DEVELOPMENT OF A BITUMINOUS PAVEMENT MATERIAL USING RECLAIMED PAVEMENTS

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ABSTRACT

This paper details the technical and commercial processes being undertaken to develop a bituminous pavement material product which has the capability to replace, in part and where appropriate, the use of hotmix asphalt.

The product is based upon recycling asphalt and basecourse material reclaimed from existing pavements and utilising recent research advances made in mix design performance characterisation of stabilised materials, mechanistic design of stabilised pavements and post-construction performance assessment.

A product development strategy is described based upon product identification, potential applications, structural characterisation, specification development, field trial evaluation and marketing.

INTRODUCTION

Resourceco is South Australia's largest recycler of construction and demolition waste. It currently recycles approximately 100,000 tonnes per annum of reclaimed asphalt and pavement material by crushing and screening to produce a quality assured granular pavement product marketed as 'Bitumate'. Whilst Bitumate is marketed as a granular unsealed pavement surfacing and low traffic basecourse, the current market is not large enough to utilise all the material that is processed.

In recent years, significant advances have been made in the area of bitumen stabilisation technology, particularly with respect to laboratory mix design characterisation and its application through the conduct of various field projects.

Resourceco considered that, given the limited funding available for road maintenance, rehabilitation and new construction works, there was a commercial opportunity to develop a bitumen-stabilised pavement material ('Bitumix') which had structural properties such that it could be considered as an economic alternative to traditional asphalt in pavement infrastructure.

Resourceco commenced a development program in 2003. More recently, with the assistance of a research and development support grant provided by Zero Waste SA (a South Australian state government authority) in 2005, a more detailed two-year research program was established in association with ARRB Group to develop the product to a commercial outcome.

This paper details the technical and commercial processes being undertaken to develop a bituminous pavement product which has the capability to replace, in part and where appropriate, the use of hotmix asphalt.

DEVELOPMENT PROCESS

A general strategy for pavement material product development is shown in Figure 1. In the development of any new road-making material, it is necessary to firstly identify the market where the product could be applied and then prove its performance. Having established the commercial and technical viability of the product, detailed product design can proceed to determine the required constituents to achieve both structural goals and performance predictions. During this process it is necessary, using laboratory characterisation, to establish mechanistic pavement design parameters to support the structural design of pavements incorporating the product. This data can then be used to develop a specification for the manufacture of the product and quality control test plans to ensure continued compliance.

Confirmation of manufacturing capability in terms of specification compliance follows in conjunction with practical field trials which also establish construction technique, structural achievement and predicted performance through ongoing monitoring under trafficking.

PRODUCT IDENTIFICATION AND RESEARCH NEED

The concept of bitumen stabilisation of Bitumate was realised when it was recognised that it contained between 2.5-3% bitumen (by mass) and that the addition of fresh bitumen, combined with a controlled aggregate grading (noting that the quality of aggregates used in the manufacture of the original asphalt were of high quality), could produce either a modified or bound stabilised pavement material.

However, whilst it is recognised that it is environmentally desirable to recycle such materials (as is the case in manufacture of some asphalt mixes), if the product is to be commercially viable, the resilient modulus of the stabilised material needs to be such that comparable pavement thicknesses similar to asphalt need to be achieved. In addition, other properties such as deformation, permeability and fatigue resistance need to be characterised if such a product is to become a viable commercial product.

The stabilisation of Bitumate with bitumen (in the form of a cold emulsion) to form Bitumix is ideally suited to manufacture in a standard pugmill facility in a controlled quality assured process with the added ability to add secondary binders such as cement or lime.

As the product is a bitumen-stabilised pavement material, it has the potential to produce a pavement material at a lower cost but with structural properties identical to those of traditional asphalt. The potential applications of Bitumix are seen as follows:

- a bituminous surfacing and structural layer for use in industrial applications such as freight yards, grain storage facilities, car parks, etc. where a traditional bituminous spray seal is unable to withstand the imposed wheel loads or new asphalt is an expensive solution
- a bitumen-stabilised pavement layer in road widening and shoulder reinforcement which may offer thinner pavements which are less sensitive to loss of strength through water ingress
- an intermediate structural layer as an alternative to new asphalt in maintenance reinstatement operations on thick metropolitan asphalt pavements which may, in the longer term, form part of new pavement configurations
- a structural layer and surfacing on bikeway pavements.

To meet these anticipated uses a range of stabilised products was adopted for consideration based upon maximum aggregate size and the inclusion of hydrated lime as a secondary binder, viz:

- 20BLE/ 20BCE – 20 mm Bitumate stabilised with bitumen emulsion and hydrated lime or cement

- 20BE – 20 mm Bitumate stabilised with bitumen emulsion
- 14BLE/14BCE – 14 mm Bitumate stabilised with bitumen emulsion and hydrated lime or cement
- 14BE – 14 mm Bitumate stabilised with bitumen emulsion
- 10BLE/10BCE – 10 mm Bitumate stabilised with bitumen emulsion and hydrated lime or cement.

PRODUCT DESIGN

The stablisation mix design to determine the quantity of bitumen with or without a secondary binder was based upon achieving an indirect tensile resilient modulus in the range E = 1,500-2,500 MPa.

Base aggregates

Bitumate, which is manufactured from the recovery and reprocessing of recycled asphalt pavement materials, is the base material for the manufacture of Bitumix. The product is produced by crushing and screening slabs of asphalt road pavement to meet a typical Road Authority 20 mm Class 2 granular material. Typical production properties are shown in Table 1.

Table 1 Bitumate specification and production quality

Particle size (mm)	Percent finer	Mean	Std Dev.
26.5	100	100.0	0.00
19	90-100	99.4	2.16
13.2	74-96	89.5	4.68
9.5	61-85	77.0	5.73
4.75	42-66	50.3	5.97
2.36	28-50	35.7	4.80
0.425	11-27	16.7	3.28
0.075	4-14	7.0	2.17
Liquid Limit	max 28	20	1.7
Plasticity Index	1-8	4	1.6
Linear Shrinkage	max 4	2.5	0.9
Los Angeles Abrasion	max 45	31	2
Bitumen content	Max 4	3	0.4

Stabilisation binders

Initially a standard 60/40 (Class 170) emulsion was adopted for laboratory characterisation and bitumen binder led to a speckled appearance as shown in Figure 2. In addition, on one trial (Mt Barker) the time to achieve sufficient strength before traffic could be applied was unacceptable (over three days) and the insitu strength well below that achieved at other trial sites.

As a result, at the commencement of the Zero Waste SA grant project a new emulsion was sourced which had the basic characteristics being sought: a higher bitumen/water content (80/20 adopted), medium setting and uniformly dispersed through the Bitumate.

The high bitumen/water content was required to keep the liquid content of the manufactured material as much below OMC as possible as well as medium setting in order to induce early strength and allow same-day trafficking. In addition, the emulsion was required to be as dispersible as possible rather than the segregated mottled appearance often associated with bitumen-stabilised materials.

To achieve higher resilient moduli of the mixes, hydrated lime or blended cement were considered in the mix design process.

Laboratory mix design

The initial mix designs undertaken in 2004 were based upon the need to identify the indirect tensile resilient modulus (wet and dry) that could be achieved with residual bitumen contents varying between 2%-4% and 0% or 1% supplementary binder (cement or hydrated lime).

The laboratory testing was undertaken in accordance with the new Austroads procedures with the indirect tensile resilient modulus being determined according to AS2891.13.1 (1995). The results of this preliminary mix design are shown in Table 2.

Table 2 Indirect tensile resilient modulus

% bitumen	bitumen only	1% cement	1% lime
wet			
2%	738	1554	2536
3%	743	1592	2238
4%	746	1700	2236
dry			
2%	3730	4678	3697
3%	2495	3737	3317
4%	1597	2562	2572

Additional testing is currently being undertaken by ARRB; the Zero Waste SA grant has allowed the following more detailed laboratory characterisation to be undertaken:

1. additional resilient modulus characterisation of the various combinations of binders shown in Table 2 for the newly sourced emulsion
2. gain in strength (resilient modulus with time) to establish working time and time required prior to trafficking.
3. compaction characteristics, both dynamic and gyratory, for consideration in construction quality control; early testing indicates that the maximum density is 2.15 t/m^3, which is significantly lower than most asphalts because the bitumate has a lower overall bulk density
4. compacted constituent proportion in terms of bitumen and voids volume
5. wheel tracking tests at elevated temperatures to characterise rutting characteristics; early indications are that, because of the high granular interlock in the product, rutting is insignificant
6. dynamic flexural beam tests to identify fatigue resistance, with particular reference to an appropriate fatigue constant for use in the mechanistic design performance model adopted.

PRODUCT FIELD TRIALS

Since the inception of product development in 2004, a number of field trials were undertaken prior to the Zero Waste SA grant to determine the field characteristics of the product and to determine if the product would meet expectations and anticipated applications. Projects undertaken included:

- Tanunda – access pavement to Booth Transport: subject to high B-double turning movements
- Tailem Bend – AWB grain facility pavement for grain storage and weighbridge haulage
- Mt Barker – Transport SA boxed out full depth seal widening

Of these the Tanunda project was evaluated in detail and the results are now reported.

Tanunda – 2004

The first field trial involved the evaluation of a 100 mm thick Bitumix (3% 60/40 emulsion) wearing course constructed over a granular crushed rock pavement. The Bitumix was delivered at OMC, placed, shaped with a grader and compacted using an 8-10 tonne vibrating smooth drum roller.

The trial involved the evaluation of manufacture-delivery-construction-field performance. The evaluation included an assessment of:

- pugmill performance, product consistency and production rate
- effect of transportation of Bitumix to Tanunda (haul time of 1.5 hours)
- grader spreading, shaping, edge segregation and joints between deliveries
- compaction, moisture variation, sponginess, surface finish
- final condition and performance under traffic, i.e. resistance to rutting, shear failure and tensile fatigue cracking
- post-construction deflection analysis.

A typical laboratory compacted specimen is shown in Figure 2, whilst photographs of construction are depicted in Figure 3 and Figure 4. During construction, it was decided to slurry the surface with water during final compaction because of the open texture of the surface. However, this induced undesirable shrinkage cracking in the surface Figure 5.

Post-construction analysis conducted using deflection data collected with a Falling Weight Deflectometer on a 100 mm asphalt pavement and the Bitumix layer were comparable as shown in Table 3. However, as a surfacing, the Bitumix could not withstand the traffic turning movements and a 50 mm thick asphalt surfacing layer was applied to complete the pavement configuration.

Table 3 Deflection statistics for Tanunda

Pavement type	Deflection statistics	Curvature statistics
100 mm asphalt (AC10E)	mean = 0.620; SD = 0.122	mean = 0.166; SD = 0.056
100 mm Bitumix (2% bit)	mean = 0.508; SD = 0.143	mean = 0.142; SD = 0.041

These first field trials indicated that, with further development, a product could be manufactured to meet the structural expectations initially identified but that more work was required to produce a consistently satisfactory surfacing.

Wingfield – 2006

The first field trial in the current project was constructed on the Resourceco access road from the end of the existing asphalt-surfaced granular pavement to the weighbridge. Five trial pavement configurations were constructed as shown in Table 4.

Table 4 Trial site pavement configurations

Pavement type (location / description)	Test Attributes	Surface (thickness) (material)	Base (thickness) (material)	Subbase (thickness) (material)
Existing access	traditional thin asphalt granular pavement	50 mm A10E	150 mm PM2/20RG	150 mm PM2/20RG
Pavement Type 1 (downhill turning)	heavy duty 14 mm wearing course – shear forces rubble basecourse in wet environment	50 mm 14BLE	125 mm PM2/20RG	existing
Pavement Type 2 (straight run)	heavy duty 14 mm wearing course – texture, skid and abrasion 14 mm product – structural layers	50 mm 14BLE	60 mm 14BLE	65 mm 14BLE
Pavement Type 3 (straight run)	light duty 14 mm wearing course – texture, skid and abrasion 14 mm product – structural layers	50 mm 14BE	60 mm 14BLE	65 mm 14BLE
Pavement Type 4 (straight run)	light duty 14 mm wearing course – texture, skid, abrasion 14 mm product – structural layers	50 mm 14BE	60 mm 14BL	65 mm 14BL
Pavement Type 5 (climbing and weighbridge entry)	heavy duty 14 mm wearing course – shear forces 20 mm product – structural layers	50 mm 14BLE	60 mm 20BLE	65 mm 20BLE

For Bitumix products requiring lime addition. the lime was added to the Bitumate as a separate operation prior to being fed into the pugmill for the addition of bitumen emulsion and water.

For the main pavement, construction was undertaken using a conventional asphalt paver and vibratory smooth-drum rollers associated with asphalt layer construction. Because of the need to maintain access to the weighbridge, construction was undertaken in half-width segments with trafficking on newly-constructed layers being applied to the new pavements immediately after construction. The construction process is depicted in Figure 6, Figure 7, Figure 8 and Figure 9.

Laboratory characterisation

Compaction

Compaction testing was undertaken to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the products. Compaction attributes are required for:

- the manufacture of laboratory test specimens from which engineering and performance parameters are determined

- the identification of the moisture content target for pugmill manufacture of the products, bearing in mind that the product needs to be manufactured as dry as possible to achieve high early strength
- the determination of a value to which field compaction (quality control and assurance) can be measured.

Two types of laboratory compaction were evaluated viz.

- dynamic compaction using Modified compactive effort in accordance with AS1289 5.2.1 (2003) associated with crushed rock technology. These tests were undertaken on laboratory-prepared mixes
- gyratory compaction using both the Servopac and Gyropac apparatus in accordance with AS2891.2.2 (1995). These tests were undertaken on pugmill-manufactured mixes.

The results of the compaction testing are shown in Table 5 whilst the dynamic compaction characteristics of the products manufactured from 20 mm Bitumate are shown in Figure 10.

Table 5 Results of laboratory compaction testing of Wingfield mixes

Product	Dynamic (Modified compaction)		Servopac (t/m^3) 80 cycles	Gyropac (t/m^3) 80 cycles
	OMC (%)	MDD (t/m^3)		
20 mm Bitumate	5.2	2.15	N/A	N/A
20BE	5.2/7.2*	2.13	2.08	2.00
20BLE	4.1/6.1*	2.145	2.05	1.99
14 mm Bitumate	5.5	2.15	N/A	N/A
14BE			2.06	2.01
14BLE			2.06	1.97

* water only/total fluids, i.e. water plus bitumen.

Resilient modulus

The indirect tensile resilient modulus was determined according to AS2891.13.1 (1995) using the Materials Testing Apparatus (MATTA). Samples were tested at a range of curing times in order that the design strength that should be adopted in the mechanistic design procedure could be determined. A typical result for 20 mm Bitumate, stabilised with 3% emulsion, is shown in Figure 11.

Post-construction evaluation

Deflection

The results of an FWD survey conducted two months after construction are shown in Table 6. Whilst a detailed back-analysis needs to be undertaken to determine relative layer stiffnesses, the following observations can be drawn based upon the premise that the deflection values are an indication of whether there is sufficient pavement thickness over the subgrade, whilst the curvature is a measure of pavement stiffness and resistance to asphalt fatigue.

1. Comparison of the data relating to the existing access pavement and the Type 1 pavement suggests that equivalent pavements have been constructed.
2. There is sufficient pavement thickness over the subgrade in all pavements, with deflections for the full depth Bitumix pavements being lower – as would be expected.
3. The addition of lime has resulted in a slight improvement in the curvature values. This needs to be investigated further through laboratory tests conducted on cores.

4. The stiffest pavement is pavement Type 5, which was expected given the use of 20 mm aggregate and lime.

Table 6 Results of deflection survey of Wingfield trial pavements

Pavement Type	Deflection statistics (mm)	Curvature statistics (mm)
Existing access 50 mm AC10E (granular)	mean = 0.316 SD = 0.087	mean = 0.121 SD = 0.030
Type 1 50 mm Bitumix 14BLE (granular)	mean = 0.316 SD = 0.119	mean = 0.114 SD = 0.037
Type 2 50 mm Bitumix 14BE 125 mm Bitumix 20BE	mean = 0.147 SD = 0.025	mean = 0.084 SD = 0.028
Type 3 50 mm Bitumix 14BLE 125 mm Bitumix 14BLE	mean = 0.222 SD = 0.072	mean = 0.096 SD = 0.023
Type 4 50 mm Bitumix 14BE 125 mm Bitumix 14BLE	mean = 0.137 SD = .009	mean = 0.075 SD = 0.002
Type 5 50 mm Bitumix 14BLE 12 5mm Bitumix 20BLE	mean = 0.151 SD = 0.025	mean = 0.072 SD = 012

Coring

Two 150 mm diameter cores were taken from each of the full depth Bitumix pavements (Types 2-5) for the purpose of determining density, bitumen and voids content, and indirect resilient modulus. These results will be compared with the results obtained on the laboratory-compacted specimens and other parameters determined in the laboratory characterisation program. A photograph of the cores is shown in Figure 12.

SUMMARY

Although the project is on-going and more technical evaluation is being undertaken, this paper has demonstrated a process by which research can be applied to the development of an alternate pavement material.

The project has demonstrated that adoption of ‘state of the art’ technologies to characterise the product in terms of intrinsic structural design parameters and application of post construction evaluations to estimate long term performance provides both credibility to the new product as well as increased confidence in its market acceptance.

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Standards Australia 1995, Compaction of asphalt test specimens using a gyratory compactor. AS2891.2.2.

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ACKNOWLEDGEMENT

This research is being undertaken under a research grant provided by Zero Waste (SA Government). The authors thank Angus Mitchell of Zero Waste for his interest and support.

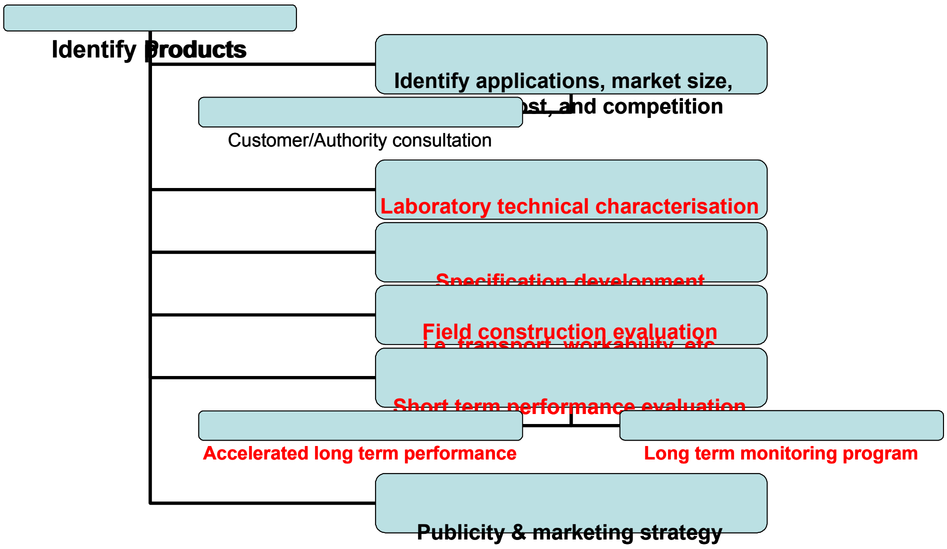


Figure 1 General strategy for pavement product development

Figure 2 Initial emulsion mix (2004)

Figure 3 Tanunda – placement and grader spreading

Figure 4 Tanunda – compaction and surface finishing

Figure 5 Tanunda surface – before and after slurrying

Figure 6 Wingfield – paver construction

Figure 7 Wingfield – compaction

Figure 8 Wingfield – finished surface

Figure 9 Wingfield – trafficking during construction

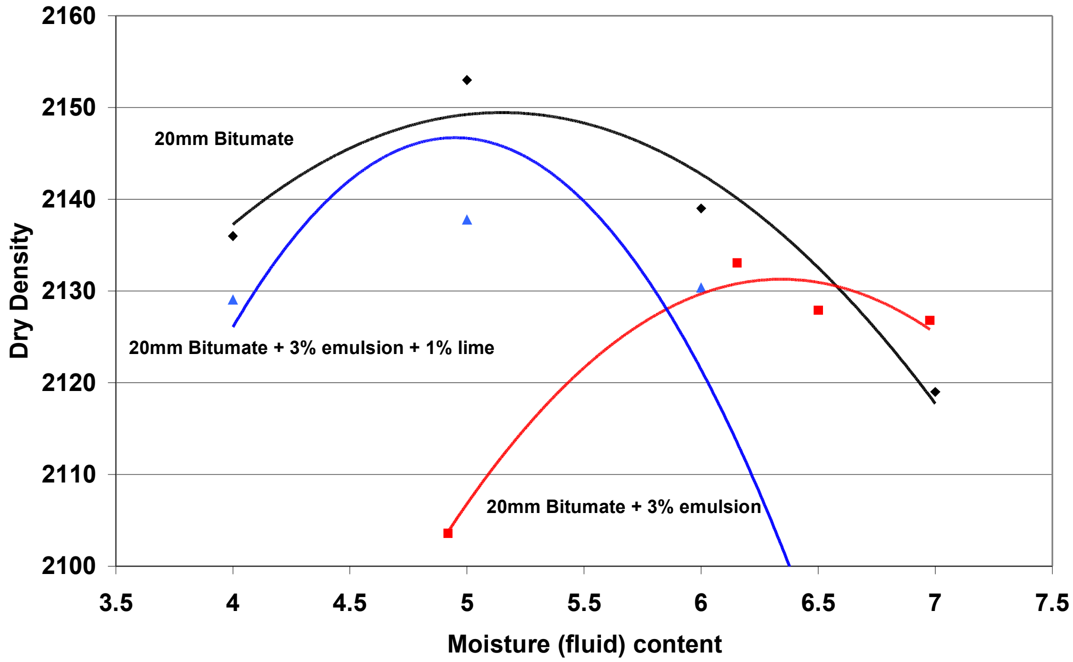


Figure 10 Dynamic compaction characteristics of Bitumate mixes

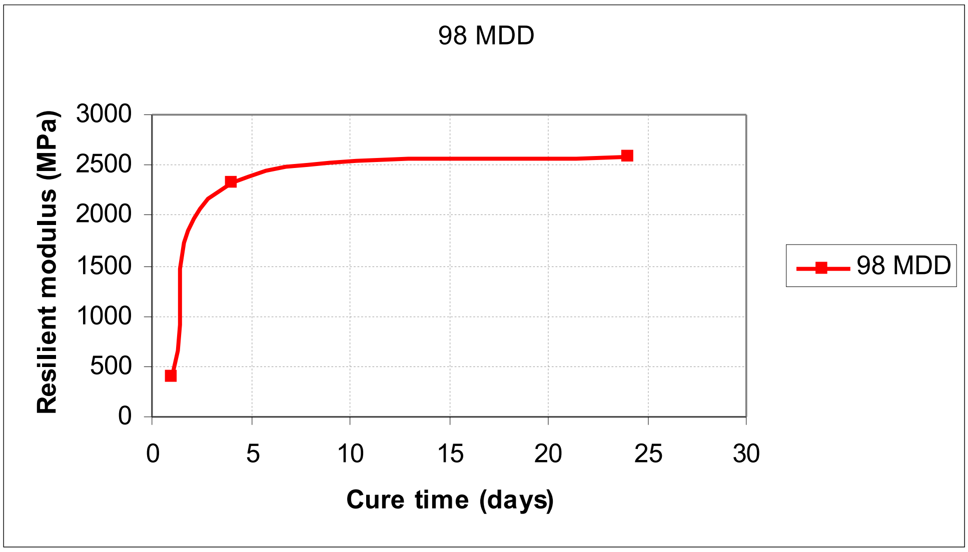


Figure 11 Increase in resilient modulus over time
(20 mm Bitumate, stabilised with 3% emulsion)

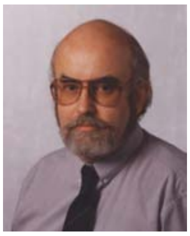
Figure 12 Cores – (1) 175 mm of 14 mm Bitumix
and (2) 50mm of 14mm Bitumix and 125 mm of 20 mm Bitumix

AUTHOR BIOGRAPHIES

Bob Andrews

Following a 38 year career in geotechnical and pavement engineering, Bob manages his own consultancy Infratechno Consultants in addition to being a Principal Engineer at ARRB Group. Bob specialises in the application and performance characteristics of unbound, marginal, industrial/mining waste, recycled and stabilised materials, mechanistic pavement design/rehabilitation and strategic asset management of unsealed road networks. He has contributed both nationally and internationally, serving on a number of research groups within Austroads, and the private sector. Bob is a member of the US Transportation Research Board Committee AFS90 ‘Mechanical and Chemical Stabilisation’ and is the principal author of the revision of the *Austroads Guide to Stabilisation*.

Kieran Sharp

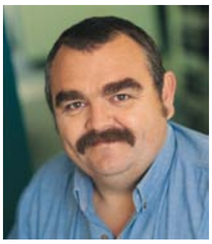


Kieran is currently the Business Manager, Asset Technology, at ARRB Group. He has worked on a wide range of pavement and materials-related research projects for Austroads, industry and the OECD, including the DIVINE project. He was the Manager of the Australian Accelerated Loading Facility (ALF) program through the 1990s.

Kieran is a member of the US Transportation Research Board Committee AFD40 and COST Committee 347 on Accelerated Pavement Testing, the American Concrete Institute Committee 325 (Concrete Pavements), the OECD/ECMT JTRC ‘Economic Evaluation of Long Life Pavements’ Working Group and various Austroads and industry-based Project Steering Committees and Reference Groups.

He is a member of the Editorial Board of the International Journal of Pavements and the Chairman of the Technical Committee of the Road Engineering Association of Asia and Australasia and a co-opted member of the Governing Council.

Mike Haywood



Mike commenced work with Resourceco in August 1999 following the restructure of the Pacific Waste Management business during its subsequent merger with BFI Waste. Mike brought to Resourceco a vast skills base that was predominantly within the waste industry and quickly adapted the principles to the processes and dynamic growth that Resourceco have undergone.

In his role as General Manager, Mike has overseen the product development of the Resourceco recycled products range to ensure that they meet the requirements of the new PM 2000 Specifications for pavement materials. Mike has also assisted in the development of the OH&S systems as well as the on-going maintenance of the Resourceco Site Management Plan. He is currently working with Adelaide Brighton Cement to develop an alternative fuels program.