Utilising Environmental Beneficial Pavement Products: Case Study at OR Tambo International Airport

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ABSTRACT: This paper reports on the use of sustainable resource enhancing bituminous products at OR Tambo International Airport (ORTIA) over the past five years. It also report on new innovative asphalt products and designs identified to be utilised and/or developed by Airports Company South Africa (ACSA) as environmentally less impacting alternatives to replace current standard pavement construction products/designs. The study evaluate the cost benefits (or premiums) and the environmental benefits of various alternative product and design technology. It was concluded that the utilised and identified new alternative products, i.e. Recycled Asphalt Mixes, High Modulus Asphalt and Foamed-Based Warm Mix Asphalt together with Long Life/Perpetual Pavements technology can bring about both significant Nett Present Value cost advantages (±20% savings) and environmental benefits (20 to 30% less CO_2, aggregate, binders) when compared to the conventional products and design methods. An implementation strategy was formulated for further use of these advantageous products and processes were put in place for project-to-project assessment of alternative product utilisation.

KEY WORDS: Airport Pavement, Sustainability, Environment, Asphalt

1 BACKGROUND

Until 2005, Airports Company South Africa (ACSA) primarily utilised new asphalt (and concrete products) and also new crushed stone layerworks materials in all their reconstruction, rehabilitation and new construction works for aircraft and road pavement structures. Rehabilitation designs typically consisted of constructing new asphalt layers on top of the old, failed layers. Alternatively, the old asphalt (and/or concrete layers) was removed to the depth of the granular layers and new (thicker) asphalt (and/or concrete layers) was inlaid and overlaid.

The milled-out old asphaltic materials were typically spoiled or used as granular selected layers. No effective recycling of these valuable bitumen bound materials was considered.

Typically, new and rehabilitation work on the asphalt pavement types at ORTIA alone, adds up to about 100 000 tons of asphalt layers per annum. This requires approximately 95 000 tons of new crushed aggregates, 5 000 tons of bitumen binder and 2 000 tons of fuel resources. The carbon dioxide emissions are estimated to be ±6 000 tons p.a. In other words ±6 000 trees need to be planted per annum to neutralise the effects of these carbon emissions. Since 2005, initiatives were put in place to recycle and re-use these valuable materials during the rehabilitation process as to effectively lower the required new resources quantities.

2 STRATEGIES USED TO IMPLEMENT THE SUSTAINABILITY ENHANCING INITIATIVE

The strategy undertaken was to formulate suitable solutions to safely optimise the use of sustainability enhancing and environmental beneficial products and construction technology, that:

- Bear no risk to ACSA (no comprising on safety or product life),
- Are cost effective enough to reduced ACSA's capital expenditure costs in order to justify implementation,
- Maximise recycling of existing materials, treating it as assets, as to reduce the use of "new" natural resources (i.e. crushed stone and bitumen) and hence enhance sustainability,
- Reduce environmental impacts by reducing harmful carbon dioxide emissions (during supply and construction).

ACSA is dependent on its regularity-body to approve funding (and recovery from the airliners) for its capital projects. All the costing and repairs need to be done cost-effectively and ACSA puts high value on innovative, value adding and cost-saving design exploration. Various contractors, producers and industry bodies (SABITA, ITT-US, CSIR) and International studies and best-practise reports and papers (Australia Asphalt Pavement Association, North American Pavement Association, International Society of Asphalt Pavements) reports and papers were consulted or studied to formulate optimal and innovative solutions based on newly developed state-of-the-art technology and manufacturing best-practise methods (Disten et al 2008, Nat Dept. Transport 2009, Pretorius 2009, Rodriques 2008).

The initial Phase 1 study (covering the use of Recycled Asphalt and Long-Life Asphalt surfacing layers) and implementation exercise (2005 to 2007) were followed by a broad and comprehensive research and international best-practise follow-up (Phase 2) study which took place over 2008 and 2009. This involved intensive investigation into advanced methods and technology application, with a view to aligning future projects with ACSA's principles of sustainability and preservation of the environment. Various product trial sections were installed to verify product performance.

Technology from France (High Modules Asphalt), Europe and USA (Recycled Asphalt and Warm-Mix-Asphalt) and selected international specialist studies (Long Life/Perpetual Asphalt Technology) were studied (Disten et al 2008, Nat Dept. Transport 2009, Pretorius 2009, Rodriques 2008). Technical design inputs were extracted from various International studies and papers (ICAP 2006, RILEM 2003/8, CAPSA 2004/7, ARRB 2003/7), AAPA and NAAPA research report and South African International publications.

3 KEY DEVELOPMENT AND IMPLEMENTATION STEPS

Development of the products utilised were divided into phases. The first phase started in 2005/6 during the initial design of the Hotel and Yankee Taxiway Rehabilitation projects. Initial development steps consisted of the following:

- Economic Analyses of all pavement layer products used in the pavement design to ascertain viable, alternative resources that are more sustainable, that can reduce costs and which lessen the impact on the environmental. The study identifies various innovative alternative bituminous products and designs, which have lower environmental impact and that can be utilised to replace current standard pavement products/designs. In quantifying the advantage versus costs of these alternatives, one innovative product, i.e. the use of recycled asphalt in new plant manufactured asphalt mixes, stood out as a viable product. Long-life shoulder asphalt mixes also hold significant sustainability and nett-present value-based cost-saving benefits;
- Design meetings with asphalt suppliers, paving contractors and ACSA followed in order to verify the efficiency and produceability of the product and to ensure performance quality and minimum product standard can be obtained.
- The worldwide body–of-knowledge on products was evaluated and assimilated as to ensure risk-free and optimal development and application of the product;
- Comprehensive laboratory mix development of the product, were done followed by various development and testing cycles until the necessary performance criteria of the mix were obtained. Specialist rut resistance and fatigue resistance simulation testing was done with highly specialised test equipment (i.e. Model Mobile Load simulator, Gyratory Compactor Study and 4-Pt Beam Fatigue test). State-of-the-art design methodologies such as the Bayley Method and Superpave Method design conventions were also utilised;
- Various field trial sections were commissioned until the constructability and design/performance criteria on field trials were verified and proven.
- Implementation on five major construction projects at ORTIA (rehabilitation reconstruction and new pavements) (see Section 6 for details);

Further studies in 2008/9 to develop and implement more comprehensive, sustainability enhancing and environmentally conscious products and designs for airport pavement asset management and construction. Development steps included:

- Detailed studies to identify implementable and developable products and design methodologies which can maximise the sustainability of resources usage;
- Cost-benefit study to measure and quantify the environmental benefits (or lowered impacts) of the sustainable/"greener" products and designs;
- Developing guideline implementation steps for future design methodologies and product selection to ensure that ACSA's strategy of environmentally responsible construction and resources utilisation is successfully implemented.
- Currently trial sections with High Modules Asphalt, perpetual pavement structures and Foamed-Based Warm-Mix-Asphalts are in process and the developed technology is planned to be implemented in pavement rehabilitation and new construction projects worth approximately R1.5 billion over the next 10 years.

4 MAIN OBSTACLES ENCOUNTERED AND IMPLEMENTATION CHALLENGES

The main obstacles were to identify products and design alternative which can preferably deliver cost-reductions over the long term (NPV) and still enhance sustainable usage of resources. New product developments generally result in higher initial capital costs (vs standard products) and ways had to be found to overcome this. Also due to the heavy-duty nature of aircraft loadings (one aircraft wheel at 22 ton loading is equivalent, in terms of damage, to ±1 000 standard 8 ton truck axles); the end product still had to be a superior, high quality layer with zero tolerance for non-performance or safety risk.

Practical obstacles encountered in verifying and developing reliable solutions included:

- Test facilities where the performance properties of the new products could be verified (i.e. fatique resistance, etc) are limited in RSA. Preparation test beds had to be constructed at the suppliers' facility to prepare representative test samples for special testing. Significant efforts and trials-and-error development followed to obtained sound representative samples for accurate performance testing;
- The airport construction environment is extremely unsuitable and difficult for new product or sensitive/specialist products[4] as construction windows are small (±3 – 7 hours at a time) and immediate loading of completed layers is required after reopening to aircraft traffic. New products and construction methodologies get subjected to the harshest possible loading conditions (heavy aircraft wheel loads within 30 minutes of completion) and no room for safety/failure risks exists;
- The design technology of new innovative products that enhance resource sustainability is very new and has mostly been developed overseas for application on roads projects. Application for Heavy duty, aircraft loading at airports leaves no room for risky designs. The development, assimilation and implementation of these technologies (including the new High-Modules-Asphalt and Warm-Mix-Asphalt) required new performance testing and performance criteria development along with comprehensive in-situ field trial verification before implementation on a full scale could be implemented.

5 PRODUCT RECOMMENDATIONS AND FUTURE SUSTAINABILITY ADVANTAGES

The following combinations of new and initially implemented proven innovations were identified for further implementation on the estimated R1.5 billion (€150 million) new and rehabilitation pavement projects to follow over the next 10 years (Phase 2 of implementation phasing):

- The use of higher content Recycled Asphalt Layers: Approximately 40% of the milled out old asphalt can be effectively mixed into new products, thereby saving meaningful quantities of new aggregate and bituminous binders as well as the energy/carbon saved due to not having to produce these omitted materials.
- The use of innovative new asphalt products, such as High Modules Asphalt (HiMA) with higher fatique resistance and stiffnesses will result in less layer thickness, resulting in less raw materials utilisation and heating fuel/carbon-dioxide emissions in the manufacturing process;
- The use of new binder modifiers and asphalt production methods, which lower the production temperature of asphalt by ±20°C, can result in ±15% lower fuel consumption and carbon-dioxide output during plant production. Various "Warm-Mix-Asphalt" types is available in RSA, each with its own unique cost premium/saving and fuel/carbon saving combination. The main types include:
    - Foamed-Bitumen Type which cost ±1% to 3% less than conventional asphalt;
    - Wax-Modifier types and Surfactants which cost ±5% more than conventional asphalt ;
- The use of innovative long-life pavement designs which decreases life-cycle costs and material usage of new flexible pavements by 20% to 25% over full design analyses periods. This saves both raw materials (aggregates and bituminous binders) as well as heating fuel/carbon-dioxide output in terms of the combined manufacturing processes over the full life cycle period.

In utilising these alternative technology and products at ORTIA alone, the following cost-reduction and resource sustaining benefits were calculated (see Tables 1 to 4, with a summary in Table 5): [Note : R10 ≈ €1]

Table 1: Potential Advantages of Reclaimed Asphalt (RA)

Cost Items and % Saving	Value of Saving/Premium	Environmental Benefit
• ±5 – 10% reduction in pavement layerworks cost (R50/ton of asphalt saving) • Rehab work (R500 million over 10 years) • New work (±R1 billion over 10 years)	≈ R35 million saving ≈ R70 million saving	• ±20% less aggregate (1.5 million ton x 0.2 = 300 000 ton) • ±5 - 10% less binder (8 000 ton) • Fuel usage same • Bituminous fumes/emissions same

Table 2: Potential Advantages of HiMA

Cost Items and % Saving	Value of Saving/Premium	Environmental Benefit
• ±20% less pavement layerworks costs • Rehab work (±R500 million over 10 years) • New work (±R1 billion over 10 years)	≈ R100 million saving ≈ R200 million saving	• ±25% less aggregate (380 000 ton) • ±5% less binder (4 000 ton) • ±20% less fuel (2 500 ton) or 7 500 ton less CO_2 • Bituminous fumes/emissions same

Table 3: Potential Advantages of Perpetual/Long Life Asphalt

Cost Items and % Saving	Value of Saving/Premium	Environmental Benefit
• ±20% less pavement layerworks costs (over 30 years life cycle; more expensive initial costs) • Rehab work (±R500 million over 10 years) • New work (±R1 billion over 10 years)	≈ #R100 million saving on life cycle costs ≈ #R200 million saving on life cycle costs	• ±20% less aggregate (300 000 ton) over 30 years • ±15% less binder (12 000 ton over 30 years) • ±20% less fuel (2 500 ton) or 7 500 ton less CO_2 • Bituminous fumes/emissions lower (±20%)

Note: #Based on life cycle cost over long analyses period, but additional initial costs will be required.

Table 4: Potential Advantages of Warm Mix Asphalt Type 1: Foamed Bitumen*

Cost Items and % Saving	Value of Saving/Premium	Environmental Benefit
• ±R3/ton asphalt cost reduction • Rehab work (±R500 million over 10 years) • New work (±R1 billion saving over 10 years)	≈ R2.5 million saving ≈ R5.0 million saving	• Aggregate and binder usage same • ±10%-15% less fuel (1 litre/ton asphalt reduction; 1 500 ton over 10 years of 4 500 ton less CO_2) • Bituminous fumes/emissions lower (>50%)

Note*: The study found that Warm Mix Asphalt Types 2 and 3 (i.e. FT Waxes and Surfactants have a ±5% cost premium and similar environmental benefits as Foamed Bitumen in Table 6D.

Table 5: Summarised Advantages of Various Viable Sustainable Resource Enhancing and Environmentally Beneficial Combinations (10 years period)

Note:This breakdown is based on the flexible pavement asphalt work estimated for the next 10 years at ORTIA (R10 ≈ €1)

Standard Products Base Values	**Reduction or Increases Relative to Base Cost/Usage Values of Standard Products#**					
	Recycled Asphalt and High Modules Asphalts for Rehabilitations	**High modules Asphalt and Long Life Pavements for new Pavements**	**Recycled Asphalt and Long Life Pavements for new Pavements**	**Warm-Mix-Asphalt for New and Rehab Pavements**	**Combined Advantages of Selected Products**	**% of Standard Product Base Values**
• Rehab cost ≈ R500 million	-R100 million	N/A	N/A	-R1 million	R101 million	20% lower
• New cost ≈ R1 000 million	N/A	-R110 million	-R110 million	-R2 million	-R222 million	22% lower
• Aggregate ≈ 1.5 million ton	-0.2 million ton	-0.16 million ton	-0.14 million ton	N/A	-0.5 million ton	33% lower
• Binder ≈ >5 000 ton	-3 000 ton	-6 000 ton	-7 500 ton	N/A	-16 500 ton	22% lower
• Fuel (CO_2) ≈ 12 000 tons (36 000 ton)	-600 ton (-1 800 ton)	-750 ton (-2 300 ton)	-750 ton (-2 300 ton)	-500 ton (-1 500 ton)	-2 600 ton (-8 000 ton)	22% lower
• Tree Equivalents* ≈ 36 000 trees	-1 800 trees	-2 300 trees	- 2 300 trees	- 1 500 trees	- 8 000 trees	#22% lower

Note: #Assumed applications: Recycled Asphalt and HiMA (6A and 6B) combined on all base asphalt layers on 75% of rehabilitation work; HiMA and Long-Life Pavement Technology (6B and 6C) combined on 40% of new projects and Recycled Asphalt and Long-Life Pavement Technology (6C and 6A) combined on further 40% of new projects; Foam WMA (6D) in 35% of work (new or rehabilitation).*Amount of trees to remove CO_2 emissions (one tree remove ±1 ton CO_2 over life of 10 – 20 years).

6 KEY BENEFITS AND ACHIEVEMENTS OF THE PROJECT

The key realised benefits of the completed implementation study of the identified environmentally beneficial and sustainability enhancing pavement products are summarised in 6.1 to 6.3 below and future benefits from full application of the study is listed in 6.3.

6.1 Recycled asphalt usage:

- Valuable construction materials (asphaltic materials), which otherwise would have been spoiled, were re-used resulting in cost savings to ACSA (±5% of new product costs). Approximately 20% was recycled into new asphalt mixes and ±70% was re-used as valuable road surfacing material;
- The spoiling or dumping of these valuable, salvageable and environmentally hazardous asphaltic materials was effectively reduced by 90% - 100%.
- Re-use of these asphaltic products, by reclaiming and recycling it to form ±15% of the mix of new asphalt production, effectively reduced the aggregate production by ±20%, the bitumen binder usage by 5% and the overall fuel usage (less aggregate production, etc.) by ±10%.
- Re-use of these recycled asphaltic products as a surfacing on lower quality/standard roads (100% re-using realised) effectively reduces new aggregate production by 100%, fuel using by ±80% (limited haulage on-site, no re-heating, no aggregate production or paving cost) and binder usage by 80% (only 1one fifth of new binder sprayed in to enhance re-bonding).

6.2 Long Life Asphalt Shoulder mixes:

- It is envisaged that the use of slightly more expensive shoulder asphalt surfacing layers (‘carbon black’, modified for enhanced durability), at ±3% higher initial cost, on three major contracts to date, will extend the estimated life-span of the mix by ±50%. This translates to a lifespan of 20 years as opposed to 13 years. On a discounted, net-present value-base, this reduces cost and resources (aggregate, bitumen and fuel) over time by ±35%.

6.3 Extent of Project Implementation and Future Implementation

The implementation process stretched over five large projects at OR Tambo International Airport between 2006 and 2009 namely:

- Hotel Taxiway Rehabilitation: ±30 000 tons of new asphalt containing 10% old recycled asphalt were placed in 2006;
- Yankee Taxiway and runway 03R/21L Rehabilitation: ±100 000 tons of new asphalt containing ±15% old recycled asphalt were placed in 2007 ±15 000 tons of long life shoulder asphalt layers placed;
- Alpha/Bravo Taxiway Rehabilitation: ±50 000 ton of new asphalt containing 15% old recycled asphalt were placed in 2008 ±10 000 tons of long life asphalt placed on shoulder areas;
- New Construction of Airside Ring Road North and Landside Permanent Haul Road: ±30 000 tons of recycled asphalt was re-used as bonded surfacing/base layer (100% re-used) on sections of the new Airside Ring Road North and the permanent haul road constructed for the Midfield Apron construction area. This resulted in 90% reduction in new aggregate and 70% lower cost to ACSA.

In addition, further strategic and innovative technologies, based on the success of these pioneer projects, were formulated. These will enable OR Tambo International Airport to meet the following sustainability/environmentally beneficial targets on their next 10 year's intended projects:

- 33% reduction in aggregates for asphalt layers (±500 000 ton reduction);
- 22% reduction in bitumen binder for asphalt layers (±16 500 tons reduction);
- 22% lower fuel and CO_2 emissions or a reduction of ±8 000 trees equivalent (to obtain carbon neutrality).

7 FUTURE IMPLEMENTATION STRATEGY AND PRODUCT STUDIES

This initiative is planned to be replicated at all nine ACSA Managed Airports (including Cape Town International and Durban International Airport) and the following strategy are foreseen:

- The feasibility of each alternative product/design to be evaluated on a project to project basis.
- All asphalt to be recycled with a minimum of 30% to be added back in new asphalt layers;
- All base layer asphalts to be either High Modules Asphalt or to make use of other long-life asphalt design methodologies in order to reduce overall material consumption over the long life cycle cost comparison period (first trial section implemented in 2009);
- Foam Based Warm-Mix-Asphalt to be used on all non-loading/non-critical areas (shoulders, low performance on outer edges of runways and taxiways) and trials on loading areas. Application on loading areas to follow after trial verification.
- High Modulus Asphalt as Apron Base layers: The replacing of more expensive concrete base layers on aprons with innovative high stiffness asphalt base layers will reduce carbon-dioxide output and therefore significantly reduce environmental impact due to the lower carbon footprint (and lower costs) of asphalt vs concrete.

8 SUMMARY AND CONCLUSIONS

Airports Company of South Africa has explored various options to align construction processes and designs with lower environmental impacting and more sustainable resource usage.

Innovative implementations of sustainable resource utilisation solutions stretched over four major projects and consisted of the research, development, testing, verification and implementation of various design methodologies (perpetual or long life pavement design) and innovative alternative products (Recycled Asphalt Hot-Mixes; Recycled Asphalt In-situ Surfacing layers, High Modules Asphalt as substitute for concrete layers and or thick asphalt base layers, Foamed-Based Warm-Mix Asphalt, Long Life Carbon Black Modified shoulder mixes).

The projects summarised in Table 6 below were successfully implemented over the last four years:

Table 6: Projects where Sustainability Enhancing Technology were Implemented

Project	Innovative Design/product Description	Sustainability Benefit Obtained	Cost Saving/ Premium (Note: R10 ≈ €1)
Hotel Taxiway Rehab (2006)	Use of recycled asphalt in new plant Hot Mix Asphalt (HMA)	Saving of 10% (3 000 tons) new aggregate, 5% new bitumen binder (75 tons)	R1 million savings
Yankee Taxiway (and RW03R/21L) (2007)	Use of recycled asphalt in new plant HMA and long life shoulder designs	Saving of 15% (15 000 tons) new aggregate, 5% new bitumen binder (250 tons)	R3 million savings
Alpha, Bravo and India Taxiway Rehab (2007/8)	Use of recycled asphalt in new plant Hot Mix Asphalt and use of long life shoulder (carbon black) mixes in untrafficked areas	Saving of 15% (7 500 tons) new aggregate, 5% bitumen binder (250 tons) for Recycled AC; 5 000 tons aggregate, 300 ton bitumen binder and 50 ton fuel (150 ton CO_2) saving for long life shoulder component	R2 million savings on Recycled Asphalt; R3 million on long life mixes
Airside Ring Road North	Use of recycled asphalt as new surfacing mix for Ring Road and Haul Road	Saving of 100% in asphalt surfacing (3 500 tons aggregate; 150 ton bitumen binder; 30 ton fuel or 90 ton CO_2 emissions)	R3 million savings

Current design and new innovative methodologies, developed over the last year, ear-marked for implementation in the next 10 year projects, hold the following additional benefits:

Table 7: Current and Future Sustainability Enhancing Implementation at ORTIA

Standard Product Base Values for 10 Year Projects	**Combined Advantages of Selected Innovative products Technologies#**	**% of Standard Product Base Values**
• Rehabilitation cost ≈ R500 million	R101 million lower cost	20% lower
• New Project Costs ≈ R1 000 million	R222 million lower cost	22% lower
• Aggregate usage ≈ R1.5 million tons	0.5 million ton reduction	33% lower
• Binder usage ≈ 5 000 tons	16 500 ton reduction	22% lower
• Fuel usage ≈ 12 000 tons	2 600 ton reduction	22% lower
• CO_2 usage (or Tree Equivalents for CO_2 Neutralising) ≈ 36 000 tons (or 36 000 trees)	8 000 ton reduction (8 000 trees)	22% lower

#Innovative products/technology includes Recycled Asphalt, High Modulus Asphalt, Foamed-based Warm Mix Asphalt on shoulders, Recycled Asphalt (100%) wearing courses and long life pavement technology).

Based on this study, ACSA has incorporated these strategies to utilise the Phase 2 and Phase 1 design methodologies and products on a project-to-project merit base as of 2010.

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