ENVIRONMENTALLY SUSTAINABLE USE OF RECYCLED ASPHALT AT OR TAMBO INTERNATIONAL AIRPORT

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ABSTRACT

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A new technology breakthrough was achieved during a recent Airports Company South Africa (ACSA) project where warmed asphalt was produced with Recycled Asphalt (RA) content of 55% using a foamed bitumen process. This was the highest amount of recycled asphalt ever produced in an asphalt plant in South Africa.

The project involved the rehabilitation of the cargo area at OR Tambo International Airport (ORTIA). The use of this environmentally sustainable technology resulted in massive cost savings to the client and allowed the contractor to effectively work in a highly congested area using conventional asphalt paving and milling equipment.

Various environmentally sustainable asphalt products have been used on ACSA airports (including foamed treated asphalt with 35% RA, haul road with only RA with a surface emulsion treatment, cold mixed RA mixes with emulsion, etc). This new approach was based on the experience gained on previous ACSA projects where RA has effectively being used. The paper will also discuss the use of RA of the full spectrum of applications from Hot mixed asphalt with small amount of RA, asphalt with high contents of RA, warm mixes with RA, cold mixes with RA (using foamed bitumen or emulsion) and the use of RA with a surface treatment.

1. INTRODUCTION

This paper discusses the environmental impacts, cost implications and energy efficiency achieved in increased quantities of Recycled asphalt (using foamed bitumen or emulsion) surfacing. These specifications have been verified through various successful trial sections and completed projects over the past 10 years at ACSA airports, particularly OR Tambo International Airport.

Continued research in addition to the success of the various proven performance and field trial sections, new technologies, innovations and both internationally and locally based references are continuously being developed in conjunction with ACSA. Ultimately aiming towards environmental sustainability and consistent cost efficiency.

Case studies of cost effective and sustainable asphalt products in various stages of development are presented in the paper. These studies portray a steady progression in the use of RA and the success of these projects. The more recent rehabilitation of the Cargo area, with its high traffic volumes, limited work hours loading and problematic base is now an added study and investigation platform in this continued development of high RA content asphalt mixes.

2. BACKGROUND

The use of RA in the pavement projects at OR Tambo International Airport is continuously researched and intensively investigated through advanced methods and technology application. This innovative application of using very high RA contents (in excess of 50%) makes use of the combination of two technologies i.e. foamed bitumen and the use of recycled asphalt.

2.1 Definition of foamed asphalt

Foamed bitumen is a combination of air, hot bitumen and small amounts of cold water. Spraying the hot bitumen with cold water creates high volume bitumen foam. This foam has the advantage of coating the aggregate better than our common liquid bitumen. While the foam state may last for a few minutes, the properties still remain similar to that of original bitumen.

Foamed bitumen can be used to produce both warm and cold asphalt using various amounts of RA.

Alternatives to foamed bitumen are generally more expensive and include modified binders for warm mixes (e.g. Sasobit) and bitumen emulsion for cold mixes.

2.2 Mixing Methods

Various methods used to mix aggregate, RA and binders using hot, warm or cold applications, include:

- Mixing by traditional equipment (loaders, graders) i.e. mostly cold mixes and high RA blends using emulsion
- In-situ recycling equipment i.e. mainly cold mixes using foamed asphalt or emulsion
- Foamed bitumen mixing plants i.e. normally cold mixes with high RA contents
- Asphalt plants with foamed bitumen system i.e. only option suited for warm asphalt with high RA contents.

2.3 Background on the use of Recycled Asphalt at Airports Company South Africa

ACSA as in the case of many road authorities, primarily use virgin construction materials in all their reconstruction, rehabilitation and new construction of pavements. In the past, many road authorities had entrenched design methods and were reluctant to allow the use of recycled asphalt (RA), especially in asphalt designs, thereby limiting the opportunity for innovation in this field. Waste materials (i.e. mill asphalt material) were mostly spoiled or used as unbound selected materials during road and airport pavement rehabilitation works.

Since 2005, ACSA has encouraged consultants to be more innovative in their pursuit of more cost effective design solutions. It has also embarked on a drive to encourage innovation that leads to more environmentally friendly and sustainable solutions. Using higher quantities of RA in construction and/or rehabilitation being on the fore front of these solutions.

Future development plans at ORTIA, which allow for a significant amount of new airfield infrastructure (up to 2 million tons of new asphalt and concrete pavement on taxiways, aprons and runways over the next 10 years), are therefore an ideal opportunity to implement the successes of the past years and to continue the research for more cost effective and sustainability enhancing materials and designs.

3. ACSA CASE STUDIES WITH MIXES USING RA

Various combination of RA and binder type (standard hot binders, foamed bitumen and emulsion) have been used at ACSA as summarized in Table 1 and discuss in this section.

Table 1: Various Recycled Asphalt related projects at OR Tambo International Airport

		Hot asphalt	Warm asphalt	Cold mixes
Percentage of RA	0	Standard asphalt		
	10			
	20	Taxiway mixes (10-25%)		
	30			
	40		Kilo shoulders (35%)	
	50			
	60		**Cargo Area (55%) - new**	
	70			
	80			November and Tango fillets
	90			
	100			Haul and patrol roads

3.1 Project where RA between 10 and 25% was used

Innovative materials design and the effective use of RA has been used with success in the following heavy-duty code F taxiway projects:

- Echo taxiway (2005) – rehabilitation and widening
- Hotel taxiway (2006) – rehabilitation and widening
- Yankee taxiway (2007) – rehabilitation and widening
- Alpha, Brava, India, Charlie taxiways (2008) – rehabilitation and widening
- Papa taxiway and Extension of Charlie Taxiway (2009) – new construction
- Kilo, Lima & Bravo intersection (2011) - rehabilitation

3.2 Projects with up to 35% RA using Foamed bitumen

- Shoulder rehabilitation on Kilo and Lima Taxiways (2011) – Objective of the rehabilitation was to improve durability in the most cost effective manner. It was concluded that this would be achieved with an overlay of the existing outer 7m of shoulder (2 x 3.5m wide) with foamed warm mix asphalt surfacing tapering from 50mm to 30mm thick. With minimal expected traffic on area, rehabilitation action is found to be appropriate and remains in durable condition.
- Whiskey Apron rehabilitation (2011) – Existing failed pavement was found to be caused by poor base conditions resulting in severe cracks penetrating through the surface. While total reconstruction was required, milling and heavy reconstruction was not possible due to budget limits and urgent deadline by the client. Geotextile was used to crack seal severe cracks then Overlay with 50mm BTB infill and 40mm Wearing Course surfacing using foamed bitumen in both case. The use of foamed bitumen enabled the contractor to achieve high densities with limited static roller compaction. Due to the poor base condition standard asphalt compaction was not possible

3.3 Projects with up to 80 % RA using Emulsion

Extension of November and Tango Taxiway shoulders (2012) – Design required the construction of new shoulder and pavement structures using 280 mm bitumen emulsion stabilised base, and an 80mm AC asphalt surfacing. The objective was to make use of the recycled asphalt already available on site, limit risk of Foreign Object Damage (FOD) when working close to runway and ensure minimal disruption of taxiway use when open to traffic.

A more practical approach was taken in the form of fillet construction (± 1200 m^2) which was efficient in terms of small construction in restricted areas and limited working hours. RA from the stockpile and emulsion were mixed on site by a loader to be used as the base. Mix was found to lack in fines when compaction results were not to specifications. Through various failed attempts, a successful mix was achieved in adding 20% crusher dust.

Projects with 100% RA

- Haul roads - A heavy-duty haul road was required to transport up to 1.1 million tons of new construction materials to the airfield. Due to pressure from the local community, the residential roads leading to the airfield accesses could not be used. A new dust free road, 1,5km long, therefore had to be constructed to carry the construction vehicle traffic.

  After a number of trials sections (that included various methods of stabilization of the recycled asphalt), the following method was effectively implemented.

  First a 150mm gravel base layer was constructed. This was covered by a 150mm un-compacted RA layer and was graded to level. The RA layer was sprayed with an emulsion at a rate of 2l/m^2 and compacted with steel wheel rollers and then immediately subjected to heavy-duty construction traffic.

  Apart from small isolated areas where poor subgrades existed, the performance on the haul road over a one-year period was excellent and limited maintenance was required compared to a standard gravel haul road.

- Patrol Roads - The RA has also been used as a temporary solution for the patrol roads. They were given a limited service of 2 years however 80% of these roads are still found in satisfactory condition after a 4year period.

4. ENVIRONMENTAL IMPACT AND SUSTAINABILITY

The cost and environmental benefits of various pavement design options, and particularly with new technologies, must be calculated very carefully to ensure that the correct decision regarding their application is made.

The environmental impact of a particular solution can reasonably accurately be estimated during a design process using published embodied energy and emission values of various construction materials.

These published embodied energy and emission values are indicated in Table 2 below:

Table 2: Typical embodied energy and emission values of construction materials

	Embodied energy	**Emissions**
	MJ/kg	**kg$C0_2$/kg**
Aggregate[1]	0.15	0.008
Bitumen[2]	44.7	1.5
Cement[2]	7.9	0.8
Fuel[2]	43	2.7
Asphalt[1]	2.41 (0.8[#])	0.14
Concrete[1]	1.24	0.127
Steel[1]	19.7	1.72

G Hammond et Al (2006)

Note 1: To be used in pavement design estimates/
when asphalt is used as waste product i.e. RA incorporated in the mix

The impact of various pavement design options can then be calculated. Using a similar approach as in the case pavement design options (costs/m^2) calculations, the total embodied energy and emission can be determined by taking the amount of material used times the units energy and emission values. Illustrated examples are shown in Table 3 below.

Table 3: Embodied energy and emission per m^2 of various broad pavement design options.

	Thickness of Layer	Total energy/m²	Emissions/m²
		MJ/m²	$kgCO_2/m^2$
Asphalt	120mm	694.1	40.3
Asphalt with 20% RA	120mm	555.3	35.0
Warm mixes	120mm	680.2	39.5
Warm mixes with 55% RA	120mm	487.5	29.7

Environmental benefits of new products, e.g. “warm mix asphalt”, need to be carefully calculated and compared to existing product by impartial/objective industry bodies. Promoters or manufacturers might not give the full picture when promoting new products. Although warm mix asphalt does have its place and certainly does offer advantages, it is important to evaluate the entire manufacture, transport, construction and life cycle of a new product when calculating costs and environmental benefits. For example, many promoters of warm mix asphalt additive emphasized the energy savings that can be obtained during manufacture, i.e. a 10% saving in fuel due to the lower temperatures at which warm mix asphalt can be constructed. However this translates to only a 2% saving in the total embodied energy of asphalt (taking into the energy values of bitumen, aggregate and transport) without taking into consideration the environmental impact of the manufacturing and transport of the additives.

5. CASE STUDY: OR TAMBO INTERNATIONAL AIRPORT CARGO AREA

The Landside Cargo Area used non South African Airways (SAA) operators (both side of the building) is made up of two sections i.e. outside area where the trucks deliver goods to the operators and the inside (also landside) where goods are placed on airside equipment to be moved to the aircraft via the North Gate 2. The outside area is severely failing with extensive base failures mainly as a result of the heavy truck loads. A factor considered is the level of the surface as the trucks needs to offload at the building that limits overlay options. The traffic loading on the inside area is significantly lower and failures are mainly due to weak pavement structures and moisture damage. In both areas, extensive patching needs to be done on an on-going basis to ensure serviceability. The layout of applicable sections is shown in Figure 1 below.

5.1 Design methodology

The consultant was commissioned at the end of September 2012 to conduct a number of rehabilitation designs for a number of landside areas, including this cargo area. Due to the fast track nature of the design stage (6 weeks allowed) and upon appointment, the appointed laboratories commenced with test pits the same day with non-destruction pavement testing commencing the next day.

The standard rehabilitation design approach was followed but not necessarily in the correct order, with same activities completed earlier (test pits) and others later (like traffic counts).

5.1.1 *Conditions*

The outside Cargo area was severely failing with extensive base failures mainly as a result of what appeared to be very heavy truck loads as the areas was congested with long waiting times for the trucks to enter the area. Visual assessment indicated that the failure was similar to the traditional Macadam base failure i.e. potholing with loose large stones. It was believed that these areas were constructed in the early 1980s with limited rehabilitation work since.

A factor considered was the level of the surface as the trucks need to offload at the building which limited overlay options.

Failures of inside Cargo were found to be mainly due to weak pavement structures and moisture damage. In both areas (Inside and outside), extensive patching needed to be done on an on-going basis to ensure serviceability.

5.1.2 Material investigations

The results from the test pit investigation are briefly summarized in Tables 4 and 5 below.

Prior to the traffic analysis, the test pits at the outside Cargo Area revealed a surprise finding. The crushed stone base was relatively thin (110mm) and with a thin asphalt layer (30mm). Below these layers a G6 subbase (mainly Ferricrete-like material) was found. Visually looking at the large amount of trucks and the age of the section, it could not be explained why such a thin flexible structure was able to cope under the traffic conditions for more than 20 years.

The test pits at the inside Cargo area, showed more expected results due to low level of traffic. The asphalt surface comprised of very thin layers made up of a seal and slurry combination. This provides limited protection for a lower quality base that will be highly sensitive to moisture ingress. These layers are underlain by a poor quality subbase that has a clay-like structure. The base layers has been damaged in many places due to water ingress and the area is patched extensively

Table 4: Cargo area – outside of building

Layer	**Type**	**Condition**
Surfacing	30 mm asphalt (AC)	Severely cracked, brittle and signs of delaminating
Base	110 mm Crushed stone Base	Old, brittle and overstressed, wet at lower levels, permeable
Subbase	260 mm G6 quality gravel	Intact, but wet
Selected layers	230 mm of G7 quality gravel	Intact, but moist
Foundation	In-situ gravel	Intact

.Table 5: Cargo area – inside area

Layer	**Type**	**Condition**
Surfacing	20 mm seal/slurry layers	Severely cracked, brittle and signs of delaminating
Base	165 mm G5 quality gravel	Old and overstressed, wet at lower levels, permeable
Subbase	455 mm G8 quality gravel/clay	Intact, but very wet
Foundation	In-situ gravel	Intact

Falling Weight Deflectometer (FWD) test results

FWD testing was conducted that generally confirmed the low level of support from the subgrade and subbase layers. The outside Cargo area had one entrance and exit gate on the south end, and the traffic loading decreases from the south end toward the north end of the cargo terminal. Table 6 and 7 show the deflection measurement data.

Table 6: Cargo Area Deflection Bowl Parameters (Positive)

STATION	LOAD	LOAD		DEFLECTION BOWL PARAMETERS		
	kPa	kN	Ymax	BLI	MLI	LLI
0.000	565	40.0	597	273	251	36
0.100	565	40.0	612	321	192	50
0.200	565	40.0	546	309	166	38
0.300	565	40.0	531	317	141	41
0.400	565	40.0	536	310	165	62
0.500	565	40.0	457	266	130	25
0.600	565	40.0	295	163	53	23

Table 7: Cargo Area Deflection Bowl Parameters (Negative)

STATION	LOAD	LOAD		DEFLECTION BOWL PARAMETERS		
	kPa	kN	Ymax	BLI	MLI	LLI
0.600	565	40.0	347	182	71	29
0.550	565	40.0	185	106	42	12
0.450	565	40.0	483	279	151	26
0.350	565	40.0	550	298	169	40
0.250	565	40.0	493	268	155	38
0.150	565	40.0	410	242	110	25
0.050	565	40.0	721	401	211	54

Note that the area closer to the gate (Stations 0.100, 0.50 & 0.150) was more damaged than the section away from the gate toward the Northern side.

5.1.3 *Traffic*

Cargo statistic indicated a current total cargo value of 350 000 tons (of which approximately 120 000 tons is done by SAA cargo). Imports (200 000 tons) are considering higher than exports (150 000 tons). To determine the critical loading at the cargo areas the import tonnages (outgoing lanes) has been considered for the design loading after considering the influence of the SAA cargo figures.

Daily import volumes at these areas were estimated at 410 tons per day equal to only around 45 legally fully loaded trucks (2 axles). Considering the amount of daily movements (approximately 200 outgoing) it is evident that the type of cargo is generally light air type of cargo resulting a lower traffic loading in term of E80s with a realistic annual expected E80s of less than 5000. The "low" level of truck traffic then explained why the thin flexible pavement structure has performed for more than 20 years.

The traffic loading on the inside areas is very light and the main consideration for the pavement design was to remove failed base layers to the same level and provide a very dense asphalt layer.

The growth rate of traffic over the next 10 years was found to be incredibly small due to limited capacity in terms of peak hour movements and parking areas available.

Design approach

Due to the failed state of the pavement, the most economical options were to reconstruct the pavement layers with a light granular structure and a thin asphalt surface, but due to the traffic conditions it was not feasible. Thin asphalt inlays were not economical and the pavement design process indicated a very thick layer was need due to the poor subbase/subgrade support.

The Capacity of the new pavement was calculated to handle traffic loading of as high as 500 000E80s over its full lifespan. This being considerably more than the actual expected traffic loading over the next 12 to 15 year design life (estimated at approximately 75 000E80s) because of the low growth rate of traffic.

The option of placing a very cost effective high RA blend (up to 80 RA) using a cold mixing process was initially considered. However due to quality control concerns, limited work hours and strict client programme deadlines, a warm mix was ultimately developed using 55% RA in combination with foamed bitumen.

At the outside cargo area, Styrene-Butadiene-Styrene (SBS) modified binder was used for the 30mm asphalt surfacing (with voids in the mix target of 4, 5%) to ensure durability. At the inside area, a low (3.5%) Voids in Mix (VIM) unmodified wearing course was used to ensure the best protection against water under light traffic conditions.

5.1.4 *Summary of the Warm Asphalt mix with 55% RA*

The mix design properties of the warm asphalt are briefly summarized in Table 6 below. It is based on a standard Bitumen Treated Base (BTB) grading. It was planned to have a few trial sections to optimize the properties of the mix (i.e. desired VIMS and workability), but all targets had been achieved with the first trial section (as selected bitumen content), and full production commenced immediately.

Table 6: Properties of production mix (using 55% RA)

	Mix properties
Sieve	
37,0	100
26.5	100
19,0	95
13,2	83
9,5	71
6,7	59
4,75	48
2,36	32
1,18	23
0,600	18
0,300	14
0,150	10
0,075	6,4

Measured bit (%)	4,3
Added bit (%)	**2,0**
VIMS (%)	5,0
VMA (%)	15,6
Filler/Bitumen ratio	1.5

5.2 Production

The production at the plant using this process is very specialized and particular attention was given to the screening of RA to ensure accurate grading and also the superheating of virgin aggregate (45% of blend) to ensure proper mixes with the RA at the correct mixing temperature.

5.3 Paving and compaction

The paving process was similar to that used for standard premix and no noticeable difference was seen, except for the lower paving temperature.

The rolling method is very important and breakdown commenced with the Kinematic rollers followed by mainly static steel wheel rolling. There was no need for vibratory compaction, as static rolling was preferred due to the poor subbase/subgrade conditions.
The project specification did not allow for paving warm joints, also emphasizing mill and fill using alternative lanes to avoid risk of paving cold joints resulting in failure. However during the first production day the contractor had to remove a wide section and pave different lanes without cutting a joint (e.g. warm joints). To motivate acceptance of the mix, densities were done on the joint and no noticeable difference was found between the joint densities and those in the center of the mat. This was a surprise finding and an added benefit of this type of mix, as good densities on warm joints of normal asphalt is not possible.

6. CONCLUSION

Successful implementation of RA containing asphalt mixes carried out at ACSA airports has resulted in saving thousands of tons of new aggregate and reduced use of new bitumen. This saving and lower impact on the environment was gained without compromising the quality of the final asphalt product or the expected pavement design life. A combination of the successfully completed projects and added research, investigations and new technology undertaken in conjunction with ACSA, more information has been made available for future projects.

In addition to the potential environmental benefits (reduced CO_2 and energy efficient), the use of Recycled asphalt also has the added benefit of handling heavily trafficked areas requiring fast rehabilitation in a short space of time. With correct quality control measures achieved at the plant, the product has the potential to perform on the same standard and in some instances even better that conventional mixes.

More confidence comes with the success rate of these successfully completed projects, allowing industry to step closer to creating basic standardized methods compatible with airport and all pavement construction and/or rehabilitation. Going a step further is using both international and local research to compile innovative ways more suited to local conditions.

The ultimate and most primary objective of such innovations and intensive research is to accomplish the most appropriate cost effective and environmentally sustainable solutions in the most energy efficient manner possible.

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