against the state of the industry ten years prior, certain conclusions may be drawn:

- Where the success of overseas universities centred around at least 60 final year students with an equivalent academic staff of at least 25, the South African scenario is generally considerably less. Most universities and technikons have between 30 and 50 students in final year undergraduate classes;
- Despite the intake of undergraduate civil engineering students in South Africa being satisfactory, the fact that pavement engineering is not offered at B.Tech level at technikons, but is included in urban engineering and transportation engineering qualifications, militates against the road sector attracting newly qualified graduates and in particular
top quality students. The Asphalt Academy is currently investigating the development of a block course in flexible pavement engineering for presentation to newly qualified civil engineers and technicians entering the roads industry to address this issue for those wishing to specialise in pavement engineering;

- Specialised laboratory equipment for pavement engineering research purposes is limited to a few institutions. In general, the equipment for specialised research at tertiary institutions is seen as poor and is also perceived as an added problem in attracting students to specialise in pavement engineering;

- Certain recommendations emanating from the 1992 survey were addressed in the following decade. In particular, the establishment of the Asphalt Academy and the SANRAL Chair at Stellenbosch University, have amongst others, assisted in achieving these goals. Several issues remain unaddressed, however, such as scholarships, resources (laboratory and library facilities) and lecturing staff. These still require attention.
A guiding principle in the provision of roads should be that the engineering standard of the road be determined by the type and volume of traffic that is expected to use that road.

Infrastructure that is "over-designed" is not only more expensive than necessary to build, but is also more costly to maintain. Engineers, many of whom have very little experience with or confidence in the design of low-trafficked infrastructure, have a tendency to promote standards that are too high for low volume transport infrastructure, and are reluctant to depart from the norms set for higher level roads.

The whole principle of Opportunity Value Assessment (OVA) is based on the concept that roads are only really valuable to the extent that they add value to other activities linked to roads. It thus follows that road (or transport policy) should be part of a holistic development strategy that determines the priorities for road investment, in the context of economic and social objectives and environmental, funding and institutional constraints.

Extract from CAPSA’04 paper:
Infrastructure financing and provision

S Muradzikwa
University of Cape Town

Infra-marginal nature of the impact on basic access to some activities — for example the marketing of agricultural produce or crafts becomes possible, or attendance at a school or clinic becomes possible, because of the project, and would be impossible without the project — means that these impacts appear less convincing than the changes stimulated by improvements to existing networks. And finally, the costs of detailed economic appraisal of individual small projects tend to make less sense than for undertakings in which the project appraisal costs are a smaller proportion of the total project costs.

Roads are only really valuable to the extent that they add value to other activities linked to roads

Infrastructure planning is also problematic in rural areas, particularly in the evaluation of benefits — which in rural areas tend to be social rather than economic. A primary problem is in the estimation of traffic volumes, which in the initial stages may be very low. Secondly, because of the high occurrence of non-motorised transport (carts, donkeys, pedestrians etc), there are problems with the evaluation of benefits. Thirdly, the...
Inter-departmental integrated development planning (of which roads are just one ‘cross-cutting’ component) need to maximise the economies to be gained from harnessing the linkages of various roads, plus other projects, into holistic development programmes. In a nutshell, road investment will only be effective if carried out in the context of an acceptable development strategy.

**Research Agenda**

The results of studies carried out on rural road infrastructure in the Ingwavuma district of KwaZulu-Natal underlines the value of appraisal of programmes rather than projects, and for concentrating on cost effectiveness of specific interventions.

**Challenge**

The real challenge lies in how to systematically model the relationship between rural infrastructure and the various dependent variables, such that the model is a fairly accurate predictor of capital-deepening and the wider socio-economic benefits of rural infrastructure provision. Such a prioritisation tool would typically be a locally adapted (calibrated) version of multi-criteria analysis.

Roads derive much of their value from their contributions to the values of other assets, such as schools, hospitals and business concentrations that they make possible, and then these assets in turn feed wealth-creating productivity. It must be noted that it is far easier to build such assets efficiently from already-existing bases than it is from conditions of acute capital deprivation. To put this into perspective, consider the following example:

Take the case of a provincial road agency debating whether to build/upgrade a road that services a small concentration of tourist facilities, or one that will enable rural farmers to drive, instead of walk their farm produce to a main highway.

---

*Rural areas, home to more than 50% of the population, account for just less than 12% of all road infrastructure*
The short term capital-asset potential of the farmers is so small on the margin that a standard cost benefit analysis (CBA) instrument will never indicate in favour of their roads unless your plug-on model is specifically designed to swamp the efficiencies the general model is supposed to measure. However, this implies that your ad hoc plug-on is doing all the work, and your model isn’t doing any!

By no means is it being suggested that one should take it for granted that rural farmers have the priority call on infrastructure funding just because they are poorer. Rather, what is being suggested is that the relatively high inequality in South Africa (measured by comparison of GINI coefficients across a basket of countries) significantly undermines attempts to make infrastructure prioritisation systematic and reliable.

With this in mind it is perhaps understandable that rural settlement areas, home to more than 50% of the South African population, account for just less than 12% of all road infrastructure. It also highlights the fact that the importance of the road network in delivering national, social and economic objectives is rarely matched by the performance of government in providing infrastructure of the appropriate quality and quantity.

A vital guiding principle of infrastructure improvements is that they should be sustainable, and any chosen project should only be carried out up to the limit of what can be maintained in the future.
Colas 1 ad here
Product Matrix copy
Safe and efficient delivery
This paper reports on the change in the properties of bitumen during bulk storage, transport, and storage on site. Using data from two South African and Australian laboratory studies into ageing of bitumen, a lack of correlation between bulk sample ageing and small sample ageing is found. It is found that changes in properties from refinery to pavement also come from micro-contamination from normal work practices.

A South African study into bitumen ageing and the in-tankage changes in the quality of bulk bitumen was done in 2002 (Coe, 2003). Four samples of about four litres each of South African 80/100 bitumen were drawn from large bulk storage at Calref refinery and distributed to participating laboratories. They were instructed to store the samples in their ovens at a temperature of 160°C or as close to this temperature as possible.

On a weekly basis, a sample was drawn from the four-litre tin and tested for penetration and softening point. Testing was continued until sample depletion, which took approximately six weeks.

<table>
<thead>
<tr>
<th>Days ageing</th>
<th>Laboratory refinery</th>
<th>Laboratory S</th>
<th>Laboratory M</th>
<th>Laboratory C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82</td>
<td>80</td>
<td>79</td>
<td>67</td>
</tr>
<tr>
<td>3</td>
<td>81</td>
<td>84</td>
<td>74</td>
<td>65</td>
</tr>
<tr>
<td>5</td>
<td>75</td>
<td>85</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>8</td>
<td>76</td>
<td>83</td>
<td>65</td>
<td>57</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>59</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>53</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>78</td>
<td>46</td>
<td>48</td>
<td>41</td>
</tr>
<tr>
<td>17</td>
<td>77</td>
<td>45</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>19</td>
<td>73</td>
<td>45</td>
<td>41</td>
<td>39</td>
</tr>
<tr>
<td>22</td>
<td>76</td>
<td>39</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>73</td>
<td>36</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>69</td>
<td>32</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Ageing of 80/100 small samples at 160°C (penetration @ 25°C, 0.1mm)
The results for penetration are shown in Table 1, and show significant variations with time as expected, but also quite a variation between laboratories. While all showed a trend to decreasing penetration upon ageing, the extent varied. The paper reports that the change in viscosity when ageing in bulk storage was found to be considerably different from that of small samples, even if properly sealed and the same bitumen source. Figure 2 shows the change in viscosity of bulk storage (mean of the three tanks in Table 3) and small samples (sealed tins of Table 2). It shows how any study on bitumen ageing can be confounded by the ageing effect of small samples, as previously suspected. It also indicates that the safe storage period for bitumen at elevated temperatures is longer than that codified. However periodic retesting of bitumen stored at elevated temperatures is warranted in view of the changes in bitumen properties over time. (Refer Table 9.)

The authors conclude that:

- Change in viscosity when ageing in bulk storage was found to occur, but to be

<table>
<thead>
<tr>
<th>Tank Size</th>
<th>Maximum storage period between bitumen re-testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 250 tonnes</td>
<td>45 days</td>
</tr>
<tr>
<td>100 tonnes</td>
<td>30 days</td>
</tr>
<tr>
<td>25 tonnes</td>
<td>15 days</td>
</tr>
</tbody>
</table>

*Table 9: Proposed bitumen re-testing requirements for bitumen stored at 120-165°C*
different from that found in ageing small samples in the laboratory;

* The ageing index (ratio of "viscosity aged" to "viscosity unaged") of bitumen stored at elevated temperatures was found to increase by 0.0034 per day in bulk storage, 0.0098 per day for bulk sea transport, 0.0137 per day for road transport, and 0.0168 per day in site storage;

* Micro-contamination occurs as a result of normal practices at the loading point of the refinery or bulk storage, but downstream of the loading arm. It occurs in the road vehicle due to current design and operating practices.

<table>
<thead>
<tr>
<th>Time</th>
<th>Control sample</th>
<th>Sealed tins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Visc60</td>
<td>Visc135</td>
</tr>
<tr>
<td>0</td>
<td>167</td>
<td>0.510</td>
</tr>
<tr>
<td>6 hours</td>
<td>176</td>
<td>0.370</td>
</tr>
<tr>
<td>24 hours</td>
<td>189</td>
<td>0.510</td>
</tr>
<tr>
<td>3 days</td>
<td>226</td>
<td>0.410</td>
</tr>
<tr>
<td>8 days</td>
<td>343</td>
<td>0.500</td>
</tr>
<tr>
<td>15 days</td>
<td>762</td>
<td>0.633</td>
</tr>
<tr>
<td>19 days</td>
<td>958</td>
<td>0.883</td>
</tr>
<tr>
<td>26 days</td>
<td>1302</td>
<td>1.250</td>
</tr>
</tbody>
</table>

Table 2: Ageing of Class 170 small samples at 163°C

<table>
<thead>
<tr>
<th>Property</th>
<th>Time in storage (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Tank 1: 2650 tonne capacity, 120°C</td>
<td></td>
</tr>
<tr>
<td>Viscosity @ 60°C Pa.s</td>
<td>150</td>
</tr>
<tr>
<td>Viscosity @ 135°C Pa.s</td>
<td>0.36</td>
</tr>
<tr>
<td>Penetration @ 25°C, 0.1mm</td>
<td>73</td>
</tr>
<tr>
<td>Tank 2: 1 400 tonne capacity, 165°C</td>
<td></td>
</tr>
<tr>
<td>Viscosity @ 60°C Pa.s</td>
<td>141</td>
</tr>
<tr>
<td>Viscosity @ 135°C Pa.s</td>
<td>0.34</td>
</tr>
<tr>
<td>Penetration @ 25°C, 0.1mm</td>
<td>75</td>
</tr>
<tr>
<td>Tank 3: 1 650 tonne capacity, 140°C</td>
<td></td>
</tr>
<tr>
<td>Viscosity @ 60°C Pa.s</td>
<td>145</td>
</tr>
<tr>
<td>Viscosity @ 135°C Pa.s</td>
<td>0.35</td>
</tr>
<tr>
<td>Penetration @ 25°C, 0.1mm</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 3: Change in a Class 170 bitumen properties in bulk storage
The policy in The Netherlands is to lay porous asphalt (PA) 0/16 as a surface wearing course on motorways especially because of the good noise reduction properties.

At this moment 65% of the motorway wearing courses consist of PA and the goal is to approach 100% in 2010. The mean service life of PA is 12 years on the right lane and 16 years on the fast lane [Verra, 2003]. The end of service life of PA is mainly caused by an excessive loss of stones from the surface called ravelling.

For environmental reasons the policy is that all asphalt must be reused at the end of service life. Therefore this project tried to combine these three policy goals: reuse PA RAP in new PA (noise reduction) with lower energy. To investigate if this is possible, a laboratory project was carried out to determine if PA RAP could be reused in PA with the half-warm process. Of course the durability and performance of half-warm foam (HWF) PA mixes must be close or equal to hot PA.

Results of experiments

Ageing of foamed bitumen

Tables are provided from which it can be seen that foamed bitumen recovered from HWF PA specimens has a lower penetration ($12 \times 10^{-1}$).
mm) and a higher softening point ring and ball (2.4°C) than recovered bitumen from hot PA, so despite the lower mixing temperature of 95°C the foam process has a higher impact on the bitumen ageing in comparison with the hot process.

Possible causes are the exposure of a larger bitumen surface to oxygen, due to the thin layer thickness of the bitumen bubbles. Table 7 may indicate that the long circulation time of 2 hours of the bitumen in the foam bitumen apparatus can also make a contribution to extra bitumen ageing. From Table 7 it can also be concluded that the additive acts like a rejuvenator.

From these limited experiences the ageing process during half-warm specimen preparation is not directly clear, so it is recommended that more detailed attention be paid to the background of ageing during the half-warm process. Gel Permeation Chromatography (GPC) is a useful tool for this purpose.

### Composition of mixes

Generally the scatter in mix composition was much more than expected, despite the 10 kg batches that were made to prepare specimens.

The scatter in grading of phase 2a mixes is greater than the phase 2b mixes. The bitumen content of the HWF mixes of phase 2b was consistently too high. Obviously it is very difficult to prepare HWF PA specimens with a low scatter in grading and close to the desired (foam) bitumen content. There could be several reasons for this:

- the PA RAP does not have the assumed homogeneity;
- during the mixing process a lot of coarse material is crushed;
- the dosage of foam bitumen in the Wirtgen apparatus WLB10 is possibly not accurate enough;
- in the batch mixer always some mortar remains, which maybe differs from time to time;

### Table 7: Properties of foamed and not foamed bitumen with and without additive

<table>
<thead>
<tr>
<th>Properties (after 2 hours at 170°C)</th>
<th>Penetration (10^{-mm})</th>
<th>T_{rab} (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eshafoam 100, not foamed, no additive</td>
<td>65</td>
<td>48.6</td>
</tr>
<tr>
<td>Eshafoam 100, foamed, no additive</td>
<td>65</td>
<td>48.6</td>
</tr>
<tr>
<td>Eshafoam 100, not foamed, with additive</td>
<td>80</td>
<td>45.8</td>
</tr>
<tr>
<td>Eshafoam 100, foamed, with additive</td>
<td>80</td>
<td>46</td>
</tr>
<tr>
<td>Eshafoam 100, original</td>
<td>81</td>
<td>45.8</td>
</tr>
</tbody>
</table>

1: Initial research on mechanical properties
2: Advanced research on durability
the optimal paddle adjustment changes in time, because the mixer paddles wear.

It is possible the mixer used is not suitable for the production of PA mixes with a sufficient accuracy in mix composition. Sand skeleton mixes like the base coarse layer Stone Asphalt Concrete (StAC) are less sensitive for this inaccuracy in comparison with PA. This was shown by Jenkins, (2000).

**Differences between lab and field**

### Is water needed?

Because the relation between the mechanical properties and the resistance to raveling is unknown, it is only possible to compare the mechanical results with the results of hot PA, hoping that these mechanical properties have a good relation with the raveling behaviour in practice. It is clear that most results of HWF PA mixes are worse in comparison with hot PA. Maybe the presence of water in HWF PA mixes is one of the causes of the disappointing results.

In the laboratory it is not possible to prepare HWF PA specimens without water, because water is needed to coat the aggregate and the PA RAP totally with foamed bitumen (Workshop Schuimbitumen, 2003).

It is remarkable that in another project it was determined that for the production of HWF PA containing new materials no water was needed in the asphalt mix plant. Visual inspection revealed that all aggregates were totally coated with foamed bitumen. Obviously there is a great difference between laboratory mixing and plant mixing, but there must nevertheless be a way to prepare HWF PA specimen in the laboratory without using water. To investigate if HWF PA mixes are as durable as hot PA it is recommended that the investigation begin with mechanical properties of plant-mixed HWF PA mixes without water. If this is confirmed one can try to simulate this process in the laboratory.

### Black rock principle?

Does the PA RAP with highly aged bitumen act like rock or does the aged bitumen in the PA RAP mix up with freshly added bitumen? Because PA is gap graded (gap between 2 and 6 mm), it is a stone skeleton mix. This stone skeleton is fixed with a binder, in this case the mortar (mix of sand, filler and bitumen). To determine if the mortar of PA RAP has some binder properties, we attempted to determine the softening point $T_{R&B}$ of the recovered mortar. It was amazing that at temperatures below 150°C it was not possible to prepare specimens for the softening point $T_{R&B}$ test (no bonding) and the mortar colour was not black! At 160°C the mortar turns black and at 170°C some bonding effect was noticed. So the bitumen in the PA RAP was aged in such a way that no flexible mortar could be created at these temperatures. Mixing between new and aged bitumen would,
especially at 95°C, be very small. Some migration could be possible in time.

In Phase 1, HWF PA mixes with foamed bitumen content between 2.5 and 4.0% were tested in the ITT. Mixes with 3.5% foam bitumen gave the best results. Hot PA mixes normally contains 4.5% bitumen, so this is an indication that maybe some of the aged bitumen of PA RAP is mixed with the foamed bitumen.

On the other hand: in a CROW project Re-use of Asphalt (CROW Publication 179, 2002) it was determined that mixes with an increasing RAP content have a better resistance to permanent deformation than mixes containing only new materials. A possible explanation is that mixes with RAP need less bitumen, because no light bitumen fractions are absorbed by RAP because RAP is already “pre-coated” with bitumen.

So the conclusion about PA RAP is that it neither acts as a black rock nor as a particle coated with bitumen because there is no total mixing between aged bitumen and new foamed bitumen. The feeling at the moment is that it approaches closer to the black rock principle. This is illustrated in Figure 4.

In The Netherlands it is common to re-use up to 50% RAP in base course asphalt mixes. To obtain the required penetration of the mix of aged bitumen from the RAP and the added fresh bitumen, the so-called log pen rule is used. With the data of the penetration of aged bitumen from RAP and fresh bitumen, and the mass ratio of aged bitumen from RAP and fresh bitumen, the penetration of the bitumen in the mix with RAP may be calculated as follows:

\[ a \log(\text{Pen}1) + b \log(\text{Pen}2) = (a+b) \log(\text{Pen mix}) \]

Where:

- \( a \) and \( b \) are expressed in mass ratio of the aged bitumen of RAP and the fresh bitumen respectively (\( a+b=1 \))
- \( \text{Pen}1 \) = penetration of aged bitumen from RAP
- \( \text{Pen}2 \) = penetration of fresh bitumen
- \( \text{Pen mix} \) = calculated penetration of the bitumen of the mix with RAP

![Figure 4: Interaction between RAP bitumen and fresh bitumen](image-url)
The log pen rule only applies to hot mixes, assuming that the aged bitumen and fresh bitumen become a one-phase system. If RAP is reused cold, one has to make do with the black rock principle. There will be no mixing of the aged and fresh bitumen at all, which will result in a two-phase system.

**Conclusions**

For lab mixing with the used laboratory mixer it is necessary to add water to coat the aggregate with foamed bitumen. Because water addition is not needed in the asphalt plant, this means that there is a difference between lab and field production. Overall the test results show that the half warm foam process could be an alternative in the near future for hot mixes, but to confirm this and because of the varying test results more research work is needed.

Because of some disappointing results of the functional and durability tests, no HWF PA mix could be recommended to apply in a test site under traffic at this moment.
In this paper the impact of risk on whole-of-life costing is addressed through a design level procedure proposed to assist in maximising the reliability of the final selection. It is the issue of risk that provides a revised view, and procedures are proposed for comparison of alternatives.

The revised whole-of-life costing methodology presented includes an overview of the issues relating to comparison of alternatives.

One of the difficulties in using current whole-of-life analysis procedures is that there is frequently little consideration of likely construction specifications, construction delivery mechanisms and skill levels or likely maintenance regimes, all of which have a significant influence on pavement performance. For effective analysis both the designer and the constructor need to be involved, and through the application of risk assessment procedures, to arrive at a closer consideration of these issues.

Improved cooperation on key issues is vital to the achievement of optimum, long-term pavement performance.

Covering ownership and funding issues, as well as a methodology for carrying out comparisons. The provision of a risk management procedure enables specific risks and their consequences to be identified and quantified. This improves the reliability of the selected alternative. The concepts presented in this paper can be used by practitioners to provide assistance in comparing alternative pavement designs with the incorporation of ownership issues.

In addition, the risks associated with each whole-of-life pavement scenario need careful consideration. Risks can be allowed for by the application of a “design reliability factor”, which is a multiplier for the calculated design traffic. Due to a lack of validation of the performance of existing pavements against design, this broad based approach has attempted to take into account a number of threats leading to poor performance such as:
• Uncertainty in estimating design traffic loading;
• Variations in in-situ materials properties as constructed and over the life of the pavement;
• Variations in pavement layer thicknesses;
• Accuracy of the design method for various pavement types.

A more rational assessment of risk, project reliability and the likely whole-of-life cost estimation can be made where these uncertainties are quantifiable and, to a certain extent, controllable for a particular project. The methodology proposed is illustrated in Figure 2.

The paper deals with all these phases and subsets in some detail. In Phase 4 Cost Comparisons it states that once the present worth of cost (PWOC) of each risk scenario of a pavement design alternative has been determined, these are combined to get a

\[
\text{PWOC}_A = \sum [P_i \times \text{PWOC}_{A_i}] + [P_{neutral} \times \text{PWOC}_{neutral}]
\]

Where

- \(\text{PWOC}_{A_i}\) = Present Worth of Cost for pavement design alternative A with risk profile I
- \(P_i\) = Probability of risk scenario I
- \(\text{PWOC}_A\) = The weighted Present Worth of Cost for that pavement alternative.
Utilise a suitable selection and design guide for flexible pavements (National guideline or specification)

Chance that the pavement will outlast the design traffic

For example:
- Under-estimation of design traffic;
- Non-achievement of materials design parameters;
- Under-thickness of pavement layers;
- Etc....

- Qualitative risk assessment to determine likelihood and consequences;
- Mitigate risks where practical;
- Quantify consequences of uncontrolled risk using suitable design analysis procedure;
- Quantify likelihood of uncontrolled risk.

Whole-of-life cost analysis using PWOC on a weighted probability basis over a common analysis period.

Apply sensitivity analysis on whole-of-life costs using appropriate variable in PWOC calculation.

Perform value judgement assessment based on identified ownership issues and rank alternatives.

Figure 2: Methodology for comparison of pavements
weighted PWOC for that pavement type.

The calculation is detailed below. Alternative pavement PWOCs are then compared to ascertain the lowest PWOC. The PWOC comparison of alternatives should include testing for sensitivity against the input parameters as reflected in the comparison in Table 9 of Full Depth Asphalt and Composite Pavements. (AAPA 2003).

These results provide input to a decision model, such as the Assessment Matrix in Table 10 below, which incorporates less quantifiable operational, environmental and social aspects of the ownership.

### Selection of candidate pavements

Candidate pavement types should be chosen by the designer, and detailed guidance in this regard is available from national pavement design guides. The desired reliability is also chosen by the designer, and should be considered on a project by project basis after considering ownership issues as suggested in Table 1.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>4%</th>
<th>7%</th>
<th>10%</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$65.82</td>
<td>$69.30</td>
<td>$70.56</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>$68.13</td>
<td>$71.48</td>
<td>$72.21</td>
<td>0.3</td>
</tr>
<tr>
<td>3</td>
<td>$66.47</td>
<td>$69.73</td>
<td>$70.84</td>
<td>0.2</td>
</tr>
<tr>
<td>5</td>
<td>$69.28</td>
<td>$72.57</td>
<td>$73.34</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>PWOC</strong></td>
<td>$66.99</td>
<td>$70.37</td>
<td>$71.39</td>
<td>FDA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario</th>
<th>4%</th>
<th>7%</th>
<th>10%</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$77.68</td>
<td>$80.93</td>
<td>$82.02</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>$82.90</td>
<td>$84.97</td>
<td>$84.23</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>$80.14</td>
<td>$82.82</td>
<td>$83.42</td>
<td>0.2</td>
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<tr>
<td>6</td>
<td>$84.36</td>
<td>$86.69</td>
<td>$86.79</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>PWOC</strong></td>
<td>$80.41</td>
<td>$83.10</td>
<td>$83.44</td>
<td>Composite</td>
</tr>
</tbody>
</table>

**Table 9 - Example of PWOC values for Full Depth Asphalt & for Composite Pavement**

The above table is based on an example with the following design inputs:
- Subgrade CBR
- WMAPT 25°C
- Design life 25 years
- Traffic growth 4%

reflected in the comparison in Table 9 of Full Depth Asphalt and Composite Pavements. (AAPA 2003).
Probable PWOC for each alternate

<table>
<thead>
<tr>
<th>Design Issues</th>
<th>Analysis of alternate through design level risk assessment and inclusion of probability to evaluation of included scenarios. A suitable variable is chosen in the PWOC analysis to identify the range of outcomes.</th>
<th>Sensitivity analysis variable</th>
<th>FDA</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Discount rate 4%</td>
<td>$66.99</td>
<td>$80.41</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discount rate 7%</td>
<td>$70.37</td>
<td>$83.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discount rate 10%</td>
<td>$71.39</td>
<td>$83.44</td>
<td></td>
</tr>
</tbody>
</table>

### Table 10. Assessment matrix for design and ownership issues (Examples of FDA and Composite pavements)

<table>
<thead>
<tr>
<th>Categories</th>
<th>Weighting of project</th>
<th>Value Judgement</th>
<th>Weighted value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FDA</td>
<td>Composite</td>
<td>FDA</td>
</tr>
<tr>
<td>Ownership Issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Investment &amp; economic strategy</td>
<td>0.7</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>2. Planning and development strategy</td>
<td>0.9</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>3. Owner risk profile</td>
<td>1.0</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>4. Construction &amp; maintenance</td>
<td>0.8</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>5. Political, social &amp; environmental</td>
<td>1.0</td>
<td>0.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Weighted score for each alternative | 3.64 | 3.69 |

Some of the risks identified, which cannot be reduced at the design phase, can then be targeted for closer attention during construction and ongoing maintenance.

Notes:
1. Suitable variable chosen to identify the range of PWOC possible from the selected alternatives;
2. Weighting for the project based on a scale of 0 to 1 where 0 is Insignificant to the category and 1 is Extremely Important;
3. Value Judgement of the Alternate to the category or detailed ownership Issue based on a scale of 0 to 1 which reflects the impact of that alternative. 1 would indicate a very positive impact and a 0 value indicates a very negative impact. Further subdivision of each category is used to highlight divergent issues or those significant to the range of alternatives proposed;
4. Overall ranking of the Alternate should identify if there is only one “best choice” i.e. lowest PWOC and highest Weighted Value. In this case the PWOC of FDA is lower but Composite Weighted Value is marginally higher. Best approach would be to test the PWOC on actual tender values.
The authors conclude that the incorporation of a risk assessment procedure in designer level whole-of-life costing analysis offers a robust input into the selection of pavement alternatives. It provides the opportunity for designers to identify, assess, and in some cases reduce, the site-specific risks associated with any particular job.

Some of the risks identified, which cannot be reduced at the design phase, can then be targeted for closer attention during construction and ongoing maintenance.
It is often confused. Bitumen is manufactured from crude oil by distillation under vacuum, whereas coal tar is derived from coal by destructive distillation at high temperatures. Bitumen and coal tar are however extremely different, in terms of physical characteristics, chemical composition and the nature and degree of hazard presented to users. In particular coal tars contain significantly higher levels of polycyclic aromatics (PCAs) and many coal tars are considered to be carcinogenic, whereas bitumens are not.

Increased interest in the potential of bitumen emissions to affect health was primarily driven by the fact that both bitumen and its emissions at elevated temperature, can contain small amounts of polycyclic aromatic compounds, some of which are carcinogenic. Whilst it is believed that the carcinogenic risk from exposure is extremely low, there remains some uncertainty. Further health studies are underway to resolve remaining issues and improved working practices adopted to reduce the potential for exposure during work with hot bitumen.

Ongoing Health Effects Research

1. Toxicological Studies

To evaluate the carcinogenic hazard potential of emissions from hot bitumen, the German Bitumen Producers Association (ARBIT) has commissioned a long-term inhalation study in rats. The material being tested is a condensate, collected from the headspace of a bitumen storage tank, maintained at a temperature of 175°C. The liquid condensate and the laboratory-generated atmosphere have been validated against exposure samples collected from the breathing zone of workers during typical 'field' paving operations. The composition, and physico-chemical properties of the condensate/exposure atmosphere, match closely 'field' exposure measurements.

The study involves the exposure of rats to a laboratory-generated atmosphere of bitumen aerosol and vapour at levels up to 100mg/m³ (THC). The maximum
The exposure concentration chosen is 10 times the current OEL in Germany, and was based on the maximum level likely to be tolerated by the rats over a 2-year exposure period. The study is scheduled for completion during 2005.

To provide additional information to assist in evaluating the results of the ARBIT commissioned study, Eurobitume is sponsoring a series of additional investigations. This work is running in parallel to the ARBIT study and is being undertaken in the same laboratory. These investigations are utilising ‘state-of-the-art’ scientific techniques, and will provide vital scientific information on the mechanisms of any toxicological response seen in the main study.

### 2. Human Studies

To address the question whether occupational exposure to bitumen is associated with any increased risk of developing cancer, Eurobitume, EAPA and CONCAWE asked IARC (the International Agency for Research on Cancer — a division of the World Health Organisation) to carry out an epidemiological study of workers in the asphalt industry. Following a technical feasibility study, IARC has completed a major ‘cohort’ mortality study of European asphalt workers. (Boffetta et al 2003)

The study investigated the causes of mortality in over 80,000 workers and compared the incidence of disease, with particular emphasis on cancer, in ~30,000 workers exposed to bitumen emissions relative to both the general population and construction industry workers who had not been exposed to bitumen emissions.

The cohort of workers was drawn from seven European and one non-European countries, and exposure assessments were documented for bitumen fume, coal tar, Poly Aromatic Hydrocarbons (PAHs), organic vapour, diesel exhaust, asbestos and silica.

Results showed a not unexpected clear ‘healthy worker effect’ with the overall incidence of mortality from all causes being lower than the general population. There was however a slight, but statistically significant, increase in the overall incidence of lung cancer in asphalt workers but the incidence was not consistent across countries.

The study was unable to draw conclusions however on the presence or absence of a cause-effect link between the incidence of lung cancer and exposure to emissions from bitumen. The main reason for this was the lack of adequate data on worker exposure to other factors that may have contributed to the slightly increased incidence of lung cancer.

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**Any risk to health from exposure to emissions from hot bitumen is extremely small**
such as smoking habits and exposure to coal tar. The data do indicate however that any risk to health from exposure to emissions from hot bitumen is very small.

In view of the inconclusive results from the cohort study, IARC recommended undertaking a further investigation into the causes of the slight increase in incidence of lung cancer.

The proposed ‘nested case control’ study will investigate in more detail each case of lung cancer and endeavour to obtain more detailed information on potential occupational and non-occupational causative factors.

Particular emphasis will be placed on smoking habits and coal tar exposure. This study is to be funded by an industry consortium and is currently in the final planning stage. It is anticipated that the study will start during 2004.

**Conclusion**

Bitumen does not present any health or environmental hazards at ambient temperature and results of existing studies on bitumen emissions arising from heating have so far shown that the risk of health effects in exposed workers is extremely low. Bitumen remains a focus for health effects research however, primarily due to the presence of very small amounts of polycyclic aromatic hydrocarbons in the product and uncertainty about the associated health risks from exposure to emissions from hot bitumen.

The bitumen industry is working closely with regulatory and scientific bodies to resolve remaining questions. Further studies are in progress, employing state of the art techniques, which should resolve finally the question whether exposure to bitumen emissions presents a cancer risk. In addition to the health effects research discussed, industry has been active in promoting strategies to reduce worker exposure to emissions from hot bitumen work.
This paper analyses the prerequisites associated with the adoption of performance-based specifications, the need for continuous research and standardisation, innovation policy, adaptation of procurement laws and above all a new state of mind.

A close cooperation between the public and private sectors can boost the innovation process. In France, developing and fostering innovation in conjunction with contracting companies has always been one of the main-springs of the French Road Directorate’s action. Two systems are described below: the Road Innovation Charter and the Technical Certificates.

1. The Road Innovation Charter

The Road Innovation Charter is a structured procedure set up by the Directorate of Roads to encourage the process of maturing and disseminating major innovations in the field of road engineering.

Coping with a sharp increase in the heavy trucks traffic, improving travel in urban areas, providing conditions of safety and comfort to meet user requirement, preserving the living environment of frontage residents and saving materials resources are examples of the challenges that have to be met.

This means prioritising specific technical choices, adapting projects, discovering and testing innovations, while also making continual progress in the quality of engineering structures.

The development of a new technique requires not only prior studies and phased site testing but, above all, a rigorous work and monitoring programme. This process may prove to be lengthy and costly. The innovation itself may entail risks for the Employer of the Contractor. It is therefore essential to set up a well-structured procedure aimed at achieving maximum efficiency.

European experiences with performance guarantee and/or product guarantee systems
The Directorate of Roads determines the themes it considers most important for the national network, on which it requires an innovation effort to be made. Any contractor can propose a project for one of these themes. To this end, it draws up a package that describes the project, details method of use, financial issues and gives the results of prior studies and tests, together with the references.

The Charter comprises four stages:
- Prospective sample sections: short sections to give an idea of the innovation in concrete terms, as far upstream as possible;
- Experimental sample sections: sections of limited length enabling the innovation to be validated after specific laboratory studies;
- Technical demonstration jobsites: sections of significant length enabling the full-scale innovation and its implementation to be technically validated, after favourable conclusions in the preceding stages;
- Economic demonstration jobsites: sections of significant length awarded once the previous stage has achieved successful results, after a competition enabling the innovation to be economically validated.

The system has proven its efficiency: by the end of 2000, 75 protocols had been signed since the beginning of the process, and 175 sites had been constructed and evaluated. Only ten of them failed.

The system has been extended to the concessionaire motorway network. For 2004, the themes that have been selected are:
- Cleanliness of the tack coats;
- Processing specific spots as far as texture and skid resistance are concerned;
- Recycling drainage asphalt at the end of their service life;
- Warm asphalt mixes for maintenance.

2. The Technical Certificates

Beside the Road Innovation Charter, a system has been established to support the development and commercialisation of new products. As a matter of fact, the simplest way to characterise a system (material, process) is to compare it to the requirements of the standards.

Standards become valid from the day of their issuance. On the other hand, new products or processes developed by contractors (or in partnership with authorities) after issuance of these standards may...
be of high technical interest without necessarily complying with the requirements of the official specifications or standards.

For these new products and processes, the contractor usually issues technical leaflets. Such a document has however a commercial connotation. Jointly with the contractors, the national road authorities have developed a system, which is an intermediate between a standard and a technical leaflet. This is the Technical Certificate “Avis technique”. This document is issued by a committee appointed by the CFTR (Comité Français pour les Techniques Routières), made up of representatives of the national road authorities and contractors, selected for their technical knowledge related to the material to be assessed. This means that the composition of the committee depends on the technique to be assessed.

This document contains three main chapters:

- Description of the material by the contractor;
- Main characteristics;
- Technical Certificate by the committee.

This type of document may be of high support for the development of innovative techniques with other employers, mainly local governments.

To date, more than 100 technical certificates have been issued in the fields of roads and bridges techniques.

3. Procurement law needs to be adapted

If new products are to be developed to meet performance-based specifications, road owners need to be able to experiment with them. This is only possible if a certain degree of freedom is introduced in procurement laws for this purpose. In this respect, recent European procurement directives have considerably harmed this development, by preventing government authorities to contract with a sole contractor by mutual agreement, even on a limited basis, for such experimental purposes.

Another issue that needs to be confronted is the adaptation of performance bonds in those countries that request them as a standard practice to guarantee the performance of the work (even if only few European countries are in that case).

Surety companies are definitely not used to evaluating the risks associated with long term contracts, where, for example, road rehabilitation work is performed for the first years of the contract and maintenance is
carried out according to performance-based specifications for the remaining duration of the contract. Performance bond requirements need to be adapted for this particular type of contract as to the duration of the guarantee and the amount of this guarantee in the maintenance period. Consultations with the surety industry might help in this regard.

**Conclusion**

The authors conclude that advances are expected all over the world, in the near future, in the field of performance-based contracts as a consequence of the development of innovative techniques, the willingness of road authorities to adopt both a problem-solving and a more service-oriented approach to the procurement of road works. For such contracts to be successful, however, it will be necessary to:

- Further invest in research and standardisation;
- Develop procurement procedures for experimental jobsites; and
- Adapt state of minds, procurement procedures and guarantee systems.

Exchange of information and best practices in all these fields will therefore become crucial for all stakeholders.
This paper reports on recent work by the Sabita Infrastructure Development Assessment Project (SIDAP) in prioritising infrastructure development plans in the uMkhanyakude District in north-eastern KwaZulu-Natal.

The primary sources of cash income for the majority of adults are the state pensions provided to elderly citizens. These are supplemented in many cases by sales of handicrafts to small numbers of nature tourists who travel in the areas.

The principal source of food for most people is subsistence agriculture, which also generates surpluses for roadside sale. Principal infrastructure assets within the area include the Jozini Dam and the N2 Highway a couple of fairly well maintained provincial roads, and a large number (perhaps 70,000 km) of access roads that are often seriously neglected or under-maintained.

Also lying within the district are the Greater St. Lucia Wetlands Park, Umfolozi-Hluhluwe Park, and the Tembe Elephant Park, significant attractions for tourists. At present, lack of road capacity is a principal impediment to hopes of promoting subsistence agricultural activities to larger-scale commercial status, since this would require more products to be transportable cheaply and efficiently enough to be competitively priced.

Lack of service infrastructure prevents most residents from being able to capitalise on the tourist flow

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The IDP process

uMkhanyakude’s IDPs as submitted by the national deadline in late 2002 did not prioritise project possibilities, or justify them, or even estimate their costs. The IDPs are effectively just ‘wish lists’ of possible projects, both large and ambitious.
It was in this context that SIDAP met with district planning officials in 2002 to discuss ways in which we could assist them in designing improved IDPs. Priorities were determined during 2003, and business plans for them were completed by February 2004. The summary of these is the main purpose of the present paper.

The uMkhanyakude IDP states that “the provision of access roads to communities, tourism areas, development nodes and other areas of importance is the precursor to any activity or programme planned for these areas. Such access provides the key to unlocking the vast potential that exists within the region.”

**Clustering**

The principal basis for project prioritisation as undertaken by SIDAP is achievement of clustering for maximum investment efficiency. SIDAP developed the project priorities below by means of the following reasoning.

- Firstly, they identified potential assets;
- Secondly, we identified clusters of new infrastructure that, if built together, could allow full exploitation of the assets identified in step one;
- Thirdly, they estimated costs; and
- Fourthly, they estimated the expected increases in the value of each asset that would be achieved by multiplier effects of interaction with the other assets in the cluster.

**Conclusion**

The authors conclude that as their long-term aim is the construction of an OVA tool it must be precisely the point of the project to develop the OVA tool to decide how money might best be allocated, through a continuous process of model-specification, infrastructure construction and recalibration, a project prioritisation tool suitable to South Africa will be developed as the output of the project. But first they need projects to test; and the ones listed might as well be sensible ones.

Ultimately, the OVA product in development will enable these surveys to be complemented with rigorous and quantitative assessment. However, it will be part of SIDAP’s mandate to promote and seek funds for these developments now, since their implementation and subsequent testing will be a crucial part of the process by which OVA is built to local conditions.
This paper demonstrates that despite a small cost premium, environmentally friendly non-tar based precoating materials can be successfully used to yield a satisfactory end result.

During the early 1980s, when bitumen rubber was introduced, followed by increased use of hot-applied homogenous modified binders in the 1990s, road engineers realised that the adhesion between the highly viscous binder and the surfacing stone became a critical parameter to ensure the success of the seals. The presence of dust on the stone also adversely affected the adhesion. A tar-based precoating fluid showed the following benefits:

- Any residual dust remaining on the aggregate is bound by the precoating fluid, ensuring excellent adhesion of the aggregate to the binder, minimising the risk of loose aggregate that can damage vehicles;
- The surface will have a uniform black appearance and forms a sharp contrast with road markings, making night driving considerably safer;
- No diluted emulsion cover spray would be required.

The tar-based fluids unfortunately have disadvantages associated with its use:

- Irritating to the skin and eyes and in some cases respiratory irritation may occur;
- When surfacing is performed in residential areas, complaints may be received from the residents due too the pungent odour;
- Softening of rubber conveyor belts on chip spreaders and premature deterioration of front-end loader and roller tyres.

The immeasurable benefits to the environment warrant the use of bituminous precoating materials

- Studies have also shown that prolonged contact with coal tar pitch can cause a high incidence of skin cancer (Sabita, 1995). Consequently, Colas recognised the need for a more user-friendly precoating fluid approximately six years ago, and after extensive trials, a bitumen based precoating fluid was developed. A number of...
major surfacing projects have been successfully completed with this material.

The product is environmentally friendly, non-irritating and after a short curing period, it is completely odourless. Excellent adhesion is obtained with all bituminous binders. Additives allow the precoating material to be used with wet or damp aggregates and the chemical additives render it suitable for coating “difficult” aggregates such as quartzites and granites.

Typical application rates appear in Table 2.

The author concludes that with the worldwide trend afoot to move away from tar-based binders, it has been shown that tar-based precoating fluids can be successfully replaced with an environmentally and user-friendly bituminous product. Despite a marginally higher cost premium, the immeasurable benefits to the environment warrant the use of bituminous precoating materials.

<table>
<thead>
<tr>
<th>Nominal stone size (mm)</th>
<th>6.7</th>
<th>9.5</th>
<th>13.2</th>
<th>19.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application rate (l/m3)</td>
<td>14 - 18</td>
<td>13 - 17</td>
<td>12 - 16</td>
<td>11 - 15</td>
</tr>
</tbody>
</table>

Table 2: Typical application rates for various stone sizes
This bulletin paper reports on practical experience in overcoming compaction difficulties of crushed stone base material by the addition of a very low percentage (0.4%) of bitumen emulsion in the compaction water.

Certain G1 crushed materials are difficult to compact to the required density, even though their gradings are correct. In one case it was found that the fines fraction contained a gritty particle which prevented the proper densification of the material. This problem was confirmed by the compaction of the material on Transportek’s vibratory compaction table. However, when 0.4% bitumen emulsion was added to the compaction water, the problem was overcome in the laboratory compaction of the sample on the vibratory compaction table.

Armed with this information the next step was to try the solution in practice, with stunning results. No slushing of the base was required and after drying back the unprimed base was trafficked in the rainy season by a substantial amount of (emergency) traffic without any signs of damage.

K-mould

Laboratory tests with the K-mould on material from another showed that the 90th percentile E-value increased from 435 MPa to 548 MPa and the rutting resistance by a phenomenal 500% from 3.8 million to 18.3 million 80 kN axle loads to cause a 10 mm rut in a crushed stone layer of 150 mm. The authors claim that the

Extract from CAPSA’04 paper:

Overcoming compaction difficulties of crushed stone base material by the addition of a very low percentage of bitumen emulsion

AO Bergh
CSIR
Transportek

PB Botha
CSIR
Transportek

CJ Semmelink
CSIR
Transportek

H Botha
CSIR
Transportek

Photograph 5: Brushed area after trafficking and "rain damage". Interlocking still secure.
dramatic improvement in the material performance is well worth the cost of the emulsion.

The authors conclude that the use of anionic emulsion (60%) as a compaction aid has the following advantages:

- The layer can be constructed in a single day;
- The layer requires less slushing and rolling and much less water;
- Reduces damage to layer if trafficked;
- Reduces damage to the layer due to rain and improves the durability of the base layer in wet conditions;
- The prime coat can be replaced with a 1 to 6 part anionic emulsion SS60 to water, applied with a water cart thus saving the costs of a distributor to do the priming;
- The emulsion prime coat dries off faster than normal prime would do in a high rainfall area with relative high humidity. This application can be repeated if required quite economically;
- The higher compaction levels that can be obtained using a compaction aid will result in increased densities and extended life of the base which is also less influenced by the penetration of moisture.
South African rural roads generally carry much more traffic than the rural road network in the rest of sub-Saharan Africa with many gravel roads carrying up to 1000 vpd. At the lower end, there is a vast network of district and community access roads carrying less than 100 vpd, which is largely unimproved and maintained only as bladed tracks. In addition, there are probably hundreds of thousands of kilometres of unimproved village roads and streets. The potential for large-scale application of labour-based road works is therefore enormous.

In the Limpopo Province it was realised early on that finding good quality wearing course gravel in itself constituted a major problem in many areas of the province, thus bringing the costs for a fully rehabilitated and gravelled 5.5m wide road to about R230 000 in some instances. Aside from depleting an increasingly scarce resource, construction and maintenance of conventional gravel roads would be very costly.

An assessment of different options for the provision and maintenance of a good gravel wearing course, in financial and economic terms as well as suitability for labour-based operations was carried out. This indicated that better use and/or improvement of in situ material by emulsion or chemical stabilisation in combination with provision of various low cost bituminous seals results in lower predicted life-cycle costs than the gravelling option for the roads in question.

20-year analysis period

The various options were analysed in terms of Present Worth of Costs (PWoC) and Net Present Values (NPV). The analyses are presented as both financial costs (i.e. the cost to the road authority) and economic costs (the cost to the road authority and the road user) and shadow costs were used for all input costs. All analyses were carried out over a 20-year analysis period using a discount rate of 10 per cent.

Six basic alternatives were analysed:

- **TRH 20** - Conventional regravelling with materials
complying with the South African gravel wearing course material standard;

- **Non TRH 20 material with extra maintenance** - This option would make use of the local materials, generally with inadequate plasticity. To avoid corrugation and ravelling, additional maintenance would be necessary but the overall riding quality would generally be poorer than the other options;

- **Chemical/bitumen treatment with a seal** - This option assessed the costs of treating the in situ material with either bitumen emulsion or a proprietary soil chemical stabiliser. Included in this option was that of importing local material from adjacent to the road, where the in situ material could not be suitably treated;

- **Sand cushioning** - This is an option that makes use of a thin layer of sand to protect the gravel wearing course from vehicle wear. It requires good conventional gravel wearing course material and regular low-cost maintenance (sand replacement and dragging), but minimises the loss of the imported gravel wearing course;

- **Paved TRH 20 material** - The option of paving material imported for a conventional gravel wearing course was assessed. This is typically a poor alternative, as the gravel wearing course necessarily requires cohesion and is thus often excessively water sensitive to perform as a good base course under a bituminous seal;

- **Paved local material** - Inspection of the local materials indicated that many of them would probably perform successfully as a base course. The options of sealing them directly as well as importing local materials from adjacent to the road were analysed.

**Conclusions**

It was clear from the results that:

- In financial terms, only the use of non-TRH20 materials with additional maintenance and the sealing of in situ local materials have direct cost advantages.

- The economic analyses indicate that all options except the sealing of TRH20 materials and the treatment and paving of imported materials are beneficial. Where the in situ materials are not suitable for sealing directly, the sealing of imported materials (2km haul) without treatment is the most cost-effective solution in all cases;

- The total savings (economic) generally exceed the difference between construction costs.
construction costs on any sections of the roads: the results thus indicate that for the roads analysed, the TRH 20 option is mostly the least cost-effective.
A design procedure was developed for the upgrading of very low traffic volume basic access streets in urban environments.

Basic access streets carry very low traffic, but are forming the bulk of the urban street network. They are currently mostly gravel or dirt streets and form the bulk of the backlog of street upgrading and construction needs in the Greater Johannesburg urban environment. The Johannesburg Roads Agency (JRA) is responsible for the upgrading of these basic access streets to provide access and mobility to the residents living in these townships in the metropolitan areas of Greater Johannesburg.

A risk managed design procedure is followed to illustrate how basic or launch risk factors need to be addressed first before the normal design procedure is followed. The launch risk factors are made up of:

- The geology;
- The environmental factors (including climate);
- The topography;
- The community benefit and needs.

Innovative approaches are advocated which are linked with a better understanding of the design domain which often are more dependant on the environmental effects than the traditional traffic volume associated factors. A catalogue of people and labour friendly street pavement structures are presented which help give realistic parameters to the risks involved.

Basic access streets carry less than 75 vehicles per day and less than 5 heavy vehicles per day.

**Associated risks**

The authors report that street design process has inherent associated risks which is not always understood or fully taken into account by the various parties involved in the design process. The design process has two distinct and inherent risk associated phases. The first phase is to determine the launch risks associated with the basic or fundamental aspects of the design environment (Red Book, 1998 and
JRA, 2003). The factors involved in the launch risks and their interaction are illustrated in the conceptual diagram in Figure 1. In Figure 2 the interaction and components of these launch risks are illustrated in more detail. In order to guide the design parties a set of questions is asked using Figure 2 as reference and guide.

The secondary launch design risk factors are inherently tied to these base or primary risk factors. The secondary launch risk factors are the traditional design aspects associated with street design. The aim is to limit or even minimise the risks associated with the basic risks and thereby lowering the secondary risk factors. The questions forming the rest of the matrix to determine the risk profile are:

- Is it a Greenfields development? (By definition this is a new development);
- Is it a Brownfields development? (By definition this is an established previously disadvantaged township with a mixed portfolio of services, levels of service and limited infrastructure);
- Is it an informal settlement/Greyfields development? (By definition this is an informal...
settlement with no layout planning, proper services or infrastructure, but identified for upgrading).

The interaction between the mechanisms of distress due to traffic volumes and the environment is clearly illustrated by means of Figure 3. Normally designs are associated with the situation of higher traffic volumes where the environment is seen as secondary to it. However, for basic access streets traffic volumes are very low and through the foregoing risk management process have been kept deliberately low by...
channelling traffic onto the higher hierarchy streets.

As demonstrated in Figure 3 the environment should be the dominant design factor in the design domain of basic access streets. For that reason the environment would need better definition. This can be done by answering these questions:

- Can the micro-climate be determined in terms of Weinert n values?
- What are the rainfall characteristics?

If these questions have been answered it can be shown in Figure 4 that the design domain for basic access streets can be managed at the lower end of design standards if the basic and
secondary launch risks were identified and managed.

It is suggested to use a Community Benefit Index (CBI) to facilitate socio-political context in the design decisions in a structured manner. CBI should be calibrated and based on aspects such as:

- Land use (residential, industrial, agricultural, educational, religious, recreation, health care, police and security);
- Functional class of streets as per the layout or community use;
- Community involvement in planning structures and forums: have objectives been set and prioritised via ward committees? Have forums participated in Integrated Development Plans (IDPs) or Local Development Objectives (LDOs)?
- Unemployment rate and social indicators (Is there a labour desk or are there community liaison persons to provide skills profiles and determine unemployment figures?)

The authors acknowledge that these are not an exhaustive list of factors for consideration for the development of a CBI, but an indicator of type of factors. The conceptual relationship between LOS and CBI to determine classes of Upgrading Priority Index (UPI) criteria versus each other on a relative scale are shown in Figure 5 to provide for UPI contour bands of high, medium and low priority.

It can be seen that it is possible for a street to have a medium rating on LOS, but a low CBI rating which puts it in the low UPI contour band. This can be used in a transparent way in determining overall priorities of projects.

In essence the community needs can be incorporated by answering these three questions:

![Figure 5: Street Upgrading Prioritisation Index (UPI) Chart](Image)
What is the Community Benefit Index?
What are the levels of service?
What is the resultant street upgrading priority index?

Secondary design factors

The paper presents a flow diagram which demonstrates the factors that need to be taken into consideration in the design process once the design domain of basic access streets have been defined. If the primary launch risk factors have not been addressed they will impose themselves in the form of costly designs. These questions are:

- Is the bearing capacity of the subgrade determined?
- Can the subgrade be improved?
- Should a subbase layer be added?
- Is any base layer necessary?

The flow diagram illustrates how the preceding question would also determine whether not just a subbase, but also or rather only a base layer would be needed. If only a base layer is needed the next question needs to be answered:

What would the pavement structure look like?

This is the culmination of choices made to this point in the design process. A summary type design catalogue of pavement structures and appropriate material selections is given. The following additional questions need to be answered to determine choices from a proposed catalogue of designs for basic access streets:

- Are labour-friendly materials and technologies available and considered? (DoPW, 1999 and JRA, 2003);
- Can phased construction be considered?
- Is cost lowest during construction the sole factor in the final selection? (Life cycle costs, premiums on some labour-friendly construction techniques and maintenance aspects could have an influence in the final choice)

Further questions posed are:

- What kind of surfacing should be used?
- What storm water features are necessary? (JRA, 2003);
- What performance and deterioration can be expected?

The style of the paper is that of a procedures document which guides design decision makers via series of questions.

It was shown how aspects such as geology, the environment (climate), topography and community needs coupled with the status of the layout planning can be managed and used to lower the primary risk. It was also shown how the design domain of such basic access streets is ultimately more strongly influenced by environmental factors than traditional traffic associated factors.
Once these launch risk factors have been handled, innovative design concepts were illustrated for use within such a defined design domain. The basis for the design concept rests on the realistic and risk-managed procedure to classify the subgrade.

Labour-friendly and innovative technologies are described which will meet the defined design domain standards and are presented in a user-friendly catalogue of designs.
Much ad
Design of structures and materials
The mechanistic-empirical design method widely accepted and implemented in South Africa for more than two decades (hereafter referred to as the ME design method) is a two-step process involving (i) the calculation of expected material responses under simulated loading, and (ii) estimating how many load applications the material can withstand - at the calculated response level - before cracking or deforming to an unacceptable level.

Despite its many advantages, the ME method has several problems associated with it. Many of these relate to the empirical element of the method, namely the transfer functions that are used to interpret the calculated responses.

This paper illustrates some of the deficiencies of the ME design method. It looks at two “structural capacity” systems:

- coarse granular materials;
- asphalt materials.

1. **Granular Layer Structural Capacity Evaluation**

For such materials, the structural capacity evaluation requires the calculation of a Safety Factor, which was formulated by Maree (1982) in the following form:

\[
SF = \frac{K\delta_3 \left[ \tan^2 \left( 45 + \frac{\phi}{2} \right) - 1 \right] + 2KC\tan \left( 45 + \frac{\phi}{2} \right)}{\delta_1 - \delta_3}
\]

... Equation 1

Where:

- \(\phi\) = Friction Angle (°), (Mohr-Coulomb Strength Parameter);
- \(C\) = Cohesion, in kPa, (Mohr-Coulomb Strength Parameter);
- \(\sigma_1, \sigma_2\) = Major and Minor principal stresses, in kPa;
- \(K\) = Constant relating to level of saturation.

The factor \(K\) depends on the level of saturation. Values suggested by Maree (1982) were 0.6 for highly saturated conditions (saturation of
40mm Asphalt overlay  
E = 2500 MPa, Poisson’s Ratio = 0.40

150mm G1 overlay  
E = 650 MPa, Poisson’s Ratio = 0.35

250mm existing cemented layer  
(cracked and deteriorated to equivalent granular)  
E = 450 MPa, Poisson’s Ratio = 0.35

150mm selected material  
E = 140 MPa, Poisson’s Ratio = 0.35

Good quality sandy subgrade (CBR > 10%)  
E = 90 MPa, Poisson’s Ratio = 0.35
designer would estimate the cohesion and angle of friction based on published values for the type of material in question.

To interpret the number of repetitions that can safely be accommodated at a given Safety Factor level, the author illustrates proposed limits in his Table 1.

**Important finding**

To illustrate the sensitivity of the ME design method to material input parameters, a design example (typical of many pavement rehabilitation design situations in southern Africa) is shown in Figure 1.

The data in Figure 2 clearly shows that small changes in pavement layer properties can lead to significant variations in predicted structural capacity. For the four variations considered, the predicted structural capacity spanned over three design classes (ES8 to ES10).

Especially relevant to most design situations is the assumed stiffness of the subbase layer. The data in Table 2 suggest that a relatively small decrease in base stiffness would reduce the expected structural capacity from 10 to 4 million load applications. This raises uncertainty about the actual structural capacity for the example.

*Figure 2: Influence of layer property and material type variations on granular base layer predicted structural capacity*
pavement, since the stiffness of the subbase will vary considerably over a project’s length and there would be no clear basis to determine what the “correct” stiffness of the subbase layer should be.

2. Asphalt Layers

In the case of asphalt layers, the structural capacity is often estimated using the relationship between maximum horizontal tensile strain and fatigue life. A widely used transfer function of this type is the Shell Asphalt Fatigue Equation, which is implemented in the following format in the Austroads design guidelines (Austroads, 2001):

As in the first example, several variations on the base case scenario were evaluated, and are summarised in Table 3 and Figure 4. All of the assumed variations are deemed to be within the expected and unavoidable uncertainties of a typical design situation. For the base-case scenario, a binder content of 10 per cent (by volume) was assumed in Equation 3.

As in the case of the first example, the evaluation of asphalt layer structural capacity shows extreme variations and again span over three design classes. Again, the

\[ N_f = 5 \left( \frac{6918(0.85V_b + 10.8)}{(S_{max})^{0.36} \cdot (\varepsilon_1)} \right)^5 \]

... Equation 3

Where:

- \( V_b \) = Volume of bitumen (%)
- \( S_{mix} \) = Stiffness of the asphalt in Mpa
- \( \varepsilon_1 \) = Tensile strain of the asphalt in microstrain

![Figure 3: Pavement situation assumed for evaluation of asphalt](image-url)
sensitivity of the predicted structural capacity to a relatively small change in the support stiffness is especially worrying.

From the data shown in the preceding sections, it is clear why some knowledgeable practitioners view the ME method as an encumbrance and a source of contention rather than a useful tool.

<table>
<thead>
<tr>
<th>Variation</th>
<th>Situation</th>
<th>Calculated Tensile Strain (microstrain)</th>
<th>Structural Capacity (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case</td>
<td>Pavement situation as shown in Figure 3, binder content 10% by volume</td>
<td>183</td>
<td>24.6</td>
</tr>
<tr>
<td>Variation 1</td>
<td>Base layer stiffness increased to 500MPa</td>
<td>158</td>
<td>51.2</td>
</tr>
<tr>
<td>Variation 2</td>
<td>Applied contact pressure increased to 750 kPa</td>
<td>223</td>
<td>9.2</td>
</tr>
</tbody>
</table>

**Table 3: Influence of Variations in Assumed Pavement Layer Properties and Material Types on Predicted Asphalt Layer Structural Capacity**

**Figure 4: Influence of layer property and material type variations on granular base layer predicted asphalt surfacing capacity.**
design aid. It is also clear that, in the hands of an inexperienced practitioner, the ME method can easily lead to an incorrect assessment of a pavement’s structural capacity. It seems fair to state that the ME design method, in its present form, is often not a robust or consistent methodology. This problem centres around two principle errors inherent in many published transfer functions. These are:

(i) the implication of a predictive ability that often is not statistically sound, and

(ii) the assumption of a constant direct or indirect relationship between the design parameter and the repetitions to failure.

A second error in principle inherent in transfer functions is the implied constant relationship between the response parameter (eg Safety Factor or Tensile Strain) and the number of repetitions to failure or allowable load repetitions. In the case of asphalt fatigue, this implication would mean that the number of repetitions to failure would infinitely increase as the tensile strain is reduced. Similarly, in the case of the granular material safety material, the use of a transfer function implies that the number of allowable repetitions indefinitely increases as the Safety

**Figure 7: Two modes of granular material behaviour (after Maree, 1982)**

errors inherent in many published transfer functions. These are:

(i) the implication of a predictive ability that often is not statistically sound, and

(ii) the assumption of a constant direct or indirect relationship between the design parameter and the repetitions to failure.
Factor increases beyond a value of 1.5.

**Recommendations**

The authors conclude that the two examples presented in this paper illustrate the sensitivity of the ME design method to material properties. It also shows how the ME design method could become a source of confusion or contention, and could easily lead to an incorrect assessment of a pavement’s structural capacity.

It was, however, shown that the high sensitivity of the predicted structural capacity is to a large extent related to the logarithmic form of the adopted transfer function, which amplifies the sensitivity of the ME method, often without statistically significant empirical support. The problem perhaps does not lie in the ME methodology, but in the manner that calculated working stresses and strains are interpreted.

A fundamental shift from the use of predictive transfer functions to a simplified classification system is therefore recommended, until such time that conclusive and statistically sound performance data is available to support the development of predictive transfer function equations.

A simplified and less precise “classification approach”, as provided, would remove many of the contradictions from the method. The author also believes that a classification approach would offer significant advantages over the quantified transfer function approach. Most important, perhaps: such a classification system would not imply an inappropriate level of precision. Practitioners and researchers would thus be explicitly aware of the limitations of the design method, and could take this into account during design and development activities.

For researchers and developers, the use of a classification system with coarse precision is perhaps even more important. This is because the explicit lack of precision and predictive ability of such a system will ensure that the ME method is implemented in an appropriate manner, and that future research activities take cognisance of the limitations of the state-of-the-art. It will also ensure that complex extensions of the mechanistic empirical method are only considered once the variability in long term performance has been adequately explained and addressed.
Under the Chair in Pavement Engineering, University of Stellenbosch, in 1998 performance testing of road surfacing seals was initiated.

The Model Mobile Load Simulator (MMLS) was identified as a suitable instrument, and a test method developed. From 1998 to 2002 a test regime using five different seal binders, and three temperature regimes, was implemented. A method was developed to enable evaluation of the seals’ behaviour. The seals were evaluated in terms of the performance criteria determined through assessment of literature and the research process (Milne, 2004). The interaction between the influencing factors, and performance criteria are provided in Figure 1.

MMLS testing enabled the seal performance evaluation in Table 1.

<table>
<thead>
<tr>
<th>Summary: Seal Performance</th>
<th>Scale 100 maximum: worst 0 minimum: best</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder</td>
<td>Overall performance Test regime</td>
</tr>
<tr>
<td></td>
<td>Binder modified 80/100 pen grade with:</td>
</tr>
<tr>
<td></td>
<td>10°C (cold)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>3% SBR</td>
<td>0-22</td>
</tr>
<tr>
<td>3% SBS</td>
<td>0-28</td>
</tr>
<tr>
<td>3% EVA</td>
<td>11-28</td>
</tr>
<tr>
<td>20% bitumen rubber BR</td>
<td>14-39</td>
</tr>
<tr>
<td>- Tosas</td>
<td>11-56</td>
</tr>
<tr>
<td>- Colas</td>
<td></td>
</tr>
<tr>
<td>80/100 Penetration grade</td>
<td>22-56</td>
</tr>
</tbody>
</table>

Table 4: Summary of Seal Performance
to be established. Each binder type has a specific regime where, for the tested base type, performance is enhanced. This is summarised in Table 5.

Milne et al’s work continues in a second paper that investigates South African seal design areas where review or updating is suggested. Seal performance

<table>
<thead>
<tr>
<th>Seal</th>
<th>Performance Testing (APT)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image_url" alt="Image" /></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1: Interaction of Influencing Factors and Identification of Performance Criteria**

<table>
<thead>
<tr>
<th>Performance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deformation</td>
</tr>
<tr>
<td>Cracking</td>
</tr>
<tr>
<td>Adhesion</td>
</tr>
<tr>
<td>Aggregate crushing/polishing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Influencing Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controllable</td>
</tr>
<tr>
<td>Non-Controllable</td>
</tr>
<tr>
<td>• Binder</td>
</tr>
<tr>
<td>• Aggregate</td>
</tr>
<tr>
<td>• Seal (design)</td>
</tr>
<tr>
<td>• Environment (temperatures and moisture)</td>
</tr>
<tr>
<td>• Traffic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Binder Ranking*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranking (1 best, 5 worst), (BR Consolidated)</td>
</tr>
<tr>
<td>Regime</td>
</tr>
<tr>
<td>Cold Ambient Elevated</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Overall</td>
</tr>
</tbody>
</table>

**Table 5: Binder Performance Ranking**

* 80/100 pen grade bitumen modified as shown
criteria are examined, and the need for a seal design method based on mechanistic principles is proposed. A prototype seal behavioural model initiating the development of a mechanistic design tool for seals and thin surfacing layers was developed using Finite Element Methods (FEM).

**Benefits**

The potential benefits to practice of the mechanistic design tool will be enhanced as the design model is developed, and initial contributions to practice, such as enhancing the understanding of the behaviour of seal components, are discussed, with the demonstration of the first multiple element seal FEM model. The original initiation of a three-dimensional seal model was undertaken in 2002 at Technical University Delft, using the CAPA research programme, and the TU Delft computer resources of required computational ability.

Work continued on the development of the seal model in 2003, resulting in the prototype seal model, of binder and seal stone. This is the subject of this paper. Subsequently a base mesh has been developed which is available for further development. For the development of a multi-element (stone, bitumen, base and wheel-load) prototype numerical model, the determination of applied loads representing as real a reflection as possible of actual traffic loading on seals was required. A detailed assessment and interpretation of current available data, focused on the geometry of the textured FEM model, was undertaken with the objective of defining a prototype model traffic load.

Two imposed load types were considered for an “average” two axle heavy vehicle:

- Driven rear wheel;
- Rolling front wheel.

Of importance to a seal model was the load on:

- A textured surface, as represented by the seal aggregate;
- Contact stresses, tangential and vertical, imposed by the vehicle tyre.

The determination of load application type, and implementation, for FEM modelling, allows inclusion of the above load types, e.g.:

- Dynamic “single wave” load application or modelled static load imposed a number of times to simulate dynamic effects;
- Loading applied to a textured surface, with texture of different depths;
- Focus on the seal model was thus on the affect of texture on the transfer of bulk stresses from the tyre to micro-level stresses in the seal stones.

**Some results**

The ability of the prototype model to differentiate between binder types was assessed by comparing
two binders: “straight” penetration grade and a modified binder.

A temperature of 25°C was decided upon for material parameter determination, as this is in the accepted zone of viscoelastic behaviour. 70/100 pen grade binder, and SBS modified (3%) binder. Figures 8(a) and 8(b) demonstrate the behaviour of the different binder types, in terms of cumulative displacements under four truck passes. The displacements of the top, central

---

**Figure 8 (a): Pen grade bitumen: Displacement under sequential loading: 25°C**

**Figure 8 (b): SBS modified bitumen: Displacement under sequential loading: 25 °C**
node of the central stone is provided for the comparison.

**Conclusion**

It is evident that there exists a need for the development of a fundamental model for seal performance prediction to complement current South African seal design codes and experience. The prototype model is a micro-mechanical model for surfacing seal performance prediction. Of course, the model may be loaded by various loads (also temperature loading), and it may be used in combination with more realistic material models.

On the basis of the linear calculations discussed, it is concluded the model will prove to give insight into seal behaviour and with development should offer the following:

- Distinction between physical/chemical adhesion (IF-behaviour) and mechanical adhesion (stone shape);
- Enable better understanding of loss of adhesion and thus loss of stone, which is a prime cause of seal damage;
- To provide insight into stress and strain development in the binder;
- To explain various types of cohesive seal cracking; and
- Prediction of deformation in the binder resulting in stone rotation.

As a result of the above, insight into stresses in the stone/binder interface is obtained.

Within the philosophy for the model discussed, future work into the prototype will include the addition of a base layer, to enable interaction between base and seal to accommodate punching of stones into the base. In addition, realistic material models will have to be developed to further refine computational output the model provides.
The bitumen foaming technique by adding water to hot penetration grade bitumen, and thereby causing a temporary expansion to enable coating of cold aggregate, was used in a pilot project on a large scale on the Same-Himo road in Northern Tanzania, reconstructed in the period 1990 to 1992. Partly natural, screened gravel and partly milled old cement stabilised pavement materials, were stabilised using a bitumen content of 4.4% applied without any addition of cement filler.

A comprehensive pavement monitoring programme has been on-going since construction of the Same-Himo road, and the last recordings were carried out late in 2003. The following are conclusions of the findings after the pavement monitoring:

- The pavement utilising natural gravel base course stabilised with foamed bitumen has performed very well on a heavily loaded trunk road in Tanzania. The pavement is currently in an excellent condition;
- The pavement on the Same-Himo road is currently near the end of its 15 years design period and has almost received the 5 million E80s it was designed to withstand;
- The pavement has received no resealing or other periodic maintenance since construction;
- There has been no pothole development on the road;
- There is no excessive development of rutting or surface roughness on the road;
- Sealing of individual cracks has been undertaken on individual sections;
- The pavement utilising natural gravel stabilised with foamed bitumen has performed very well throughout most of its design period on a heavily loaded trunk road in Tanzania.

The findings suggest that the TG2 design manual could produce conservative designs.
Following the Same-Himo pilot project the bitumen foaming technique has had considerable use in large scale pavement rehabilitation and new construction in Tanzania and Zambia during the 1990s, amounting to well over one million tonnes of placed material. The method was subsequently adopted in the Tanzania Pavement Design traffic (million E80s)  |  Asphalt Academy, RSA, base course layer thickness (mm)  |  Design traffic (million E80s)  |  Tanzania standard base course layer thickness (mm)  
--- | --- | --- | ---  
0.001 - 0.003  |  75  |  < 0.2  |  60  
0.003 - 0.01  |  100  |  60  
0.01 - 0.03  |  100 - 125  |  80  
0.03 - 0.1  |  100 - 150  |  100  
0.1 - 0.3  |  100  |  125  
0.3 - 1.0  |  100 - 175  |  150  
1.0 - 3.0  |  125 - 175  |  ---  

Table 1: Layer thickness, bituminous base course (foamed bitumen)

**Placed material**

Following the Same-Himo pilot project the bitumen foaming technique has had considerable use in large scale pavement rehabilitation and new construction in Tanzania and Zambia during the 1990s, amounting to well over one million tonnes of placed material. The method was subsequently adopted in the Tanzania Pavement Design traffic (million E80s)  |  Assessment, Same-Himo monitoring sections 2003/04  |  *WARNING (Measured only once, after 10 years in service. Criteria for 'lightly cemented' base course is used)  |  *WARNING (Approached WARNING after 7 years since construction, but rut development has levelled out and there has been no increase since that time.)  |  *WARNING to SEVERE, however this is related to subsoil conditions*  
--- | --- | --- | ---  
0.001 - 0.003  |  SOUND (One section barely approaching WARNING, however this case is related to subsoil conditions rather than pavement distress.)  |  Sound: <0.35mm  |  Sound: < 5mm  |  Sound: < 10% (all cracks)  
0.003 - 0.01  |  WARNING (Measured only once, after 10 years in service. Criteria for 'lightly cemented' base course is used)  |  Warning: 0.35 - 0.85mm  |  Warning: 5 - 15mm  |  Warning: 10 - 30% (all cracks)  
0.01 - 0.03  |  Severe: >0.85mm  |  Severe: >6m/km  |  Severe: > 15mm  |  Severe: > 30% (all cracks)  
0.03 - 0.1  |  Warning: 3 - 6m  |  Warning: > 6m/km  
0.1 - 0.3  |  Severe: > 6m/km  
0.3 - 1.0  |  Severe: > 6m/km  
1.0 - 3.0  |  WARNING (Approached WARNING after 7 years since construction, but rut development has levelled out and there has been no increase since that time.)  |  Sound: < 5mm  
3.0 - 10  |  Severe: > 15mm  

Table 2: Condition rating of the Same-Himo monitoring sections  

and Materials Design Manual-1999, to which a comparison with the Asphalt Academy manual of South Africa has been made (see Table 2).

**Discussion:**

The findings of the Same-Himo investigation suggest that the TG2 design manual could produce conservative designs. Long Term Pavement Performance (LTPP) results have shown this section of foamed bitumen stabilised pavement to outperform TG2 predictions.
The stress-dependent and nonlinear behaviour of granular pavement materials is well known. It is however expensive and time consuming to determine the properties of such materials in a laboratory — i.e. using triaxial testing.

As part of pavement investigation, the drop sequence of the Falling Weight Deflectometer (FWD) measurements can be successfully adjusted and used in the determination of material characteristics. Experience from an investigation of pavements on highly trafficked roads is used to demonstrate the role of a FWD in the determination of material properties to describe the nonlinear and stress-dependent material behaviour of in situ pavement materials.

Two different approaches are compared for determining the stress-dependent material parameters of a pavement, namely a linear-elastic and a stress-dependent method. To facilitate the analysis, FWD deflections were measured at four different load levels, with five drops at each load level.

In the first method, back-calculations of the layer moduli were made using a linear-elastic finite element method. By repeating this procedure for each of the load levels, an indication of the stress-dependent behaviour could be obtained.

The finite element method provides more realistic stiffness for the deeper layers in the structure.

The benefits of using a finite element model as opposed to a conventional mechanistic analysis method, are shown in Table 5. The finite element method provides more realistic stiffness for the deeper layers in the structure, and to some degree addresses the
overestimated subgrade moduli commonly expressed in back-calculations of FWD in southern Africa.

The second method of backcalculation required the development of specialist software, i.e. PaveFEL by SJ Bredenhann, for the analysis. Stress-dependent backcalculation is an unconventional approach and the following features should be noted:

- With this method the material parameters, eg. $K_1$, $K_2$ of a specific model, are backcalculated rather than the E-moduli, as in the linear-elastic case. It is only really possible to calculate one material parameter at a time, so one parameter is selected and the second parameter is back-calculated;
- A number of different material models can be used (and were) with this approach, namely the Bulk-Stress ($K-u$) model, the Huurman-van Niekerk model, the Uzan model and the Thomson and Elliot bi-linear model. A model such as the Huurman-van Niekerk model is complicated and has many parameters.

Prior knowledge of some of the material parameters, or those of similar materials, is helpful in estimating other parameters. Even with the $K-u$ model, it is recommended that the $K_1$ value is based on material testing and only $K_2$ is determined. The procedure followed included the initial back-calculation of the material parameters for the 40 kN drop weights, followed by the testing of these parameters for the 30kN, 50kN and 60kN levels. If the fit is not satisfactory for the other load levels, adjustments can be made to the parameters. These adjustments are not made randomly, and should take cognisance of the relevance of the parameter, eg. in the $K-u$ model, $K_1$ indicates material quality and density, while $K_2$ is the measure of stress dependency. The material parameters are not mutually exclusive, and parameter sets are therefore not necessarily unique. Adjustment of one parameter can require a repeat of the whole fitting process.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Elastic Modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Finite Element</td>
</tr>
<tr>
<td>200 mm Base Course</td>
<td>490</td>
</tr>
<tr>
<td>150 mm Subbase</td>
<td>100</td>
</tr>
<tr>
<td>250 mm Selected Subgrade</td>
<td>70</td>
</tr>
<tr>
<td>400 mm Subgrade 1</td>
<td>280</td>
</tr>
<tr>
<td>400 mm Subgrade 2</td>
<td>370</td>
</tr>
</tbody>
</table>

Table 5: Comparison of Back-calculation with Linear-elastic Multilayer and Finite Element Methods for Normalised 40 kN Load Level
**Application**

This paper provides an example of a pavement rehabilitation design using the material parameters obtained from FWD back-analysis. For advanced pavement design using stress ratios in granular and foamed bitumen treated materials, it is essential to use the material parameters for the finite element analysis.

**Conclusion**

It has been shown that the FWD can be used to extract more information out of an existing pavement than is evident in current practice. Parameters describing the characteristic material behaviour of *in situ* pavement material can be successfully determined by adjusting the FWD drop sequence. Material parameters for the foam treated material were determined through triaxial tests in the laboratory. The combination of FWD measurements and laboratory testing proved to be an economical way to develop more sophisticated pavement design models.
There is some incentive for practice to come to terms with the reality of tyre pressure distributions, which are significantly different from those of 1995, as a basis for transfer functions used in analytical-empirical design methods.

Changes in the stress patterns under heavy loads and high tyre inflation pressures are not currently compensated for in a statistical approach to current mechanistic design principles to develop conclusions as to the most appropriate choice and application of stress and load parameters.

No attempt is made to re-evaluate the current design methods, but merely to provide an additional function to assess the risk of accelerated pavement deterioration, within the accepted norms and proven practice of pavement design.

The South African Gross Combination Mass (GCM) is currently far in excess of the corresponding limits in many other countries.

Freight transport in South Africa was fully deregulated in the early 1990’s, in close conjunction with the increase in Gross Combination Mass (GCM) to 56 tonnes and the increase in axle load to 9 tonnes in 1996. The South African GCM is currently far in excess of the corresponding limits set in many other countries. Freight technology advancements in fuel efficiency and improvements in tyre technology have resulted in not only excessively high loads, but also tyre inflation pressures...
reaching the 1000 kPa level on standard haulier vehicles; a range that was, until recently, reserved for the use of super-single tyres only.

The combined effect of all these factors is unprecedented loading and applied stresses on major roads throughout the country. Toll road concessions are being instituted on a national scale throughout South Africa, with many additional toll concessions planned within the southern African region over the next 5 years. Control of loading is a crucial aspect of toll operations and thus sophisticated equipment has been introduced.

Weigh-in-motion equipment currently provides large databases of pavement loading and truck configuration information. The authors claim that the advances of the freight industry and ever increasing risk assessment required by toll operators have outstripped improvements in design practices utilised internationally and in southern Africa.

**Axle loading**

The load of a given set of tyres is expressed in terms of the weight each tyre supports, the contact pressure exerted at the tyre/pavement interface and the number of tyres. Comparison of South African and international axle load limits illustrate that the variation in maximum axle load is contained between the 8 to 9 tonne limit. The GCM in South Africa is currently set at 56 tonnes with the maximum standard axle load of 9 tonnes.

**Tyre inflation pressure**

Tyre pressures have a significant effect on the stress in the pavement. This is particularly relevant on the upper layers (i.e. surfacing and base). Tyre pressures on truck tyres have increased from around 555 kPa in 1960’s to approximately 750 kPa in 1995 (De Beer, 1998).

Three pavement sections of the N3 Toll Road consisting of two general pavement structures, were identified. The pavement structures (designated Pavement A, B and C) are shown in Figure 2.

![Figure 1: Historical measured tyre inflation pressure distributions (De Beer et al, 1999)](image-url)
The philosophy of Equivalent Damage Factors (EDF) was selected for the expression of the effect of increased tyre inflation pressure and axle load on pavement life in the statistical formulation of the “weighted effect” of these two parameters on the analysed pavements.

Figure 5 illustrates the cumulative distribution of the random axle load sample captured. From the curve it is evident that overloading amounts for approximately 10% of all axles measured. Note that overloading in this case is defined as axle overloading and not gross combination mass.

Conclusions

The authors conclude that truck tyre inflation pressures have increased significantly over the
last decade, with over 84% of all measured truck tyre inflation pressures exceeding the generally accepted design norm of 700 kPa.

The effect of truck tyre inflation pressure plays an important role in combination with axle load in the deterioration of flexible asphalt pavements.

The trucking industry has optimised axle loading, successfully making use of the 5% grace on axle load prosecution. Over 35% of all axle loads fall within the previous axle load limit of 8 tonnes and the current maximum prosecution load of 9.45 tonnes.

E80/HV ratios as specified in the design method are outdated, and need to be re-evaluated, particularly when applied to high profile roads carrying major truck traffic levels. By incorporating the actual truck and tyre inflation pressure distributions in analysis, the sensitivity of designs to overloading and overstressing can be quantified.

The results of the analysis contained in this report clearly illustrates that truck tyre inflation pressure needs to be re-evaluated in currently utilised mechanistic design methods, both with regards to applicability of the design method and the recommendation included in the design method regarding standard norms of truck tyre inflation pressure.
Image analysis techniques have been used to provide quantitative information on the orientation and distribution of aggregates in asphalt after gyratory, vibratory and slab compaction.

Consistency in compaction in the laboratory and on site is necessary if accurate correlation is to occur between laboratory performance and the observed site behaviour. Since the method of compaction has a direct impact on the aggregate orientation and internal structure of an asphalt mixture, this paper discusses the observed differences in the asphalt matrix as a function of compaction and the resulting differences in mechanical performance.

**Gyratory Compaction**

The SHRP recommended compaction parameters were used in the gyratory compaction study.

**Vibratory Compaction**

The vibratory compaction was achieved by a vibrating Kango hammer, applied to both faces of the specimen (prEN 12697-32, 2000).

**Slab Compaction**

The slab compactor produces slabs 300 mm X 300 mm X 100 mm in height. This method is the most mechanically similar to site ‘roller’ compaction.

**Mechanical performance and the asphalt matrix**

Mechanical performance testing was undertaken on the specimens to investigate the effect of the mode of compaction. Two types of testing have been reported in this paper, Repeated Load Axial Test.
(RLAT) and the Indirect Tensile Stiffness Modulus (ITSM).

**Repeated Load Axial Test**

In the RLAT a number of load pulses are applied to the specimen, on the flat (cut) surface, with the resulting deformation recorded. The axial strain obtained at the end of the test is a valuable measure of the specimen’s resistance to permanent deformation. This test is destructive and was carried out using the following test parameters:

- Test Temperature — 300°C;
- Test Duration — 7200 secs (3600 cycles), with a cycle consisting of 1 second of applied load followed by a one second recovery period;
- Axial Stress — 100 kPa;
- Conditioning Stress 10 kPa for 120 seconds.

In this study 10 specimens were tested for each mode of compaction, the results are summarised in Table 3.

The results indicate the mould based compaction methods produce specimens which are approximately twice as resistant to permanent deformation as the slab compacted specimens.

<table>
<thead>
<tr>
<th>Mode of Compaction</th>
<th>Mean Air Voids (%)</th>
<th>Mean Permanent Axial Strain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyratory</td>
<td>6.1</td>
<td>0.55</td>
</tr>
<tr>
<td>Vibratory</td>
<td>6.3</td>
<td>0.65</td>
</tr>
<tr>
<td>Slab</td>
<td>6.4</td>
<td>1.21</td>
</tr>
</tbody>
</table>

**Table 3: RLAT results for gyratory, vibratory and slab compaction**

**Indirect Tensile Stiffness Modulus**

The stiffness moduli of the asphalt specimens were measured using the ITSM test, which was undertaken using the following test parameters:

- Test temperature — 200°C;
- Loading rise-time — 124 milliseconds;
- Test Duration — 12000 secs (6000 cycles), with a cycle consisting of 1 second of applied load followed by a one second recovery period;
- Axial Stress — 100 kPa;
- Conditioning Stress 10 kPa for 120 seconds.

<table>
<thead>
<tr>
<th>Mode of Compaction</th>
<th>Mean Air Voids (%)</th>
<th>Mean Stiffness (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyratory</td>
<td>3.05</td>
<td>7906</td>
</tr>
<tr>
<td>Vibratory</td>
<td>6.03</td>
<td>6762</td>
</tr>
<tr>
<td>Slab-roller</td>
<td>2.99</td>
<td>7321</td>
</tr>
</tbody>
</table>

**Table 4: ITSM results for gyratory, vibratory and slab compaction**
Peak transient horizontal deformation — 5mm on a 150 mm diameter specimen. Thirty specimens were manufactured and tested for each compaction method with the results presented in Table 4.

The air voids content of the vibratory specimens was approximately twice that of the gyratory and slab compacted specimens making comparisons difficult. However the mean stiffness of the gyratory specimens is 8% greater than that of the slab compacted specimens. This result is commented on in the context of the aggregate structure in the discussion.

**Summary**

This demonstrates that mechanical performance testing highlights the effect aggregate structure has on permanent deformation resistance and stiffness modulus. Mould based compaction methods appear to create specimens which are approximately twice as resistant to permanent deformation (RLAT) as slab compacted specimens. A less distinct difference between the performance of the specimens has been observed in the stiffness modulus (ITSM) tests.
S

S

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S

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S

A 700m section of this road, located on a steep gradient (+10%), was upgraded to blacktop standards during 1995 by constructing a single layer of foamed bitumen treated material on top of a prepared subbase layer. The single slurry seal that was applied soon after construction proved adequate for three years before requiring a competent surfacing.

In 1995, this steep section was identified as a candidate project for upgrading using a technology that was then in its infancy in South Africa - foamed bitumen stabilisation. Accordingly, a foamed bitumen treated base was constructed as an experiment using two different types of material.

The road has performed beyond original expectations and this paper investigates the reasons why. Initial construction records were reviewed to obtain the details of what was actually built. Two years after construction, the CSIR evaluated the pavement and compiled a report with predictions for life expectancy.

Seven years later, the road is still performing well in spite of the large number of heavy loads emanating from the crusher, asphalt plant and pre-cast yard. It has exceeded the life span originally predicted and is showing few signs of distress.

Construction

During March 1995, material for the new base of MR504 was mixed using the Soter plant and placed in stockpile. Two different types of material were used. The foamed bitumen application rate for the...
reclaimed asphalt pavement RAP/crusher dust blend was 1.7% and 3.5% for the weathered granite material/1% hydrated lime.

Both material stockpiles were tested two weeks after mixing and again two months later. The test results are shown in Table 2. These results showed that, unlike the weathered granite mix, the RAP blend experienced no significant degradation as a result of standing in stockpile for an extended period. Both materials remained in stockpile for a further month before being transported to the road and used in the construction of a new base layer.

Section A was constructed with 175mm of foam-treated RAP, Section B with 175mm of foam-treated granite and Section C with 150mm of foam-treated granite.

**Construction**

The work was carried out by one of KZN DoT’s construction units, commencing with the new subbase layer. Foamed bitumen treated base construction started on 23rd June 1995 with the second RAP section (A2). Material was hauled to site from stockpile (approximately 10km), tipped, placed by grader and compacted whilst traffic was accommodated in half-widths. Thereafter, some 100m was constructed each day with the last section (C) being completed on 12th July 1995. Densities achieved for the foamed bitumen treated material (measured as a percentage of Modified AASHTO dry density) were as follows: Section A: 100.9%; Section B1: 95.6%; Section B2: 102.6%; Section C: 101.4%.

**Benkelman Beam**

Surface deflection measurements were made across the trial sections using a Benkelman Beam in July 1995 and February 1996. Some sections of the trials with foamed bitumen showed a reduction deflection after seven months of trafficking (on steep uphill grades with heavily laden trucks) compared with sections of increased deflection with downhill grades and unladen trucks. At best

<table>
<thead>
<tr>
<th>Parameter/property</th>
<th>Mix design</th>
<th>Delay after mixing</th>
<th>Mix design</th>
<th>Delay after mixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry stability kN</td>
<td>28</td>
<td>23.7</td>
<td>23</td>
<td>13.7</td>
</tr>
<tr>
<td>Soaked stability kN</td>
<td>19</td>
<td>17.4</td>
<td>16</td>
<td>11.5</td>
</tr>
<tr>
<td>Retained stability %</td>
<td>67.9</td>
<td>73.4</td>
<td>69.6</td>
<td>83.9</td>
</tr>
<tr>
<td>Resilient modulus MPa</td>
<td>1950</td>
<td>1503</td>
<td>2350</td>
<td>No test</td>
</tr>
<tr>
<td>Dynamic creep MPa</td>
<td>22</td>
<td>No test</td>
<td>94</td>
<td>No test</td>
</tr>
</tbody>
</table>

**Table 2: Results of tests on stockpiled material**
the deflection measurements were highly variable. In 1997 KZN-DoT employed CSIR Transportek to assess three separate pavements that were constructed with foamed bitumen-treated bases during 1994 and 1995, including MR 504. Rut depth measurements that were made in the left-hand (downhill) lane showed the foamed RAP to have an average of 3 - 7mm of permanent deformation, and the foamed granite to have 4-15mm of rutting.

Three separate exercises were carried out to derive the resilient moduli values, namely: empirically using the penetration rate of a DCP cone, back-calculated using the results of the FWD survey, and repeated-load indirect tensile tests on core specimens.

The results are shown below:

<table>
<thead>
<tr>
<th>Section</th>
<th>DCP analysis</th>
<th>FWD back-calculated</th>
<th>Repeated load test</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1326</td>
<td>1771</td>
<td>1355</td>
</tr>
<tr>
<td>B1</td>
<td>471</td>
<td>360</td>
<td>1261</td>
</tr>
<tr>
<td>B2</td>
<td>587</td>
<td>1230</td>
<td>1295</td>
</tr>
<tr>
<td>C</td>
<td>964</td>
<td>1715</td>
<td>No cores</td>
</tr>
</tbody>
</table>

Table 7. Stiffness moduli derived from different sources

In 2004, a subsequent investigation was undertaken incorporating DCPs, Benkelman beam and cores with appropriate testing

Discussion

The two different materials treated with foamed bitumen in the pavements on MR 504 appear to be performing beyond their expectation.

Predictions for structural capacity proposed by the CSIR in their 1997 report (FWD and DCP tests) as well as those derived using the transfer functions in the recently published TG2 guideline document and the AA Loudon investigation...
(cores, DCP and Benkelman Beam) appear to be very conservative.

The traffic loading pattern carried by this pavement presented an ideal opportunity to check one of the theories postulated by HVS test results: the resilient modulus of a foamed bitumen treated material reduces when subjected to repeated loads. The heavy traffic carried by the right hand (uphill) lane on MR 504 is far higher than that carried by the left hand (downhill) lane. However, after nine years of service, there is little evidence that there is any appreciable difference between the behaviour of the two lanes. To the contrary, judging by deflection measurements, the heavily loaded lane on the foamed bitumen treated RAP section appears to be in a superior condition.

Foamed bitumen treatment is clearly different from other types of stabilisation. The investigations reported in this paper have shown that high deflections are not synonymous with early failure, as would be the case with a semi-rigid pavement. The models that have been postulated for performance predictions are clearly imperfect and need to be revised.
Having studied the spectrum of trucks on the N3-TCC (Traffic Control Centre) system near Heidelberg, and applying four-pad Stress-In-Motion (SIM) technology, the authors propose improved loading models for thinly surfaced flexible pavement designs.

From Figures 14 and 15 in the paper (reproduced here) it is clear that especially for pavements with thin asphaltic surfaces, including surfacing seals, the vertical contact stress footprints obtained from real world trucks are non-circular and non-uniform. It is the opinion of the authors that "shape and profile" of the contact stresses (3D) should therefore be introduced during the design stage of pavements and pavement surfacings.

Figure 14: SIM test 297: Vertical contact stress contour footprint of a normal "n"-shape - axle 1 - steering tyre - right side
The way forward

Evidence from the measured SIM data and limited analysis so far, points to the fact that non-uniform tyre-pavement contact stresses should be used for pavement design, instead of the usual uniform and circular shapes, and:

- Improved tyre loading models are crucial for improved optimisation of the pavement design efforts for flexible pavements with thin (50 mm) surfacings, including textured seals;
- For overloaded/underinflated tyres the fatigue “life” of thinly surfaced flexible pavements will be significantly reduced as a direct result of increased horizontal tensile strains under the edges of the tyre.

Finally, the authors recommend that an improved load equivalency concept for damage of the surfacing of flexible pavements be investigated. The rather simplistic power law for relative damage based on load level only appears not to be the best option for the design of thin surfacings of flexible pavements.

Figure 15: SIM Test 306: Vertical contact stress contour footprint of abnormal “m”-shape - axle 5 right outer tyre
The evolution of bitumen specifications has been dramatic in the last 15 years. Simple empirical tests based on mechanical properties formed the first types of binder tests. More recently however, fundamental, visco-elastic and damage characterisation methods have been adopted.

Changes in specifications have been motivated by various factors and have had various consequences in different parts of the world. In this paper, the authors bring together their experience of working in three different continents, to evaluate various bitumen specifications and discuss merits of different concepts used from as early as 1950 to 2003.

In the early 1990’s, the Strategic Highway Research Program (SHRP) project in the USA resulted dramatically by two developments:

- The introduction of “new” rheological testing methods;
- The concept of Performance Grading (PG) to relate pavement, temperature and traffic conditions to fundamental properties. This resulted in the development of binder-blind specifications (regardless of whether modified or not).

The authors claim that both developments were successfully implemented in the USA but are lagging in other parts of the world. One of the logical reasons is the cost and complexity of the new rheological test equipment. Although the concept is best implemented using rheological properties, it can be applied using various types of test results, eg. those derived from Penetration and Softening Point.

It is possible to establish an indirect PG system without costly binder testing equipment in the introduction of SuperPave binder specifications after decades. As a result, the bitumen specification world was changed dramatically by two developments:

- The introduction of “new” rheological testing methods;
- The concept of Performance Grading (PG) to relate pavement, temperature and traffic conditions to fundamental properties. This resulted in the development of binder-blind specifications (regardless of whether modified or not).

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Europe

Penetration grade bitumen specifications in Europe have
always been seen by the industry as indirectly related to performance. The Bitumen Test Data Chart (BTDC) as developed by Heukelom and van der Poel nomograph are examples of tools for use in this performance link.

Since 1990, the European specifications for paving grade bitumens have been developed in two stages:

- First generation: Production of harmonised specifications and test methods for paving bitumen. For use in Europe, based on national standards;
- Second generation: Produce specifications that are more directly Performance-Related, with existing or new properties and test methods where appropriate.

**United States**

The first bitumen specification implemented by the American Association for State Highway and Transportation Officials (AASHTO) in the USA dates back to 1931 (Roberts et al., 1996). These specifications recognised bitumen as a semi-solid and therefore consistency measures were used to develop the Pen-grading system.

In the early 1960s the viscosity grading system was introduced. Testing included penetration at $25^\circ C$, the viscosity at $60^\circ C$, and the kinematic viscosity at $135^\circ C$. Ageing was also considered and the thin film oven test was used to measure relative ageing of bitumen.

In the mid 1980s specifications grew exponentially across the USA, and there were more than 35 different bitumen specifications, which created major problems for bitumen suppliers limited by storage capacity and localised markets. In 1987 the SHRP was initiated to include significant focus on developing national uniform specifications.

While initially it was expected that the national bitumen standards would include compositional properties, it was very quickly found that only physical properties that describe the visco-elastic nature of bitumen would be included. In 1991 the first version of performance grading system based on fundamental rheological properties was introduced. It took 5 to 6 more years to implement what is today the SuperPave PG grading throughout the USA.

**South Africa**

The South African bitumen specifications date back to 1951, with the first publication of penetration requirements. Thereafter a revision was made in 1966 and the Rolling Thin Film Oven Test (RTFOT) introduced in 1972.

**Compositional balance**

The 1995 SA binder specifications did not address compositional balance of the bitumen directly. This was a point of concern and subsequently van Assen and van
de Ven (1996) investigated this aspect and reported on it at CAPS’99. Following the recommendations of a panel of international experts, the Bitumen Specification Task Group agreed on certain changes and rulings:

- That viscosity at 60°C be the specification grading;
- That viscosity at 135°C should include upper limit specification;
- Low temperature ductility was considered important, although the specification of 100cm ductility requirement was considered conservative;
- The minimum Softening Point value after RTFOT and maximum change value were adopted.

**The PG concept linked to the standard SA specifications**

The authors suggest that a potential improvement to the current “bitumen production-based”, rather than performance-based specifications, is the use of a direct approach in which grades are based on actual performance factors at which common criteria are specified using performance-related properties, similar to the approach used in the SuperPave specifications. The difficulty in the direct approach is the need for directly measured performance-related properties such as G* and phase angle.

This approach requires expensive and complex equipment that is out of reach of many pavement engineers. Grades are developed as performance-based in this approach, and directly related to traffic and pavement conditions.

This is not totally a novel approach. In the 1980’s the Shell company introduced a complete pavement design manual based on using Penetration and Softening Point and estimating rheological and damage resistance properties of asphalt mixtures using numerical models as given in the Shell Handbook (1991).

What is novel in this paper is the use of the concept to derive a Bitumen Performance Grading System using the commonly measured index properties. In the following section the approach is used to demonstrate how it could be implemented for South African conditions.

To achieve this it is necessary to define the models that can be used to derive bitumen constitutive models based on Penetration and Softening Point measures, i.e. using van der Poel’s nomograph.

Furthermore, the distribution of pavement temperatures, such as the maximum and minimum design pavement temperatures, could be taken from weather data bases in SA and used to define the performance grades needed for various regions in the country. The distribution of maximum pavement temperatures in various regions in South Africa with the range (minimum and maximum) for selected stations in the country was decided upon. Therefore a set of bitumen grades could be selected.
Based on discussions with pavement engineers and experts in SA at a workshop in May 2003, it was decided to work with three main high temperature grades, PG-52, PG-58, PG-64. To consider high traffic volume and/or slow moving traffic, a PG70 grade could be added. To avoid creating an unmanageable number of grades and to simplify the system, it is believed that a three high temperature grade system with PG-58, PG-64, and PG70 is a good concise system for South Africa.

To cover the low temperature range, it can be seen that temperatures range between -5°C and +80°C. It is therefore reasonable to use a system of +6, 0.0, and -6.0°C. For a full factorial system a three high temperature and a four low temperature grid would result in 12 grades, which is more than double the grades used today in SA. To minimise this multiplicity of grades, a partial system could be used to include 8 grades as shown in rows (1) and (2) of Table 3.

Finally, the performance related properties should be selected and the acceptable limits for acceptance of bitumen have to be defined. Following are the properties selected:

- **For workability** the viscosity at 135°C as used in the current specifications could be used. However, in a performance specification the limits should not be changed; they should remain the same for all grades since contractors are expected to use same practice regardless of the binder source or grade. A range of 0.12 - 0.65 Pa could be recommended based on the ranges listed in the current SA bitumen specifications (SABS 307-1972 amended in 1997);

- **For rutting resistance** it is proposed that the penetration and softening point be used to calculate the PI for the grades currently used in SA. The PI values are used to calculate the stiffness modulus at speeds of traffic normally seen in the field (at a typical speed of 60 Km/hr, for a pavement surface layer thickness of 100mm, the loading time is 0.015 seconds). The average PI for such grade is assumed to be = -0.5 with a softening point of 54°C (40/50 Pen in P658 Zone). Using these values in solving the van der Poel nomograph indicates that such bitumens give a S(0.15) value of approximately 100 Kpa. This can then be used in the new specification table for all grades. For higher grades (64 and 70) this stiffness minimum value should be met at 64°C and at 70°C respectively. Also, to consider the effect of RTFO ageing a

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*The objective is an improvement to the current specification, rather than performance-based specifications*
separate row is added to Table 3 to require a minimum stiffness that is 2.5 times the unaged condition;

- **For fatigue resistance** it is recommended that average pavement temperatures be used because fatigue is most critical when bitumen is relatively stiff but subsurface layers are not frozen. In fatigue it is assumed that stiffness should be below a certain maximum value so that bitumen can deform repeatedly without damage. To derive stiffness limits, the nomograph published by Shell Research (1991) for estimating the fatigue life of mixtures from the PI of bitumen and mixture stiffness can be used. A typical pavement structure is assumed with strain levels of $1.0 \times 10^{-4}$ mm/mm for stress controlled condition and $5.0 \times 10^{-3}$ for strain controlled conditions. Specifying a minimum fatigue life of $1.0 \times 10^6$ cycles, the required mixture stiffness is approximately $3 \times 10^9$ Pa for a PI value in the range of (-0.5 to 0.0). Using a volume concentration of 13% bitumen in a typical asphalt mixture, the maximum allowable bitumen stiffness at 0.015 second loading time should be 50,000 kPa. To insure proper application of this limit the PI value of the aged binder should be less than 0.0. In the specification system shown in Table 3, the S(0.015) is limited and also the PI value for the PAV aged material;

- **For low temperature cracking** the stiffness at 60 seconds is estimated at temperatures that are 10°C higher than the minimum grade temperature. The shift in temperature is used to offset the effect of short loading time of 60 seconds as used in the SuperPave specifications. In addition, the logarithmic creep rate ($m(60)$) should also be controlled to minimise stress build up in bitumen due to high elasticity. Using the properties of the Pen 150-200 and assuming that the bitumens of this grade performed well in cold climates in SA, the limits of S(60) = 400 000 KPa and $m(60) = 0.300$ could be derived.

**Disadvantages of the proposed grading system**

Although the proposed grading system shown in Table 3 appears reasonable and does not depend on using expensive sophisticated testing devices, one should not ignore some of the important shortfalls of such a system. These shortfalls could be resolved by gradual replacement of the estimated engineering properties with actual measured values using rheometers and extensiometers.

The reasons for these are the following:
Nomographs are only approximate and show general trends rather than accurate values of stiffness or elongation at break; the nomographs are based mostly on conventional unmodified bitumen. It is well known that modified bitumens are more complex rheologically than...
conventional bitumens and thus these nomographs could be misleading;
• Accumulation of damage and sensitivity of service life to traffic conditions are not directly considered and using a multiplication factor of 10 to consider speed or volume is only an approximation;
• Such system will need continuous verification and calibration to establish predictability and build confidence in estimated engineering properties.

**Recommendations**

The paper shows how the Bitumen Test Data Chart (BTDC), and the van der Poel nomograph, which is based on penetration and softening point, could be used to link the empirical test results to performance related properties such as stiffness and strength and how these derived measures could be linked to traffic volume, traffic speed and pavement design temperatures similar to the SuperPave PG system. The approach is used to discuss the current South Africa Specification and to propose a possible performance grading system for South Africa using actual climatic and traffic data.

It is apparent that there are tangible benefits in using a performance grading (PG) system for binders compared with solely empirical testing and reliance on experience for binder selection. The PG system offers:

• A systematic approach to taking account of climate, traffic speed and degree of traffic loading in the area that the binder is to be used thus minimising subjective and non-optimal binder selection, and a potentially unified approach for adjudicating binders regardless of whether they are unmodified or modified (although more developmental work is required before the Superpave PG system is fully functional in this respect).

It is possible to establish an indirect PG system without the use of costly binder testing equipment e.g. rheometers etc. However, there are differences between a direct PG system e.g. Superpave, and indirect PG system as proposed in this paper.

Certain assumptions need to be made to develop the proposed indirect grading system with regard to creep stiffness and elongation at break. It is recommended that actual measured values for such engineering properties be obtained for the relevant binders using rheometers.
The N7 route between the intersection with the N1 and kilometre 18 north of the intersection (direction of Malmesbury) needed upgrading to carry the predicted 9 million 80 kN standard axle loads over the design period. Cracks in the surfacing showed that water ingress into the base layer was an important reason for the current state of the road. The existing base layer consisted of a good quality crushed stone (G2) material, the subbase layer of a granular G5 material and the subgrade of sandy material (G7).

Due to the fact that the base materials are of a good quality, cold mix recycling was considered a cost-effective method for the rehabilitation of the pavement. To save transportation costs of a new base material it was chosen to recycle the top 200-250 mm of the pavement in situ with a Wirtgen WR-2500.

For the cold-mix recycling two different bituminous binders are frequently used i.e. bituminous emulsion and foamed bitumen. The two binders have different characteristics and it is dependent on the type of aggregate, the moisture content, the climate, etc., which is the binder of choice.

The quality of the plain G2 material is higher than the two blends. A logical conclusion is to continue the research with the plain G2 aggregate mix. For the N7 project, however, it could not be guaranteed that only G2 material would be mixed without accidental addition of G5 material. Basing the research on the G2 material only can therefore result in conclusions that are to optimistic. The addition of the crusher dust showed higher results than with the addition of G5, but the difference in strength is not significant and importing crusher dust onto the site is...
expensive. Therefore, it was decided to continue the research with the blend of 80% G2 and 20% G5. Triaxial testing was also considered for the G2 + G5 blend. This included monotonic and dynamic testing. Only the results of the monotonic triaxials are provided below, including samples prepared from a trial section.

**Conclusions**

The research has shown that for the N7 there is no obvious choice between bituminous emulsion and foamed bitumen. Other factors, such as constructability became deciding factors. The field moisture content of the granular layers that were recycled, which was close to optimum moisture content, dictated that the addition of fluids would have to be limited to a minimum to ensure that compaction was achievable without first drying back the mixture. This could be best achieved with foamed bitumen and the rehabilitation project proceeded with this option rather than...

**Figure 3: ITS test results for different aggregate blends**

<table>
<thead>
<tr>
<th>Bitumen</th>
<th>Aggregate</th>
<th>Cement (%)</th>
<th>Bitumen (%)</th>
<th>C (MPa)</th>
<th>$\phi$ ($^\circ$)</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam</td>
<td>Laboratory</td>
<td>1</td>
<td>2.3</td>
<td>0.414</td>
<td>44.2</td>
<td>-</td>
</tr>
<tr>
<td>Emulsion</td>
<td>Laboratory</td>
<td>1</td>
<td>2.3</td>
<td>0.374</td>
<td>48.4</td>
<td>-</td>
</tr>
<tr>
<td>Foam</td>
<td>Trial Section</td>
<td>1</td>
<td>1.0</td>
<td>0.420</td>
<td>32.8</td>
<td>0.997</td>
</tr>
</tbody>
</table>

*Table 5: Test results monotonic triaxial test*
than bitumen emulsion. The mix that was used in the field was stabilised with 1% cement and 2.3% foamed bitumen.

The tensile strength of the material (tested with the ITS) is good, considering the short curing time. The tensile strength is only dependent on the moisture.

The cohesion and angle of internal friction results are similar for foamed bitumen and bitumen emulsion treatment, and because of a slightly higher cohesion and a slightly lower angle of internal friction the foamed bitumen, in this case, could be expected to exhibit slightly less stress dependency than the bituminous emulsion mix.

The cohesion and angle of internal friction results are similar for foamed bitumen and bitumen emulsion treatment, where foamed bitumen is a little less stress dependent in proportion to the bitumen emulsion.

Stabilised cold-mix materials exhibit stress dependent behaviour similar to that of granular materials.
The author claims that current specification used in South Africa for the strength of aggregates for bituminous surface seals is probably too stringent for low volume roads.

South Africa has a large network of unsealed roads, which carry significant traffic and warrant, on both social and economic grounds, upgrading to sealed standards. Aggregate for surfacing stone is currently very tightly specified and as a result, the construction of conventional bituminous surfacings is expensive and often requires haulage of suitable aggregate over large distances.

Upgrading of many of rural unsealed roads can be carried out cost-effectively using marginal base materials and thin pavement structures, and it is considered perhaps unnecessary to use the standard surfacing stone specification. The use of marginal surfacing stone can have significant cost savings but it does, however, have associated risks. Wright et al indicated that savings of up to 30% of the surfacing stone cost and as much as 7% of the total cost of the seal can be achieved by using marginal aggregate.

This paper discusses an investigation using the Transportek Heavy Vehicle Simulator (HVS) to determine the impact of using aggregates softer than specified in chip seals and to propose possible relaxations in the currently specified strength requirements.

**Background**

The investigation made use of various aggregates screened from natural materials or prepared by crushing boulders of appropriate materials, including a control sample of crushed quartzite.
Relevant aggregate properties are summarised in Table 1.

The conclusions drawn from this study were:

- For light pavement structures, a significant relaxation of the current aggregate specifications is possible;
- Depending on the average daily heavy traffic, minimum 10% FACT values of 80, 100 and 150 kN were proposed compared with the current minimum specified value of 210 kN;
- Rolling of the aggregate during construction should be limited to the use of pneumatic tyred rollers.

It was also clear that for lightly trafficked roads, limited breakdown of surfacing aggregate does not necessarily mean failure of the road. Precautions such as precoating the aggregate, providing a good penetrating prime to strengthen the top of the base, applying a fog spray on top of the aggregate and trafficking the seal (preferably with construction traffic immediately after completion of construction) will improve the performance of seals with marginal aggregates.

### Table 1: Summary of selected material properties

<table>
<thead>
<tr>
<th>Material/Property</th>
<th>Quartzite</th>
<th>Sandstone</th>
<th>Crushed Calcrete</th>
<th>Screened Calcrete</th>
<th>Ferricrete</th>
<th>Chert</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% FACT (kN)</td>
<td>315</td>
<td>100</td>
<td>105</td>
<td>145</td>
<td>42</td>
<td>86</td>
<td>42</td>
</tr>
<tr>
<td>10% FACT (wet) (kN)</td>
<td>266</td>
<td>97</td>
<td>85</td>
<td>102</td>
<td>23</td>
<td>64</td>
<td>41</td>
</tr>
<tr>
<td>10% FACT ratio (w/d)</td>
<td>84</td>
<td>97</td>
<td>81</td>
<td>70</td>
<td>55</td>
<td>74</td>
<td>98</td>
</tr>
<tr>
<td>Riedel &amp; Weber value</td>
<td>0.5</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Bulk relative density</td>
<td>2.8</td>
<td>2.58</td>
<td>2.54</td>
<td>2.53</td>
<td>2.32</td>
<td>2.42</td>
<td>1.84</td>
</tr>
<tr>
<td>Apparent relative density</td>
<td>2.82</td>
<td>2.67</td>
<td>2.72</td>
<td>2.72</td>
<td>2.95</td>
<td>2.95</td>
<td>2.3</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td>0.2</td>
<td>1.2</td>
<td>2.6</td>
<td>2.7</td>
<td>9.2</td>
<td>3.9</td>
<td>10.9</td>
</tr>
<tr>
<td>Flakiness index (%)</td>
<td>22.7</td>
<td>25.2</td>
<td>7.7</td>
<td>5.5</td>
<td>3.6</td>
<td>9.7</td>
<td>16.4</td>
</tr>
<tr>
<td>Average least dimension (mm)</td>
<td>9.8</td>
<td>6.9</td>
<td>7.9</td>
<td>8.3</td>
<td>7.7</td>
<td>7.7</td>
<td>6.6</td>
</tr>
</tbody>
</table>
The following materials were used in the HVS test trials:

- Quartzite (control);
- Screened calcrete;
- Screened chert;
- Screened sandstone.

Sections were also constructed using pre-coated material to evaluate the effect of pre-coating on the actual performance of the marginal materials tested. The following materials were used:

- Pre-coated screened calcrete;
- Pre-coated screened chert;
- Pre-coated screened sandstone.

In addition, a sample of crushed silcrete from Botswana was tested. This material had a dry 10% FACT of 265 kN and a wet value of 165 kN. The wet-dry ratio was thus only 63%, classifying this as a marginal aggregate in terms of traditional specifications.

Based on a small-scale laboratory and field investigation using the HVS, the author proposes a relaxation of aggregate strength specifications for lightly trafficked roads as shown in the blue box below:

<table>
<thead>
<tr>
<th>Traffic Intensity</th>
<th>10% FACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3 heavy vehicles per day</td>
<td>80 kN</td>
</tr>
<tr>
<td>3 - 6 heavy vehicle per day</td>
<td>100 kN</td>
</tr>
<tr>
<td>6 heavy vehicles per day</td>
<td>150 kN</td>
</tr>
</tbody>
</table>

Precoating of the low strength aggregates results in a significant improvement in their performance.

It should be noted, however, that the HVS could not simulate particle whip-off by faster traffic, particularly of crushed aggregate particles. While this is recognised as an unavoidable deficiency in the experiment, close observation of the test panels indicated that voids were not formed in the seal. For lightly trafficked roads, treated periodically with a fog spray, it is considered that low strength aggregates can be successfully utilised.
In recent years, much of the Gauteng Heavy Vehicle Simulator (HVS) related research has focussed on foamed bitumen and emulsified bitumen treated materials (FBTMs and EBTMs), with specific emphasis on developing structural design models for incorporation into the South African Mechanistic-empirical Pavement Design Method (Theyse, 2000).

This paper discusses the typical behaviour of FBTMs and EBTMs and selects appropriate transfer functions based on this behaviour. The development of transfer functions for these materials is discussed, detailing the data sets used, the analyses procedures and the enhancements made to the procedures and models as progress was made. The transfer functions developed to date are presented and the limitations thereof discussed.

It must be noted that these are not the only HVS tests on EBTMs, but they are the only tests for which the complete set of necessary laboratory and HVS data were collected. In all the above sections, multi-depth deflectometers (MDDs) were installed to collect information on elastic deflections under a load, and the permanent deformation at various depths in the pavement.

These data are used extensively in the analyses. On all the HVS sections included above, at least two HVS sections were tested at each test location. The tests include a test using a 40 kN wheel load (E80 axle load) and another test at a higher load. All the HVS data are detailed and analysed in the references given.

Behaviour observed under the HVS

The typical behaviour observed in the early stages of an HVS test is that the resilient modulus of the treated base layer starts of at a relatively high value and then decreases under the action of traffic until a constant resilient modulus is reached. This occurs relatively early in the life of the pavement, and can occur rapidly under heavy traffic loading.

The constant modulus reached is typically similar to the modulus of the untreated parent material and has been referred to as the...
“equivalent granular state”. This term is somewhat misleading because the material is equivalent in resilient modulus only, and not in the condition of the material, i.e., the treated material is not in a loose, particulate state. To reduce the confusion, this “equivalent granular state” will be referred to as the “constant stiffness state”.

**Strain-at-break test**

The strain-at-break test is a four-point monotonically loaded flexural beam test that measures the flexibility and tensile strength of treated materials (Theyse, 2000). The flexibility is measured by the strain-at-break and the tensile strength is measured by the stress-at-break. The test was performed on all the materials used to develop the transfer functions. The effect of compaction and moisture regime was also by means of monotonic triaxial tests, as shown in Figure 4.

![Figure 4: Maximum allowable principal stress at various combinations](image)

**a) Phase 1 (stiffness reduction) life as a function of the strain ratio**

The duration of Phase 1 and strain ratios are plotted in Figure 6 for the three sets of materials. To obtain the fatigue life transfer function, a log-linear model of the form shown in Equation is fit to the data, as illustrated by the three straight lines in the Figure.

\[ N_{ef} = a(SR_e)^b \]
b) Permanent deformation transfer function:

Permanent deformation transfer functions were developed separately for foamed bitumen and emulsion materials. A log-cubic model was used as shown in Figure 8.

Figure 6: Phase 1 (stiffness reduction) life transfer functions

Figure 8: Laboratory predicted and HVS structural capacities for EBTMs (17% plastic strain)
A comparison of predictions developed from this data is shown in Figure 9.

Conclusions

This paper describes the use of HVS and laboratory data to develop mechanistic-empirical structural design models for foamed bitumen and emulsified bitumen treated materials. Two types of transfer functions are developed to capture the two-phase behaviour of these treated materials, firstly, a reduction in modulus, and secondly, permanent deformation.

Transfer functions have been developed over the last few years in an incremental manner, and the paper describes the procedures used to develop the transfer functions and discusses any changes made to the procedures during the analyses. The paper attempts to highlight the continual improvements made to the analysis techniques, which improve the final results.
Traditionally the contractor is required to develop an asphalt mix design that complies with specific empirical and or performance related criteria. However, it has been found that compliance with these design criteria, does not necessarily guarantee future performance of the asphalt mix.

This is specifically a problem where it concerns resistance to deformation and distress due to wet trafficking. The engineer is faced with the dilemma that new mix compositions (or designs) can only be assessed after having been exposed to traffic loading over a period of time. For this reason, the specification calls for rut resistance tests to be performed as a final check before the mix can be approved. This paper discusses a case study in which accelerated pavement testing (APT) using the model mobile load simulator (MMLS3), was used to address this problem (ITT,2003).

Asphalt surfacing and base course trials for rehabilitation of the 03 - 21R runway of Johannesburg International Airport, were constructed with approval of the engineer, after complying with all laboratory test criteria.

Subsequently, rutting performance of the mixes proved to be suspect under MMLS3 field trafficking. Gyratory compaction and dynamic creep performances did not predict excessive deformation under the MMLS3 trafficking.

Several studies served as benchmarks for the interpretation of the results of rutting performance under MMLS3 trafficking. In two extensive studies (Smit et al, 2003, Martin Epps et al 2002, and Walubita et al, 2002), the relationship between truck trafficking and MMLS3 trafficking was investigated. It was shown that it is reasonable to relate the rutting performance of the respective trafficking systems on a one-to-one basis, provided...
temperature, load frequency, wheel path wandering, and effective traffic volume is taken into account. It was also shown that extrapolation of the rutting results after the application of 100,000 or 200,000 MMLS3 axles gives a very good estimation of the ultimate rutting of the pavement after 1 million MMLS3 axles.

These findings were used to draft the following interim rutting protocols that are currently being used to evaluate rutting performance of asphalt under dry and wet heated trafficking with the MMLS3:

- The rutting performance can be analysed fundamentally by considering vertical stress profiles under the respective wheels are used for purpose of comparison. The limiting rut depth has to be determined in terms of expected traffic, lateral wander, lateral load wander and load frequency, climatic conditions during life cycle, tyre pressure and layer thickness;
- The following are general guidelines for field rutting performance at critical temperature (generally 50°C or more) and 7200 load applications per hour are:
  - <3mm after 100 000 MMLS3 load applications on highways; and
  - <1.8mm after 100000 MMLS3 load applications on airports.
- For determining moisture susceptibility of asphalt pavements using wet trafficking after 100 000 applications at 50°C heated wet MMLS3 axles:
  - SCB residual strength of hot mix asphalt 80%;
  - SASW residual stiffness (Lee et al. 1997) 80%; and
  - SCB fatigue ratio 50% for hot-mix asphalt.
- Composite pavements require special consideration to evaluate entrapment of water;
- Critical temperature conditions are determined from the hottest seven (7) period according to SHRP Manual 648A (Huber 1994) with due regard to the local study reported by Everitt et al (1999).

In order to estimate full scale rutting from scaled MMLS3 tests, certain adjustments need to be made. These include:

- Adjustment for stress distribution under the smaller surface contact area of the MMLS3 wheel (divide by 0.4 to 0.45);
- Adaptation for geometry of test set-up, whether in the laboratory or in the field (see Table 7 below) (multiply by factor);
- Adjustment for lateral wander in real life versus channelised MMS3 tests (multiply by 0.6).

If all the above factors are taken into account, the effective
downward rut due to the deformation of the upper 95 mm after ten years of trafficking is theoretically estimated as set out in Table 8.

**Laboratory MMLS tests**

During construction it was noticed that the rutting of two sections of newly completed runway, manifested different early rutting.

<table>
<thead>
<tr>
<th>Material type</th>
<th>Field trafficked in situ</th>
<th>Laboratory trafficked cores</th>
<th>Laboratory trafficked briquettes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfacing layer</td>
<td>1.25</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Base layer</td>
<td>1.3</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1.55</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Composite layer: Surfacing + Base</td>
<td>1.27 (estimate)</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 7: Relative rutting relationship between various modes of trafficking**

In the region of the southern threshold, the surface had rutted about 3mm under traffic of departing aircraft while the rut 700m to the north was about 7-8mm deep. MMLS tests on cores from these sections yielded the results shown in Table 9.

**Table 8: Analytical calculation of downward rut of upper 95mm of HMA**

<table>
<thead>
<tr>
<th>Downward rut of surface layer (test 10)</th>
<th>(0.6 X 1.25 X 5.5mm)/0.45 = 9.2mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plus: Downward rut of base layer (test 5)</td>
<td>(0.6 X 1.55 X 1.3 X 2.8mm)/0.41 = 8.3mm</td>
</tr>
<tr>
<td>Estimated total downward rut</td>
<td>= 17.5mm</td>
</tr>
</tbody>
</table>

**Table 9: Estimated theoretical rut depth of composite surfacing and base layer under aircraft loading**

<table>
<thead>
<tr>
<th>Ch 725</th>
<th>Downward rut of surfacing and base composite as-built layers</th>
<th>(0.6 X 1.27 X 3.5mm)/0.30 = 8.9mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch225</td>
<td>Downward rut of surfacing and base composite as-built layers</td>
<td>(0.6 X 1.27 X 1.8mm)/0.30 = 4.6mm</td>
</tr>
</tbody>
</table>
Conclusions

From the results of the tested cores and the related rutting performance under MMLS3 trafficking, it was possible to establish the extent to which sections were susceptible to distress due to trafficking. The nature of the procedure is such that it provides a basis for taking account of climatic conditions during the life cycle of the pavement through a rational approach.

Overall, the procedure provides confidence in determining long-term performance characteristics of an asphalt mix even before the paving trial has been performed. The constructed rutting performance findings appear to indicate that the general protocol for limiting field rutting for aircraft may be slightly conservative. However, this is dependent on the relationship between core and field performance. It should therefore be retained until currently used relationships are further validated. The successful application of the MMLS3 design procedure is a basis for enhanced performance prediction of asphalt mixes.

This should result in measurable economic benefits. In this regard it would be prudent to implement a modest system of long term monitoring of the level of the pavement surface and the underlying base course at a number of cross sections of the runway. This will serve to increase confidence in the use of the MMLS3 system and the related performance protocols.
This paper compares the strength parameters and optimum foamed bitumen contents of foamed bitumen treated materials. Correlations between Indirect Tensile Strength (ITS) and Unconfined Compressive Strength (UCS) of 100 mm and 150 mm diameter briquettes are established for 23 samples treated with varying quantities of foamed bitumen and cement/lime. The samples were taken from three different project sites in South Africa and Greece. Optimum foamed bitumen contents derived from the different strength parameters are compared and the treated materials are classified based on the correlations established.

Results indicate that the current use of UCS as a primary parameter for treated material classification and the use of the soaked 150 mm ITS as an indicator of treated material moisture sensitivity is not necessary. The results highlight inadequacies in the current material classification system.

Background

In the past, 100 mm diameter (Marshall) briquettes were used for mix design and field quality control for foamed bitumen treated materials (Lewis et al., 1995). The ITS was used as an indicator of relative strength in the dry state and as an indicator of moisture sensitivity in the soaked state.

Subsequent research led to the release of Interim Technical Guidelines: The design and use of foamed bitumen treated materials, TG2 (Asphalt Academy, 2002). The mix design procedure in TG2 is more extensive than was used previously, and 150 mm rather than 100 mm diameter specimens are used.

The TG2 guideline classifies foamed bitumen treated materials

Extract from CAPSA’04 paper:

Correlations between different ITS and UCS test protocols for foamed bitumen treated materials

M Houston
Loudon International

F Long
CSIR Transportek

It is redundant to use both the UCS and ITS tests
according to ITS and UCS on 150 mm diameter briquettes compacted at 100% Modified AASHTO compaction. Based on the treated material classification, structural design calculations could be made. The motivation for the use of both the UCS and ITS was to capture both the compressive strength and the flexibility of the mix.

**Briquette preparation**

**100mm diameter briquettes:**

The 100mm diameter briquettes were prepared in accordance with past practice (Lewis et al., 1995). This method was adapted from the Marshall method (for asphalt) with modifications to the compaction temperature and curing procedures. Soaked briquettes were subjected to 24 hours in water at 40°C as opposed to soaking under a vacuum for 1 hour.

The properties and moisture regimes tested included:

- Dry ITS (ITSdry100). Briquettes were cured at 40°C for 72 hours. This procedure dried the briquette out to less than 1% moisture content without excessively softening the bitumen;
- Soaked ITS (ITSwet100). Dry briquettes were soaked in water for 24 hours at ambient temperature (approximately 25°C).

**150mm diameter briquettes**

The 150mm diameter briquettes were prepared in accordance with TG2 (Asphalt Academy, 2002). The properties and moisture regimes tested included:

- ITS at equilibrium moisture content (ITSeq150). Briquettes were allowed to stand unsealed at ambient temperature for 24 hours and then 48 hours in a sealed plastic bag at 40°C. The moisture content using this method is aimed at simulating field equilibrium moisture. The cured moisture contents were a function of the compaction moisture content (which varied from sample to sample) and material type; they were found to be between 2.5 and 6%;
- Soaked ITS (ITSwet150). Briquettes cured to equilibrium moisture content were soaked in water for 24 hours at ambient temperature (approximately 25°C);
- The UCS tests were performed at equilibrium moisture content, i.e. the same curing procedures as the ITSeq150 briquettes were followed.

**ITS and UCS Relationships**

From the investigations it was apparent that correlations could be established between many of the variables tested, with varying degrees of fit.
Conclusions

The following conclusions and recommendations are made:

- A FB1 treated material can be classified with 100 mm diameter briquettes with a reasonable level of confidence. All other material classes can be derived from the ITS_{\text{dry100}}, but with a low level of confidence. It is therefore recommended that 150 mm diameter briquettes be used for mix design and material classifications, and for field quality control;
- ITS_{\text{eq150}} can be used to derive UCS and ITS150wet. It can also be used, on its own, to determine the optimum foamed bitumen content;
- The ITS_{\text{wet150}} tests show a good correlation with the IT_{\text{Seq150}}. This may demonstrate either that the ITS_{\text{wet150}} is not a good indicator of the moisture sensitivity of a mix or that ITS_{\text{eq150}} is a satisfactory indicator of moisture sensitivity. It is not possible from these data to determine which statement is more correct. It is recommended that an alternative test for moisture sensitivity be investigated;
- The mix design procedures and classification system of foamed bitumen treated material contained in TG2 should be revised, as it is redundant to use both the UCS and ITS tests. A test that actually measures the flexibility of a material, such as the strain-at-break four-point beam test, should be investigated further for possible use in the material classification;
- Use of either the UCS or ITS in the mix design procedure should be sufficient for determining the optimum binder content.

![Figure 3: ITS_{\text{dry100}} versus ITS_{\text{eq150}}](image-url)
**Figure 7.** $\text{ITS}_{eq150}$ versus $\text{ITS}_{wet150}$

$y = 0.670x + 14$
Correlation = 0.92

**Figure 9.** $\text{UCS}$ versus $\text{ITS}_{wet150}$

$y = 0.117x - 8$
Correlation = 0.92
A self-regulation initiative to address the heavy vehicle overloading problem in South Africa

PA Nordengen                      F Oberholzer
CSIR Transportek                  Forest Engineering

Heavy vehicle overloading continues to be a major problem in South Africa despite efforts at more effective overload control by the authorities. Overloading causes premature road deterioration and, together with poor vehicle maintenance and driver fatigue, contributes significantly to South Africa’s poor road safety record.

One of the tasks of the Department of Transport’s National Overload Control Strategy was to investigate the possibility of implementing some form of self-regulation in the heavy vehicle transport industry. An international review found that the National Heavy Vehicle Accreditation Scheme (NHVAS) that has been implemented in Australia over the past few years has a number of components appropriate to the South African situation. The aim of the initiative is to increase the responsibility of the transport operator and/or consignor/consignee for loading vehicles correctly, thereby reducing the occurrence of overloading and under-loading.

The self-regulation initiative was developed and implemented as the NHVAS and covered two distinct modules: mass management and maintenance management. A third module for fatigue management is likely to be launched during 2004.

The NHVAS allows heavy vehicle operators to demonstrate, through audit of their transport management systems and vehicle or driver assessments that their vehicles and drivers comply with regulatory standards.

In reviewing the Australian scheme, which extends beyond vehicle mass/overload control to the crucial safety issues of vehicle condition and driver fatigue, it was clear that the fundamentals are well-grounded and that the...
scheme was developed with input from a wide range of stakeholders.

The paper describes an initiative in the timber industry which resulted in a pilot project, initially funded by the Department of Trade and Industry (DTI) and Forestry South Africa under the DTI’s Sector Partnership Fund (SPF). The project commenced in August 2003 and to date a number of aspects have been addressed, all of which have involved consultation with representatives of the timber industry and other role players:

- Underlying principles and business rules;
- Rules of compliance for accreditation;
- Proposed incentives/concessions for accredited operators;
- Heavy vehicle management system incorporating vehicle loading, vehicle maintenance, load safety and driver wellness;
- Monitoring of vehicle combination masses at destinations (pulp mills);
- Implementation plan (Application, pre-accreditation and accreditation phases);
- Development of training modules;
- Training workshops for senior management;
- Meetings with the KwaZulu-Natal Department of Transport, Mpumalanga Provincial Government and TRAC (N4 Maputo corridor concessionaires).

The project is essentially driven by the private sector with involvement and support from government. It is viewed as a proactive response to the impending amendments to the Road Traffic Act such as extending the responsibility of overloading to the consignor and/or consignee and the introduction of a road damage “fee” over and above fines for overloading.

**Vehicle load monitoring**

An important aspect of the project is the load monitoring that is done (in the case of the timber project) at the consignee weighbridges. Currently, only the total vehicle or combination mass and not the individual axle and axle unit masses are measured and monitored. The weighbridge data is made available to the project team, allowing the monitoring of overloading and under-loading by operator and by mill. This enables a certain amount of benchmarking to be done and reporting on best and worst practice in the industry.

The tare masses of the various vehicle combinations are also monitored, again giving an indication of best practice. For example, the tare mass of seven-axle vehicle combinations (1222) used for transporting timber has reduced from approximately 27 tons in 1992 to less than 17 tons in 2002. This has resulted in an increase in the legal payload of 34%.

Although not considered as one of the rules of compliance, a
prerequisite for becoming an accredited operator is that 96% of all vehicle/combination masses must fall within the legal load plus the tolerance for a minimum of three consecutive months. Opinions have been expressed that allowing 4% of vehicle trips to be prosecutable (more than 5% overloaded) is unacceptable.

However, a pragmatic approach has been adopted initially. In any event, an improvement by an individual operator from 40% (or as much as 100%) of vehicle trips being prosecutable to less than 4% is a significant improvement! These statistics would never be observed at provincial weighbridges, as in most cases less than 5% of all overloaded vehicles are weighed at provincial weighbridges and in addition, there are numerous routes in the country where no overload control is done at all.

### Phases of accreditation

Three phases of accreditation have been defined as part of the pilot project:

- **Application:** During the application phase, the transport operator is required to attend a Load Accreditation Programme (LAP) training workshop (where the Heavy Vehicle Load Management System manual is distributed) and commence with meeting the requirements of the rules of compliance. In the case of “mass” industries, monitoring of the vehicle loads either at the origin or destination would commence. At this stage the prerequisite for advancing to the pre-accreditation phase is to achieve a minimum of 96% of vehicle combination masses complying with the legal load plus the 5% tolerance for three consecutive months;

- **Pre-accreditation:** At this stage of the project the LAP steering committee conducts an audit once the transport operators indicates that he is ready for an external audit.

- **Accreditation:** Operators will be awarded full accreditation once the system has been implemented through the South African National Accreditation System (SANAS). Audits (and certification) will then be carried out by SANAS-approved accreditation bodies. Monitoring of the vehicle loads will continue during the accreditation.

The success of the project is to a great extent due to the active involvement of the consignees and consignors

In some cases, where not all the requirements have been met, one or more follow-up audits are required. To date, three transport operators have been pre-accredited;
phase. Annual audits will be required by an auditor from a SANAS-approved accreditation firm.

Conclusions

Since vehicle monitoring commenced in November 2002, the incidence of prosecutable vehicle overloading (overloads greater than 5%) in the timber industry has reduced by 24% (as of June 2004). Furthermore, the average overload per vehicle has reduced by 14% during the same period. These figures are impressive, particularly as only three transport operators have been accredited to date. Others are in the application phase, preparing for an external audit.

The success of the project is to a great extent due to the active involvement of the consignees and consignors. At certain mills a penalty has been introduced which is applied to any vehicle that arrives at the mill and is found to be more than 5% overloaded on total vehicle mass. At these mills, improvements of more than 80% in terms of incidence of vehicle overloading have been observed.

The enactment of the pending legislation regarding the responsibility of the consignor and/or consignee in terms of ensuring that vehicles are legally loaded is likely to add significant momentum to the LAP initiative.
Ninham-Shand ad here
Member contributions
Ultra thin friction courses (UTFCs) are specialised asphalt wearing courses, designed specifically as cost-effective surfacing or re-sealing layers, with enhanced long-term surface texture and sealing properties. Worldwide, these thin surfacing types are typically developed as proprietary products designed for specialised application.

The authors have undertaken comprehensive market research into the development of a range of application differentiated UTFCs, each tailor-designed for specific southern African applications. This work was done for Zebra Bituminous Surfacing as part of a product development initiative. It was found that this type of surfacing offers greater:

- skid resistance;
- road noise reduction;
- spray reduction; and
- surface sealing over the full design life at cost-effective rates compared to conventional alternatives.

The strict performance criteria developed for these specialised products, and the binder and sealing membrane durability aspects, were thoroughly tested and analysed. Various case studies on the design and performance testing and product selection process were undertaken in conjunction with the Provincial Government’s Western Cape Road Branch, including the N7 resurfacing contract between Cape Town and Malmesbury.

User requirements focus on safety and comfort, while the road authority requires low cost and long-term durability

Need for UTFCs in southern Africa

The road user and the road authority have different needs and expectations concerning the performance of road surfacings, especially in developing countries, where the road authorities’ budget constraints are generally high.
User requirements focus on safety and comfort while the road authority requires low cost and long-term durability. This translates into a complex series of engineering properties to be addressed by the road designer, including:

- adequate low speed and high speed skid resistance;
- low noise production from vehicle tyres;
- smooth ride;
- minimal spray;
- good visibility of markings; and
- low construction and maintenance costs.

The concept of ‘separation of layer functions’ argues that structural layers can meet the load bearing capacity of the pavement, while the surfacing layer design can meet road-engineering requirements. This concept has given rise to the new class of thin and ultra-thin surfacings.

**Definition and characteristics**

UTFC’s are technically defined as a special group of open to gap-graded asphalt mixes which generally have less than 25% of aggregates passing the 2.36mm sieve and the remainder of the aggregate consisting of a single size stone (6.7 mm, 9.5 mm or 13.2 mm). UTFCs are less open graded than Open-Graded Asphalt (OGA) mixes with:

- 12-19% Voids In Mix (Vim’s) against the 20-30% of OGA’s;
- 22- 30% Field Voids against 28-35% of OGA’s.

![Figure 1](image-url)
They also have greater long-term durability and design life than OGA's. A modified tack spray process is used to ensure excellent adhesion to the "base" and durable waterproofing of the interface. Thickness varies from 15mm to 22mm depending on the maximum stone size used. A rough comparison of gradings for Continuously Graded, SMA, UTFC and Open Graded mixes is shown in Figure 1.

**Case study: N7 Cape Town**

**UTFC Mix optimisation study:** Various high performance UTFC mix designs were evaluated with performance simulation testing to derive optimum mixes for use on the N7 resurfacing contract between Cape Town and Malmesbury. The design traffic was eight million equivalent 80kN axle loads and the major design requirements on this high-speed rural highway were:

- Long-term friction/skid resistance; Low spray generation;
- Low rutting potential and high durability to last 12 to 15 years.

External noise reduction was not an essential requirement.

The preferred layer properties required were therefore:

- High initial (2.0mm) and end-of life (1.5mm) surface texture;
- High interconnected field voids (16 initially, 12 at end of life);
- High durability (film thickness 10.5 micron; Cantabro) to ensure a 12 year life;
- High aggregate polish resistance (PSV 48).

Three UTFC mixes (a 13.2mm mix and two 9.5mm mixes, one of which contained more cubical aggregate) were evaluated, each at two binder contents, to identify the optimal mix.

**Observations:**

- The texture depths and interconnected voids of the 13.2mm mixes were consistently higher over the full loading spectrum;
- The visual end condition of the 13mm mixes, especially on the higher binder contents, confirmed their superior characteristics compared to the 9.5mm mixes;
- The 13mm mixes also showed 50% less rutting (2.5mm after 100 000 simulated loadings) than the best of the 9.5mm mixes (3.5 - 4.0mm rutting);
- The pendulum friction test and field tests with the Grip Tester at 50km/h and 80km/h confirmed the excellent friction properties of all three mixes with the 13.2mm mix again standing out as the best;
- Based on the main selection criteria - surface texture and interconnected voids to be optimal over the full functional life - the 13.2mm mix was identified as the preferred mix;
• All mixes satisfied the rutting resistance criteria (less than 3.5mm at 100,000 MMLS repetitions);
• The 9.5mm mix, with the less cubical aggregate, was the second best mix due to its higher durability and film thickness compared to the other 9.5mm mix. However, this mix was only recommended for areas of traffic loading lower than 7 million E80’s.

Conclusions

The study concluded that these UTFC’s offer better all-round and long-term functional properties than Coarse Graded Asphalt (CGA), Stone Mastic Asphalt (SMA) and Surfacing Seals. They are comparable to, and in some cases less expensive than the conventional alternatives, especially if the accident cost saving aspect is discounted.
In the March 2003 edition of the Sabita Digest there was an article on the historical development of the pre-fabricated, bitumen-rubber bound road patch developed by AJ Broom Road Products (Pty) Ltd.

To fully appreciate the many advantages of prefabricated products for road maintenance it is important to break down the operation of repair using conventional hot or cold pre-mixed asphalt for routine and emergency road maintenance.

In the case of a pothole, the crew will excavate all poor quality surface and base material as well as increase the area of the excavation. This is necessary to accommodate the compaction machinery needed to compact the base-course material that is back-filled to a level between 20mm and 50mm below the top surface of the surrounding wearing course.

Furthermore, it is necessary to cut the edges of the excavated area square to accommodate compaction against the edges of the excavation.

These details are shown in Figure 1.

All of these operations are time consuming and in most cases result in a larger area than is necessary being repaired. With a pre-fabricated product it is not necessary to cut the excavation larger than the failure, nor is it necessary to square cut...
the edges because the pot hole is filled to the same level as the surface of the top of the wearing course, and the road patch applied over the backfilled area.

Details of the pre-fabricated method of pothole repair are shown in Figure 2.

For a comparison of the productivity of the two methods refer to Figure 3.

These factors do not take into account wastage of materials which can be as high as 35% with hot or cold pre-mixed asphalts, but nil with pre-fabricated products. There are similar but greater differences in the comparison between the utilisation of conventional and pre-fabricated materials for repairs to crocodile cracking. The most profound difference is that with pre-mixed asphalt it is necessary to excavate in a similar method to that described under pothole repairs above, whilst with a pre-fabricated road patch the product may be applied directly on top of the cracked area to reseal the wearing course. This is solely dependant on there not being considerable deformation and/or rutting.

Figure 4 shows the productivity comparison for the two methods of surface treatment. Emergency repairs necessary because of mechanical damage to the road structure caused by accidents, floods, etc. are both swift and simple to undertake anywhere and at anytime due to

Figure 2

![BRP Road Patch Diagram](image1)

Figure 3: BRP productivity factors for road maintenance activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Conventional Method</th>
<th>Using BRP Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pothole Repair (in hours/m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Clean</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Backfill</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td>Prime/Tack</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Re-seal</td>
<td>1.00</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>SUB TOTAL</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td>Equipment &amp; Transportation</td>
<td>+ 40%</td>
</tr>
<tr>
<td></td>
<td>Requirements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>3.29</td>
</tr>
</tbody>
</table>

Productivity Ratio = 8.5 x 1.0
the pre-fabricated products’ ambient temperature installation without expensive or complicated tools. The absence of a limiting storage life makes the product always available.

Many more authorities in southern Africa, Africa and overseas are seeing the benefits both technical and economic of pre-fabricated products and subsequently are specifying and using greater volumes annually. These road maintenance authorities have accepted that products should not be bought primarily on price but on comparison of the cost of various repair processes wherein different products are utilised.

<table>
<thead>
<tr>
<th>BRP PRODUCTIVITY FACTORS FOR ROAD MAINTENANCE ACTIVITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTIVITY</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>2. SURFACE TREATMENT e.g. Crocodile Cracking</td>
</tr>
<tr>
<td>- Excavate</td>
</tr>
<tr>
<td>- Box out</td>
</tr>
<tr>
<td>- Backfill</td>
</tr>
<tr>
<td>- Prime / Tack</td>
</tr>
<tr>
<td>- Re-seal</td>
</tr>
<tr>
<td>SUB-TOTAL</td>
</tr>
<tr>
<td>Equipment &amp; Transportation</td>
</tr>
<tr>
<td>Requirements</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
<tr>
<td>Productivity Ratio</td>
</tr>
</tbody>
</table>

*Figure 4BRP productivity factors for road maintenance activities*
Colas Namibia has developed a new and innovative bitumen-emulsion based technology to solve one of Namibia’s most persistent road maintenance problems.

Faced with recurring damage to the edges of roads throughout the country — damage which progressively narrowed the usable width of surfaced roads, forced heavy vehicles to travel partially on the shoulders when facing oncoming traffic, and impacted negatively on general road safety — the Namibian Road Authority sought a cost-effective rehabilitation measure which was both possible within the budget constraints of the Namibian Department of Transport, and which made optimum use of scarce physical resources.

A system was developed using a coarse-graded emulsion based slurry mixture applied by a continuous-mixing slurry machine fitted with a special spreader box. Using this system, the company has now completed more than 175 km of edge-widening on a section of Trunk Road 1 between Rehoboth and Mariental.

Background

“Damage to the edge of a bituminous surfacing becomes a major maintenance problem especially if the seal width is narrow,” according to Mr Ako Jaf, a regional engineer in the former Namibian Department of Transport. “Traditional widening of the pavement with the placement of narrow but deep pavement layers is difficult and costly to construct, with the added difficulty of achieving adequate compaction using small plant. This invariably results in a post-compaction edge drop, itself a safety problem, and leads to premature failure of the widening and adjacent in situ pavement.

“The Namibian Road Authority is faced with this problem on many of its routes in the less populated areas. The road between Rehoboth and Mariental, which forms part of

The use of bituminous slurry for shoulder protection

TDistin
Colas SA (Pty) Ltd
the main North-South arterial route, carries up to 700 vehicles per day 20% of these being heavy vehicles. Although the original bituminous surfacing had been constructed to a width of 6.2 m, ongoing edge-break has reduced this surfacing to just 5.8 m in some places. This resulted in an unsafe road with high maintenance costs due to the ongoing edge-break repairs. The narrowing of the surfaced road also caused a confined feeling when travelling at 120 km/h, with heavy vehicles tending to straddle the centre-line of the road,” said Jaf.

Given the level of traffic, the recommended level of service required a minimum lane width of

- Uses large quantities of gravel—a scare resource which needed to be hauled long distances;
- Difficult to construct and achieve proper compaction of the narrow strip with small plant;
- Failure and/or post compaction at the joint of the newly placed material and existing surface;
- Lengthy construction periods resulting in longer traffic delays.

These problems dictated a more cost-effective and efficient method which would render a fit-for-purpose remedial treatment within the limited budget constraints of the Namibian Department of Transport.

“The initiative was taken in 1998 when I was regional engineer responsible for this section of road,” Jaf said, “and I approached Mr Johann Essmann of Colas Namibia (formerly Road Binders) to develop a non-traditional solution for widening the surfacing. The desired outcome of our investigation was to find a low-cost treatment, which would perform adequately under the traffic loading (particularly under the outer wheel of heavy vehicles) and thus improve road safety. The construction method employed should also result in reduced

---

**The desired outcome was to find a low cost treatment which would perform adequately under traffic loading**
gravel usage and lower maintenance costs.”

The end result was the development of what is today known as the ‘Akoseal’ — an edge-widening process using a coarse-graded emulsion-based slurry mixture.

**Investigation**

The edge-breaks manifested in the breaking away of the surfacing at the edge of the carriageway and was pronounced all along the entire route. The unpaved shoulders exhibited extensive wear, which resulted in a step between the edge of the surfacing and the shoulder. From visual inspections it was determined that the shoulder gravel was more or less a G4 quality material. Although no tests were done it was felt that the in situ material had sufficient bearing strength to continue carrying the heavy vehicle loads - probably as a result of increased compaction by traffic over the years.

Falling Weight Deflectometer tests were conducted during 1998, and the average remaining life of the pavement was estimated at 14.1 years. This meant, from an economic perspective, that an appropriate holding action was needed to postpone heavy rehabilitation for at least 10 years.

**Construction Methodology**

An inspection of the damaged edges revealed that the existing gravel surface was still intact. Any attempt to cut and level the existing surface with a grader resulted in larger rocks being dislodged, disturbing the density of the in situ material. Also, placing and compacting a levelling coarse of gravel, in order to minimise the use of gravel, led to the formation of a biscuit layer.

It was concluded that if the gravel shoulder could be protected from the effects of the traffic, the application of a coarse-graded slurry, placed with a continuous-mixing machine, could be a cost-effective remedial treatment for widening the surfacing.

The shoulder was prepared as follows prior to the application of the slurry:

- The shoulder was first treated with weed killer before removal of the existing vegetation by hand;
- The existing shoulder was then swept by hand to remove any loose material.

![Figure 1: Primed shoulder](image)
This material was reused in later re-shouldering;
- Inverted bitumen emulsion prime was then sprayed at an application rate of 0.9 litres per square metre on the swept shoulder and left open to cure.

The use of slurry seals for resealing existing bituminous surfaces is fairly common practice in Namibia. However conventional slurry does have limitations in that it cannot be applied in a single layer with a thickness greater than 1.5 times the maximum aggregate size. For the COLTO coarse 9.5 mm graded slurry, this limits the overlay thickness to 15 mm.

In order to place a thicker layer which could withstand the heavy traffic loading it was necessary to utilise a continuous graded aggregate with larger size stones. A blend of 13.2 mm and 9.5 mm single sized stone aggregate and -6.7 mm crusher dust was used. Anionic stablemix 60% emulsion was added to the aggregate and cement was used as a setting agent. Sufficient water was added to achieve the desired workability of the mix. It was important that the mix had sufficient workability to flow into the crevices of the existing road edge, but still stiff enough to form a sharp outside edge after placement.

A string line was erected on the shoulder to demarcate the outside edge. The coarse graded slurry was mixed in a continuous mixing machine and poured into a purposely-designed box for placing in a single pass. Initially the slurry was poured via a chute and spread by hand between the road edge and steel shuttering. Once confidence had been built up in the performance of the slurry mixture, a spreader box was used to place the slurry, eliminating the need for shuttering.

**Average depth**

The box was designed to be dragged from an arm behind the machine. The bulk of the box ran on the existing surface, while the outside edge operated on a spring-loaded skid. A strike-off plate ensured that the freshly placed slurry would be kept level with the existing road surface. The average depth of the slurry was 35 mm, with a maximum of 50 mm at times. The fresh, widened slurry edge was rolled with a pneumatic-tyred roller three hours after placement, prior to opening to traffic.

*Picture 2: Placing coarse graded slurry*
Costing and benefits

The typical daily production rate achieved for mixing and laying the slurry for the edge widening was 60 m³. This equated to a unit cost rate of R14.43 per running metre or R1,374.00/m³ for mixing and placing the slurry to a width of 300 mm by 35 mm deep. This cost is, however, minimal when compared to the conventional method of boxing out and replacing with gravel and surfacing with asphalt, which would have been in excess of R45 per running metre.

This rate excludes compaction of the slurry, labour for traffic control and sweeping the base. The cost of priming the shoulder was R1.18 per running metre. All the latter costs would need to be included in both methods of construction.

The main benefits of widening the road surfacing using a coarse-graded slurry placed with a continuous-mixing machine can be summarised as follows:

- Provides a low cost alternative to conventional widening techniques;
- Reduces the construction time considerably;
- Minimises the disruption to traffic during construction;
- Minimises the use of non-renewable materials;
- Reduces the routine maintenance costs;
- Improves the safety by providing a wider carriageway without a sharp drop-off.

Conclusion

“The slurry method of edge widening has considerable time, cost and material resource advantages over conventional methods,” said Mr Ako Jaf, who is currently the division maintenance manager for the road contracting company. “However this method is only appropriate to roads where suitable shoulder material is present. This was the case on Trunk Route 1 between Mariental and Rehoboth, where some 175 km of edge-widening has been completed as part of a routine maintenance between 1998 and 2003. The decision to use coarse-graded slurry to widen the road edge — rather than conventional hot-mix asphalt — was found to be the most cost effective option at the time in light of the limited funds available.”

The method described has been successfully used on many roads in Namibia. The earlier sections are still performing well after being subjected to traffic for five years without any signs of failures.

Lastly the development and implementation of this technique can also be seen as a good example of how a partnership can work between the client and supplier to provide a cost-effective remedial solution to overcome a severe road safety problem within the confines of a limited budget for road maintenance.
Colas Ad: Modified Binders
New generation modified binder used in KwaZulu-Natal

Trevor Distin
Colas SA (Pty) Ltd

Colas’s new generation modified binder has been successfully used in a record-breaking 1,9-million litre spraying operation in KwaZulu-Natal.

The contract, the largest ever undertaken using an SE-2, specified the resealing of the 60 km four-lane undivided N2 highway between New Guelderland and Mtunzini using a modified binder conforming to the SE-2 specification for the double seal on the shoulder and slow lane. The fast lanes received a double seal constructed with an unmodified binder.

The company had to consider using a high softening point binder given the high road temperatures experienced on this section of the route in summer. A further consideration was the large percentage of heavy and light vehicles travelling in the slow lanes. This influenced the selection of an SE-2 rather than an SE-1 binder, with a minimum softening point 50°C. The problems that have been encountered with spraying an SE-1 (SBR) binder at the required minimum softening point of 57°C also supported the decision to utilise an SBS modified binder.

Background

The high volumes of traffic encountered on the majority of South Africa’s national roads, and the concomitant increase in tyre pressures, has resulted in accelerated deterioration of existing road surfaces. Research has shown that the engineering properties and performance characteristics required to withstand these traffic induced forces can no longer be adequately met by conventional penetration grade road binders. The result was a pressing demand on the blacktop industry to develop higher performance binders able to deliver more cost effective and durable road surfacings.

To answer this challenge an elastomeric binder known as COLFLEX was developed. This binder enhances the rheological properties of the base bitumen through the addition of a special grade of SBS polymer and additives. The SBS polymer used forms a highly elastic, three-dimensional network in the
bitumen, dramatically increasing the softening point and elastic recovery properties of the base bitumen. This means that a surfacing, when subjected to heavy traffic at high road temperatures, will be less susceptible to bleeding in the case of a seal, while asphalt will be more resistant to rutting.

**Storage**

In addition to its enhanced properties, the product is storage-stable at application temperatures, unlike other commonly used SBR or rubber crumb hot modified binders. It is also applied at much lower temperatures than the latter, which means cost savings in heating and less time delays on site.

**Supply**

The new modified binder is manufactured under controlled conditions in purpose designed plants. Three grades are available, all complying with the new TG1 guideline specifications for use in surfacing seals, hot-mix asphalt or crack sealing.

The modified binder for the North Coast contract was supplied from Colas’s Durban ISO 2000: 9001 listed factory to the site 120 km away. Samples were taken daily prior to spraying, and were tested on-site for compliance with the specifications. The average softening point recorded for the product was 71ºC, while the softening point of the 80/100-penetration bitumen varied between 44 and 48ºC.

**Application**

The binder was sprayed at a binder temperature of 180ºC, simultaneously across the shoulder and slow lane, with a Bearcat distributor using a 6 m spray bar. The transverse distribution of the spray bar was checked regularly using the ‘bakkie’ test method to ensure uniformity. The spray rates were adjusted according to texture depth and ball penetration values, and 30% of the 1.1-million m² of existing asphalt surface was given a texture slurry pre-treatment. The spray rate for the tack coat varied between 1.3 - 1.4 litres per m² prior to the application of the 13 mm stone, while the penetration spray rate varied between 1.0-1.1 litres per m² prior to the application of 6.7 mm

<table>
<thead>
<tr>
<th>Grade</th>
<th>Application</th>
<th>TG 1 Classification</th>
<th>Softening Point Min ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Chip &amp; spray</td>
<td>S-E2</td>
<td>57</td>
</tr>
<tr>
<td>A</td>
<td>Hot-mix Asphalt</td>
<td>A-E2</td>
<td>60</td>
</tr>
<tr>
<td>C</td>
<td>Hot pour crack sealant</td>
<td>C-E1</td>
<td>80</td>
</tr>
</tbody>
</table>

*Table 1: Application and properties*
stone. The newly constructed double seal was closed overnight before opening to traffic.

**Benefits**

Some of the main benefits derived from constructing the double seal using an SBS modified binder can be summarised as follows:

- The relative lower spray temperature of SBS vis-à-vis SBR modified binder equates to $\pm 15^\circ C$, which renders a savings in heating costs and overtime of $\pm 1.5$ hours per day;
- The high stability of the SBS modified binder supplied on this contract resulted in no reblanding or product rejections, thereby minimising on-site delays and back hauling costs;
- The higher softening point and improved adhesion of the SBS modified binder meant that the newly constructed seal could be opened to traffic sooner than the 80/100 used in the fast lane, without the risk to chips whipping off at high road surface temperatures;
- The premium of the SBS modified binder being R0.97 per litre (R2.65 vs R1.68) amounts to an increase of only 6% in the cost of construction - which is more than offset by the improved rheological properties of the binder.

**Conclusion**

The use of modified binders in the application of surface seals on roads subjected to high volumes of traffic (with a substantial percentage of heavy vehicles) can be an economical means of carrying out periodic maintenance to prolong the service life of a section of road before full rehabilitation/reconstruction is required. The degree of binder modification would be determined by the design criteria i.e., traffic, climate, existing surface texture and most importantly, the concentration of heavy vehicles on a particular section of road.

This contract demonstrated that a highly modified SBS binder, conforming to the SE-2 specification, can be sprayed with a 6-metre spray bar at a binder temperature of 180$^\circ C$ without the risk of stone stripping due to poor transverse binder distribution or blocked nozzles. This makes it a cost effective user-friendly binder for surface dressings.

Although samples were taken from the distributor and tested on site for compliance prior to spraying, the results were always found to be in excess of the minimum value. This provides the contractor and the engineer with the confidence that the modified binder can be transported and handled on site over time without the risk of the product degrading under heating.

The product is thus ideal for use on contracts where the engineer does not have the luxury of an
an on-site laboratory for doing binder tests.

“While no incidents of severe stone loss were recorded after opening to traffic, the decision to keep the section closed to traffic overnight improved aggregate retention. A slightly higher aggregate loss of 6.7mm from the unmodified sections was evident when compared with the modified binder sections,” Swart said.

Colas acknowledges the input of the South African National Roads Agency, the consulting engineers BCP/Stemele Bosch and contractor Haw and Inglis, in the execution of this contract.
Colas on the road for 75 years ... and still counting

TDistin
Colas SA (Pty) Ltd

The Colas name has been synonymous with bitumen binders in southern Africa’s road construction industry for the past 75 years.

The roots of the company in southern Africa date back to 1928, when a bitumen emulsion factory was established at Bellville in the Cape. Since then the firm has undergone numerous developments, including acquisitions of constituent companies, changes in shareholders, and different corporate identities. In fact the wheel has turned a full circle: when the company first commenced operations it was called Colas South Africa (Pty) Ltd. Later, this name was changed to Colas Southern Africa (Pty) Ltd, part of the Murray and Roberts Group. Then, in March 2000 Colas France acquired this company, which was registered under the original trading name — Colas South Africa (Pty) Ltd.

Evolution

The Colas name is derived from the wording COLd ASPhalt. In the early 1920’s an English scientist discovered and registered the first patent for bitumen emulsion. This event became the foundation of a new company, which Royal Dutch Shell registered under the COLAS trade name. As Shell expanded its petroleum refining and marketing activities abroad, it also established downstream companies under the Colas trade mark. The main purpose of these companies was to further process the bitumen (produced from the refining of crude oil) into emulsion for ease of handling and application.

In southern Africa the company moved from Bellville to Maitland, also establishing factories in Johannesburg, Durban, East London, Port Elizabeth, Bloemfontein and Hectorspruit. In 1936 operations were extended into Zimbabwe and later Zambia. An East Africa division was formed in 1956 with a factory in Nairobi. In 1968 an emulsion factory was established in Namibia at Okahandja. The group was strategically well placed to supply road binders to the market within southern and eastern Africa.
Shareholders

During the growth and consolidation of the company since its inception, there have been several major shareholders, including Royal Dutch Shell and Anglovaal. In keeping with Shell’s worldwide trend of disinvestment in its non-core businesses, the constituent Colas companies were consolidated under a single shareholder, Murray & Roberts in 1991. In very much the same vein, Shell sold its main holding in Colas France to the local construction giant Bouygues. It came as no surprise in March 2000 when Colas France decided to consolidate its worldwide bitumen emulsion business by acquiring the binders portion of the southern African operation from Murray & Roberts.

Constituent companies

The main constituent companies to evolve within the group were Petrocol (1967), Much Asphalt (1965), Protea Asphalt (1976) and African Bitumen Emulsions (1930), which - in 1977 - fell under the holding company Abecol (Pty) Ltd. In 1996, the decision was made to regionalise and unify all these companies under one umbrella and one trading name, Colas Southern Africa, which prevailed until restructuring took place at the end of 1999.

With the takeover of the binder assets by Colas France, the asphalt manufacturing business has continued to operate under the Much Asphalt name within Murray & Roberts, and the contracting arm of what used to be part of Protea Asphalt Natal that continues to operate within Murray & Roberts Civils. Later developments included the take-over of Vialit from Engen in February 1997, a move that included the acquisition of a number of binder plants. The overall result was a comprehensive rationalisation and streamlining of the bitumen binder business, which saw the integration of the company’s Isando plant with that of the Vialit plant at Chamdor (Krugersdorp) and the integration of the Maitland operation with the Vialit plant at Epping in Cape Town.

Recent Developments

With the acquisition of the binders business from Murray & Roberts, the company has gone through a consolidation phase. With its head office in Cape Town, Colas now operates:

- factories in Cape Town, Port Elizabeth, Durban and Johannesburg;
- depots in East London, Bloemfontein and Hectorspruit;
- factories outside the country in Namibia, Zambia and Kenya.

The company also has numerous mobile manufacturing plants and a wide range of application equipment which include:

- 3 mobile emulsion plants;
- 3 mobile polymer modified binder plants;
• 2 mobile bitumen rubber blending units;
• 28 binder distributors;
• 11 slurry and micro-surfacing machines;
• 13 mechanical horses;
• More than 150 static and mobile trailers.

In keeping with the stated intention of upgrading local plant and equipment with proven international technology, the company in South Africa has commissioned seven new binder distributors during the past two years.

Yet our greatest asset is still our people — a team of 200 committed individuals, recognised as leaders in their fields. Each Colas branch employs indigenous people who are encouraged to develop their markets in an autonomous manner.

As a wholly owned subsidiary of the world’s largest bitumen emulsion supplier — with factories and depots strategically positioned countrywide, our commitment to the entire South African road-construction industry is total.
The seal that has stood the test of time

TR Distin
Colas SA (Pty) Ltd

The Kruger National Park attracts more than 600 000 visitors annually, and remains one of the major draw cards for international tourists to southern Africa.

To facilitate gameviewing, the Park is serviced by a well-planned and maintained road network consisting of 1800 km gravel and 900 km of surfaced roads. All the surfaced roads are sealed with sand seals, which have remained unchanged in design from that used when the first surfacing operations began in 1964. The materials utilised in the construction of the sand seal consist of natural alluvial sands and hot penetration grade bitumen.

Bulk supply

The Kruger National Park has just completed the resealing of about 70 kilometres of surfaced roads as part of its annual road maintenance program, for which Colas South Africa supplied and sprayed 650 tons of hot bitumen. However some things have changed. In the original road works bitumen was supplied in drums and decanted on-site into a heating kettle before application by a tractor drawn sprayer. In subsequent years the bitumen was supplied in bulk and sprayed by self-propelled pressurised distributors by companies Hot Bulk and Vialit.

Sand seal construction

The road pavements are constructed to a width of 10.2m, with a surfaced width of 7.2m. For new construction the sand seal is applied in two layers consisting of a primary seal followed by a secondary seal. The newly constructed base course is firstly primed using MC 30 cutback bitumen. A 150/200-penetration grade bitumen tack coat is applied after the prime has cured, and the river sand is spread immediately thereafter.

Once the freshly spread river sand is rolled, the road is immediately opened to traffic. Back brooming of the loose sand with a drag broom is carried out during the first month of the seal to ensure maximum aggregate retention. The new surface is subjected to traffic for a period of up to six months before the second sand seal is applied.

When resealing, only a single hot tack coat is sprayed on the existing aged sand seal, followed
by a layer of sand. The resultant compacted thickness of the new layer is 6 mm.

The construction and maintenance of the Park’s roads is primarily undertaken by Park officials. The daily production rates achieved for sand sealing vary between 40,000 and 60,000 m$^2$. To achieve these production rates, the sand is stockpiled at intervals of five km. (The sand is excavated from the riverbed and screened through a vibratory sieve with an aperture of 12 mm). The bitumen distributor is fed from a bulk road tanker positioned at the sand stockpile area.

Trevor Distin, Colas’s marketing manager, stressed that “good means of communication between the refinery and the bulk haulier is essential to ensure continuity of supply at remote locations within the Park. As the bitumen used in the recent reseals was supplied from the Engen refinery in Durban, we had to have six dedicated bulk road tankers on hand to meet the daily bitumen demand of the surfacing team.”

**Environmental considerations**

The park has seen an increase in the annual number of vehicles from three in 1929, the first time motor vehicles visited the Park, to 150,000 in 2003. While the traffic speed limit is only 50 km per hour on all roads outside the camps, the maximum road surface temperature in the northern part of the park can easily reach up to 72°C in summer months, making it one of the warmest regions of South Africa.

Despite initial resistance from the environmentalists, it was decided to surface the gravel roads, which were elevated above the adjacent terrain, for improved viewing and drainage. The result saw a reduction in dust generated by vehicular traffic, which ensured that game would feed on the now dust-free vegetation close to the road. According to Soekie Schoemann, manager of roads in the Kruger National Park, a survey conducted in 1994 showed that 60% of the visitors preferred to ride on the surfaced roads when viewing the game.

The importation of aggregates is also limited by the possibility of introducing alien vegetation. The roads are therefore constructed using materials from local borrow pits, comprised mainly of granitic and basaltic gravel. The angularity of the coarse alluvial quartzitic sand used in the seal creates an ideal micro texture for a thin surfacing. The rivers in the Park flow from the west to the east and the granulometry depends on the distance the sand is transported.

The Park also believes it is essential to ensure that there is no silt deposit within the sand as this can lead to blemishes in the
surfacing. This distance travelled by the floodwater has an influence on the extent of the silt deposited.

Detailed records have been kept by the Park’s officials of all sand sealing operations since 1964. Experience has shown that the typical expected maintenance free life of a new sand seal is 14 years. The Park also uses a pavement management system to identify and prioritise maintenance requirements of their surfaced road network. The main modes of surface distress are edge breaks due to erosion by stormwater runoff.

The use of sand seals for new construction and reseals has proven very cost effective, with current resealing costs in the Skukuza area running at R4.86 m² which equates to a life cycle cost of R0.35/m²/year.

**Renewable resource**

The reduction of dust and channelisation of water has also resulted in abundant vegetation on the verges adjacent to the surfaced roads, leading to increased animal feeding activity. Due to the low fines content of the river sand, very little dust is also generated under traffic during the early life of the seal.

The sand used in the seals is washed down during the flooding of the rivers and redeposited in the old river borrow pits. This makes it a renewable source unlike the gravel roads, where it is estimated that some 70,000 m³ of gravel is lost per year. The cost to the Park of reblanding and regravelling was estimated at R3.1 million in 2000.

**Reduced costs**

The incidence of injury to the wild animals during the hot bitumen spraying operations is minimal, as the animals avoid the construction site due the high levels of activity. And because the sand spreader follows directly behind the bitumen distributor, the exposed binder is covered within a very short period. Disruption of traffic during the surfacing operations is minimal, as the newly placed surfacing can be opened to traffic immediately after rolling. Unlike a stone seal, the risk of windscreen damage from loose chips is also minimised.

Other benefits include inter alia reduced road user costs and road maintenance costs when compared to that of gravel roads.

The Kruger National Park’s road maintenance programme demonstrates that the appropriate use and successful construction of cost-effective durable thin bituminous surfacings using locally available materials is viable, to the benefit of the road user and the natural environment.
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