Greener Roads Practices

DBFO Urban Tollway

ERR No 15 • RGRA
FALL 2009
Egis Road Operation is part of Egis group, a world leader in the field of infrastructure projects development, engineering and operation.

Egis Road Operation's business is the operation and maintenance of toll motorway and tunnel infrastructure projects throughout the world.

Egis Road Operation has extensive tunnel operation expertise in:

- design review, procedures and manuals, equipment specifications and commissioning, daily operation, asset management, ...
- taking over tunnels already in operation,
- all safety related issues,
- ensuring operation levels of service for a guaranteed price.

Egis Road Operation owns and manages:

- 18 motorway operation companies in 14 different countries,
- with 3200 people,
- for a global network of 1550 km,
- with 47 km of tunnels,
- daily used by 900 000 vehicles.

Egis Road Operation's tunnel key references:

- Dublin Port Tunnel in Ireland, the largest urban tunnel in Europe,
- Athens Ring Road tunnels in Greece,
- M5 East tunnel in Sydney, Australia,
- Melbourne City Link tunnels in Australia.

Egis Road Operation
11 avenue du centre, CS 30530
78286 Guyancourt cedex, France
www.egis-roadoperation.com
The big question

The big question is: will the heads of states gathered together actually save the planet as they wrap up the Climate conference currently held in Copenhagen?

We, the road builders are not so ambitious and merely endeavour to be pragmatic. We leave to experts in climate change the task of determining how much carbon dioxide release will impact the earth’s average temperature.

We only know that mitigating traffic congestion by building appropriate infrastructures results in a limitation of CO₂ emission. It also is a source of economy and natural resource savings.

The Attica toll motorway is a good example of such a “win-win” situation. Moreover, it is also an emblematic DBFO (Design, build, finance and operate) project in an urban area. An environmental monitoring organisation enhancing its positive impact certainly contributed to its recognition by several international institutes which granted it prestigious awards.

Similarly, the International road federation (IRF), convinced that better roads can only be built by practitioners fully aware of the comprehensive ecological impacts of their activities, presents its CHANGER system, a methodology for the calculation and modelling of greenhouse gas (GHG) emission from road construction projects.

However, environmental concerns cannot be limited to CO₂ emission control; other chemical releases are also paid due attention by our industry. New storable cold mixes containing no volatile organic compounds (VOC) are now available and used effectively thanks to innovative high performance bio-flux agents.

Even sulphur additives introduced into bituminous mixes are now far less harmful than they used to be decades ago while their positive impact on pavement mechanical properties is still improved. A dramatic decrease in H₂S emissions resulting from new conditioning and improved temperature control allows these objectives to be met together with a reduction in overall energy consumption.

We wish to conclude this panorama of innovations by paying a tribute to the action of the Forum of European national highway research laboratories (FEHRL) which celebrates 20 years of membership collaboration currently extending to over 33 countries, far beyond the borders of Europe.

Europeanroads review wishes you all an excellent new year 2010, abounding with better roads, less chemical emissions and an improved economy.
Environmental analysis of road projects

CHANGER, the IRF GHG Calculator

Better roads can only be built by practitioners who are fully aware of the full ecological repercussions of their activities, and of the growing potential for enhancing positive while reducing negative impacts. The International Road Federation (IRF) has designed a methodology for the calculation and modelling of greenhouse gas (GHG) emissions from road construction projects. The ultimate purpose of CHANGER is multifaceted: 1. Facilitating a detailed environmental analysis of road projects; 2. Providing an authoritative basis for comparative analysis of various road-building techniques and materials; 3. Optimising road construction site supply schemes with respect to raw material providers, choice of suppliers, delivery locations and material transport modes; 4. Enabling detailed estimation of GHG emissions that are specifically attributable to the road construction industry.

Bio-fluxing agent

A new range of storable cold mixes with no volatile organic compounds (VOC)

As part of its endeavour to protect the environment, improve working conditions, promote renewable resources, save energy and reduce greenhouse gas (GHG) emissions, Colas has developed high-performance bio-flux agents that can be used in every type of road surfacing. In addition, bio-fluxes have proven to be the perfect choice in the design and manufacture of storable cold mixes, which usually require a heavy dose of oil-based – hence volatile – flux. The use of conventional flux, which is also flammable, leads to the evaporation of volatile organic compounds in the atmosphere, a potential danger for the people involved and a risk for the environment, not to mention a waste of fossil fuel.

Bio-fluxing agent

A new range of storable cold mixes with no volatile organic compounds (VOC)

As part of its endeavour to protect the environment, improve working conditions, promote renewable resources, save energy and reduce greenhouse gas (GHG) emissions, Colas has developed high-performance bio-flux agents that can be used in every type of road surfacing. In addition, bio-fluxes have proven to be the perfect choice in the design and manufacture of storable cold mixes, which usually require a heavy dose of oil-based – hence volatile – flux. The use of conventional flux, which is also flammable, leads to the evaporation of volatile organic compounds in the atmosphere, a potential danger for the people involved and a risk for the environment, not to mention a waste of fossil fuel.

Bio-fluxing agent

A new range of storable cold mixes with no volatile organic compounds (VOC)

As part of its endeavour to protect the environment, improve working conditions, promote renewable resources, save energy and reduce greenhouse gas (GHG) emissions, Colas has developed high-performance bio-flux agents that can be used in every type of road surfacing. In addition, bio-fluxes have proven to be the perfect choice in the design and manufacture of storable cold mixes, which usually require a heavy dose of oil-based – hence volatile – flux. The use of conventional flux, which is also flammable, leads to the evaporation of volatile organic compounds in the atmosphere, a potential danger for the people involved and a risk for the environment, not to mention a waste of fossil fuel.
Low temperature sulphur technology

Shell Thiopave® modified sulphur pellets for asphalt paving mixtures. Focus on use of available resources

Sulphur extended asphalt (SEA) mixtures were used commercially in the 1970s and 1980s in North America as well other parts of the world, i.e. Middle East and Europe (France, United Kingdom). Performance properties of sulphur extended mixtures were shown to be equal or sometimes even better than conventional asphalt mixtures. However, handling and safety issues were of concern, as molten sulphur was difficult to use and sometimes generated unacceptably high H₂S emissions. Asphalt mixture containing sulphur is resurging as an alternative to meet high energy demand forecasts and Shell has made efforts to develop a new sulphur technology. This technology, based on sulphur in pellets, initially known as Shell SEAM has been further developed and is now known as Shell Thiopave.

Jacques Colange, Nicolas Lunot, Simon Banbury

Tunnel Safety in Operation and Maintenance

Tunnel Safety Officer: Roles and responsibilities

The last events occurred in European Tunnels since 1999 demonstrated the needs for preventing and mitigating tunnel accidents. The European Directive 2004/54/EC details the responsibilities for owners of tunnels longer than 500m, one of them is about the Tunnel Safety Officer who is nominated by the Tunnel Manager and gives advises about preventive and safeguarding measures. This article provides a brief overview of the reaction of the tunnel community and the role of a Tunnel Safety officer, who is particularly involved in Operation and Maintenance activities.

Yannick Mallet

Testing equipment for pavement

Equipment and methods used for non destructive tests on airport runway pavements

Security is a key factor in the field of transport, and a particularly sensitive topic in air transport. In order to keep an optimal level of services, the managers of airport platforms, vital organs of the network, must have a perfect knowledge of their conditions states. A certain number of normalized index allow to access the quality of these infrastructures and therefore rationalizing management and planning maintenance operations. Rincent BTP group is an independent company which carries out one part of its activities of measures and diagnostics, in the field of runway and road pavement. It is at the service of airport managers, realizing diagnostic works, but also developing, selling and maintaining innovative materials in accordance with the requested quality demands. The company is very much in demand in the airport field and achieves some works on the five continents.

Joseph Vinsu, Anthony Gauthier, Jean-Claude Tijou

Road research laboratories

20 Years of FEHRL

FEHRL (The Forum of European National Highway Research Laboratories) celebrates 20 years of road engineering research and coordination. Registered as an International Association with a permanent Secretariat based in Brussels, Belgium, FEHRL provides a coordinated structure for the interests of over 30 national research and technical centres from Europe, together with associated Institutes from around the world. Developed over the past 20 years, it has grown from a meeting of associations held on October 23 – 24, 1989 to investigate the general interest among the road research laboratories for closer cooperation. To today, where this collaboration has grown into a membership of 33 countries, including members throughout the European Union States, European Free Trade Association (EFTA) countries, and Eastern and Central European countries, as well as three non-European Countries – Israel, South Africa, and most recently, the United States.

Claude Van Roonen, Valerie Henry
Susanna ZAMMATARO
Deputy Director General
International Road Federation (IRF)
Geneva Programme Centre
(Switzerland)

Environmental analysis of road projects

CHANGER, the IRF GHG Calculator

Better roads can only be built by practitioners who are fully aware of the full ecological repercussions of their activities, and of the growing potential for enhancing positive while reducing negative impacts. The International Road Federation (IRF) has designed a methodology for the calculation and modelling of greenhouse gas (GHG) emissions from road construction projects. The ultimate purpose of CHANGER is multifaceted:

1. Facilitating a detailed environmental analysis of road projects; 2. Providing an authoritative basis for comparative analysis of various road-building techniques and materials; 3. Optimising road construction site supply schemes with respect to raw material providers, choice of suppliers, delivery locations and material transport modes; 4. Enabling detailed estimation of GHG emissions that are specifically attributable to the road construction industry. The resulting calculations are given in CO₂ equivalency by reference to all or any of the various stages of road infrastructure construction, and take into account a wide range of different scenarios and construction techniques.

Introduction

In today’s demanding world, no industry can afford to ignore its impact on the environment and, in particular, on climate change. As we move into the future, better roads must be built by practitioners who are fully aware of the whole ecological repercussions of their activities and of the growing potential for enhancing positive while reducing negative impacts. Already, modern road transport systems increasingly reflect the commitment of road builders, scientists and city planners in these respects – as well as their growing ingenuity in efforts to ensure and safeguard a better living environment.

Sustainability has become a key watchword, not only in the design phase but also in the construction and implementation stages of road schemes. Factors such as potential for recycling materials as well as risks of water contamination, noise pollution and GHG emissions are comprehensively taken into account, and detailed consideration is given to appropriate measures to avoid or remedy any potentially negative impacts or issues that may arise.

Alongside other sectors, the road infrastructure industry is assuming the new challenges and responsibilities of our times. Committed to the green economy and to being at the forefront of global efforts to stimulate change for a sustainable future, the IRF has designed a greenhouse gas calculator – CHANGER (Calculator for Harmonised Assessment and Normalisation of Greenhouse gas Emissions for Roads) – specifically tailored to road infrastructure projects.
Objectives

The main objectives of the CHANGER project are to achieve tangible, long-term benefits for the global environment and to contribute proactively to the shaping of dynamic sustainable road development policies going forward. Easy to use, and fully compatible with Intergovernmental Panel on Climate Change (IPCC) guidelines, the tool enables public and private entities to monitor and assess GHG emissions generated during the various stages of the road construction process.

The ultimate goal of this tool is multifaceted:
- Facilitating a detailed environmental analysis of road projects;
- Providing an authoritative basis for comparative analysis of various road-building techniques and materials;
- Optimising road construction site supply schemes with respect to raw material providers, choice of suppliers, delivery locations and material transport modes;
- Enabling detailed estimation of GHG emissions specifically attributable to the road construction industry.

Concept and modelling approach

CHANGER adopts a comprehensive "input-output" modelling approach (Figure 1).

The calculation model is based on a set of equations that enable accurate estimation of overall GHG emissions (outputs) generated by each identified and quantified source (inputs).

CHANGER currently comprises two main modules (Figure 2):
- Pre-construction (clearing and piling, cut export and fill import transport);
- Pavement (on-site impacts, construction materials, materials transport, construction machines).

Every single module follows the same structure (Figure 2). Firstly, input data is entered by the user of the calculator. Then, a first calculation is carried out in order to obtain the material quantities, material transport, electricity used, etc. These quantities are finally assessed with emissions factors in order to output the total GHG emissions attributable to every stage of the road construction process.

The research

The research has been organised in a series of successive and interlinked stages:
- Compilation of an exhaustive inventory of GHG emission sources by reference to the different stages of road infrastructure construction;
- Estimation of the level of intensity to be applied for evaluation of the emissions sources thus identified;
- Research and compilation of the applicable emissions factors, in accordance with guidelines provided by the Intergovernmental Panel on Climate Change (IPCC);
- Set up of the equation for the calculation:

\[
\text{Emissions} = \sum \text{Source}_i \times \text{Emission Factor with Source: } S_i = (A^\times I^\times)\
\]

where the sources are specified in units compatible with the emission coefficient; A = activity level and I = intensity.
Environmental analysis of road projects

Emissions sources

The calculator has been designed as a flexible tool that can accommodate a wide range of different user needs — from gross 'pre-project phase' estimations right through to comprehensive end-project assessment.

The pre-construction module

It takes into account:
- **Clearing and piling**: based on the ground surface area cleared per unit of road surface, an estimation can be generated for both machine use and fuel consumption. Transportation of trees removed is also taken into account (the tool does not account for either the loss of CO\textsubscript{2} absorption by the removed trees or for their replacement with new or replanted trees in the areas concerned).
- **Cut exports and fill imports transport to and from the road site**: based on a simplified diagram, the user selects the relevant sites and enters the respective distances, tonnages and transport modes (road, rail or inland water).

The pavement module

It takes into account:
- **On-site impacts**: electricity and fuel consumption on the construction site as identified and evaluated.
- **Pavement construction materials**: this section encompasses several menus (unbound materials, hydraulically bound materials, bituminous bound materials, metals, rubber and plastic, etc.), from which the user can easily select the materials required for construction of the different layers of the given pavement.
- **Materials transport**: once again, a simplified diagram has been set up to help visualise and assess the emissions generated by transportation of the materials identified (Figure 3):
  - For aggregates: two possible quarry sites are considered. Aggregates are transported either directly to the road site (granular materials for sub-base and filter drain) or first to the mixing plants (granular materials used for mixtures) and then to the road site;
  - For bituminous materials: the system considers bitumen transport from the refinery to two possible mixing plant sites, and then from the plants to the road site. The model also accounts for the transport of emulsions directly from refinery to site;
  - For cement: the system caters for both transport of cement directly to the site or via a mixing plant.

- For concrete: transport of concrete directly to the road site is similarly included as an option.
- **Construction machines**: the model assesses the number of working hours per type of machine and type of pavement layer. The total consumption of fuel is determined on the basis of the characteristics and efficiency of the material used.

Once assessed, the GHG emissions generated throughout the various stages of the road construction process are converted to carbon dioxide equivalent. Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalent (MMTCO\textsubscript{2}Eq)".

CHANGER automatically generates comprehensive reports — either aggregated (total) or disaggregated (inherent to one or more steps of the process) — that can be conveniently exported to Excel, Word, PDF and HTML (Figure 4).
Validation process

By virtue of its extensive and varied membership — both in terms of geographical coverage and fields of specialisation — IRF has benefited from technical support from a wide range of industry and technical partners throughout the development of the project. This has been particularly invaluable for ongoing review and validation of the modelling approach and databases, as well as for testing and comparison. The LAVOC (Traffic Facilities Laboratory) of the Swiss Federal Institute of Technology (Ecole Polytechnique Fédérale de Lausanne – EPFL) has analysed and validated both the quality and reliability of the databases and the calculation procedures.

Current state of progress and future developments

CHANGER has been conceived as an evolving tool, subject to ongoing review and development so that it ultimately covers every phase and aspect of road construction. Already, work is underway on complementing the existing pre-construction and pavement modules with a new module devoted to maintenance activities. Similarly, the databases will be regularly updated to reflect the very latest science as well as cutting-edge research on techniques, materials and equipment.

References

- For more information on CHANGER, as well as details on how to order your CD-ROM copy of the software, go to http://www.irfghg.org
Landmark Rural Roads Convention and Workshop on Governance held in Arusha, Tanzania

A highly successful Rural Roads Convention, co-convened by IRF, the global Transport Knowledge Partnership (gTKP) and the Tanzania Roads Association (TARA), was held in Arusha, Tanzania from 25-27 November, 2009. This landmark event attracted some 215 delegates from 30 countries covering all continents. Participants were drawn from a comprehensive range of backgrounds, including politicians, policy makers, academics, partners in development, road users and leading representatives from the private sector, civil society and international organisations.

The Convention was opened by the Prime Minister of Tanzania, The Hon. Mizengo Kayanza Pinda, Prime Minister, United Republic of Tanzania; Abdul Awadh, Chairman, Tanzania Roads Association.

The main theme of the Convention, "Rural Roads for Economic Development, Social Cohesion and Poverty Reduction," was, indeed, particularly relevant to the development agenda of Tanzania and other developing countries.

During the Convention, internationally-renowned experts in the fields of rural roads and rural transport presented 26 papers over five interrelated sessions covering respectively the importance of rural roads; planning and management of rural roads; financing of rural roads; construction and maintenance of rural roads; and rural road safety.

An authoritative set of resolutions emerged with a view to assisting delegates in their efforts to influence and encourage government agencies to give renewed priority to the importance of rural road networks.

The Convention was preceded by a Workshop and Round Table discussion on Governance in Transport, which brought together 80 participants. Comprehensive introductory presentations by a panel of experts sparked lively, highly constructive dialogue on the range of governance challenges facing transport sector Ministries in African regions.

The Organising Committee of the Rural Roads Convention is currently compiling a CD-ROM of the conference proceedings, which will be circulated to all participants and stakeholders.

Highly successful IRF Seminar in Cairo addressing Road Safety and Private-Public Partnership

Road infrastructure representatives from all over the world gathered in Cairo on 12-13 October 2009 for a major IRF Road Safety and Public/Private Partnership (PPP) Seminar.

The Seminar, which was fully subscribed, brought together an exceptional cast of international speakers and experts around two of the key challenges facing the road sector today. Over an intensive two-day period, participants were able to benefit from direct access, in highly conducive surroundings, to an expanding network of international professionals, including delegates from government departments, local government, communities, universities and leading private and third sector organisations.

The approach was both authoritative and comprehensive.

IRF Chairman, Jean Beauverd, opened the first session with a keynote address in which he stressed the importance of being able to dedicate an entire day focused exclusively on Road Safety issues, with the aim of distilling clear guidance for concrete future actions, notably in developing countries.

The second day opened with a keynote speech by Hisham M. Fouad, Senior Technical Advisor to the Egyptian Ministry of Transport. Mr. Fouad highlighted the importance of the Seminar in terms of contributing to transfer of authoritative knowledge on all aspects of PPPs; and the sessions that ensued specifically addressed the widening funding gap for road development and works.

The Cairo Seminar was highly appreciated by the participants, as attested by the results of an evaluation survey conducted at the conclusion of the two days. The level of discussion and the quality of presentations received particularly positive feedback. The Seminar enabled participants to benefit at first hand from widely renowned expertise, cutting-edge knowledge and latest best practice.

Full proceedings, in the form of a CD-ROM compiling all the presentations made during the Seminar, are available from the IRF Secretariat (info@irfnet.org).
Bio-fluxing agent

A new range of storable cold mixes with no volatile organic compounds (VOC)

As part of its endeavour to protect the environment, improve working conditions, promote renewable resources, save energy and reduce greenhouse gas (GHG) emissions, Colas has developed high-performance bio-flux agents that can be used in every type of road surfacing. In addition, bio-fluxes have proven to be the perfect choice in the design and manufacture of storable cold mixes, which usually require a heavy dose of oil-based – hence volatile – flux. The use of conventional flux, which is also flammable, leads to the evaporation of volatile organic compounds in the atmosphere, a potential danger for the people involved and a risk for the environment, not to mention a waste of fossil fuel. Bio-flux agents have a very high flash point (>130°C), thus reducing flammability, an equivalent rise in binder cohesion compared to oil-based fluxed binders thanks to the Colas process, and often provide better solvent properties than oil-based fluxes for the same use. Bio-fluxes offer considerable savings in terms of energy and GHG emissions, and have already been used in a number of projects.

Introduction

In France, an estimated 35,000 tons of flux are used in cold mixes and surface dressings (anhydrous). To provide an alternative to this type of oil-based product, Colas has launched a research program focusing on the development of bio-products, mainly using plant-based derivatives (Vegeproducts line) that are made from natural renewable resources. Today, fluxing agents are used to reduce the viscosity of bitumen in the road industry and are principally composed of volatile compounds that emit VOC, which can have an undesirable impact on people and the environment. To remain in line with sustainable development criteria – ensuring the safety of people and the environment, renewing and managing resources, saving energy, reducing greenhouse gas emissions – the Colas Group decided to develop alternative products that use less energy and are safe for people’s health and for the environment.

Several years ago, Colas designed and patented a bio-flux called Vegeflux, in collaboration with the R&D department at Valagro. It is now being produced on an industrial scale and is often used today to replace volatile, petrochemical fluxes in surface dressings and storable asphalt mixes.

High performance mixes in laboratory tests and on the road

Designing storable mixes in the lab

The mixes were designed to comply with performance-based targets in the fields of coating, handling and cohesion. Studies were set up...
A new range of storable cold mixes with no volatile organic compounds (VOC)

to design VOC free mixes with performance levels that remain equivalent or better than mixes made with conventional volatile flux.

Coating tests
In order to properly assess coating in mixes as a function of the binder’s flux content, coating tests were performed using samples from coating plants taken at various temperatures (20°C, 15°C, 10°C, 5°C, 0°C and -5°C), with emulsions that had been kept at 20°C and 60°C. The emulsions were all manufactured with the same aqueous phase whereas the anhydrous phase was composed of fluxed bitumen containing different amounts of Vegerflux (level 1 to 4). A single coating formula was used (Table 1) and the binder content is constant.

<table>
<thead>
<tr>
<th>Parts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry materials</td>
<td>100</td>
</tr>
<tr>
<td>Vegerflux emulsion</td>
<td>7.5</td>
</tr>
<tr>
<td>Total</td>
<td>107.5</td>
</tr>
</tbody>
</table>

Table 1
Coating formula

The materials were coated in planetary mixers, even the smallest batches, because hand mixing using this type of emulsion did not provide fully representative findings.

The most pertinent temperatures for the aggregates are -5°C, 5°C, 10°C, 15°C and 20°C, due to the fact that storable mixes are mainly manufactured and used to repair and maintain road surfaces in the winter.

Photos were taken and coating quality was compared according to the temperature of the aggregates before coating and the binder’s Vegerflux content. It was then possible to classify coating quality from mediocre, satisfactory to full (Table 2). In this series of photos, the emulsion temperature during coating was set at 20°C.

Findings showed that the amount of flux required for proper coating in this mix, at very low temperature, is level 4. It can be decreased to the level 1 in moderate ambient temperatures (>15°C).

Tests were also performed with emulsion at 60°C and findings showed that better coating is achieved compared to an emulsion at 20°C with materials at 5°C, regardless of the binder’s flux content. With 60°C emulsion and high Vegerflux content (close to that used in the control mix), full coating is achieved at 0°C and satisfactory coating at -5°C.

According to the temperature of use, minimum flux contents may be recommended for technical and economic reasons.

Evaluating workability
Prior to launching the tests, a method had to be defined to quantify workability in storable mixes. As of yet, no single test has been approved by the industry or by laboratories involved in cold mix design.

Using STV pseudo-viscosity evaluation as a starting point, a test was designed to measure flow time of a given volume of storable mix through an orifice. The time recorded is correlated to the mix’s workability. Three parameters can impact flow time: the size of aggregates, the binder’s flux content and the trial temperature. The findings are always compared to a control mix, the workability of which has already been measured on site.

<table>
<thead>
<tr>
<th>T°C</th>
<th>Level 1</th>
<th>Level 1</th>
<th>Level 1</th>
<th>Level 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2
Evaluating coating in storable mixes
The test is called PMEES, French for pseudo-workability of storable mix by flow (Table 3).

A number of tests were doubled up and a conventional flux mix design that is considered by customers as workable was used as a reference. Mix designs with level 4 Vegeflux content show flow times that are similar to the reference mix at low temperatures. At 20°C, the flow times are practically identical. These test findings prove just how important the temperature parameter is when designing storable mixes.

In parallel, the findings are correlated with observations made on site.

Evaluating cohesion

The rise in cohesion of this type of storable mix was evaluated over time. The mix was stored at room temperature in a hermetically closed vessel. Duriez samples were molded on two occasions, at 40 days and at 80 days (Table 4).

The figures are low, regardless of the type of flux used, but this level of performance is sufficient in the majority of cases if one remains in the realm of storable mix application. When the same aqueous phase has been used to prepare all the emulsions, the findings of workability and coating tests as a function of temperature lead to the following recommendations:

- summer: level 1 Vegeflux emulsion,
- late autumn: level 2 Vegeflux emulsion,
- winter: Vegeflux emulsion level 4.

In parallel, the non-volatile nature of Vegeflux makes it possible to reduce the amount of initial binder required (no loss of flux, stable richness modulus). This means that the emulsion content or binder content can be lowered, making for reduced consumption of non-renewable resources in the mix. Coating quality, handling and cohesion are verified to ensure that there is no negative impact. Tests are done on a case-by-case basis to adjust both dosage and the type of reduction possible, e.g., decreasing the amount of emulsion or the amount of binder in the emulsion.

On roads

Colas Ile-de-France Normandie (ldFN), a subsidiary of the Colas Group, has decided to replace all traditional volatile flux with Vegeflux, starting with surface dressings.

<table>
<thead>
<tr>
<th>Mix no. 1</th>
<th>Mix no. 2</th>
<th>Mix no. 3</th>
<th>Mix no. 4</th>
<th>Mix no. 5</th>
<th>Mix no. 6</th>
<th>Mix no. 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts</td>
<td>Parts</td>
<td>Parts</td>
<td>Parts</td>
<td>Parts</td>
<td>Parts</td>
<td>Parts</td>
</tr>
<tr>
<td>Material</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Level 1 Vegeflux</td>
<td>7.5</td>
<td>Level 1 Vegeflux</td>
<td>7.5</td>
<td>Level 2 Vegeflux</td>
<td>7.5</td>
<td>Level 3 Vegeflux</td>
</tr>
<tr>
<td>Level 4 Vegeflux</td>
<td>7.5</td>
<td>Level 4 Vegeflux</td>
<td>7.5</td>
<td>Control</td>
<td>7.5</td>
<td>Control</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Flow time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>73 76 59 56 44 41 43</td>
</tr>
<tr>
<td>10</td>
<td>41 43 39 28 25 27 24</td>
</tr>
<tr>
<td>20</td>
<td>10 15 10 10 8 8 8</td>
</tr>
</tbody>
</table>

Table 3
Evaluating workability in mixes

Table 4
Compression resistance

<table>
<thead>
<tr>
<th>Time</th>
<th>Oil-based flux</th>
<th>Vegeflux</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 days</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>80 days</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 4
Compression resistance
A new range of storable cold mixes with no volatile organic compounds (VOC)

Since 2008, their storable mixes, which are heavily flux-consuming, have been manufactured with Vegeflux. Vegeflux mixes do not give off any unpleasant smell and help save a significant amount of material: because the flux does not evaporate, it contributes to residual binder after reticulation. In addition, less flux is required.

In March 2009, the following mix was manufactured (Table 5).

<table>
<thead>
<tr>
<th>Parts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregates</td>
<td>100</td>
</tr>
<tr>
<td>Vegeflux emulsion</td>
<td>7.5</td>
</tr>
<tr>
<td>Total</td>
<td>107.5</td>
</tr>
</tbody>
</table>

Table 5

In situ conditions
The conditions on site were as follows:
- Ambient temperature morning: 5°C,
- Ambient temperature afternoon: 12°C,
- Cold emulsion: 12°C,
- Warm emulsion: 36°C,
- Materials: 10°C,
- Water content of materials: 4.3%

Coating is complete and the breaking water is clean. Colas' Maromme plant has manufactured more than 4,000 tons of storable Vegeflux mix since 2008 (photos 1 to 3).

A favorable environmental footprint

Vegeflux storable mixes do not emit VOC or any unpleasant odor as is sometimes the case with oil-based fluxes, some of which give off a long-lasting stench. A smaller amount of flux is needed, roughly 5 to 30% less depending on the application temperature.

Lastly, better bonding with aggregates used in the road industry has been observed. Among Vegeflux's main advantages, in addition to non-volatility, one can cite the use of renewable natural resources, energy savings and reduced GHG emissions. A partial life cycle analysis on Vegeflux compared to fossil fuels has shown that Vegeflux bitumen uses 40% less non-renewable energy than fossil fuel-fluxed bitumen. GHG emissions (in CO₂ equivalent) are 12% lower with Vegeflux binders.

The same is true for cold mixes. Gains in terms of energy consumption and GHG emissions with Vegeflux have been calculated compared to oil-based flux mixes (Jean Philippe Gillet – R&D Engineer Colas).

Findings show savings of 17% in energy consumption and 44% in GHG emissions (Tables 6 and 7, Figures 1 and 2).

The impact cited above only takes a part of the life cycle into account, meaning the production of raw materials required for one ton of mix. The analysis does not include other phases involving the manufacturing of the emulsion and the mix, nor its application, the impact of which, in theory, is independent of that of the product and will not change the absolute deviation between the two options. It is also important to consider the unit of absolute deviation that can be multiplied by the actual tonnage of cold mix on a project, or used annually.
### Table 6
Energy consumption (MJ/T)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Binders</th>
<th>Aggregates</th>
<th>Mixing</th>
<th>Transport</th>
<th>Application</th>
<th>Total</th>
<th>Comparison/ Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emulsion-based mixes (oil flux)</td>
<td>517.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>517.7</td>
<td></td>
</tr>
<tr>
<td>Emulsion-based mixes (Vegeflux)</td>
<td>426.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>426.7</td>
<td>-17.6%</td>
</tr>
<tr>
<td>Deviation</td>
<td>-91.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Figure 1
Energy consumption (MJ/T)

- Emulsion-based mixes (oil flux)
- Emulsion-based mixes (Vegeflux)

### Table 7
GHG emissions in CO₂ equivalent (kg/T)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Binders</th>
<th>Aggregates</th>
<th>Mixing</th>
<th>Transport</th>
<th>Application</th>
<th>Total</th>
<th>Comparison/ Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emulsion-based mixes (oil flux)</td>
<td>13.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.33</td>
<td></td>
</tr>
<tr>
<td>Emulsion-based mixes (Vegeflux)</td>
<td>7.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.43</td>
<td>-44.3%</td>
</tr>
<tr>
<td>Deviation</td>
<td>-5.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Figure 2
GHG emissions in CO₂ equivalent (kg/T)

- Emulsion-based mixes (oil flux)
- Emulsion-based mixes (Vegeflux)
A new range of storable cold mixes with no volatile organic compounds (VOC)

This can be converted into easily-identifiable equivalents (wind power, cars per year, number of homes heated, etc.) For example, using a base figure of 1,000 tons of cold mix, savings in terms of energy and GHG emissions are respectively 91.1 GJ (giga Joule) and 5.9 tons of CO₂

Conversions into easy-to-identify equivalents for 1,000 tons of cold mix are as follows:

• With an average passenger vehicle (6L/100km of diesel fuel): equivalent of driving 38,100km;
• With a well-insulated apartment (12 MWh and 1,600 kg of CO₂ per year, 80 m², C category): equivalent emission given off by heating four apartments for one year;
• With energy content of a barrel of oil (7.3 bbl/t of oil): savings of 16 barrels.

Conclusion

Vegeflux provides an efficient, advantageous replacement for volatile oil-based fluxes in surface dressings and cold mix techniques, with equivalent, even superior performance levels and a favorable ecological footprint. The end results have been consistently remarkable on the numerous Vegeflux cold mix projects involving wearing courses, penetration prime coats, emulsion-based surface dressing and additive agents for slurry seals.

As a convincing industrial approach to sustainable development issues, Vegeflux is now part of the new generation of bio-products designed by the Colas research and development teams. These include Vegeclean and Vegeprotect which replace toxic volatile products designed to clean and protect equipment, Vegemark, a 100% plant-based binder for road markings, Vegecol which replaces bitumen, and more. In addition, Colas, in partnership with Valagro, won support for its development of bio-additives from AGRICE®.

References

[1] AGRICE, Agriculture for Chemicals and Energy, is a French scientific interest group that focuses on coordinating, funding, monitoring and evaluating research and development programmes that further enhanced value for agricultural products and byproducts as energy, chemical and materials feedstocks. AGRICE was founded in 1994 by the French government ministries for Agriculture, Environment, Industry and Research, in collaboration with ADEME, the French Agency for Environment and Energy Management.


[1] “Procédé de préparation d’esters d’acides gras d’origine naturelle fonctionnalisés par oxydation utilisables comme fluxants pour bitume” filed in the names of Colas and Valagro in France on October 11 2005 as no. 05 53086, in Europe on October 10 2006 as no. 06 820 274.6

[1] “Liant routier à base de bitume, de fluxant d’origine naturelle fonctionnalisés et de cire”, filed in the name of Colas in France as no. 0650931 on March 17 2006 and in Europe as no. 07 300 865.8 on March 16 2007


16th IRF World Road Meeting

Lisbon Congress Centre, Portugal
25-28 May, 2010

Mobility, transport, infrastructure / Road Safety & Security / Sustainable Roads / Road Finances & Management / Techniques & Innovations

Organisation contact:
Thibaut Jouvet – Package Organisation
Cité internationale - 10, quai Charles de Gaulle
69463 Lyon cedex 06 – France
Phone: +33 4 78 176 238 - Fax: +33 4 78 176 257

contact@irf2010.com
www.irf2010.com
We invented the coating that gobbles up exhaust gas.

And what if roads and noise barriers could capture the NOx gas that causes pollution spikes? Our research specialists have developed a process that neutralizes up to 30% of this gas using only natural light as an energy source. Roads whose active principles are a benefit to all? There's another new idea.

Eurovia
Paving the way for new ideas.
Eurovia, 18, place de l'Europe, 92565 Rueil-Malmaison Cedex, France
Attica Tollway is the 65-kilometre-long urban toll motorway that forms the Ring road around the city of Athens, Greece. The Tollway operates under a flat-rate, open toll system regime and it is a 24-year Design-Build-Finance-Operate (DBFO) project. Attica Tollway was the first Hybrid – PPP road infrastructure project and the first Tollway in Greece to implement 7/24/365 traffic management, road maintenance, environmental monitoring, thorough customer care and provision of advanced Electronic Toll Collection (ETC) services during its operation stage, thus setting a standard for new concession projects, including the entire National Network of Toll Motorways that followed and that is currently under development. Attica Tollway has resulted in greatly reduced travel times in the Athens Metropolitan area, it has contributed to the overall improvement of the state of transportation around the Greek capital, while it has also contributed to the extensive real-estate development in the areas that now enjoy easy access. It has also been a catalyst for the creation of thousands of employment opportunities in the area. Its success can be verified by the fact that the traffic levels, currently exceeding 300,000 vehicles entries per day, are surpassing initial estimates forecasted at 240,000 vehicle entries per day.

The project

Attica Tollway, one of the biggest peripheral roads in Europe, constitutes an infrastructure project which has revitalized the congested area around Athens, since it is essentially a fully access-controlled tollway within a metropolitan area with acute traffic congestion problems. The 65km-tollway consists of 3 traffic lanes and an emergency lane in each direction and a high speed rail runs along its central strip. The payment of tolls is carried out via both manual (toll collectors), as well as electronic (transponders) methods. The ETC system installed back in 2002 was a first, not only for the tollway, but also for the entire country, and currently penetration stands at about 45%. The general layout of the tollway is shown in Figure 1.

The tollway is part of the Trans-European Network (TEN). The project enables quicker access to areas which, until recently, required a great amount of travel time, as it is a road axis that connects 30 municipalities of Attica and meets the transportation needs of millions of people, on an annual basis.
Toll Motorway Projects in Greece: The case of Attica Tollway

Attica Tollway
Athens, Greece

Figure 1
Attica Tollway
general layout

Its development faced significant difficulties because of the complexity of constructing a motorway in a dense urban area, within a limited area for expropriation and a congested road network. However, difficulties were overcome and the success of the project has exceeded expectations.

Attica Tollway has been constructed on a concession basis; it constitutes one of the largest co-financed road projects in Europe. It belongs to the first generation of co-financed projects awarded in Greece during the 1990's. The project was developed as a PPP in order to:

• **Minimise public funding**
  Public funding (including European Union Structural funds) covered 34% with the private sector providing the remaining 66% project funding, through contractor's equity and loans.

• **Allocate risks to the private sector**
  The project structure allowed the Greek Government to allocate construction, time schedule and operation risks to the sponsors.

• **Make use of EU funding**
  To close the financial gap, turning the project into a hybrid PPP since EU structural funds represented more than half of the Greek State's funding.

**History and Milestones**

The need for a northern ring road running from the west of the city of Athens to its eastern suburbs was identified as far back as 1963, when Wilbur Smith, a full-service transportation and infrastructure consulting firm, came from the United States to undertake the first ever regional traffic planning study for the city of Athens and its metropolitan area.

Sprawling development to the north of Athens over the years, the decision in the late 1970s to build the new International Airport in its present location at Mesogeia and the decision to build a city connector road along the foothills of Mount of Imittos in the early 1990s departed from the original concept of a limited access facility and transformed Attiki Odos (as the road is known in Greek) into an urban freeway, "free" of grade intersections and obstructions but not "free" in terms of money, forming a toll "ring" road, that serves the heart of the city.

Many decades had passed without any serious attempts to initiate this road project, due to funding shortfalls and the high forecasted project cost. Progress began in 1985 when it became part of the official transportation infrastructure plan for metropolitan Athens, along with the goal of organizing the Centennial Olympic Games in 1996 (they marked the 100th anniversary of modern Olympic Games). The bid for organizing the 1996 Olympic Games in Athens failed,
but the plan to build the Toll Road was not dropped. In the early 1990’s, the Greek Ministry of Public Works adopted the method of building the road through co-financing on the basis of a DBFO contract, hence giving the project the funding solution it required.

The list below may appear as a detail; however it helps to appreciate the time difficulties encountered throughout the various milestones for the development of the tollway:

- Issuing of tender documents: 14/02/1992
- Tenders submitted (3 bids): 28/02/1995
- Concession awarded: 23/05/1996
- Ratification of contract: 16/12/1996
- Full Financial Close: 06/03/2000
- First Drawdown: 04/08/2000
- First section in operation: 19/03/2001
- Completion of the project: 24/06/2004
- Current estimated concession end: 05/10/2024

The operation period extends until October 2024, or earlier at the date when the preagreed Return on Equity (ROE) of the concessionaire is reached.

**Difficulties**

The realization of a project of such scale met with significant difficulties along the way. The financial closing kept being delayed, mainly because of uncertainties surrounding the project. These uncertainties increased the risks for the banks, delaying the signing of the financial agreements and forced the Greek State and the sponsors to provide funds to begin construction activities before financial close, so that non extendable milestones, such as the opening of the new Airport, could be met. Difficulties were raised due to variation orders issued by the State, mainly for environmental reasons, which involved significant design changes. Furthermore, the concession contract did not include a mechanism for extensions of time and delay make-up in case of State-instructed variations. Solutions were found following extensive negotiations between all parties involved and amendments to the concession contract were introduced, leading to financial closure.

Additionally, because of absence of legislation specifically authorizing PPP’s, the contract needed to be specifically ratified by the Parliament. Problems were also introduced by the interference of the surrounding municipalities. Construction activities were proceeding in 30 different municipalities of Attica, each with their own traffic needs and requirements, resident desires and concerns on minimization of disturbances to the surrounding urban areas. Last but not least, a stretch of the road had to be altered to accommodate a judicial decision on environmental impact of the project. In addition to the cost overrun, there were subsequent delays as construction came to a halt in the disputed route area. There were also delays, due to design changes ordered by the State and therefore the concession period was eventually expanded (from the original time horizon) by another 19 months to account for these delays. Despite the aforementioned issues, Attica Tollway was built on time and on budget and became thereafter the backbone of the transportation network during the execution of the Athens Olympic Games in 2004.

**Characteristics**

The motorway forms the link which connects the Athens – Lamia National Road with the Athens – Corinth National Road, bypassing the centre of Athens.
Toll Motorway Projects in Greece: The case of Attica Tollway

Being a closed tollway, it has full control of its access points and consists of two sections, which are perpendicular to one another:

- The Elefsina – Stavros – Spata Motorway (ESSM), extending approximately 52km long,
- The Imittos Western Peripheral Motorway (IWPM), extending approximately 13km long.

The major technical characteristics of the Tollway can be summarized in Table 1.

**Stakeholders/ Contracting parties**

The major stakeholders of the project are the following:

- EYDE/LSEP (from the Greek acronym for Special Agency of Public Works/Operation and Maintenance of Concession Projects) is the special service of the Ministry for Environment, Physical Planning and Public Works, which had undertaken the supervision of the project’s construction and which today monitors (on behalf of the Greek State) the tollway’s operation.
- "Attiki Odos S.A.", is the concession company of the project, which undertook the design, construction, financing, operation and maintenance of the motorway, through the execution of a contract with the Greek State. Initial shareholders included 14 companies: Aktor SA, Attikat, Egis Projects SA, Ergas, Meton SA, Sarantopoulos, TEV, Alte, Avax, Elliniki Technodomiki, Etheth, Pantechniki, TEG, and Zeus. Currently, after several mergers, acquisitions and market revolutions, the shareholders of Attiki Odos are Aktor Concessions (60%), J&P Avax (30%) and Attikat (10%), all Greek companies.

The Concessionaire, in order to undertake the construction of the road, entered into a contract with "Attiki Odos construction joint venture", a joint venture of all Greek contractors participating in the project. As it relates to operation, the Concessionaire entered into an O&M Agreement with "Attikes Diadromes SA" (known as Attica Tollway Operations Authority), for the undertaking of all routine operation and maintenance activities of the project. Figure 2 summarizes all entities involved in the project.

**Table 1**

**Major technical characteristics of Attica Tollway**

<table>
<thead>
<tr>
<th>Project features</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total length</td>
<td>65.20km</td>
</tr>
<tr>
<td>Service / side roads network</td>
<td>150km</td>
</tr>
<tr>
<td>Interchanges</td>
<td>29</td>
</tr>
<tr>
<td>Roadway bridges / Overpasses</td>
<td>100</td>
</tr>
<tr>
<td>Roadway bridges / Underpasses</td>
<td>25</td>
</tr>
<tr>
<td>Railroad bridges</td>
<td>38</td>
</tr>
<tr>
<td>Stream bridges</td>
<td>21</td>
</tr>
<tr>
<td>Pedestrian Overpasses</td>
<td>12</td>
</tr>
<tr>
<td>Tunnels / Cut &amp; Cover Sections</td>
<td>56</td>
</tr>
<tr>
<td>Total length of Tunnels and Cut &amp; Cover Sections</td>
<td>15.36km</td>
</tr>
<tr>
<td>Flood protection works</td>
<td>66.7km</td>
</tr>
<tr>
<td>Customer Service Centres</td>
<td>9</td>
</tr>
<tr>
<td>Toll Stations</td>
<td>39</td>
</tr>
<tr>
<td>Total number of toll lanes</td>
<td>195</td>
</tr>
<tr>
<td>Toll lanes with ETC capabilities</td>
<td>55 – 92</td>
</tr>
<tr>
<td>Toll lanes with manual toll</td>
<td>103 – 140</td>
</tr>
<tr>
<td>collection capabilities</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2**

Main contracting parties
**Concession structure**

The project was structured as a real toll DBFO project with strong government financial backing during construction. It followed the structure shown in Figure 3. Overall, the Greek government was able to transfer construction, and operation risks (subject to a standard non-compete clause) to the sponsors under the concession contract. The lenders to the SPV (Concessionaire) were therefore fully exposed to these risks, mitigated as they might be through the construction and operation subcontracts.

However, European Investment bank’s (EIB) policy is that they do not accept construction risk, and they will usually accept remaining project risks only after a period of satisfactory operation and the demonstration of acceptable cover ratios. Accordingly, as is usually the case, the EIB loan was guaranteed by the other lenders (a number of commercial banks, with Bank of Tokyo – Mitsubishi acting as the Inter-creditor Agent). Once construction was complete, these guarantees were transferred to the Greek government. This way, the Greek government did effectively transfer construction risk to the SPV, but has taken traffic risk back through the guarantee, albeit at a reduced level compared with the risk at the outset.

**Project financing**

The project financing has been ensured through State contribution (including European Commission (EC) Structural Cohesion Funds), Concessionaire equity and bank loans. Construction cost (about 1.3 billion Euro) was covered as follows:

- 34% Greek State contribution,
- 16% Concessionaire equity,
- 50% loans (9% Commercial Banks loans and 41% EIB loans).

Expropriation cost was undertaken entirely by the Greek State.

---


*Construction companies included the 14 sponsors mentioned above.

---

**Figure 3**
The Concession structure of Attica tollway
The operational success of Attica tollway

One of the main issues affecting the success of a new, tolled road is the fact that the public generally opposes the payment of tolls. This fact greatly jeopardizes the success of any tollway, as it can make financing very difficult, while in the case of a DBFO project, it can affect the project’s revenues. In order to mitigate the risks of people’s opposition to paying tolls (and hence, refusing to either use the new tollway, or limiting their trips), it is essential to provide not only what is required by contract but also a level of service which is offering people "their money’s worth", contributing to the user's feeling that they are getting what they pay for. In Attica Tollway, a high level of service is provided in various fields: safety, traffic and incident management, maintenance, ETC performance resulting in overall customer satisfaction. As a result of this, Attica tollway has exceeded forecast expectations of traffic demand, as shown in Figure 4. Demand forecast had to be at the level of 240,000 vehicle entries per day in 2010, but in 2008, the average daily traffic was almost 300,000 vehicles per day!

The main reason for this difference between anticipated and real traffic is that Attica tollway is offering significant improvements to traffic conditions in the metropolitan area, as well as it benefits the economy by modernizing the overall infrastructure. Also, as far as safety is concerned, road-user satisfaction with regards to level of safety currently stands at 92.7%, despite the continually increasing traffic volumes. Time-savings, and hence reduction in fuel consumption, have also been significant. Figure 5 demonstrates time-savings, as perceived by the users of the tollway and as shown, more than half of the trips in Attica tollway occur with significant time savings in the order of 16-30 minutes per trip.

Figure 5

Time-saving (per trip) as stated by users from the use of Attica tollway in 2009

Attica tollway played a critical role in the development of urban and land-use planning requirements for the metropolitan area of Athens. The presence of Attica tollway was a major stimulus for the development of the Mesogia Basin (east boroughs of the metropolitan area),

Annual Average Daily Transactions (Mar. 2001 - Dec 2008)

Cumulative traffic growth (real: anticipated):

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>33,600 vpdl</td>
<td>36,500 vpdl</td>
<td>125,500 vpdl</td>
<td>231,542 vpdl</td>
<td>248,784 vpdl</td>
<td>270,602 vpdl</td>
<td>295,160 vpdl</td>
<td>300,993 vpdl</td>
</tr>
</tbody>
</table>

Figure 4

Actual traffic vs. anticipated traffic in Attica tollway
Noise barriers installed along Attica tollway to protect from traffic-generated noise

since it provided a direct link of these areas with the centre of Athens. In addition, Attica tollway contributed to the improvement and modernization of the road infrastructure, the creation of thousands of employment positions, while also providing direct links between all means of transport and infrastructures (airports, metro, suburban railway, containers stations). In terms of environmental impacts, Attica tollway has greatly improved the quality of life of the inhabitants of the greater metropolitan area of Athens, not only by providing significant time savings, but also by continuously monitoring and improving the surrounding environment, in terms of air quality, noise, planting, flood protection etc. Over 18km of noise barriers (Photo) have been installed to protect people living close to the motorway from traffic-generated noise, and continuous measurements and remedial actions are performed to ensure minimum disruption. The cut and cover sections (Photo) constructed have been densely planted and currently serve as recreational areas and provide safe passages for the local fauna. Finally, its successful implementation has lead to the realization of the next generation of PPP motorway concession projects in Greece (such as Olympia Odos, Moreas, Aegean Motorway, Ionia Odos, Nea Odos), starting a new era for the construction of large-scale road infrastructure projects in Greece.

Achievements and recognition

The concessionaire’s and the Operating Agency’s dedication to the environment and the strive for the constant improvement of the overall operation of Attica tollway has been recognized by the industry and various prestigious international organizations as Attica tollway operations Authority has been proudly recognized by the following awards:

• 2003: Attica tollway operations Authority was awarded the "Décibel d'or" prize (Gold medal) from Conseil national du bruit (CNB) of Paris, France, in the category “City and Transport” and for the program "Management and reduction of Road Noise Pollution from the Operation of Attica Tollway."

• 2005: Attica Tollway Operations Authority was awarded 1st Prize on Road Safety by the International Road Federation (IRF) for its proactive initiatives making Attica Tollway the safest Motorway in Greece and amongst the safest in Europe.

• 2008: Attica Tollway Operations Authority was awarded 1st Prize in the Global Road Achievement Award competition in the category of Environmental Mitigation, by the International Road Federation.

• 2009: Attica Tollway Operations Authority was awarded IBTTA'S (International Bridge Tunnel & Tumpike Association) "Toll Excellence Award" in the category of Administration for its method of monitoring the operational success of the Tollway. This constitutes one of the Toll Industry’s most prestigious Awards.

In addition, the Operating Agency is ensuring that all procedures followed are standardized and widely used and it adheres to the requirements of the following certification processes with which it has been certified, as:

• ISO 14001: 2004 for Environmental Management Systems,

• BS OHSAS 18001: 2007 for Occupational Health and Safety.

Above all measures taken by the Leadership and the Management of the Tollway and over any kind of industry recognition, the most important award for the Agency is the trust and the confidence of its users, as this is widely expressed in all independent opinion polls.

Vrilissa Cut & Cover

Nosie barriers installed along Attica tollway to protect from traffic-generated noise
Actually, building a road requires only a little bitumen.

Have you any idea how much intelligence goes into building a road? Eurovia builds roads that deactivate polluting gases, drain rainwater, and absorb noise. Safer roads that enhance braking and are more resistant to heat, frost and poor weather conditions. Roads that help reduce natural resource consumption. Intelligent roads resulting from our personnel’s combined talent.

Eurovia
Paving the way for new ideas.
Eurovia, 18, place de l’Europe, 92565 Rueil-Malmaison Cedex, France
Sulphur extended asphalt (SEA) mixtures were used commercially in the 1970s and 1980s in North America as well other parts of the world, i.e. Middle East and Europe (France, United Kingdom). Performance properties of sulphur extended mixtures were shown to be equal or sometimes even better than conventional asphalt mixtures [1]. However, handling and safety issues were of concern, as molten sulphur was difficult to use and sometimes generated unacceptably high H₂S emissions. Asphalt mixture containing sulphur is resurging as an alternative to meet high energy demand forecasts and Shell has made efforts to develop a new sulphur technology. This technology, based on sulphur in pellets, initially known as Shell SEAM has been further developed and is now known as Shell Thiopave. Shell Thiopave improves health, safety and environment (HSE) aspects compared to SEA technology and maintains enhanced structural properties of modified sulphur asphalt mixtures compared to hot mix asphalt (HMA). Like the SEA technology, this new technology is a bitumen extender therefore, can replace part of the bitumen that is required and is also an asphalt mix modifier. This technology contributes to the conservation of resources by replacing some of the bitumen (derived from crude oil) with sulphur, whose availability is increasing through the processing of hydrocarbons with higher sulphur content and the removal of sulphur from fuels for environmental reasons.

Introduction

Experiments in the 1930s [2] showed that sulphur combines with bitumen (asphalt cement) and modifies the bitumen properties. Sulphur extended asphalt (SEA) mixtures were introduced in the 1970s [3, 4] and continued in the early 1980s as an alternative technology to reduce bitumen consumption. Road surveys indicated that the performance was comparable or sometimes better than conventional HMA [1]. Over 100 road projects in the US alone were constructed during this period mainly utilising hot liquid sulphur in addition to asphalt paving mixtures. Whilst odour and vapour emissions from the hot paving mixtures during road construction were in compliance with legislated health standards at the time, they were a regular source of worker complaints.
A sulphur pastilising process was developed in the late 1990s that facilitated the handling of elemental sulphur in a solid form. This technology was further enhanced with the incorporation of plasticisers in the sulphur pellets that allowed the sulphur to be added to asphalt mixtures with emissions and odour greatly reduced when compared to the liquid sulphur asphalt mixtures. These improvements did not affect the asphalt mixture performance and laboratory studies show that the advantages obtained with the old SEA technology were at least conserved and sometimes improved. These advantages and further improvements in handling, HSE conditions and asphalt mix performance properties have generated interest from road industry in using this modified sulphur pellet technology in paving mixtures.

**Differences between SEA and Shell Thiopave technologies**

A comparison between the main features of the former Sulphur Extended Asphalt technology and the Shell Thiopave technology is summarized in Table 1.

<table>
<thead>
<tr>
<th>Sulphur extended asphalt (SEA)</th>
<th>Shell Thiopave</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sulphur conditioning</strong></td>
<td>Liquid (*)</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>In a dedicated hot-storage tank</td>
</tr>
<tr>
<td><strong>Sulphur storage and handling temperature</strong></td>
<td>124°C - 154°C (sulphur storage) 124°C to 149°C (bitumen and sulphur blending) [6]</td>
</tr>
<tr>
<td><strong>Use of sulphur</strong></td>
<td>Hot in line mixing: • Direct mixing with aggregates and asphalt • Pre-blending with bitumen</td>
</tr>
<tr>
<td><strong>Mixing temperature</strong></td>
<td>150°C max</td>
</tr>
<tr>
<td><strong>Compaction temperature</strong></td>
<td>Above 125°C</td>
</tr>
<tr>
<td><strong>HSE</strong></td>
<td>Issue with hot storage, and emissions with sulphur degassing and venting. Tank maintenance and corrosion issue (***)</td>
</tr>
</tbody>
</table>

(*) The process using liquid sulphur was more often used.

(**) Sticking to this temperature range when manufacturing the mixture is required for a safe and good application of the product.

(***) No major issue has been reported on mixing and paving equipments when using SEA or Shell Thiopave up to date. However, sulphur vapour can condense on the walls of equipments and should be removed during normal maintenance period. Also, Thiopave mix residues must be removed before any HMA production (made at higher temperature) in order to avoid emissions and odours from over-heating sulphur. This can be done by running HMA production at a lower temperature (145°C max) or by putting aggregates through the system.

In the past, liquid sulphur required special attention to storage conditions because emissions caused by sulphur degassing and crystallization due to heterogeneous heating could be an issue. Good temperature control during sulphur blending with bitumen was also required to deliver a homogenous blend to the mixer [5] thereby, keeping emissions as low as possible. Sulphur powder was also experimented with in the direct mixing process but required special attention to avoid the formation of an explosive dust atmosphere.

Using Shell Thiopave helps improve the handling of sulphur in asphalt in two ways:

• First, the fact that the product is pelletised is a major step forward in terms of avoiding liquid sulphur handling and related emission issues.

• Second, the modification of the sulphur allows effective mixing and compaction at significantly lower temperatures. Asphalt mixtures containing Shell Thiopave have a target manufacturing temperature of 130°C, which gives customers a 20°C operating window below the temperature (150°C), after which emissions start to rise notably. 150°C was the maximum target mixing temperature for the liquid sulphur asphalt mix technology.
The supply of sulphur used to manufacture sulphur-enhanced asphalt has always come mainly from the oil and gas industry. The former SEA technology was very sensitive to the purity of sulphur used. The combination of high mixing temperatures and varying levels of encapsulated H2S (hydrogen sulphide) in sulphur led to the sulphur off-gassing and odours being released which negatively impacted HSE conditions in the mixing plant and further on the paving site. Furthermore, when the sulphur asphalt binder was prepared and stored in vessels or tanks, the H2S quickly built up in the vapour space within a matter of minutes reaching levels of several percent even when temperature was maintained at 140°C [7].

With the new technology there is no emission issue with binder storage as the product is stored at ambient temperature and only added during the asphalt manufacturing stage. The pelletisation process includes modification of the sulphur with additives acting as pre-cursors to significantly reduce odour and emissions (with a magnitude above 10 times) which positively impact further HSE conditions when mixing and paving.

Thiopave pellets are manufactured to meet the SUDIC (Sulfur Development Institute of Canada) specifications for premium sulphur products.

**Roles of the modified sulphur pellets**

The modified sulphur pellets are used as an additive in asphalt paving mixtures. The pellets, when melted, act as both a binder extender and an asphalt mixture modifier. Modified sulphur pellets, as shown on Photo 1, are made based on Shell's experience in sulphur technology.

As already mentioned above, it uses a process for forming sulphur pellets including plasticizers and pre-cursor agents for reducing odour and emissions that have the following benefits:

- Increase in the workability of the asphalt mixture allowing asphalt to be manufactured at a cooler temperature (125°C - 145°C) than the liquid sulphur asphalt mixtures in the 1970s.
- Reduce of sulphur-based emissions as previously mentioned with the asphalt mixture being produced at a cooler temperature.

**Role of Shell Thiopave in the paving mixture**

The modified sulphur pellets are added at ambient temperature to the hot mixture of aggregates and bitumen during the mixing process. They are not pre-blended with bitumen, (as could be the case with the former SEA technology), thereby avoiding separation and fume emissions during storage. The pellets melt quickly above 120°C and are easily dispersed in the asphalt mixture during mixing. The modification of the sulphur helps to better disperse Shell Thiopave in the asphalt mixture. This modified sulphur combines with bitumen in a similar way to previous liquid sulphur technologies. As an example, Figure 1 shows the portion of sulphur that chemically combines with the bitumen (dissolved), thus acting as a bitumen extender, compared to the sulphur that remains available for restructuring (crystalline). The latter part of sulphur forms the lattice that gives structural performance enhancement [4].

![Figure 1](image)

**The sulphur/bitumen chemistry**

is similar when using modified sulphur pellets, compared with older liquid technology, except that it is obtained at lower temperatures (125°C to 145°C). The older technology required achieving the pre-blend of bitumen and liquid sulphur at a temperature range of 124-149°C [6]. However, when this blend was added to the hot aggregates, the recommendation was to keep the mix temperature below 150°C. A field trial [5] reported average manufacturing temperature of 136°C at the mixing plant, but for the same trial, an average of maximum temperatures of 162°C was also reported which is unacceptable from an HSE perspective. In this case, the issue was to manage...
Shell Thiopave® modified sulphur pellets for asphalt paving mixtures
Focus on use of available resources

properly the temperatures of the bitumen (supplied at a temperature above 150°C), the liquid sulphur and the aggregates. Other trials reported hot mix production at 149°C [4] with subsequent sulphur vapours and emissions.

Asphalt mixture design with modified sulphur pellets

The combination of sulphur and bitumen results in some of the bitumen being replaced by sulphur in the mix design. As the specific gravity of the modified sulphur pellets is nearly 2 (virtually twice that of bitumen), the binder content of the paving mixture made with modified sulphur pellets, in terms of mass, is generally increased to achieve the same volume of binder as the conventional hot mix asphalt (HMA). In the past, the replacement was regularly made at a lower total volume of binder [1, 6] which occasioned some premature failures. Today, to achieve good durability of the mixture, it is recommended that the binder volume is maintained at the same level as the conventional HMA.

The quantity of modified sulphur pellets in the binder content depends on the type and the application of the sulphur modified mixture. In order to get a paving mixture with enhanced structural properties, a bitumen/sulphur mass ratio of 60w%/40w% is generally recommended whereas for general application the ratio should be switched to 70w%/30w%. However, these ratios are indicative and the choice depends on the mixture formulation, material and bitumen qualities. Therefore, it is recommended that a mix design be carried out to check the asphalt mixture properties. The paving mixture design made with modified sulphur pellets does not require changes other than replacing part of the bitumen (around 15% to 25% of the bitumen mass may be replaced) in order to gain significant enhancement of the paving mixture properties.

Review of asphalt mixtures performance modified with Thiopave

Resistance to rutting

As expected from enhancement of structural property, paving mixtures made with modified sulphur pellets have better resistance to permanent deformation in comparison with HMA. This is shown in Figure 2 with two types of mixtures;

the mixture difference being the aggregate quality and grading curve [8]. The binder volumes were similar using a performance grade PG 58-28 for the conventional HMA and 60% mass of the PG 58-28 and 40% Shell Thiopave for the modified mixture. The Asphalt Pavement Analyzer (APA) was used to carry out testing at 58°C. Some other studies have shown that Shell Thiopave could contribute to use lower quality aggregates as also shown in Figure 2 [5, 8].

<table>
<thead>
<tr>
<th>Sandy aggregates mixture</th>
<th>Highly crushed aggregates mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional HMA</td>
<td>Paving mixture with modified sulphur pellets</td>
</tr>
<tr>
<td>Conventional HMA</td>
<td>Paving mixture with modified sulphur pellets</td>
</tr>
</tbody>
</table>

Figure 2 Rutting behaviour of different asphalt mixtures

Water sensitivity

Paving mixtures made with modified sulphur pellets generally exhibit equal resistance to water ingress compared to conventional asphalt mixtures. However, some specific studies have assessed the effect of water both on loose paving mixtures and compacted specimens made with limestone aggregates and modified sulphur pellets in comparison with HMA and found contradictory results. Again, the modified paving mixture was made, at the same binder volume content as HMA and with 60% bitumen and 40% modified sulphur pellets in mass. Immersion of loose mixtures in hot water (60°C) indicated no significant difference in binder film detachment for a period of time up to 72 hours and indicated no difference in the effect of water saturation for both mixture types [9]. However, with this limestone aggregate, the retained Marshall stability and the tensile strength ratio (TSR) were found to be reduced by 10% for paving mixtures made with modified sulphur pellets compared to conventional asphalt mixtures. Exploratory Hamburg wheel-tracking tests of specimens submerged in hot water confirms the same trend. Typically, with these aggregates, the use of anti-stripping agents such as amine additives has been found to significantly improve the water resistance properties. This demonstrates that when any new mixture is developed, it is good engineering practice to examine the water sensitivity characteristics.
**Stiffness**

As stated above the asphalt mixture stiffness is generally increased with Shell Thiopave when the concentration of the modified sulphur pellets in the binder is above 30% by mass. The increase is significantly improved at elevated temperature and lower frequencies than at lower temperature and higher frequencies. Thus the asphalt mixture is less sensitive to temperature and loading time than conventional HMA. Figure 3 illustrates this in a representation of 3 asphalt mixture Master Curves, built at a reference temperature of 15°C, that can be described as:

- Conventional HMA (Béton bitumineux semi-grenu, BBSG) with a 70/100 pen grade bitumen,
- Two Shell Thiopave mixtures, same grading curve, same volumetric properties but with 30% and 40% Thiopave in the binder.

![Master Curves Reference Temperature at 15°C](image)

This figure shows that 40% of Shell Thiopave in the asphalt mixture exhibits a stiffness increase while 30% leads to the same level of stiffness as the conventional mix but with a lower bitumen content. This confirms that it is important that mix design is followed by performance based testing to ensure that benefits will be reflected in the pavement behaviour.

**Fatigue**

The fatigue performance depends on whether the test is at imposed strain or stress. In an imposed strain test the allowable strain would be lower because the modified mixture is stiffer and generates higher stresses during fatigue testing. At imposed stress the modified mixture behaves better with higher allowable stresses. This is illustrated in Figures 4 and 5 in a four point bending test (AASHTO T321-03) with asphalt mixtures being similar (same grading curve and volumetric, conventional mixture made with a 70/100 pen grade bitumen and modified mixture with 60% of 70/100 pen and 40% Shell Thiopave).

![Fatigue test at imposed strain](image)

As previously stated, the asphalt formulas were similar with the exception of the binder. Depending on the test that is being considered (imposed strain or stress), the optimisation of the formula can be tailored to reach fatigue specification criteria. This is particularly important in the French mix design with the 2 point bending test and is currently under Shell consideration for heavy-duty applications.

**Cracking resistance at low temperature**

The low temperature performance of paving mixtures made with modified sulphur pellets was assessed in the TSRST (Thermal Stress Restrained Specimen Test), according to the AASHTO TP10 test method, with some modifications.
Low temperature sulphur technology

Shell Thiopave® modified sulphur pellets for asphalt paving mixtures
Focus on use of available resources

to the specimen size. The temperature conditioning of TSRST does not attempt to simulate the in-situ temperature cycling condition, which causes low temperature fatigue cracking. Moreover, it monotonically decreases temperature until the specimen fails in tension (single event thermal cracking). However, some studies have shown that low-temperature behaviour of asphalt concrete pavements can be predicted by the TSRST [10, 11].

This study indicated that the presence of modified sulphur pellets in the binder does not detrimentally affect the low temperature performance of the mixture when compared to the conventional asphalt mixture as shown in Figure 6. The development of the induced stress in the specimens, with the temperature decrease, was very similar for both types of asphalt mixtures. It even showed slightly higher stress and lower fracture temperature for the asphalt mixture made with the modified sulphur pellets. The conventional HMA was made with 70/100 pen grade bitumen and the sulphur modified mixture was made with the same bitumen and 40% sulphur modified pellets by mass. Both asphalt mixtures had the same total volume of binder.

TSRST with 70/100 with and without Thiopave

Figure 6
TSRST tests at a temperature decrease rate of 10°C per hour

Figure 7 shows the fracture temperature and the induced stress for the same type of asphalt mixture in which different quantities of sulphur modified pellets were introduced. The general trend of the figure, representing the mean value of 3 tests per asphalt formula, shows that the specimens made with modified sulphur pellets behave the same or even slightly better in terms of cold fracture temperature and induced stress as compared to the conventional asphalt mixture.

Asphalt mixing operations with modified sulphur pellets

Manufacturing and handling protocols have been developed that include control of the temperature to maintain a range of 125°C to 145°C when using Shell Thiopave. The minimum temperature, i.e. 125°C, is required to melt the pellets. Normally, the modified sulphur pellets are added to the asphalt mixture at a mixing temperature of 130°C.

As mentioned before, the chemical combination between modified sulphur and bitumen requires close control of the temperature during the mixing process to ensure that hydrogen sulphide (H₂S) and sulphur dioxide (SO₂) emissions are managed and are within their respective short and long-term Occupational Exposure Limits (OEL).

As an example, some typical values recorded during Industrial Monitoring for a client project in Qatar are given in Table 2. This project aimed to produce and lay a binder course and a surface course including Shell Thiopave at 40% mass in the binder. The Thiopave mixture was produced at a temperature varying between 132°C and 141°C. The monitoring consisted in measuring the H₂S and SO₂ emissions at the mixing plant and at the paving site and at different locations as summarized below. This table shows that the emissions measurements comply with regulation defined for this trial. As Qatar had not specific OEL for H₂S and SO₂, the ACGIH (American Conference for Industrial Hygienists) TLV (Threshold Limit Value) were adopted and are reported for comparison with emissions measurements in Table 2.
Finally, materials that are produced above 145°C should be disposed of in a segregated and controlled manner, as there is the potential for gas to be released from small pockets during laying and compaction work. The temperature target can be easily maintained because the type of binder that is typically used for paving mixtures made with modified sulphur pellets is a relatively soft, with high temperature performance grade range from PG 46 (300/400 pen) to PG 70 (60 pen) bitumen. Furthermore, because the modified sulphur has a viscosity reducing effect on the bitumen, it helps in achieving the ideal viscosity of the binder necessary for coating at a lower temperature [8].

Health, Safety and Environmental (HSE) management of modified sulphur pellets

Product stewardship principles and actions

Shell has given particular attention to management of the product according to classic product stewardship principles in order to:
1) Ensure that the process HSE risks are identified over the entire life cycle.
2) Assess the impacts that these risks may have on users.
3) Ensure that suitable and sufficient controls are put in place to allow workers to use, ship, handle, store and dispose of the product safely.

In order to build the product stewardship manual, a Shell Hazards and Effects Management Process was developed for the modified sulphur pellets described herein. Following baseline assessment, a number of actions were undertaken, such as “controlled” intentional product-abuse trials, to ensure that all risks had been considered and could be managed [14]. The trials were carried out in China and conducted in order to determine the temperature at which the operation can safely be run and to check how the gaseous emissions complied with Chinese regulations on Occupational Exposure Limits (OEL). Worst case scenario trials were also conducted which included processing and paving over-heated, over-stored virgin paving mixture made with modified sulphur pellets to compare it with conventional asphalt mixtures.

Typically the scenario parameters were:
• Manufacturing temperatures set at 140°C and 170°C.
• Asphalt mixture storage time in the plant silos set at 2 and 6 hours.

During these specific worst case scenarios, industrial hygiene air monitoring was conducted to determine potential worst case exposures of the mixing plant operators, truck drivers and the paving crew to hydrogen sulphide (H₂S), sulphur dioxide (SO₂) and total hydrocarbons from modified sulphur off-gassing. It must be emphasized that the operating conditions in these specific trials were not representative of the processing conditions for typical paving mixtures made with modified sulphur pellets. As a result, it was concluded that the overall moving average and time-weighted average exposures for SO₂ emissions were below the occupational exposure limits defined in this country. Fifteen-minute moving averages were also calculated for H₂S concentrations and these were also below the Maximum Allowable Concentration (MAC) of 7 ppm as used in China. These limits are given in Table 3.

<table>
<thead>
<tr>
<th>Minimum and maximum values</th>
<th>8-hour TWA (Time Weighted Average)</th>
<th>15-minute STEL (Short Term Exposure Limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H₂S (ppm)</td>
<td>SO₂ (ppm)</td>
</tr>
<tr>
<td>Truck loading area (mixing plant)</td>
<td>&lt; 0.2</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>At the paver console</td>
<td>&lt; 0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>At the paver screed (paving site)</td>
<td>&lt; 0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>ACGIH TLV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLV 8-hour TWA</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>TLV 15-min STEL</td>
<td>15</td>
<td>5</td>
</tr>
</tbody>
</table>

(¹) No comparative data are available with conventional HMA to be able to quantify the emissions from the exhaust pipes of the trucks and the paving machines.

Table 2
H₂S and SO₂ emissions compared to ACGIH TLV for a client project in Qatar
Shell Thiopave® modified sulphur pellets for asphalt paving mixtures
Focus on use of available resources

<table>
<thead>
<tr>
<th>Occupational Exposure Limits (OEL) in China</th>
<th>H₂S (ppm)</th>
<th>SO₂ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-hour TWA</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>15-minute STEL</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>MAC (Maximum Allowable Concentration)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(similar to 15-minutes STEL (ppm))</td>
<td>7 (*)</td>
<td></td>
</tr>
</tbody>
</table>

(*) Only a MAC (Maximum Allowable Concentration) for H₂S is defined in China

Table 3
Occupational Exposure Limits in China

During this trial, some peaks of H₂S were detected on occasion, when the manufacturing temperature was set to 170°C. But no emission concentrations with the potential to cause serious injury were recorded during any of the different trial phases. Typically these peaks exceeded the ceiling limits of 15 ppm that is, for example, taken into account in Canada and for which engineering control measures must be put in place to comply with HSE regulations. This trial confirmed the limit that was set for the maximum temperature for manufacturing the modified asphalt mixture i.e. 145°C.

Emissions comparison with the SEA technology

Environmental and HSE aspects were also studied in the past with the SEA technology and some projects were monitored for H₂S, SO₂, particulates and sulphur emission during mixing in both drum mixer and batch mixer [7]. In this paper it was concluded that the Canadian occupational and environmental limits were not exceeded but only occasional peaks of H₂S and eye irritation were observed. For information, these limits are given in Table 4 with the ACGIH TLV that were adopted in most Canadian Provinces.

Only the batch plant (Renfrew) and the emissions measured at this plant and at the paving site are considered in this paper. They are reported in Table 5. The emissions above the truck were measured after the asphalt mix was dropped into the truck.

### Table 4
Ambient air objectives and occupational exposure limits in Canada [7]

<table>
<thead>
<tr>
<th>Canadian Acceptable Air Quality Objectives</th>
<th>ACGIH TLV (8 hour/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hour average</td>
</tr>
<tr>
<td></td>
<td>3 ppb</td>
</tr>
<tr>
<td></td>
<td>0.11 ppm</td>
</tr>
<tr>
<td>Particulates</td>
<td>120mg/m³</td>
</tr>
</tbody>
</table>

At that time, it was considered that temperature above 150°C would be of concern regarding emissions. Also the Occupational Exposure Limits that were considered were only the ACGIH TLV 8 hour/day with a limit of 10 ppm maximum for H₂S and 5 ppm for SO₂ as shown in Table 4. Nowadays, a Short-Term Exposure Limit has been introduced (STEL 15-minute) and certain limits have been drastically reduced in some countries. UK has a TWA (Time Weighed Average) 8-hour of 5 ppm and a STEL of 10 ppm for H₂S and the ACGIH removed the TWA and reduced the STEL to 0.25 ppm for SO₂.

With Shell Thiopave the mixing temperature range is 125°C to 145°C but the targeted temperature is definitively 130°C. A recent project carried out in India has shown that it is possible to comply with the proposed new ACGIH TLV (Threshold Limit Values) TWA (8-hour) of 1 ppm and STEL (15-minute) of 5 ppm for H₂S and marginally exceed the very stringent TLV STEL of 0.25 ppm for SO₂. This project aimed to compare the emissions at the mixing plant (batch plant) and at the paving site between a HMA and a Thiopave mixture.

The emission measurements are reported in Table 6 for H₂S and in Table 7 for SO₂.

It can be seen that exposure to H₂S during the trial were below the Indian limits and the lowest current exposure limits (TWA and STEL) and would have been up to the new ACGIH TLV TWA of 1 ppm if that limit were to become adopted in the future.

It can be seen from the Table 7 that exposure to SO₂ during the trial is within the Indian Limits (TWA and STEL) and exceeded the ACGIH TLV STEL.
of 0.25 ppm at all positions, with Thiopave mixture, excepted the control room at the mixing plant and at the paver screed on paving site. However, this limit is also exceeded for the HMA at the paving site, on the paver, certainly due to the exhaust emissions of the trucks and of the paver [15]. Even if the comparison between the emissions from the SEA technology, as reported above and the emissions from Shell Thiopave technology must be taken with care, in view of the differences between the type of materials used for manufacturing the asphalt mix, the measurement protocols and the equipment used to measure the fume emissions, the SEA technology shows higher H₂S emissions in this reported cases. It must be emphasized that Shell Thiopave has been designed to encompass a sulphur modification that aims at reducing the H₂S emissions from the raw liquid sulphur that comes from the oil and gas industry. This was not the case in the past with the SEA technology.

The benefit of this modification on the reduction of the amount of entrapped H₂S in sulphur is shown in Figure 8 for five different raw sulphur supplies (from A to E).

![Figure 8](source.jpg)

*Effectiveness of sulphur modification on H₂S emissions*

---

**Table 6**

Comparison of the workplace H₂S measurements with various exposure limits for a project in India

<table>
<thead>
<tr>
<th>H₂S results (ppm)</th>
<th>8-hour TWA</th>
<th>15-minute STEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HMA</td>
<td>Thiopave mixture</td>
</tr>
<tr>
<td>At the mixing plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck loading</td>
<td>0</td>
<td>0.5 - 0.8</td>
</tr>
<tr>
<td>Control room</td>
<td>0</td>
<td>Up to 0.1</td>
</tr>
<tr>
<td>Mixer</td>
<td>0</td>
<td>Up to 0.1</td>
</tr>
<tr>
<td>At the paving site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paver console</td>
<td>0</td>
<td>0.4 - 1.0</td>
</tr>
<tr>
<td>Paver screed</td>
<td>0</td>
<td>0.1 - 0.5</td>
</tr>
</tbody>
</table>

| UK OEL            | 5   | 10            |
| ACGIH TLV (Current)| 10  | 15            |
| ACGIH TLV (Notice on Intended changes) | 1   | 5             |
| Indian Limits     | 10  | 15            |

**Table 7**

Comparison of the workplace SO₂ measurements with various exposure limits for a project in India

<table>
<thead>
<tr>
<th>SO₂ results (ppm)</th>
<th>8-hour TWA</th>
<th>15-minute STEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HMA</td>
<td>Thiopave mixture</td>
</tr>
<tr>
<td>At the mixing plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck loading</td>
<td>0-0.02</td>
<td>0.07 - 0.29</td>
</tr>
<tr>
<td>Control room</td>
<td>0</td>
<td>Up to 0.05</td>
</tr>
<tr>
<td>Mixer</td>
<td>0</td>
<td>Up to 0.05</td>
</tr>
<tr>
<td>At the paving site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paver console</td>
<td>0 - 0.30</td>
<td>0.1 - 0.53</td>
</tr>
<tr>
<td>Paver screed</td>
<td>0 - 0.34</td>
<td>0.03 - 0.22</td>
</tr>
</tbody>
</table>

| UK WEL             | None | None          |
| ACGIH TLV          | None | 0.25          |
| Indian Limits      | 2    | 5             |
Shell Thiopave® modified sulphur pellets for asphalt paving mixtures
Focus on use of available resources

CE marking
From 1st March 2008, the Construction Product Directive stipulates that hot asphalt mixtures sold in the European market must be CE marked. This implies that the manufacturing process must be certified and that asphalt mixtures comply with the “Type Testing” standard (EN 13108-20) and with the relevant harmonized standard (EN 13108-1 to EN 13108-7). The certification of the manufacturing process shall conform to the “Factory Production Control” standard (EN 13 108-21). Although bituminous binders and aggregates are CE marked, Shell Thiopave as a raw material is out of the scope of the CE marking. Indeed, the Factory Production Control standard allows using non-CE marked products provided the asphalt mixture conforms to the relevant harmonized asphalt mixtures standard (EN 13108-1 to EN 13108-7).

Impact of REACH
Shell Thiopave has been pre-registered with ECHA (European Chemicals Agency) for REACH compliance with step 1 (pre-registration). Shell Thiopave is a preparation meaning it contains several substances. For the time being Shell Thiopave is imported from Shell Canada into Europe. Shell UK and Shell France have registered the product as “Shell Thiopave” importing companies. Regarding step 2 of REACH registration, this would be completed before end of 2010 as by this time Shell Thiopave would be imported in quantities above 1,000 ton per year.

Recycling Shell Thiopave mixes
Proper road management should indicate where Thiopave mixtures have been laid in order to identify and segregate such RAP (Reclaimed Asphalt Pavement). If this is not the case, the presence of Thiopave in asphalt can be determined on site with 2 alternative methods [16]. The presence of sulphur in the pavement was also considered in the SAMARIS project [17]. Due to temperature constraint, HIR (Hot in Place Recycling) is not recommended as it can generate fume emissions. Recycling techniques that can be considered for Shell Thiopave mixtures are cold recycling and hot in plant recycling. While cold recycling does not present any difficulty or HSE issue as sulphur is not leached by water, hot in plant recycling requires some care and needs to be investigated at the mixing plant. Although some former studies have showed that SEA could be recycled up to 50% [7, 18] with virgin overheated mixtures without more subsequent fume emissions than for fresh SEA mix, it is important to re-validate this part of the life cycle for Shell Thiopave mixture. Also the recycling aspect is currently being updated for different RAP concentrations of Thiopave mixture in virgin HMA, virgin Thiopave mixtures with RAP from HMA or Thiopave mixtures. A preliminary laboratory study has indicated that again the temperature at which the Thiopave is introduced is the main factor controlling the emissions.

LCA (Life Cycle Analysis) or Carbon footprint
Life Cycle Analyses that measure the impact of construction projects on the environment are becoming an important reference for the road industry to choose materials that extend pavement life and reduce environmental impacts. Shell Thiopave is essentially based on a co-product from sour gas processing or crude oil refining that is turned into a valuable product for pavement applications. An LCA is currently in progress which means only some of the features where testing has concluded can be addressed in this article:
• For the time being much of the CO₂ impact is coming from transporting product. As implementation progresses, the establishment of manufacturing sites closer to final markets would help reduce transportation CO₂.

Laying of a Shell Thiopave asphalt mixture on a 24km section of US Highway 71 in Missouri
• At the mixing plant, it is stored at ambient temperature, no heated tank is required.
• It replaces some of the bitumen quantity (15 to 25% mass) therefore, can save energy or use this energy for other applications. However, and as explained in the section about asphalt mix design with modified sulphur pellets, the higher binder content of the modified mixture must be taken into account.
• It is produced at lower temperature as compared to HMA (130°C).
• Due to its higher bearing capacity, it may extend pavement life or reduce pavement thickness (subject to pavement design based on asphalt mixture performance properties).

Pavement behaviour

This new sulphur technology is the latest development of the sulphur technology used for SEAM (modified sulphur in pellets). This technology of modified sulphur pellets has been in use for 6 years now and more than 40 projects have been carried out in countries including Canada, USA, China, India, Middle East and United Kingdom [19]. Some pavement surveys are on going and initial results show that the pavements are performing very well. Some projects and project follow-ups are reported below:
• Pacific Coast Terminals Company Limited in Port Moody British Columbia
  A HMA 12.5mm was laid on this heavily loaded site in 2004 with 4.4% and 3.3% SEAM. This site is performing well without cracking and deformation.
• A 3-lane highway from Dammam to Jubail in Saudia Arabia
  It is still performing well being laid in 2006 (full depth and overlay sections with 30% and 40% SEAM).
• An overlay on a cement concrete area was built in Nantong port in China
  A dense-graded asphaltic concrete was modified with 30% SEAM and after 3 successful years of service the port authorities decided to pave another section in 2007. All sections are performing well to date.
• A 12km section (Photos 2, 3) was built in 2006, in China in the Yunnan Province (Getun Highway).
  The Shell sulphur technology was chosen to meet the first class highway specifications regarding the Marshall mix design and the resistance to permanent deformation. Resistance to rutting was given particular attention because it is one of the main issues on this highway.

Photos 2 & 3
views of the Getun highway, surface layer texture (photo 2) and traffic (photo 3)

The base layer was made with a 60% bitumen and 40% SEAM while the top layer used a 65%/35% ratio. Up to now the traffic has been assessed to 4,500 vehicles per day including around 400 heavy trucks. The standard axle load taken into account for the pavement design in China is 100kN. An inspection of the site in 2008 revealed that the section was in very good condition. The survey is expected to last 4 to 5 years. Rutting as well as reflective cracking and moisture damage will be given particular monitoring.

Conclusions

Compared to the old SEA technology, Shell Thiopave represents a major step forward:
• It is easy to store and requires little or no asset investment on top of existing mixing plant facilities and paving equipment.
• It is easy to handle and incorporate during the asphalt mixing process provided pellet integrity is maintained (no abrasion).
• It lowers emissions during pellets manufacturing with subsequent benefits during asphalt mixture production and laying because Shell Thiopave is designed to reduce H₂S emissions and it allows manufacturing and compacting at lower temperature as compared to the SEA technology.
Shell Thiopave® modified sulphur pellets for asphalt paving mixtures
Focus on use of available resources

This innovation also provides the following enhanced asphalt mixture properties:
- It improves workability and ease of compaction at operating temperatures dedicated to warm mix asphalt technology.
- It significantly improves resistance to permanent deformation for heavy trafficked roads.
- It does not have a negative impact on asphalt cold temperature properties. The low temperature properties, as measured in the Thermal Stress Restrained Specimen Test for modified sulphur concentrations up to 40% mass on the binder, are even slightly improved when compared to conventional asphalt mixture.
- Asphalt mix design can be tailored to meet asphalt mixture specifications at both low and high temperatures; for example, softer bitumen grades may be used for the benefit of better thermal cracking resistance while still meeting resistance to permanent deformation requirements as obtained with conventional bitumen grades.
- It typically reduces bitumen requirements by 15-25% (depending on the Shell Thiopave concentration in the binder). It also reduces fuel consumption due to mixing at lower temperature and opens up the potential for conserving other road-building materials as the pavement design can take benefit of its higher bearing capacity. This later point must be addressed in a pavement design study.

In order to get the full benefit of this technology, it is recommended that a mix design be carried out to check the mechanical properties and also check the resistance to water ingress. This can be problematic with some aggregates but the mix design (void content, binder content) as well as the use of anti-stripping agents generally solves the issue.

Product stewardship guidance needs to be respected in order to work in safe conditions and to achieve the benefits of asphalt mixtures modified with Shell Thiopave pellets.
Bring Research on Emulsions Forward

What do you have in common with a researcher in the field of pharmaceuticals, cosmetics? Come to share your point of view with your counterparts in other sectors of activity at the World Congress on Emulsions.

11 October - World of Emulsions
Emulsion Producers' Day
www.world-of-emulsions.com

www.cme-emulsion.com

CME / Package Organisation
Cité Internationale – 10, quai Charles de Gaulle – 69463 Lyon cedex 06 – France
Tel: +33 (0)4 78 166 238 – Fax: +33 (0)4 78 176 257 – Email: contact@cme-emulsion.com
VECTRA: All over the World

ROAD ENGINEERING: FROM MEASUREMENT TO SOLUTION

Deflection, radius of curvature

SFC (Sideways Force Coefficient) - Macrotexture

Longitudinal Profile

Retroreflection

Geographic Information System

Distresses Digital images database

Skid resistance of Airport runways

Itinerary diagram

VECTRA
34, rue de Panicale
78320 La Verrière - FRANCE
Tel: 33 (0) 1 30 66 01 77
Fax: 33 (0) 1 30 62 90 06
E-mail: vectra@vectra.fr – www.vectra.fr
FEHRL (The Forum of European National Highway Research Laboratories) celebrates 20 years of road engineering research and coordination. Registered as an International Association with a permanent Secretariat based in Brussels, Belgium, FEHRL provides a coordinated structure for the interests of over 30 national research and technical centres from Europe, together with associated Institutes from around the world. Developed over the past 20 years, it has grown from a meeting of associations held on October 23 – 24, 1989 to investigate the general interest among the road research laboratories for closer cooperation, to today, where this collaboration has grown into a membership of 33 countries, including members throughout the European Union States, European Free Trade Association (EFTA) countries, and Eastern and Central European countries, as well as three non-European Countries – Israel, South Africa, and most recently, the United States.

**A brief history**

In October 1989, representatives from 13 European road research Institutes met at the Transport and Road Research Laboratory (now TRL) in Crowthorne, U.K. The group – some of whom had never met before – managed to define not only a name for its future organisation, but also membership, professional subject areas of interest and the role of the organisation. A mission statement, objectives, and methods were also established and agreed upon by the end of the meeting. Most of the agreements – with minor modifications – are still the foundation of FEHRL today. One of the primary objectives established was to provide opportunities for identifying research priorities and to create a positive climate for cooperation between its Institutes in providing their public oriented goals. By further bringing together research centres and road authorities, FEHRL positioned itself to address a wide range of road infrastructure needs and to provide appropriate solutions to underlying problems.

**FEHRL's main areas of expertise**

FEHRL and its national Institutes work closely with road authorities to provide research services and advice to aid the continued development of safe and efficient operation and management of Europe’s road system. In their individual Institutes and collectively, the scope of the services provided are subject to continual review ensuring that they can meet current and future needs.
20 Years of FEHRL

FEHRL's members

Austria
Österreichisches Forschungs- und Prüfzentrum Arsenal Ges.m.b.H. (AIT)

Belgium
Belgian Road Research Centre (BRRC)

Bulgaria
Central Roads and Bridges Laboratory (CRBL)

Croatia
Institut Građevinarstva Hrvatske (IGH)

Czech Republic
Centrum dopravního výzkumu (CDV)

Denmark
Vejdirektoratet - Vejteknisk Institut (DRI)

Estonia
AS Teede Tehnokeskus (TECER)

France
Laboratoire central des Ponts et chaussées (LCPC)

Germany
Bundesananstalt für Straßenwesen (BAST)

Greece
Kentriko Ergastirio Dimosion Ergon (KEDE)

Hungary
Közlekedésstudományi Intézet (KTI)

Iceland
Vegagerðin (ICERA)

Ireland
National Roads Authority (NRA)

Italy
Centro Sperimentale Stradale (ANAS)

Latvia
Ceļu Laboratorija (LAD)

Lithuania
Transporto ir kelių tyrimo Institutas (TKTI)

Luxembourg
Institut national de recherche routière (INRR)

Netherlands
Rijkswaterstaat Dienst Verkeer en Scheepvaart (RWS DVS)

Norway
Statens vegvesen (NPRA)

Poland
Instytut Badawczy Dróg i Mostów (IBDiM)

Associate Members

Israel
Israel National Roads Company (INRC)

South Africa
Council for Scientific and Industrial Research (CSIR)

USA
Turner-Fairbank Highway Research Center (TFHRC)

Federal Highway Administration (FHWA)
FEHRL's main areas of expertise include, pavement engineering, traffic operations, telematics, bridge engineering, road safety, sustainable construction, asset management, environmental issues, and geotechnics.

Providing opportunities for identifying research priorities still stands and continually defines the work of FEHRL today. Its view of cooperation "in diversity" is one of the main drivers to strengthen its position and become the European road research centre for the creation, transfer and application of knowledge in all road transport matters.

Affiliated Institutes are also aware that close cooperation with the European Commission, CEDR (Conference of European Directors of Roads), and other organisations whose aims are compatible are crucial to the realisation of FEHRL's aim to provide the solutions for the roads of today and tomorrow.

The SERRP Programmes

To accomplish this, an on-going Strategic Road Research Programme (SERRP) has been developed, defined by a series of detailed implementation plans. SERRP I was published in 1994 to ensure that many of FEHRL's research topics were pursued with the assistance of the EU Framework Programme of Research and Technological Development (RTD) and the COST Programme. Following early successes a network of Research Coordinators was established in the member Institutes, providing effective and expert communication routes within the organisation. This was followed by the development and adoption of FEHRL's 5-year Development Plan and the preparation of SERRP II in consultation with CEDR – one of FEHRL's and the industry's main client bodies. This long-term approach was also adopted in the elaboration of the ongoing SERRP III setting out the research needs for the years 2002-2006.

SERRP IV followed as the programme for the period of 2006-2011. It focuses on enhancing collaboration between its Institutes whilst providing solutions for the problems facing the road of today and tomorrow. Coupled with the FEHRL Vision, it sets out a research programme to satisfy the shared requirements of the many stakeholders involved in helping to refine the process. It is recognised that structurally – and politically – infrastructure research (and especially implementation) is not the same as industrial research. To be successful, a greater number of countries need to be involved in the research, in order to avoid the 'not invented here' and the 'it cannot work here' syndrome. At a national level, partnerships with industry have traditionally worked very well. The challenge of SERRP IV will be in lifting this up to the European level.

From SERRP I to SERRP IV

**SERRP I 1994-1998**

SERRP I included 15 research topics, organized around the following subjects:

- **Materials** (Recycling and waste materials, bitumen and bituminous mixtures, concrete, polymer products as new geotechnical materials, unbound materials)
- **Design** (Development of new pavement designs)
- **Road site equipment** (Road lighting and markings)
- **Construction and maintenance** (Development of new pavement maintenance technology, Construction and maintenance technologies of structures)
- **Management** (Pavement management systems and economic models for whole life costs, new pavement monitoring equipment and methods, long term pavement performance, structure management systems and methods for structure assessment)
- **Road-vehicle interaction** (Measurement of dynamic wheel, axle and vehicle loads)
- **Road users** (Improving road user safety, impact of road transport on the environment)
From SERRP I to SERRP IV

SERRP II 1998-2002
SERRP II became a combination of SERRP I topics and new topics, taking into account the experience already gained with EU research programmes, as well as future needs in road transport research.

The final draft, comprised the following subjects:
- Materials (Bituminous, cement concrete, sub-grades, waste materials/by-products, bridges/tunnels/retaining walls)
- Construction and maintenance (Maintenance techniques for recent pavement types, optimisation of maintenance techniques, road-vehicle interaction, structures: condition assessment, tunnel construction, sub-automated highways)
- Road management (Innovative maintenance, maintenance to reduce road closures, high-speed condition assessment)
- Environmental Sustainability (Methods for impact studies, methods for life-cycle analysis, road traffic noise reduction, reduction of pollution, natural disasters, integrating roads into the landscape)
- Road safety and infrastructure (Infrastructure assessment, road conditions generating accidents, forgiving road environment, harmonisation of road signing and VMS, visibility under adverse road conditions)
- Telematics (Requirements for vehicles and roads, road infrastructure communication networks)
- Institutional issues (Implementation of results of earlier programmes, technology transfer, barriers to innovation, and procedures for road financing)

SERRP III 2002-2006
SERRP III comprised of the following subjects:

Common Transport Policy
- Mobility (Optimisation of the use of the existing capacity, traffic calming measures, ITS, road pricing, automated vehicle guidance)
- Safety (speed limitation/traffic calming, road markings, safety oriented maintenance management systems, integral safety approach to design, construction and maintenance, forgiving road environment)
- Environment (Noise mitigation, air and ground pollution, landscape intrusion, energy, recycling)
- Asset management (Life cycle analysis/design, quality level for road users, innovative contracting, Public-Private partnerships)
- Innovations (Advanced wearing courses, improving existing technologies, pavements on poor quality soils, innovations in monitoring technologies)
- Road and rail transport (Optimisation of road-vehicle system, rail-vehicle interaction)
- Accession countries (Upgrading of axle load to 115kN and vehicle width to 2.55m)

European Research Area
- Coordination of national programmes
- “Blue Skies” research

TERN (Trans European Road Network) and Road Transport Research
- Innovation in road construction
- Competitiveness of road transport
- Asset management

SERRP IV 2006-2011
In SERRP IV a collaborative approach was planned for:
- Optimising capacity of the network and increasing the efficiency of goods transport,
- Preventative and mitigating Road Engineering for safety,
- Reducing energy consumption, environmental impact and nuisance and societal/cultural impacts,
- Implementation of innovation,
- Development of better – integrated – standards & Directives.
Throughout the period 2006 – 2011, FEHRL will be implementing this fourth version of the SERRP programme in conjunction with the growing body of interested stakeholders. This will lead to ever closer integration of FEHRL Institutes and the realization of a fully integrated programme of European road research delivering solutions for the roads of today and tomorrow.

The 20th Anniversary

The 21st FEHRL General Assembly took place in Budapest, Hungary, on October 2009, celebrating 20 years of FEHRL. The event was hosted by Hungarian members, KTI.

Guest speakers included László Ruppert, Director of KTI, who gave a warm welcome to all attendees, and Claude Van Roonen, President of FEHRL, who spoke about the past 20 years and its primary achievements, as well as what can be expected in the future.

On the program was a panel discussion with the heads of the European Commission (EC) and Conference of European Directors of Roads (CEDR). Discussions included the future of road transport and the importance of research and innovation, as well as the new "Forever Open Road" project which was outlined and widely debated.

FEHRL is governed by a Board from whom a President and vice-President are elected to serve on three year terms. The FEHRL Executive Committee (FEC) under a Chairperson elected by the Board supervises day-to-day business. The FEC is responsible for implementing the Board’s decisions ensuring that all possibilities for pursuing FEHRL objectives are identified and nurtured, and that relation with other appropriate organisations are encouraged and maintained.

The General Assembly elected Mr. Bojan Leben (ZAG, Slovenia) as the new FEC Chairman. B. Leben is succeeding Mr. Govert Sweere who served as FEC Chairman from 2006 - 2009. Martin Pipa (CDV, Czech Republic) and Sandra Erkens (DVS, the Netherlands) were also elected to join the Executive Committee. All of the newly elected members will serve on the FEC through 2012.

FEHRL was proud to welcome and announce the FHWA – US Department of Transportation Federal Highway Administration, as an Associate Member, showing another important step in FEHRL’s international recognition and cooperation.

The active participation of the FHWA will be ensured through the Turner-Fairbank Highway Research Center (TFHRC).

To close the event, some interested participants were invited to visit the newly built MO "Megyeri-hid", bridge in Budapest where they could experience first hand the latest techniques in bridge building technology, its structural elements, and enjoy a marvelous view.

Looking ahead

FEHRL’s evolution continues towards growing into a true centre of excellence for road research. Through the diligence of the national Institutes, the excellence aspect is well covered.

FEHRL is actively seeking partnerships particularly with the private sector to help deliver advanced solutions for the crosscutting issues on the European agenda that concern various client groups. Staff and management are key to the FEHRL Association becoming a true Centre of Excellence. For this reason it is vital to continue to invest in people and expertise through continuous training.

To support an extensive portfolio of activities, the development of the FEHRL Knowledge Centre is key to disseminating knowledge to members and major stakeholders. The FEHRL Secretariat is continuously developing a common resource and projects database to encourage the transfer of research results among Institutes, to facilitate exchange of staff, and to encourage and support shared use and/or development of expensive road testing equipment.

Through the number and quality of many successfully completed European research projects, FEHRL has shown its potential as an effective European research body in the area of road infrastructure, mobility, safety, and environment.

References

• www.fehrl.org
Our performance bitumen products provide durable and sustainable solutions to asphalt design.

Nynas is a different kind of oil company. We're specifically focused on bitumen and the delivery of its value and functional requirements. As proof of our commitment, we have introduced the Performance Programme. We've realigned our bitumen solutions into three performance categories; Regular, Extra and Premium. Each is designed to deliver Nynas quality while we have your specific needs in focus. At Nynas that's what we call – Taking oil further.
The last events occurred in European Tunnels since 1999 demonstrated the needs for preventing and mitigating tunnel accidents. The European Directive 2004/54/EC details the responsibilities for owners of tunnels longer than 500m, one of them is about the Tunnel Safety Officer who is nominated by the Tunnel Manager and gives advises about preventive and safeguarding measures. This article provides a brief overview of the reaction of the tunnel community and the role of a Tunnel Safety officer, who is particularly involved in Operation and Maintenance activities.

more effective safety systems and greater awareness among users (car and truck drivers) on how to behave in emergency situations. One of these initiatives led in 2004 to the European Directive on minimum safety requirements for tunnels on the Trans-Europe Road Network. This European Directive 2004/54/EC details duties and responsibilities for owners of tunnels longer than 500m, whether it is a public or private operator, and also sets a number of traffic management requirements.

The main guidelines of the Directive

The primary objective of this Directive is the prevention of critical events that endanger human life, the environment, tunnel structures and installations. The secondary objective is the reduction of possible consequences of events such as accidents/incidents. Organisational and technical requirements, as well as operational requirements and information for road users, have been set up in the Directive and consequently the main guidelines of the Directive are:

- Design criteria for new tunnels,
- Effective management and possible upgrading of tunnels under operation,
Tunnel Safety Officer: Roles and responsibilities

New information and better communications with tunnel users. The European Directive 2004/54/EC also defines for each road tunnel the respective roles and responsibilities of the Administrative Authority, Tunnel Manager, Tunnel Safety Officer and Inspection entity.

**Tunnel Safety Officer (TSO)’s functions**

According to the Directive, the role of the Tunnel Safety Officer (TSO) is to "coordinate all preventive and safeguarding measures to ensure the safety of users and operational staff". The exact wording of the TSO's tasks/functions is the following:

- Ensure coordination with emergency services and take part in the preparation of operational schemes;
- Take part in the planning, implementation and evaluation of emergency operations;
- Take part in the definition of safety schemes and the specification of the structure, equipment and operation in respect of both new tunnels and modifications to existing tunnels;
- Verify that operational staff and emergency services are trained, and take part in the organisation of exercises held at regular intervals;
- Give advice on the commissioning of the structure, equipment and operation of tunnels;
- Verify that the tunnel structure and equipment are maintained and repaired;
- Take part in the evaluation of any significant incident or accident as referred to in Article 5 (3) and (4).

The main role of the TSO can be summarised as an overall independent and experimented person analysing all tunnel safety issues.

**The French TSO group and the UK TSO forum**

This list of tasks can generate many interpretations about the exact role and responsibilities of the Tunnel Safety Officer. That is why the different French TSOs decided to share their experience and knowledge. A French TSO group was subsequently created in 2006 including representatives from Autoroutes du Sud de la France (ASF), Autoroutes Paris-Rhine-Rhone (APRR), Cofiroute, Mont-Blanc tunnel (ATMB), Fréjus tunnel, Escota and Egis Road Operation. The current TSO of Dublin Port Tunnel belongs to Egis Road Operation's staff; he is in close contact with the UK TSO forum in order to exchange information and experience. The main issues which have been identified in both these groups are the TSO's legal responsibilities, his skills, experience, knowledge, his independence level in relation with the Operations of the tunnel and his involvement in the Operation company on a full-time or part-time basis.

All these points are discussed regularly and some clarifications can be given to a certain extent, knowing that each case is a particular case. Generally speaking, there are two kinds of TSO: the ones who are employed full time in the Operation company, having the internal support of the Operation company.
(Escota, APRR, ASF, etc.) and the ones who only devote part of their time to this role, having the technical support of an internal or external Engineering & Design company (Egis Road Operation, Mont-Blanc, Fréjus, etc.). The variety of approaches however leads to equivalent results considering the very similar background and experience of the various individuals acting as TSOs in the respective organisations.

The specific role of the TSO in Egis Road Operation and his internal support

Egis Road Operation has extensive experience in Operation & Maintenance (O&M) activities thanks to its in-house team of experts all of whom come from O&M Motorway companies. This experience is the result of Egis Road Operation’s capacity.

The Dublin Port Tunnel Project, it is...

The Dublin Port Tunnel provides a direct link between the M1 Dublin-Belfast Motorway and the Dublin Port. The primary aim of the Dublin Port Tunnel is to ease traffic flow to and from the Dublin Port and to reduce the number of heavy goods vehicles using surface streets in the historic centre of Dublin.

The Dublin Port Tunnel generates other benefits for Dublin City such as a continued development of the Dublin Port and the improvement of the City centre environment. The tunnel is used by 6,000 HGVs and 8,000 light vehicles per day. The tunnel opened to traffic on 20th of December 2006.

The Dublin Port Tunnel is a flagship project in Ireland’s National Development Plan. The tunnel is a 4.5km twin tube tunnel. Each tube is equipped with emergency facilities such as vehicles and pedestrian passages between tunnel tubes, lay-bys, emergency phone network, Variable Message Signs, Close Circuit Television (CCTV) and other safety equipment. All safety and maintenance services are operated by Transroute Tunnel Operations with an operation building positioned at the southern end of the tunnel.
Tunnel Safety Officer: Roles and responsibilities

to benchmark and give assistance to different O&M motorways companies (currently 18 O&M subsidiaries around the world), having different cultures and operating in different countries (Ireland, Germany, Austria, France, Croatia, Poland, Greece, Portugal, Hungary, Korea, Philippines, Australia, etc.). The TSO is part of this expert team which is composed of Toll, Traffic, Maintenance and Tunnel experts. This know-how is very useful to better understand the best way to manage a motorway at each stage, from the pre-operational phase to the operational one according to the specificity of the project and the local environment. The knowledge of the TSO is often associated to the knowledge of design experts from Egis Tunnels and Egis Mobilite. This integrated association of O&M experts, TSO and Design experts is seen as a differentiating factor by our clients.

The Dublin Port Tunnel case

Within Egis Road Operation, the TSO has been particularly involved in the Dublin Port Tunnel. The client decided in September 2006 to hire the services of an experienced Tunnel Safety Officer, from Egis staff, with expert support from Egis Tunnels. Dublin Port Tunnel is a major project in Ireland and the largest civil works project ever completed by the Irish government. Its main purpose is geared towards heavy goods vehicles (HGVs), with a view of freeing-up Dublin City Centre from these vehicles. Transroute Tunnel Operation (TTO), a fully owned subsidiary of Egis Road Operation, has been successfully operating this urban tunnel since 20 December 2006 with the highest possible level of safety for the users using the appropriate methodology for such a complex piece of infrastructure. This was made possible thanks to the significant involvement of Egis Road Operation (setting up an adapted O&M organisation, drafting of the full set of procedures, providing assistance in risk assessment and management, implementation of emergency plans, advising in liaison with key stakeholders such as the Fire Service, conducting operational audits, training staff), both during the operations start-up phase and on an on-going basis.

Within Egis Road Operation, the individual acting as TSO is also involved in many activities and studies relating to user safety and the way to operate a tunnel: for example, the heavy maintenance programme in Mont-Blanc tunnel, the procedures review and risk assessments in Carmelton Tunnels in Israel and other assistance programmes for existing tunnels.

It is critical for a TSO to keep in very close contact with a number of different tunnel operators and motorway companies. This allows the TSO to stay on the cutting edge of new ideas and methods, which is directly linked to the real concerns of tunnel operators.
New Shell Bitufresh –
The Low Odour Bitumen Additive

Bitumen and asphalt operations are facing increasing public concern about smells especially for urban production facilities. These complaints can mean significant investment to treat off-gases or in some instances threaten the continued operation of the plant. That's why we have developed Shell Bitufresh, an easy to use additive designed to effectively reduce bitumen smells.

- Effective bitumen smell reduction for a period of at least two weeks
- No impact on bitumen performance
- Better conditions for residents and staff

www.shell.com/bitumen

Delivering Innovation to your Advantage
Testing equipment for pavement

Equipment and methods used for non destructive tests on airport runway pavements

Security is a key factor in the field of transport, and a particularly sensitive topic in air transport. In order to keep an optimal level of services, the managers of airports platforms, vital organs of the network, must have a perfect knowledge of their infrastructure conditions. A certain number of normalized index allow to access the quality of these infrastructures and therefore rationalizing management and planning maintenance operations.

Rincent BTP group is an independent company which carries out one part of its activities of measures and diagnostics, in the field of runway and road pavement. It is at the service of airport managers, realizing diagnostic works, but also developing, selling and maintaining innovative materials in accordance with the requested quality demands. The company is very much in demand in the airport field and achieves some works on the five continents.

Introduction

The evaluation/assessment of runway pavements, for maintenance and renovation are a paramount topic, for the upkeep of the assets for the airports managers, as well as for acceptable safety level. Rincent BTP is an independent company which carries out a part of its activities in diagnostics and measures in the airport and road fields. In order to ensure a continuous improvement of the safety and its tests, Rincent BTP develops and promotes innovative materials and methods.

Review of the testing methods for a runway pavement

Two main types of tests are used in order to appreciate the runway pavement quality: the Service Index, SI (waterproofing, surface integrity and deterioration) and the Pavement Classification Number, PCN. Rincent BTP is carrying out regularly international studies in order to determine theses parameters (Tunisia, Mali, Latvia, Polynesia, Morocco, ...).

The Service Index (SI)

The service index was initiated in France in 1986. Its three targets are:
- To appreciate the service level of a runway pavement and its behavior.
- To estimate the needs with a long term (testing and maintenance works).
- To estimate the maintenance costs.

The service index is a number between 0 and 100, which indicates the state of the runway. SI equal to 100 is for a new pavement, whereas a SI lower than 10 leads to a runway closure.
It is calculated from the visual deterioration statement, with the three following parameters:
- anomaly type,
- gravity level,
- anomaly surface (or length).

The combination of these three parameters allows getting a value depending on the deterioration density by an abacus. Another abacus gives a connected value Vdc, (corrected deduced value) in relation with Service Index.

\[ SI = 100 - Vdc \]

SI is then calculated for each homogeneous section. The final SI is the average value of all SI found for the various sections.

Two additional SI values are also determined: the structural SI, in relation with a defect in bearing capacity and the superficial SI, in relation with a surface defect. STAC (French technical service for the Civil Aviation) has established a catalog, giving the types of abnormalities. It distinguishes between the structural abnormalities (rutting, settlement, cracks, fracture...) and the surface abnormalities (break, crocodile cracks, excessive bitumen, lack of joint...) [1].

A central threshold of 65 is established, which demands a regular and frequent follow up; the alarm threshold is 50 and the reparation threshold is 30.

**The ACN/ PCN method**

It is an international system which defines the plane eligibility on airport pavement, for a plane to land on a runway, depending on the pavement resistance.

The ACN (Aircraft Classification Number) is a number which gives the plane aggressiveness on a pavement (flexible or rigid) for a given soil. The ACN values are published by the International civil aviation Organization (ICAO) for each plane type, as a function of the soil (4 types) and the pavement (flexible or rigid) [2].

The PCN (Pavement Classification Number) is a number in relation with the soil bearing capacity.

PCASE is a software, developed by US army, used to calculate PCN for each point HWD (High weight deflectometer) and from data collected on the pavement structure. The calculation integrates forecasting on traffic on a period of 10 years. This prevention is given by Civil aviation’s managers.

As an example: PCN = 27/F/AfWIT
- The number 27 is a classification number of the pavement.
- The first letter corresponds to the pavement type:
  - F= Flexible pavements (asphalt concrete),
  - R= Rigid pavements (concrete).
- The second letter gives the soil resistance quality:
  - A= high resistance,
  - B= medium resistance,
  - C= low resistance,
  - D= very low resistance.
- The third letter gives the tyre’s pressure, expressed in MPa
  - W= no limit,
  - X= 1.5 MPa,
  - Y= 1 MPa,
  - Z= 0.5 MPa.
- The fourth letter indicates the evaluation method:
  - T= technical evaluation,
  - U= empirical evaluation.

A plane can land on a runway pavement, if:
- ACN < PCN
- If ACN > PCN, limitation should be applied (weight of plane or move number),
- The tyre’s pressure does not exceed the allowable pressure on the pavement.

For flexible pavements, Californian bearing ratio, CBR test is used for the soils resistance, whereas for rigid pavements, reaction modulus is used.

**The testing equipment**

Rincent BTP develops its expertise in the testing field and in the maintenance and the development of its testing equipments. So it has developed and built special testing equipment dedicated to the airport and road pavements.

---

**Photo 1**
Euradar in service on secondary runways of Rennes Airport (France)
Equipment and methods used for non destructive tests on airport runway pavements

EURADAR equipment

Euradar equipment (Photo1) is patented, made and maintained by Rincent ND (non destructive) technology. The process consists in the emission of an electronic wave on the pavement and the measurement of the reflected waves on the various pavement layers. This process generates an image of the pavement structure (Figure 1).

Consequently, the coring and the bore holes can be located, so that the PCN index can be known. Note that IDD, linked to Rincent BTP group, has got a sophisticated radar (Photo 3), able to carry out subsoil investigations. Two series of seven antennas produce a 3D picture. Tests are carried out on road as well as on runway pavements. Thus subterranean abnormalities or voids can be shown.

EURADAR gives the layers thickness and detects the abnormalities (humidity, voids, metal, bad interface...). This radar is unique in Europe (Photo 2).

Furthermore, it is an "open structure" equipment, which allows an access to the rough signals. So each entity can do its own interpretation and the user can analyze the signals depending on his needs. Overseas, the national laboratories are asking for this consideration. Then, areas of similar structural behavior are determined: they are homogeneous areas.

HWD (High Weight Deflectometer)

The target of the measures carried out by the HWD, is to estimate the allowable load on a pavement and to select areas of homogeneous resistance (Photo 4).

A dynamic load is applied to simulate a stress equivalent to the plane move. The deformation basin is measured by seven strain-gauges, whereas the applied load is recorded on the computer.
The HWD equipment is made, on the company's requests, according to accurate specifications. One specificity concerns the size. Now, the equipment can be easily forwarded and allows testing runways on islands or difficult areas (Photo 5). The same equipment allows also testing on roads, by changing the dynamic loading. For instance, Rincent BTP Brazil carries out these tests on two road sections of 400km, with a test every 40m.

Friction test equipment

Rincent BTP is using the SARSYS STFT equipment designed and marketed by Sarsys. It is used to measure the longitudinal friction coefficient (CFL) according to the French norm NF P98-220-2 (Photo 6).

This equipment got the official acceptance by STAC and ICAO. The equipment is using a wheel under the carriage with a 120kg loading. The measures are carried out at a speed of 65 to 95km/h on wet pavement.

A special device allows keeping a constant water film of 1mm thick, between the tyre and the pavement (Photo 7).

The friction value is necessary for the airport managers, because it is a safety key factor, particularly during the plane breaking. Besides, many accidents occurred during heavy rain, due to a wrong evaluation of the surface pavement. It was asked to the company to develop a specific device, able to measure the water film thickness on the pavement, with a good accuracy and reliability (Photo 8). The designed equipment measures values between 1 and 20mm, with a 0.2mm accuracy, by capacity effect. The ICAO recommendations (annex 14) requires a change in the landing procedures beyond a film water thickness of 3mm and a runway closure above 12mm.

The friction test equipment

Photo 5
HWD in transportable position before sending to « La Réunion »

Photo 6
Friction tests Polynesia

Photo 7
Water thickness measurement device

Photo 8
Radar auscultation of runway pavement, Tunisia
Equipment and methods used for non destructive tests on airport runway pavements

Auscultation example in Tunisia

Rincent BTP Ausculation has carried out in May 2008 for the Airport and Civil Aviation Office (OACA) an ausculation of all aeronautical areas of the 7 Tunisian airports: Tunis-Carthage; Monastir-Habib Bourguiba; Djerba; Sfax-Thyna; Gafsa; Tozeur (photo 9); Tabarka.

The ausculation results lead to a diagnostic survey, concluded in May 2009 by the supply of a technical detailed report for each of the 7 Tunisian airports. The aim was to determine the main characteristics of the airport pavements: adherence, SI and bearing capacity ACN/PCN.

As said previously, the best measurement which allows appreciating planes adherence on an airfield pavement is the longitudinal friction coefficient (CFL). For each runway, the results concluded on the needs to carry out rubber removing works for the lowest adherence zone.

References
Written by experts from SFERB and published by RGRA, this new version incorporates the newest developments having occurred during a 15-year period in the fields of physicochemical research, standards, HSE, manufacturing and applications of bitumen emulsions, including equipment and on-site spraying, laying and mixing techniques.

<table>
<thead>
<tr>
<th>FRANCE</th>
<th>OTHER COUNTRIES</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit price (excl. VAT): €95</td>
<td>Unit price: €95</td>
<td></td>
</tr>
<tr>
<td>+ 5.5% VAT</td>
<td>+ carriage</td>
<td></td>
</tr>
<tr>
<td>+ carriage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Payment requested upon receipt of the invoice.

To be invoiced to:

- Full name: ____________________________
- Company: ____________________________
- Title: ________________________________
- Address: ____________________________
- ZIP code: __________ City: ____________
- Country: ____________________________
- E-mail: ______________________________
- DATE: ________________________________

Signature: ____________________________

**REVUE GÉNÉRALE DES ROUTES ET DES AÉRODROMES**
132 rue de Rivoli 75001 Paris (France)
Tel.: 33 (0)1 40 73 80 00 Fax: 33 (0)1 49 52 01 80 rgra@editions-rgra.com

www.rincentbtp.fr

- Diagnostics and expertise on buildings Roissy
- Technical road survey
- Surface water thickness measuring equipment for airport runways
- Transportable Heavy Weight Deflectometer
- Radar Euradar® Tunisian Airports

> Works sites control and supervision
> Tests laboratories (concrete, materials, roads)
> Tests on airports and roads pavements
> Non destructive tests on deep foundations
> Static and dynamic load tests
> Instrumentation monitoring
> Solid waste underground centers
> Technical improvement, technical assistance and training

"Parc Elysée" - 39, rue Michel-Ange - 91026 Evry cedex
Tél. +33 (1) 60 87 21 25
PadovaFiereSpa

asphaltica

novembre 24-26 November

Salone delle soluzioni e tecnologie per pavimentazioni e infrastrutture stradali.
Exhibition of equipment and technologies related to the asphalt industry.

In collaborazione con:
SITEB
Associazione Italiana Bitume Asfalto Strade
Colas is paving new ways

Colas paves the way... to sustainability.
Colas gives as much importance to environmental realities as it does to human issues.
It focuses on preserving the quality of life for neighboring residents, improving comfort for motorists and offering its employees optimized working conditions.

A great number of innovations help support this drive for sustainable development. For example, roads reveal silence with Nanosoft and nature with Vegecol; they cut energy consumption with 3E asphalt mixes and reduce greenhouse gas emissions with Vegeflux.

This is how Colas is opening up new paths, making roads more environmentally-friendly and more people-friendly too.

Colas paves the way... naturally.

www.colas.com