

# A CONTRACTOR'S PERSPECTIVE ON BITUMEN RUBBER ASPHALT MANUFACTURE AND PLACEMENT

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## ABSTRACT

Bitumen Rubber Asphalt (BRA) has been used in South Africa since the early 1980's with varying degrees of success. There are projects which have performed exceptionally well and have exceeded their design life, with one specific example of a BRA surfacing which is still performing well after 25 years. There are also BRA projects that have had their fair share of problems with some recent projects having up to 20% of their asphalt placed failing prematurely. This paper will cover the BRA experiences of contractors over the past 10 years in South Africa, highlighting challenges experienced as well as measures taken to limit risks of premature failure.

## INTRODUCTION

The advantages of using BRA are well documented throughout the world as well as in South Africa, with the increased fatigue resistance and reduction in ageing of the binder being the major drivers for its use. The increased focus on the influence of the construction industry on the environment and ways of reduction and re-use of waste material has also been influential in motivating the use of BRA. The manufacturing and placing of BRA does however require special measures to be put in place to ensure the envisaged advantages are materialised.

Early defects that have appeared in BRA need to be taken cognisance of when designing and specifying BRA on future projects. The objective of this paper is to give snapshot view of BRA projects that have been completed in the past 10 years in South Africa, highlighting challenges that were faced as well experience gained from these projects.

The use of BRA has been very cyclic over the past 10 years with the majority of projects being on our National Road Network. The mostly commonly used BRA mix type was Bitumen Rubber Asphalt Semi Open Graded (BRASO) followed by Bitumen Rubber Asphalt Continuously Graded Wearing Course (BRACC). To the author's knowledge no continuously graded fine mixes were manufactured over this period. Potgieter et al (1998) reported that a large number of BRA projects in the Western and Eastern Cape provinces were done in the 1980s and 1990s but there were limited BRA projects constructed in these provinces since then. The majority of BRA projects were in the province of Gauteng with 11 Projects where BRASO was used as well as three projects where BRACC was used. This excludes the Gauteng Freeway Improvement Projects (GFIP) where BRASO was specified on 8 projects totalling in the region of 500 000t. Due to the sensitivity

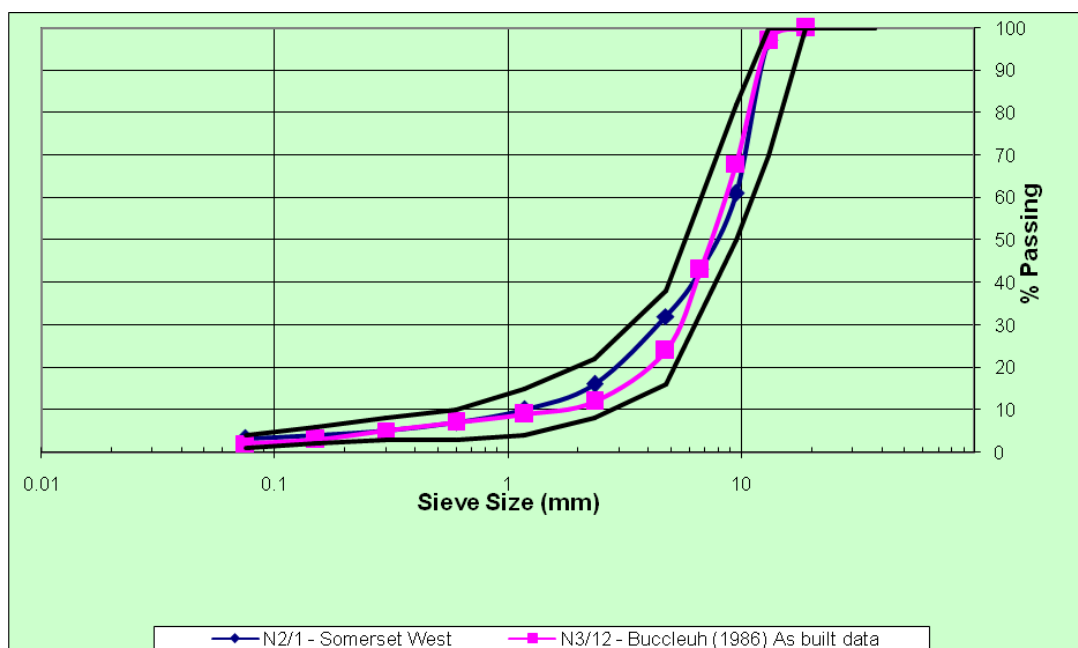
around the premature failures on some of these projects at the time of writing this paper, they are not discussed in depth.

This paper will cover the BRA experiences of contractors over the past 10 years in South Africa, highlighting challenges experienced as well as measures taken to limit risks of premature failure.

## BRASO

### History of BRASO

The first BRASO was done in 1984 and the initial mix was placed as a trial on a severely distressed pavement as a holding action on the old N3 – Potgieter et al (1998). Due to the success of the BRASO it was then later specified on two major SANRAL projects which were done in 1986 with the one project in Gauteng on the N3/12 in Johannesburg on a very busy interchange. This asphalt performed very well and was partially milled and then overlaid in 2003 – again with a BRASO. The other project was in the Western Cape on the N2 -1 – Swartklip to Somerset West where it was used as an overlay of a distressed concrete pavement. This asphalt surfacing is still intact after 25 years of service. This is after early indications were that this layer was failing due to stripping of the binder from the aggregate in the middle third of the asphalt layer. The stripping was attributed to high viscosities of the bitumen rubber binder (above 50 dPas) at the time of mixing – Lourens et al (1989). The asphalt was however left in place and no deformation or failures were noticed. It was due to the success of these two BRA projects that BRASO was again specified on various projects in Gauteng and later in the Western Cape. Both the BRASO mixes had binder contents in the region of 8.0% and average Marshall void contents were 6.6% for the Gauteng project and 6.1% for the Western Cape project.



**FIGURE 1** Gradings of early BRASO mixes

## **BRASO 1998 - 2005**

The BRASO mixes placed during this time period performed very well with only one project that was done in 2002 having extensive premature failures within 18 months from completion of the project. The first signs of the failure were the occurrence of bleeding and fattening up of the layer – especially in the slow lanes. This was followed by rutting and shoving of the asphalt and investigations revealed that stripping started to occur in the BRASO, as well as in the top of the old asphalt surfacing that was overlaid. A number of investigations were carried out on behalf of the different interested parties and no real consensus could be reached to the root cause of the failures (a field for further research), but as in most failures it was a combination of a number of factors such as:

- Moisture that was trapped in the BRASO layer after summer rains;
- Higher than normal early summer temperatures;
- Early heavy traffic resulting in post construction compaction;
- High VFB of BRASO (Too high binder content);
- Asphalt paved in late winter and early spring more prone to failure than asphalt paved in late summer;
- Aggregate grading of asphalt slightly finer on failed section compared to sound sections;
- Average time from completing asphalt mixing to paving asphalt 1.5 hour longer on failed sections (average maximum age of the asphalt is however still below recommended maximum age of 6 hours);

The age and over digestion of the binder was also postulated as a probable cause but this was proved to be unfounded. It is also important to note that the BRASO supplied to this project complied with the project specification and no major changes to specifications were made on later BRASO projects to prevent recurrence of such failures.

Although the other BRASO projects constructed in this period performed very well, some limited defects did occur and should be studied in order to prevent these defects from becoming major failures on future projects. The defects were:

- Rutting and deformation at heavily trafficked climbing lanes and intersections;
- Localised bleeding and fattiness on the surface – associated with spillages (oils or diesel) or isolated high binder contents as well as accumulation of binder-rich fines on construction equipment deposited on the surface;
- “Pumping” of fines onto the surface not related to stripping – excessive fines in BRASO;
- Manifestation of small “bumps” on the surface in areas with low traffic volumes such as shoulders and fast lanes – especially on gradients such as super elevations and inclines in summer rainfall areas (see photos 1 and 2);
- Stripping of layer below BRASO surfacing due to trapped moisture – BRASO is permeable at areas of segregation and lower compaction;
- Yellow and grey staining on the surface of un-trafficked areas - associated with crushed stone base course with high levels of soluble salts, that are transported to

the surface by water vapour after summer rain spells – typical of crushed Reef Quartzite in Gauteng

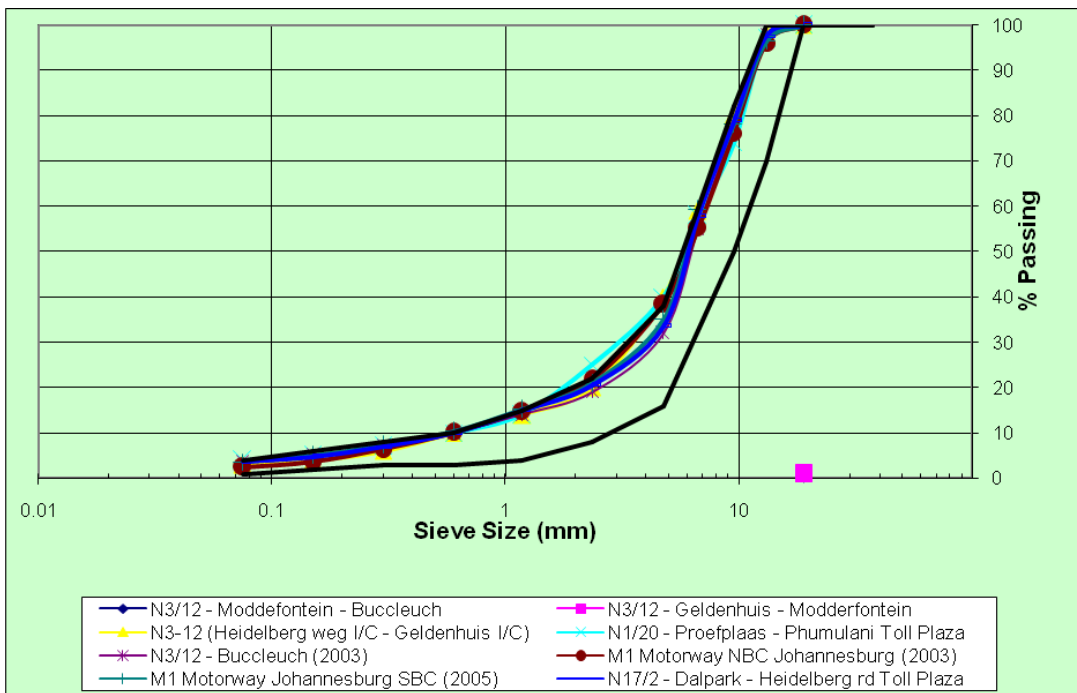


**PHOTOS 1 and 2: Manifestation of small “bumps” on the surface in areas with low traffic volumes**

The BRASO that was constructed in this time period had very similar grading curves as well as binder contents as can be seen in Figure 2, with binder contents ranging from 7.3% – 7.5%. This is in contrast with the first two major BRASO projects where their gradings were coarser and the binder content was in the region of 8.0%. The grading curves are consistently finer than the original two BRASO projects and are close to the upper envelope of the COLTO grading specification. The Marshall void contents were in general also lower and ranged from 4.1% to 5.2% with one project having an average void content of 6.6%, as shown in Table 1.

**TABLE 1 Volumetric Properties of BRASO mixes placed from 1998 – 2005**

Project	N3/12 - Moddefontein - Buccleuch	N3/12 - Geldenhuis - Modderfontein	N3-12 (Heidelberg weg I/C - Geldenhuis I/C)	N1/20 - Proefplaas - Phumulani Toll Plaza	N3/12 - Buccleuch (2003)	M1 Motorway NBC Johannesburg (2003)	M1 Motorway Johannesburg SBC (2005)	N17/2 - Dalpark - Heidelberg rd Toll Plaza
Number	1	2	3	4	5	6	7	8
Year	1998	1999	2001	2002	2003	2003	2005	2005
Binder content (%)	7.5	7.5	7.5	7.4	7.4	7.4	7.3	7.5
Voids (%)		5.0	5.2	4.1	6.6	4.8	4.8	
VMA (%)		20.5	21.2	19.2	22.9	21.2	20.8	
VFB (%)		78.3	75.4	78.6	71.2	77.6	76.8	
Film Thickness (micron)		20.5	21.9	19.6	26.9	22.6	21.8	
Aggregate type	Quartzite	Quartzitic Hornfels	Quartzite	Quartzitic Hornfels	Quartzite	Quartzite	Quartzite	Quartzite



**FIGURE 2 BRASO Gradings 1998 – 2005**

### **BRASO 2006 – 2010**

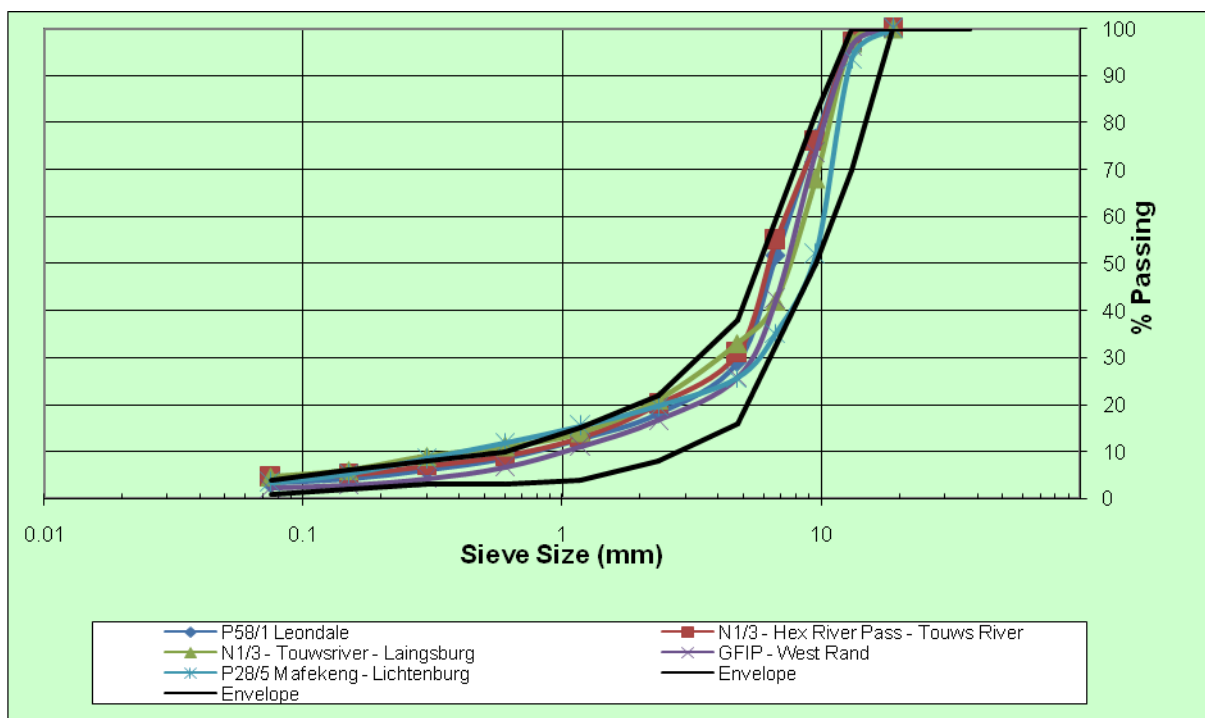
BRASO mixes placed during this time period had varying levels of success and the BRASO constructed in Gauteng in 2006 is performing well with only isolated areas - where the asphalt deformed at highly trafficked intersections – being repaired in the maintenance period. The mixes placed in the Western Cape however started showing signs of premature cracking in the wheel tracks. On the one project the cracking was attributed to frost damage during a very cold spell after winter rain, (almost an unheard of rapid freeze-thaw situation) and the fines that were pumped to the surface (Photo 3) were believed to have originated from the BRASO. At this project localized bleeding also appeared soon after construction but was attributed to construction related issues. On the other Western Cape project cracking appeared on areas where no Stress Absorbing Membrane Interlayer (SAMI) was applied before construction of the BRASO overlay. In the first few years after construction the cracks appeared in winter after rain, but appeared to “mend” itself in summer.



**PHOTO 3 Cracking and pumping of fines through BRASO surfacing in the Western Cape**

The BRASO mixes placed on the GFIP in 2009 showed extensive signs of bleeding early in the summer of 2010 which led to a number of investigations to find the root cause of the failures. At the time of writing this paper some of the investigations are still under way and only measures taken to limit risk of further failures can be discussed. With the very high asphalt paving volumes required before the 2010 Soccer World Cup, it necessitated quick decision making to limit risks of premature failing BRASO mixes, which could delay the GFIP projects. A BRASO workshop that involved all the interested parties was held in January 2010 where information was shared on the BRASO mixes paved to date. Subsequent to the meeting the GFIP projects took measures to mitigate further failures. The measures taken were as follows:

- Reduction in binder content (targeting higher Marshall voids)
- Reduction in mixing and paving temperatures
- Limiting of the asphalt age before paving
- Verify binder content of BRASO before paving
- Reduce compactive effort to ensure BRASO is not compacted to above 96% of MTRD
- Keep traffic off newly constructed BRASO as long as possible



**FIGURE 3 BRASO gradings 2005 – 2010**

Although the gradings of the first two projects constructed in this time period were similar to all the BRASO mixes paved in the previous time period the rest of the mixes were coarser and closer to the middle of the envelope. The BRASO of the GFIP projects on the West Rand was purposely made coarser in order to simulate the first BRASO that was done in the Western Cape as it was also paved on a concrete pavement. The binder contents of the BRASO mixes ranged from 7.1% to 7.8% but last mentioned binder

content was reduced to 7.5% after extensive bleeding started to occur on the project. Table 2 shows the characteristics of these mixes.

**TABLE 2 Volumetric Properties of BRASO mixes placed from 2006 - 2010**

Project	P58/1 Leondale	N1/3 - Hex River Pass - Touws River	N1/3 - Touwsriver - Laingsburg	GFIP - West Rand	P28/5 Mafekeng - Lichtenburg
<b>Number</b>	9	10	11	12	13
<b>Year</b>	2006	2006	2006	2009	2010
<b>Binder Content (%)</b>	7.1	7.48	7.6	7.8	7.5
<b>Voids (%)</b>	5.8	5.44	5.1	5.5	3.8
<b>VMA (%)</b>	21.7	21.1	20.8	22.1	18.7
<b>VFB (%)</b>	72.8	74.3	75.4	74.9	79.6
<b>Film Thickness (micron)</b>	24.5	21.39	21.7	33.6	22.2
<b>Aggregate type</b>	Quartzite	Eucrite	Tillite	Quartzite	Quartzite

#### **Discussion of limited defects of BRASO**

It should be noted that a number of the defects that occurred – although limited – can be attributed to permeability of the BRASO and this should be taken cognisance of when designing or specifying a BRASO. Permeability of the BRASO cannot be “cured” by adding more binder as this will result in reduced deformation resistance of a mix that is already susceptible to deformation at severely trafficked climbing lanes and intersections. Air permeability values of BRASO mixes tested over the past two years in general conformed to the specified value for conventional asphalt mixes of  $< 1.0 \times 10^{-8}$  with 4 values – of 14 samples tested - being slightly above ranging from  $1.13$  to  $3.55 \times 10^{-8}$ . This is, however, no guarantee that these BRASO mixes will prevent water ingress which will result in water entrapment thus causing further damage to underlying layers.

The manifestation of the small “bumps” in the BRASO layer is also believed to be attributed to the permeability of the layer. The postulated mechanism of formation of the bumps is that on hot summer days, during typical afternoon summer rain storms, water penetrates the asphalt layer through inter-connected voids. The expansion of the water vapour that is formed due to the high asphalt temperature, results in the asphalt being “pushed up” as the vapour cannot escape quick enough through the same connected voids. This type of defect is not limited to BRASO but has also been noticed on other Open Graded Asphalt Surfacing materials, and normally starts within the first 18 months after construction and becomes progressively worse with time. It is more frequent in less trafficked areas such as fast lanes, shoulders, on inclines as well as super elevations where the gradient of the road results in rain water staying on the surface longer. The “bumps” in less trafficked areas are more pronounced as there is less heavy traffic that can reduce the effect of the interconnected voids - due to post construction compaction -

and can also “push down” the bumps when they appear. This defect is currently under further investigation and will be reported on once investigations have been completed.

### **Sampling and Testing of BRA**

Sampling, sample preparation and testing of BRASO mixes is quite a challenge due to the “sticky” nature of the binder. The determination of the binder content is also a challenge especially if the indirect extraction method is used (TMH1 method C7b) where a correction factor (CF) needs to be determined. The bitumen rubber binder is not completely soluble in the solvents used for the test. The procedure is explained in the SABITA Manual 19, but there is still no agreement in the South African road construction industry to how often the CF should be determined. On some projects the CF is determined every time an asphalt sample is taken while on other projects one CF is used for every blend of bitumen rubber used. There were even instances where one CF was used throughout a project without verifying the factor of each blend of bitumen rubber. This, however, is not the norm and CF’s are determined for at least every blend of bitumen rubber. The CF is influenced by the following:

- The amount of rubber added during blending;
- The amount of “old” blend being reconstituted in the new blend;
- The age of the bitumen rubber blend – how much of the crumb has been digested/”dissolved” into the bitumen;
- The grading of the rubber crumbs (finer particles will dissolve quicker);
- The time the tester keeps the correction factor sample on the hot plate when mixing the binder and aggregate. (The longer the time the lower the correction factor);
- The temperature at which mixing takes place as well as the temperature of the hot plate when mixing;
- Age of the asphalt and time asphalt was at mixing temperature before cooling down for testing;

From the above points it is clear that the bitumen rubber binder content determination could be challenging and after problems were experienced on one project extra measures were put in place to verify the binder content of the BRASO. These were:

- Determination of the CF for every blend of bitumen rubber;
- Determine binder content of asphalt at the plant before it is sent to site for paving (limiting the influence of time on the binder content determination);
- Verify binder content with calibrated ignition oven test method;
- Verify binder content with nuclear gauge test method;
- Verify binder content by calculating the binder content using the MTRD of the asphalt;
- Verify binder content by calculating the binder content from materials used (aggregate, binder & filler as well as waste generated)



The test results of the three different test methods were compared and are given in Table 3. The test results compared very well and the two “new” binder content test methods will be included as new South African National Standard (SANS) tests.

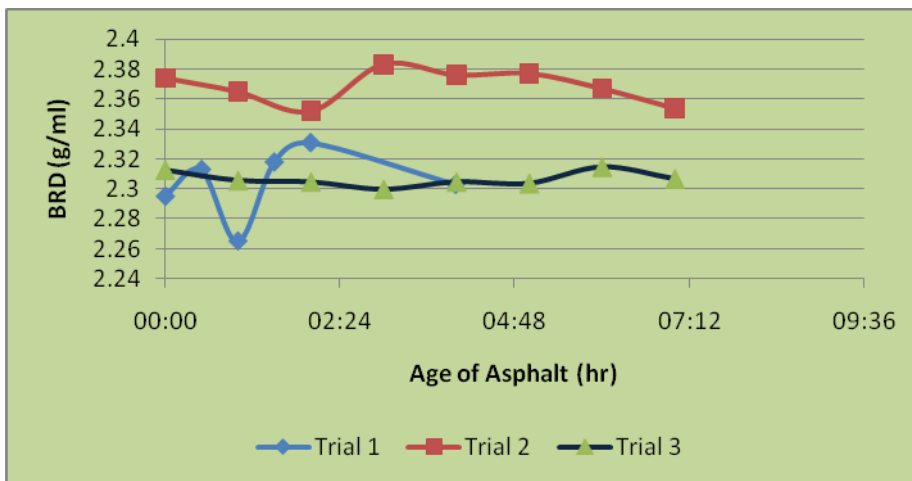
### Volumetric Properties of BRASO

As reported by Potgieter (2003)(4) the Marshall design method is still used in South Africa to determine the most appropriate design grading and optimum binder content, and briquettes are compacted with 75 blows per side. The Superpave gyratory compactor is also used but only the 300<sub>nmax</sub> void contents are generally evaluated as an indication of deformation resistance. These void contents were found to be close to the Marshall void content or even higher with values of 4% - 6% frequently recorded.

**TABLE 3 Binder Content test results using three different test methods**

Statistical analysis	Extraction (TMH1 Method C7b)	Oven (ASTM D6307)	Nuclear gauge
Number of Samples	86	86	86
Maximum (%)	8.191	8.167	8.333
Minimum (%)	6.962	6.933	7.100
Average (%)	7.502	7.556	7.621
Median (%)	7.497	7.508	7.600
Standard deviation	0.163	0.219	0.225

The influence of time on the viscosity of bitumen rubber binder during which it is kept at elevated temperatures is well documented, and one would expect the BRASO to compact easier at the same temperature as the viscosity of the binder reduces over time. In an effort to determine the influence of time, various time trials have been done on different BRASO mixes. The asphalt was kept on a delivery truck to simulate what would happen on a construction site where the asphalt was kept at elevated temperatures for extended periods of time. Samples were taken at different time intervals and the volumetric properties determined by compacting Marshall briquettes. The compaction temperature was kept the same for all the samples and the Bulk Relative Density was performed on the briquettes. The BRD test results were inconclusive and it could not be proven that the BRD increase over time as would be expected, and this could be an indication that the Marshall volumetric properties are not giving a true reflection of compactibility of the BRASO. (Refer to Figure 4). It should however be noted that these trials were performed on BRASO of which the binder was manufactured using 1 – 2% of extender oil and 19% - 20% of rubber crumbs as is predominately the case in South Africa.



**FIGURE 4: Effect of Age of Asphalt on Marshall BRD**

On a project in the Western Cape where BRACC was supplied to a contract with a long haul distance and where the asphalt was in the region of 6 hours old when paved. The binder that was used was bitumen rubber consisting of 60/70 penetration grade base binder with 20% rubber crumbs **without the addition of extender oil**. Big differences in volumetric properties were recorded by the Consulting Engineer’s laboratory as a result of the samples that were taken from the road (six hours after manufacture) being taken back to a laboratory in Cape Town and reheated the next day for testing. The Marshall voids were consistently lower than the process control test results which necessitated a time trial being performed to determine the influence of ageing of the BRACC on the volumetric properties of the mix. BRACC samples were kept at 170°C in an oven for six hours and then allowed to cool down followed by re-heating the samples in an oven the following day to compaction temperature of 140°C before compacting the Marshall Briquettes. The test results indicated that the Marshall voids reduced from 5.3% to 3.0% after 4 hours ageing and remained at 3% even after the asphalt was kept at 170°C for 6 hours, allowed to cool down and then reheated to compaction temperature the following day. In instances like these it would be recommended that the volumetric properties of the asphalt when placed be agreed upon and time trials be used to determine what volumetric properties should be targeted on freshly mixed BRA.

## CONCLUSIONS

BRA has been used successfully on the majority of projects where it was applied over the past 10 years with BRASO being the most often used. A few projects had premature failures and other projects had limited defects, shortly after construction. Bleeding and cracking was the major modes of failure and the main cause of the limited defects that occurred can be ascribed to water penetrating the BRASO layer causing stripping, pumping of fines as well as the formation of small bumps on the surface. Cognisance of these factors should be taken when designing and specifying BRASO.

Binder content determination of BRA is challenging and measures as well as further test methods to improve confidence in test results can be implemented. The determination of Marshall volumetric properties would appear not to be indicative of compactibility and

performance properties of BRASO mixes, and do not seem to be sensitive to the age of BRA, when extender oil is used in the manufacture of Bitumen Rubber. The opposite is however true when no extender oil is used.

The current specification for BRASO in South Africa is no guarantee that the asphalt will be fit for purpose and will perform as expected.

## **ACKNOWLEDGEMENTS**

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