Pavement Sustainability and Bituminous Emulsions

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Introduction

Sustainability in relation to roads has grown in importance as a global challenge with increasing awareness of and concern for the growing depletion of non renewable reserves such as quality aggregates and petroleum as well as the impact on the environment. Fragmented world cooperation on climate change, which is an integral part of sustainable development, highlights this challenge, where ethical considerations are in conflict with economic imperatives. Despite the difficulties in reaching a binding international framework for carbon dioxide (CO_2) reduction at the Copenhagen climate conference in December 2009, progress is being made on an ad hoc individual basis with many cities adopting their own carbon reduction policies without a global agreement and national direction (1). It, however, remains to be seen whether this will converge into an effective global consensus and action.

A commonly quoted definition of sustainable development is that in the Brundtland Report (2) and is very broad i.e. “Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs”. In relation to sustainable pavements a definition that offers a practical interpretation contends that such “a pavement minimises environmental impacts through the reduction of energy consumption, natural resources and associate emissions while meeting all performance conditions and standards” (3). While this definition encompasses the whole process of road construction the scope of this paper focuses on flexible pavements with specific emphasis on pavement surfacing and the role that bitumen emulsions can play in achieving so called “green” road objectives that fall under this definition.

In Australia, the current population of just over 22 million is expected to grow to 36 million by 2050 and with this growth comes the challenge of providing efficient transportation as well as mobility for individuals while meeting community expectations of reduced emissions.

Australia has an extensive road network of over 800,000km, of which some 20% are sealed. Local roads make up over 680, 000 km of roads or 80% of the road network, and cost over A$3.1b to maintain for 2007/8 financial year. Key transport policy elements include sustainability and reduction of greenhouse gases as clear goals (4). Despite Federal Government funding assistance to Local Government through its Roads to Recovery program, adequate funding for local roads in Australia continues to be an issue with increasing pressure for cost effective and environmentally sustainable solutions.

Bitumen emulsions

Bituminous emulsions have been applied to road maintenance for over a century with humble beginnings in 1903 as a dust suppressant (5). As technology has evolved so has the number of applications, such that today bitumen emulsions are universally used in road construction and maintenance. These advances in emulsion based products, in many instances, not only result in comparable performance of hot asphalt applications but also reduce the environmental impact in the process and support progress towards sustainable development.

In particular, emulsions are able to support sustainable development by facilitating;

- conservation of raw materials (in situ recycling)
- reduced energy consumption
- reduced environmental impact

An overview of emulsion technologies that support sustainable development are presented by Bouteiller (14) and include; structural improvements, cold in situ recycling, microsurfacing and chip sealing.

Conservation of raw materials

Pavement materials recycling predate modern concerns about sustainability, essentially because it has always made good commercial sense. However, advances in recycling technologies have improved efficiency and performance enormously and now also address a wide range of sustainability issues such as emissions, energy and carbon footprint. Typically these processes still utilise heat to facilitate the recycling process and essentially reducing material transportation energy and raw materials consumption.

While there is extensive use of recycled asphalt (RAP) in Australia the country has not embraced in situ recycling (ISR) to any significant extent. The reasons for the lack of uptake of ISR are not known, however, it is suspected that as reported in a New Zealand study (6) the major reason is the lack of experience and confidence by industry in these technologies. Another reason is that use of traditional life cycle costing analyses (LCCA) in the absence of sustainability drivers may not have favoured investment in the ISR technologies which were actively tested in Australia over a decade ago.

While the challenge for countries such as Australia is to revisit in situ recycling technologies that are already available there is still the need for continued development of this technology to ensure that field performance is at least comparable to conventional hot mix techniques across a wide range of pavement service conditions. While life cycle costs for in situ recycled pavements would be expected to be cost competitive with conventional processes, it is vital that life cycle analyses (LCA) models be used to reflect sustainability factors such as energy consumption and emissions in their findings. Under these conditions a suitable weighting could be applied to sustainability parameters when assessing and costing projects to arrive at an appropriate sustainable option.

Reduced energy consumption

Bitumen emulsions based surfacings are inherently suited to conservation of energy as they are associated with low temperature applications and contribute low or negligible emissions relative to comparable hot applied overlays. An analysis by Takamura (7) based on a an environmental profile considering; raw materials use, energy, emissions, potential health effects and risk potential concluded that emulsion based microsurfacing had a smaller environmental footprint than thin hot mix overlay technologies as represented by regular hot mix and modified hot mix, and provided a better balance between cost effectiveness and environmental impact.

The reduction of energy requirements associated with flexible asphalt pavements features mutually beneficial outcomes where cost savings to the producer are accompanied by reduced adverse impact on the environment.

In recent years significant advances have been made with the introduction of warm mix technologies in asphalt concrete applications. Although this trend today represents a small proportion of total asphalt production it is a growing one.

Emulsions have featured in these technologies as has foamed bitumen and chemical additives. For example, foamed bitumen and bitumen emulsions are able to lower energy requirements for in situ recycling (ISR) by eliminating on-site heating. It is estimated that cold in situ recycling uses between 15% and 35% less energy on overlay projects and 60% to 70% less than reconstruction (8).

Another way in which bitumen emulsions contribute to these developments is through their use as high performance tack or bondcoats, particularly in support of thin overlay technology.

High performance tack or bond coats have evolved to overcome problems of tack-off as well as well as improving the quality of the bond between the pavement and asphaltic overlay (9). The latter characteristic is of critical importance to thin overlays which are well accepted as an effective pavement preservation strategy capable of significantly extending pavement service life. As the thickness of these surfacing treatments can be less than 15mm, the tensile stresses at the interface with the sub-layer can be considerable. Consequently, a strong interfacial bond is of critical importance to achieving a satisfactory service life of these thin wearing courses.

In the area of chip seals, emulsions have the potential to play a more direct role in energy reduction as storage and application temperatures are much lower than for hot sprayed binders. However, the challenge of transportation distance is one that needs to be addressed to fully capitalize on this inherent advantage in a country as large as Australia. The use of mobile plants may be one solution for larger projects into the future.

Environmental impact

Environmental impact of paving processes now includes a wide range of environmental factors including, emissions, resource consumption, land use, energy consumption health effects and risk potential (10). These issues are discussed in some detail by Miller and Bahia (11) who conclude that emphasis must be on energy consumption, emissions and environmental impact and among promising ideas suggest a need for improved tools to benchmark current practice by contractors in relation to potential improvements in sustainable practice and advancement of cold asphalt application specifications and test methods. The latter recognises that hot binder technologies in the US have seen significant advances through SHRP while emulsion based technologies have lagged.

Emissions

A large impact on the environmental comes from road works with a significant contribution from atmospheric emissions arising from road paving. These emissions are typically associated with hot products, transportation, production and laying processes.

Emissions arise from;

- heating employed to process, store and apply materials
- use of volatile hydrocarbons in binders and
- transportation of raw materials and products.

The impact of these emissions falls into two broad categories, namely local environmental air pollution and global effects such as carbon dioxide equivalent (CO_{2e}) emissions.

Austroads, the peak body representing Australian statutory road authorities, commissioned a study into the environmental impact of bitumen emulsions by the CSIRO, whose findings were published in 2000 (12). The study compared the environmental atmospheric impacts of hot bitumen and cutback bitumens with that of emulsions and foamed bitumen. The specific aspects considered were;

- photochemical smog
- greenhouse gas effect, and
- ozone depletion

The study noted that while cutback bitumens were more polluting than emulsions with nearly 7.5 times more non-methane volatile organic compounds (NMVOC) emissions, these emissions were largely outside of urban areas (only minor impact on immediate environment) with preference for emulsions over cutback bitumen from an air pollution stance. The CO2e contribution of hot bitumen and cutbacks approximated that of emulsions (emulsion transportation contribution to CO_{2e} roughly equated to that from heating associated with hot bitumen and cutbacks). However, the Global Warming Potential (GWP) of hydrocarbon emissions (NMVOC) for hot bitumen and cutback bitumens was estimated to be 8.5% higher than if bitumen emulsions were substituted. These findings are illustrated in the Appendix.

The challenge to further reduce the carbon footprint of emulsions in Australia is the reduction in transported water. Since the CSIRO study, there has been increased use of emulsions in sealing and primer sealing areas. These applications typically use high solids emulsions which reduce transportation water.

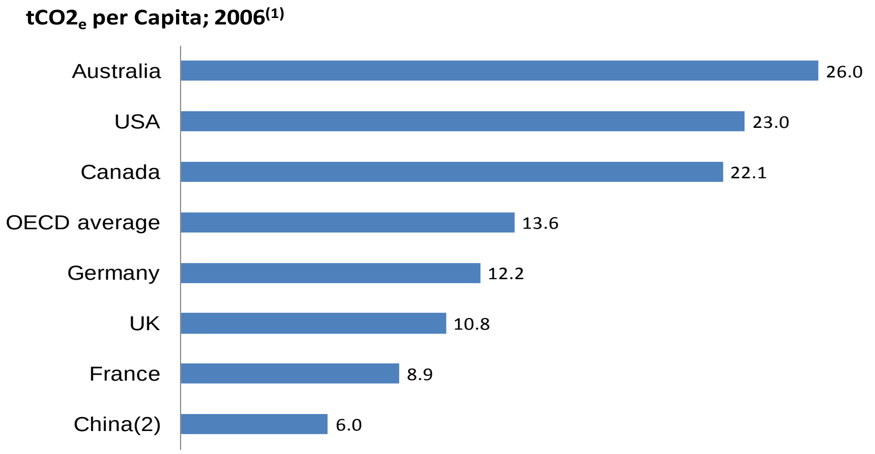
Greenhouse gases and global warming

Australia is one of a number of relatively small emitters of greenhouse gases (GHG) but as a major exporter of coal and gas has an important ethical and practical role in the reducing its impact on global CO_{2e} emissions. The majority of emissions growth is expected to be from increased emissions from industry and mining, transport and stationary energy (power stations).

Even though total Australian emissions amount to less than 2% of Global CO_{2e} emissions as a large supplier of resources including coal it contributes a high CO_{2e} burden per capita.

The table below from a study by ClimateWorks (13) compares these per capita emissions with other countries.

Table 1



(1) Includes all localemissions , regardless of where locally manufactured or created goods (e.g. cattle or aluminium) are consumed
(2) Cina data is 2005
Source: UN statistics Division (2009), US Congressional Research Service (2008)

Bitumen emulsions represent a small but growing area of opportunity to contribute to sustainable development in the road construction and maintenance area. In particular, some specific road construction and maintenance areas where bituminous emulsions can assist in achieving progress towards a “green” future include;

- Replacement of cutback bitumens
- Extending use of thin eco- efficient overlays
- Cold mixes and in situ recycling
- Low emission high performance modified binders
- Reducing environmental impact of road works

The CO_{2e} contribution of emulsions relative to cutback bitumens did not show any marked difference for Australia (refer Table 1 above) at the time of the last investigation. By contrast work in France where there are many more emulsion plants which are more evenly distributed across the country reducing transportation emissions per tonne of emulsion delivered, it was reported that emulsions gave a 6.3% reduction CO_{2e} emissions over cutbacks (14).

The imperative of GHG reduction has been acknowledged by most nations and active programs are in place in both developing and developed countries.

Specialty bituminous emulsion and sustainability

Prime examples of specialty emulsions that facilitate a cost effective and sustainable approach to pavement maintenance are rejuvenating and enrichment treatments. In particular a combination of these can optimise the available benefits. Their major contribution to sustainability is the ability to conserve existing pavements and delay the more costly resurfacing process well into the future thus promoting the efficient use of scarce aggregates and bituminous binders.

Enrichment treatments have been in use for many years for the restoration of weathered pavements on both roads and airfields. In the past a common sprayed enrichment surface treatment or SEST, has been one based on cutback bitumen. This involved the spraying bitumen dissolved in kerosene where the latter can make up around 50% of the blend. These cutbacks when applied to a pavement allow penetration of the fresh bitumen into the old pavement and the filling of fine cracks; however, the process can take some time to cure and in cool weather the slow evaporation rate of the kerosene may necessitate application of a sand cover. This adds to the cost of the process and can present particular problems on airport runways that are grooved. Emulsions provide an alternative to cutbacks in SEST type maintenance to eliminate hydrocarbon emissions and to avoid the use of sand cover.

Similarly, rejuvenation treatments have been in use for many years where suitable heavy, often aromatic petroleum oil is applied in emulsion form. These treatments while enlivening the old bitumen, are slow to cure and are normally sanded to prevent pick up on tyres. The primary function of these treatments is not to replenish binder in the pavement but to extend the life of the existing binder by reducing its viscosity thus making it less brittle, particularly under cool conditions.

In more recent years combined treatments have been offered where both enrichment and rejuvenation can be carried out on aged pavements in the one application. In particular one system is described here that addresses both of these objectives.

Early trials with a sprayed enrichment rejuvenation treatment emulsion (SERT) on an aged airport pavement achieved a reduction in the original bitumen viscosity of more than 60%. The emulsion was designed to top up the existing old bitumen with a high performance modified binder containing rejuvenating agents. Test results are summarised graphically in Fig.1 below.

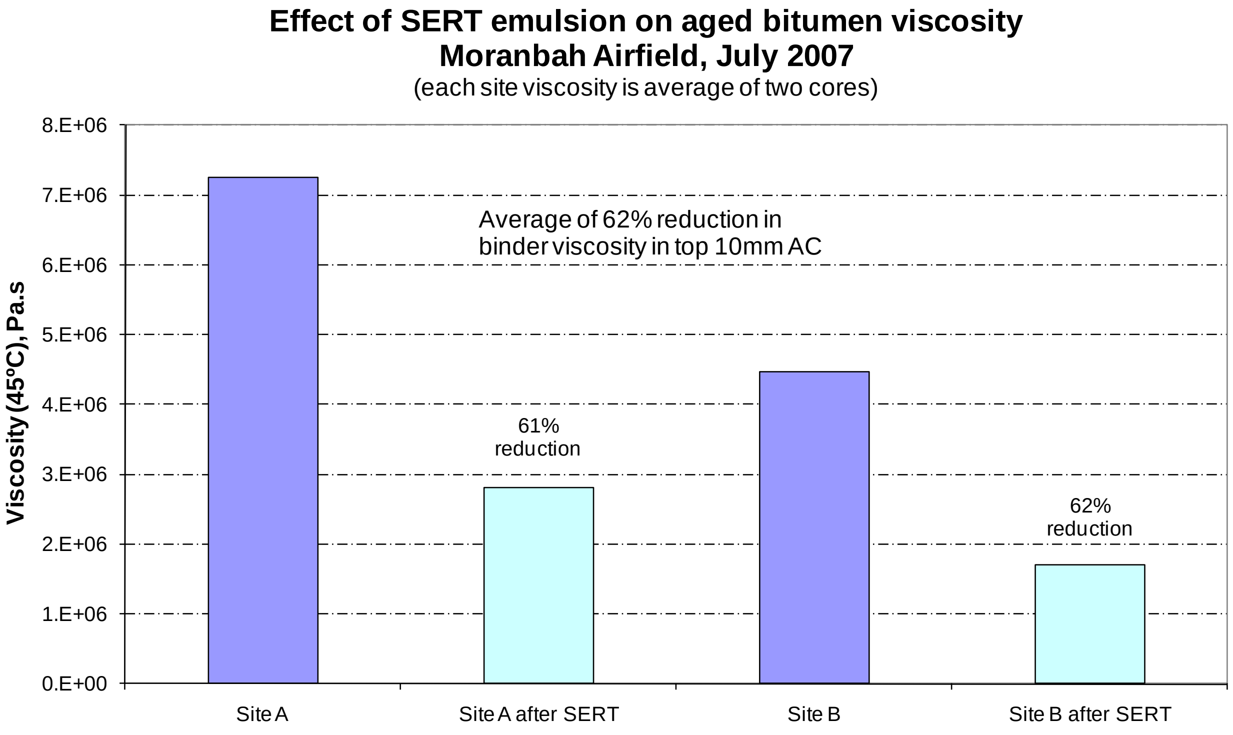


Fig. 1

Laboratory testing according to AS2341.13 (effect of air and temperature exposure) indicated that the binder from a specialty SERT emulsion hardens more slowly than residual bitumen from a conventional bitumen emulsion enrichment treatment, effectively extending binder service life by around 20%. The improved resistance to ageing of this emulsion is shown in Fig. 2.

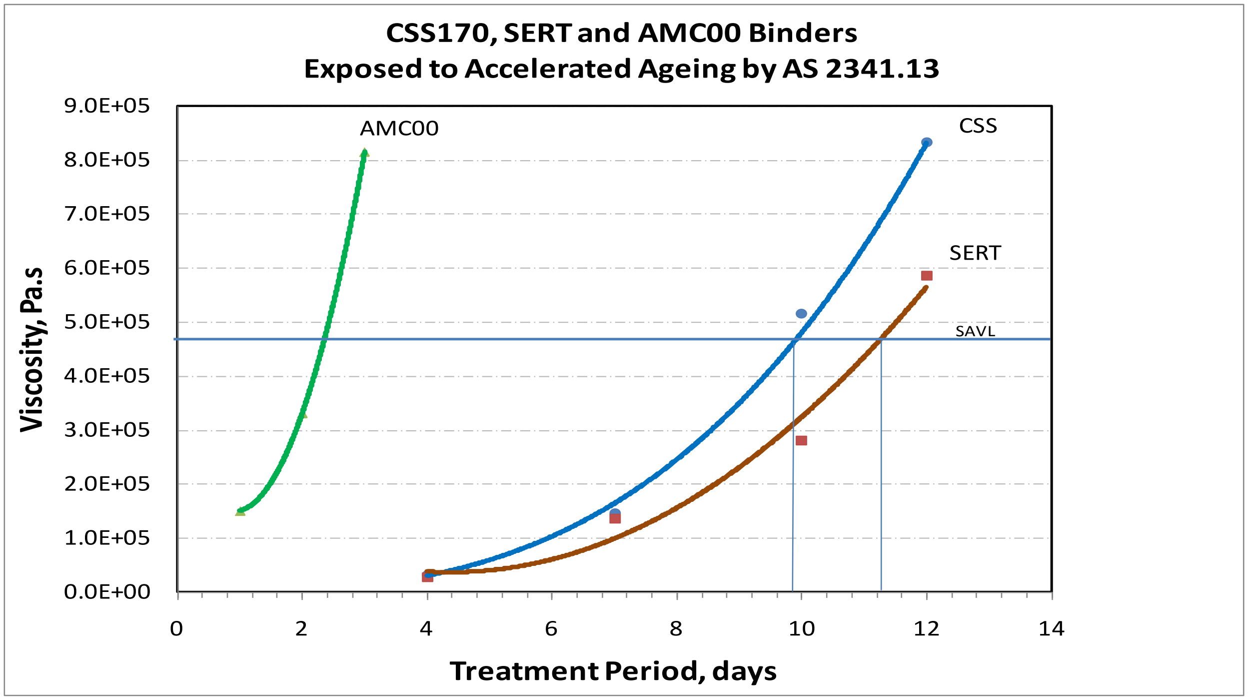


Fig. 2

By contrast, a more marked difference was observed when an AMC00 cutback binder was tested. As illustrated in the same Fig. 2 ageing under the same laboratory test was significantly accelerated. The reason for this is not is not clear, however, one explanation could be that the cutter combines with some of the lighter bitumen fractions and, during the process of evaporation (azeotropic), accelerates their removal. This pronounced hardening of the cutback residual binder and would indicate a significantly reduced life for the enrichment treatment.

A field trial carried out in conjunction with the NSW RTA in 2010 established that the SERT emulsion when applied to an aged chip sealed pavement;

- sealed significant pavement surface cracks
- provided a satisfactory surface macrotexture
- had only a very short term effect on surface microtexture
- enlivened underlying binder within one month of application

The crack sealing effect is illustrated in the photos below.

Original cracked pavement

Water retained after SERT application

The surface texture after teatment is summarised in Table 2. As reproduced from the RTA summary report (15).

Surface Texture Depth*, mm (Outer wheel path, southbound)			
Segment	Treatment	Before Treatment	After Treatment
3525	SERT	2.4	1.9
3440	CSS/170-60	1.7	1.4
3445	CSS/170-60	2.4	2.1
3650	CSS/170-60	2.8	2.2

* RTA T240

Microtexture test data is summarised below and is based on the Briish Pendulum test also as reported in RTA report (15).

British Pendulum Number				
Segment	Treatment	Before Treatment	After Treatment	After Initial Traffic
3440	SERT	62	55	61
3445	CSS/170-60	72	39	61
3525	CSS/170-60	58	32	56
3650	CSS/170-60	-	40	60

Conclusion

The growing global trend towards sustainable development principles and practice through adoption of environmentally sensitive policies and plans in major developed countries will provide more challenges for road construction and maintenance into the future. The inherent low emission characteristics of bitumen emulsions and their ability in many instances to support sustainability goals by improving utilisation of non renewable resources to extend service life of pavements will position them well to play an effective role in meeting these challenges.

References

(1) *Georg D., Engineers. Australia* Vol.82 No.1 , Jan. 2010

(2) World Commission on Environment and Development (WCED), 1987

(3) Miller T, & Bahia H,: *Sustainable Asphalt Pavements: Technologies, Knowledge Gaps and Opportunities,* Modified Asphalt Research Center, University of Wisconsin, Feb.2009)

(4) Australian Local Government Association, The National Local Roads and Transport Policy Agenda 2010-20

(5) Lay M G, *Ways of the World,* Primavera Press, 1992 p247

(6) Patrick J,and H. Arampammoorphy, *Quantifying the Benefits of Waste Minimisation*, Land Transport NZ Research Report, 2007

(7) Takamura et al (7) *Microsurfacing for Preventative Maintenance: Eco-efficient Strategy*, BASF 2001

(8) Thenoux, G. et al *Energy Consumption Comparison for Different Asphalt Pavement Rehabilitation Techniques Used in Chile,* Resources, Conservation and Recycling, Vol. 49, No.4, 2007 p325)

(9) Lysenko J.E., *Development and Shear Testing of a Bond Coat Emulsion, Third World Emulsion Congress, Lyon France Oct.2006*

(10) Wall C, *Eco- Efficiency Analysis : Chip Seal Asphalt Resurfacing,* BASF Report, 2004

(11) Miller T.M. & Bahia H.U., *Sustainable Asphalt Pavements: Technologies, Knowledge Gaps and Opportunities,* Modified Asphalt Research Center, University of Wisconsin, Feb.2009)

(12) *Environmental Assessment of Emulsions,* Austroads Report AP-R153 2000

(13) ClimateWorks Australia*, Low Carbon Growth Plan for Australia, Summary Report* March 2010

(14) IPCC Le Bouteiller E, *Asphalt Emulsions for Sustainable Pavements*, Los Angeles, US April, 2010 p627

(15) Bligh, D and Yin, S, *Enrichment Treatment Evaluation, Summary Report* June 2010.

Appendix

Emission estimates for Australia (1992)

Table 1

	CO2, Gg (based on actual consumption)		NMVOC, Gg (based on hypothetical total emulsion use)	
	Hot & cutback Bitumen	Emulsion	Hot & cutback Bitumen	Emulsion
Manufacture:				
• Bitumen	30.30	32.83		
• Cutter& Flux	2.22	0.02		
Transport:				
• Product	10.33	10.33		
• Solvent/water	0.18	4.28		
Application:				
• Evaporation	-	-	11.2	1.5
• Heating	4.00	Negligible		
Total	47.23	47.46	11.2	1.5

Source: Austroads report AP-R153, from Tables 8 and 9 (excluding secondary effects due to higher cost of emulsions).

Notes:

1. Gg = 1000 tonne
2. NMVOC = Non-Methane volatile organic compounds