PAPER 1

THE REHABILITATION OF A PORTION OF JAKES GERWEL DRIVE USING RECLAIMED ASPHALT AGGREGATE FOR THE PRODUCTION OF BSM BASE

DISCLAIMER

This project was the subject of a paper entitled "RECLAIMED ASPHALT AS A VIABLE AGGREGATE SUBSTITUTE IN BITUMEN STABILISED MATERIAL: THE REHABILITATION OF JAKES GERWEL DRIVE" which was published at the 13th Conference on Asphalt Pavement Technology for South Africa (CAPSA) in 2023. The authors for this paper being submitted for the IMESA conference were also co-authors for the CAPSA paper. Data and figures from the CAPSA paper have been reproduced in this Paper

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ABSTRACT

The City of Cape Town generates large quantities of reclaimed asphalt (RA) annually through its roads resurfacing and rehabilitation programs. The RA is stockpiled for re-use as gravels and other "low value" uses at various depots located within the City. To maximize the value held in the material, the City commissioned a study to determine the optimum utilization of RA. This resulted in two framework contracts being awarded for the treatment of RA. The treated RA was then utilized in the full-depth rehabilitation of portions of Jakes Gerwel Drive between the N1 and the N2.

The first framework contract entailed the crushing and screening of the stockpiled reclaimed asphalt, with the first project being implemented at the City's largest stockpile in Ndabeni, a facility with over 25,000m^3 of stockpiled RA. RA for the use in the Jakes Gerwel rehabilitation project was crushed and screened and ring-fenced in advance at the Ndabeni depot.

The second contract for the supply of bitumen stabilised material (BSM) using the reclaimed asphalt was awarded and commenced mid-way through 2021. This was utilized concurrently the rehabilitation project to supply BSM to the contract.

The pavement design for Jakes Gerwel Drive considered four options: i) bitumen stabilised material ii) bitumen treated base course (BTB), iii) cement treated base course (CTB) and iv) granular material. The project required the road to accommodate heavy traffic loads, have a uniform pavement structure and be open to traffic every morning during the construction period, due to the large volumes of traffic. BSM was consequently selected as the most suitable base material. The BSM base was produced from 100% RA using the cold recycling process. This process requires less energy and produces fewer emissions than hot mix asphalt. This pavement rehabilitation solution proved that the use of reclaimed asphalt in the production of bitumen stabilised materials not only addressed growing stockpiles and contributed to the circular economy, but also provided a structurally equivalent and cost-effective alternative to conventional construction methods.

1. INTRODUCTION

The City of Cape Town's (CCT) Road Infrastructure Maintenance (RIM) departments, which falls within the Urban Mobility Directorate, maintains a road network of approximately 10 400km. Depending on the annual maintenance budget, CCT can resurface up to 200km of road per year. This work generally involves removing (by means of milling) the existing asphalt wearing course and replacing it with new asphalt surfacing, either as patching, including bituminous base patching or full width resurfacing. The annual resurfacing program creates largest quantities of reclaimed asphalt (RA). This RA material is then hauled to the City RIM departmental depots and stored as a source of versatile material for use in various maintenance applications throughout the City.

The consistency of the resurfacing program created a greater supply of RA than could be utilized by the depots and the stockpiles at the depots grew to a point that was becoming problematic. The City identified the need to investigate further possible uses of RA, in higher quantities and in higher value applications. BVi Consulting Engineers Western Cape (Pty) Ltd was commissioned to carry out a study on uses of RA.

The study resulted in the creation of two contracts for the processing and recycling of RA. The first contract was for the crushing and screening of RA and the second contract was for the processing of RA using recycling technology to produce Bitumen Stabilized Material (BSM). The two contracts were the foundation for the Rehabilitation of Jakes Gerwel, which

FIGURE 1: *Locality of Jakes Gerwel Drive Rehabilitation project*

used BSM supplied by the City, through these contracts, to rehabilitate this section of road.

2. PROJECT BACKGROUND

The investigation for the alternative and optimized used of stockpiled RA was commissioned in 2017. Part of the recommendations of this study was to "*implement crushing and screening of the material into various aggregate sizes smaller than 20 mm. This option allows for a wider range of applications of the RA material...*".

This recommendation led to the establishment of a framework contract, 268Q/2017/18, in 2018, for the establishment of crushing and screening plants, and crushing, screening and stockpile management of RA at any depot or site within the boundaries of the Metro.

The RA utilization study also recommended that the highest use application for the processed RA was in the manufacture of hot (or warm) mix asphalt. This application was however not deemed economically or procedurally feasible. A further solution that was proposed involved the manufacturing of bitumen stabilised material utilizing the recycled RA. This specific option was chosen and led to the establishment of a framework contract in 2019 for the establishment of a specialized recycling plant and the processing of RA into BSM at any depot of site within the boundaries of the Metro.

BVi Consulting Engineers Western Cape (Pty) Ltd were also appointed in 2017 to carry out the investigation and design of the rehabilitation of portions of Jakes Gerwel between Bluegum Street and Viking Way, in the Langa, Bonteheuwel and Epping areas of Cape Town. The detailed investigation and design report that emanated from this appointment recommended a deep rehabilitation using a new BSM base using reclaimed asphalt with an asphalt surfacing.

With the two RA processing framework contracts in place and a large project rehabilitation project that was suited to the use of BSM base, it was the perfect opportunity to utilise large quantities of RA for a high value application.

3. JAKES GERWEL DESIGN

Jakes Gerwel Drive is classified as a Class U2 Urban Major Arterial by TRH26[5]. It serves economic activity centres such as Epping and Goodwood industrial areas as well as residential areas such as Langa and Bonteheuwel, with periodic signalised intersections. It is also the major link between Epping Industria, National Route 1, National Route 2, National Route 7 and the Cape Town International Airport. The location of the project route is illustrated in Figure 1.

The project was divided into two sections; namely full rehabilitation in the south between Viking Way and Bluegum Street, and maintenance in the form of patching in the north between Frans Conradie Drive and the N7/N1 interchange ramps.

3.1. Traffic Information

Traffic count information for the northbound and southbound carriageways was obtained in October 2017. The information showed that Jakes Gerwel is a highly trafficked road with a high percentage of heavy vehicles (approximately 8.8%).

The traffic data was further analysed to determine daily traffic patterns. The northbound carriageway had a distinct peak traffic period of over 2000 vehicles per hour between 6am and 9am and then maintained a relatively high traffic volume of around 1500 vehicles per hour until about 5pm.

The southbound carriageway showed a distinct peak in the afternoon, reaching 2000 vehicles and higher between 3pm and 7pm. During the day from about 8am, there were also relatively high traffic volumes of between 1500 and 2000 vehicles per day. This high volume of traffic, along with the distinct peaks was a very important design consideration when weighing up design options.

FIGURE 2: *Typical northbound carriageway geometry*

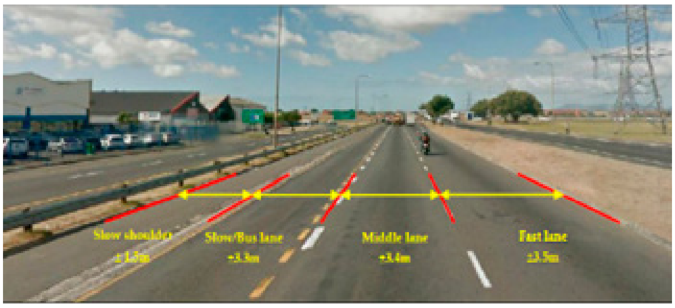

FIGURE 3: *Typical southbound carriageway geometry.*

3.2. Existing geometry

The road geometry typically consisted of three lanes in each direction, with a design speed of 60km/h and an average width of approximately 12m on each carriageway.

The pavement investigation data discussed below, indicates that the road was widened at some point and that various, non-uniform pavement designs were used in the widening, creating a highly variable pavement structure across the road.

3.3. Existing pavement condition

A detailed pavement and condition assessment, consisting of the following investigations was undertaken:

- Detailed visual assessment.
- Falling weight deflectometer (FWD) measurements; and
- Material investigation (test pit and test trench evaluation).

The major causes of pavement distress along Jakes Gerwel Drive were identified to include:

- Degree 3 to 5 cracking along construction joints,
- Degree 3 to 5 crocodile cracking and associated pumping of fines,
- Degree 3 to 5 shoving and rutting of the asphalt wearing course.

Figure 4 below shows a typical example of the pavement condition.

The following conclusions were drawn from the visual assessment, FWD data and materials investigation analysis:

FIGURE 4: *Crocodile cracking and pumping on northbound lane*

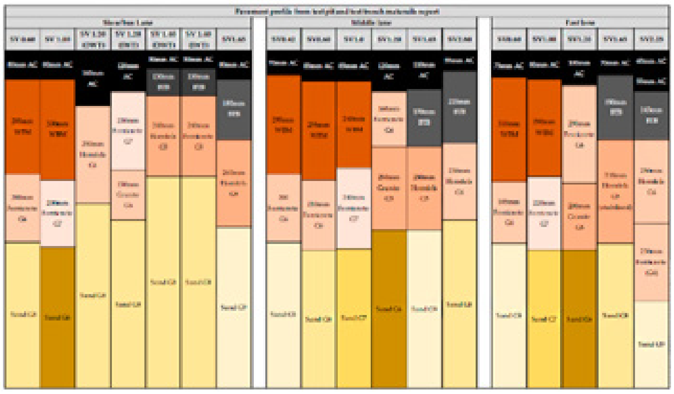

FIGURE 5: *Pavement profile of northbound carriageway*

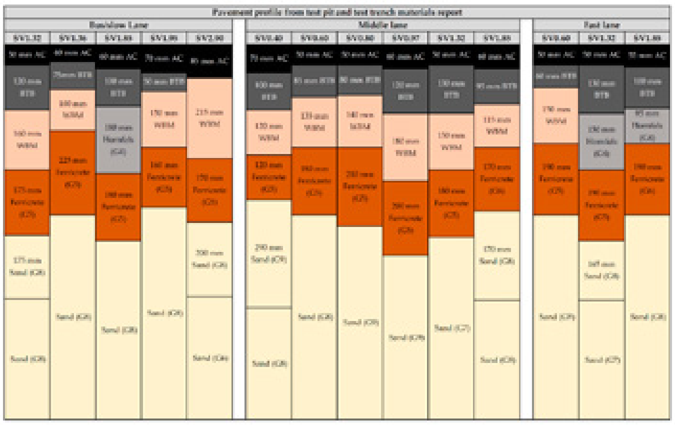

FIGURE 6: *Pavement profile of southbound carriageway*

- The layer stiffness values derived from the surface modulus plots and back-calculation were considered to be reasonable and further supported by the visual assessment, FWD data and material investigation conducted as part of the pavement assessment,
- To ensure that the base layer along the slow bus lane has sufficient capacity to carry the estimated design traffic loading, rehabilitation of the pavement layer was required, and
- An evaluation of the existing pavement in the middle and fast lanes revealed that the base layer required rehabilitation, and a new asphalt inlay was needed along various sections of the project.

3.4. Existing pavement structure

The test pit and test trench investigation of the existing pavement revealed a non-uniform pavement structure, both longitudinally and transversely. Figures and 5 and 6 show a summary of the test pit results highlighting the variability in the pavement layerworks.

The thickness of the asphalt varied significantly, and the base materials under the asphalt varied in material type (water-bound Macadam, granular materials (ferricrete and hornfels)) and thickness. Similarly, the subbase materials also varied in material type and thickness, with test pits showing ferricrete, hornfels and granite subbase materials. The subgrades were however mostly a similar sand but found at varying depths.

The non-uniform nature of the existing pavement structure meant that in situ recycling was not a viable rehabilitation option.

3.5. Design traffic

The design traffic loading, in terms of millions of 80kN Equivalent axle loads (MESA) was carried out for each carriageway, using a sensitivity analysis of various traffic growth scenarios. Based on these various growth scenarios, the following recommended design traffic was calculated:

Southbound:

- Slow lane/bus lane and Middle lane: 22.3 MESA
- Fast lane: 19.1 MESA

Northbound:

- Slow lane/bus lane and Middle lane: 17.7 MESA
- Fast lane: 15.1 MESA

3.6. Pavement rehabilitation design options

The pavement rehabilitation design, taking the design traffic of 20 MESA into account, had to consider several factors:

- Address moisture ingress and moisture sensitivity – highly durable
- Carry heavy traffic load – be fatigue resistant, rut resistant
- Create a safe driving surface – skid resistant
- Create a uniform pavement structure – longitudinally and transversely for ease of future maintenance
- During construction, accommodate in excess of 50 000 vehicles per day without disruptions to peak hours - Three design options were considered:
- Option 1 - mill and replace existing asphalt surfacing with an asphalt wearing course.
- Option 2 - construct a new BSM basecourse and a new wearing course.
- Option 3 - construct a new cement stabilised subbase, new bitumen treated basecourse and new wearing course.

Table 4 discusses the pros and cons of each of the options, including a comparative cost comparison for each option.

Based on the findings from the evaluation of existing pavement and the advantages/disadvantages of the pavement rehabilitation design options presented, the following recommendations were made:

- The use of recycled road materials in road construction deviates from the conventional practice of using entirely new materials and offers a more sustainable and potentially cost-effective alternative.
- The rehabilitation method selected for the project was Option 2 (BSM using RA, with A-E2 asphalt surfacing) as a cost-effective alternative to conventional construction and the most suitable pavement option when compared to other pavement options based on the above advantages. It met all the desired requirements, specifically the requirement to limit traffic disruption.

4. REHABILITATION OF JAKES GERWEL DRIVE

4.1. Rehabilitation layerworks construction

The rehabilitation of Jakes Gerwel Drive between Bluegum Street and Viking Way involved replacing the existing base with a BSM 1 quality material and placing a new asphalt surfacing using A-E2 modified binder. To accommodate the high peak hour and daytime traffic volumes, work was limited to take place at night between 20h00 and 06h00.

The base repair process had to be carried out in a single night-work shift to open the full road to traffic before the morning peak hour. The process entailed:

- Removing the existing asphalt wearing course and stockpiling the RA on site for re-use
- Excavating the existing base to the desired depth. The contractor transported the excavated base material off-site for use in future projects.
- The excavation floor of the box cut was compacted before the new basecourse layer was constructed.
- The BSM, which was manufactured off-site using crushed and screened RA, was then transported to the job site.

TABLE 4: *Design option comparisons*

Option	Description	Advantages	Disadvantages	Cost estimate
1	Mill and replace the existing asphalt wearing course with an A-R1 wearing course.	• Easy to implement • Can be trafficked daily • Reduces moisture ingress with high binder content surfacing • Suitable as a holding action	• No structural improvement • Does not address non-uniformity of pavement structure • High binder content asphalt has a risk of shoving at intersections • Existing cracks in lower layers are expected to reflect through to the surfacing over time • Short term solution that will require further action in 5 to 10 years	X
2	New BSM base (RA) and new A-E2 wearing course.	• Increased structural capacity • Reduces moisture sensitivity compared to untreated granular materials • Increased durability • Can be reinstated in a single work shift to top of BSM • BSM can be trafficked daily for limited period if surface is treated • Reduces moisture ingress with surfacing • Reduces RA stockpiles • BSM failure criteria is permanent deformation, which can be repaired by a mill and replace operation • Crack resistant Creates a far more uniform pavement structure for ease of future maintenance	• Removal of waterbound Macadam and base layers creates more spoil material • Contractual risk of running two inter-dependant contracts simultaneously	2.6X
3	New cement stabilized subbase layer, BTB layer and A-E2 wearing course	• "Traditional" rehabilitation design – familiar to contractors • Reduces moisture sensitivity compared to untreated granular materials • Increased durability • Reduces moisture ingress with surfacing • Creates a more uniform pavement structure for future maintenance	• Existing materials not suitable for in situ recycling • Removal of waterbound Macadam and base layers creates more spoil material • All new/virgin materials will be required for CTSB • 7 day curing period for CTSB required • Long term lane closures will be required, resulting in heavy traffic disruptions • Reflective cracking from CTSB may be expected over time	4.2X

- The BSM was placed in two layers, with the first layer being applied by either a grader or paver, depending on the subgrade material encountered, and the second layer using a paver.
- Before the lane was opened to peak morning traffic, a fog spray was applied to the BSM.

The completed layer was paved 20mm higher than the design final road level and maintained under traffic by the application of cationic bitumen emulsion fog spray and the regular removal of loose stones.

It was specified that the base layer could only be exposed to traffic for a maximum of 7 days before having to be surfaced.

Prior to surfacing, the layer was milled to final level, and the asphalt wearing course was applied. All asphalt surfacing also took place at night. The reclaimed BSM that was milled off prior to surfacing was reintroduced into the existing processed RA stockpile.

The median island layerworks were constructed using gravel recovered from the pavement, or from BSM from the milling process. The sidewalk and shoulder layer works were also reconstructed using the existing recovered basecourse or BSM.

4.2. BSM design and manufacture

The BSM was produced through a separate contract, and the City acted as the material supplier to the main rehabilitation contract. This meant that two interdependent contracts were being managed simultaneously, and delays caused by either contract could cause delays and associated costs to the other. This was mitigated through continuous coordination between the two contracts. BSM can be stockpiled for up to 7 days before its strength characteristics start to deteriorate. This, along with the continuous monitoring and coordination between the two contracts, helped ensure a steady supply of BSM material to the rehabilitation contractor.

BSM needs to be manufactured at temperatures above 15°C and as such, the BSM contractor worked during the day producing BSM, while the rehabilitation contractor worked at night.

The results of the BSM mix design process showed that optimum strength and shear parameters were attained using 1.0% lime as an active filler 2.0% bitumen. Based on these results, the plant trial mix at the depot was undertaken using a mix design of 1% lime and 2.0% bitumen.

4.3. BSM production

Once the mix design was determined, the trial mix at the depot was carried out. Quality control on production was undertaken by carrying out Indirect Tensile Strength (ITS) testing to ensure that a consistent product that met the specifications of a BSM 1 was being produced.

The ITS results of the trial batch met the specification and production could then begin. However, the initial result of the first production runs all failed despite the mix design being correctly applied.

Production was stopped and an investigation into the cause of the low ITS results revealed that the RA stockpile had a very high moisture content, much higher than the optimum mixing moisture content and the moisture content at which the laboratory testing was undertaken. The strength of a wet BSM is reduced because of the water acting as a lubricant and weakened particle bonding, making the material less cohesive and more susceptible to internal tensile forces. It was further determined that the higher moisture content was caused by the RA stockpiles standing uncovered for a long time due the early crushing and screening that took place in preparation for this project. This was exacerbated by the first tender for the Jakes Gerwel rehabilitation contract being cancelled. A second tender period meant the stockpiles were exposed to the Cape Town weather for much longer than anticipated. Moisture was retained in the stockpile due to the size/height of the stockpiles (area at the depot was limited) and poor drainage at the base of the stockpiles.

The problem with the high moister content was overcome by spreading RA over a large area in a layer of 400mm to 500m thick and turning it over with a grader every few hours. When rain was expected, the material was brought into stockpile and covered with plastic, before being opened again in clear conditions. It was found that the moisture content was reduced by approximately 40% to 50% over the course of 2 days using this method. The trial mix using the dried RA materials produced satisfactory ITS results and production then continued successfully for the remained of the project.

4.4. BSM acceptance control

Acceptance control testing for the BSM manufacture was based on ITS results (both wet and dry). Theoretically, the material could only be accepted (and paid for) and subsequently transported to the site once the materials' results were received and had passed. However, the timeframe that elapsed between sampling, testing and reporting was often as long as nine days. The delay in test results could have had a subsequent impact on the construction of the BSM by the rehabilitation contractor. To mitigate this, preliminary acceptance of the material was provided based on the input materials meeting the mix design specification in terms of moisture content of the RA, and bitumen and lime content of the mix. Final acceptance was provided once the ITS test results were received and compared to the specification.

Acceptance control for the BSM base construction was based on density testing using a nuclear density gauge. This method is known to have its limitation due to the bitumen content of the material, and the impact that it can have on test results. The bitumen in the material can affect the moisture content measurement of the nuclear density gauge, which in turn affects the density measurement. It was found that density results improved over time, with higher density results being achieved after 4 days than on the night of construction. The acceptance control specification was amended during construction to allow the material to be tested 4 days after the final layerworks construction. Testing was however still required to be undertaken, and results received meeting the compaction specification, before the asphalt surfacing could commence.

4.5. Problems encountered during construction

- While the BSM held up to traffic loading very well for the most part, unusually heavy rain downpours resulted in the BSM ravelling under traffic load in certain instances, and frequent maintenance was required to ensure road user safety. The ravelling resulting in too much loose material on the road and an uneven driving surface. The rains also resulted in project delays

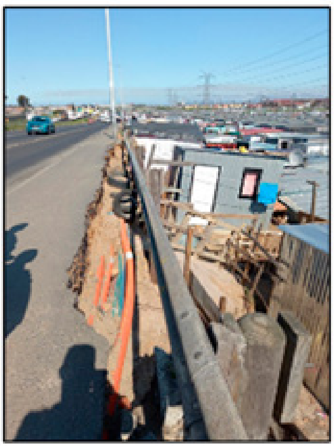
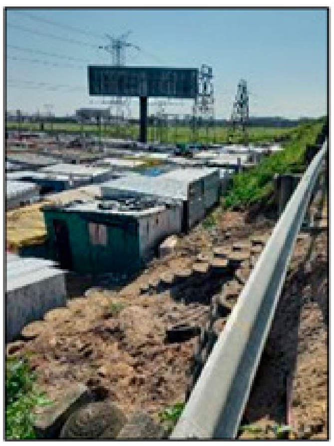

FIGURE 7 & FIGURE 8: *Encroachment onto fill embankment*

- The thorough test pit investigation and trial-hole profiles that was carried out during the design phase of the project were shared with the contractor during the tender process. Additional test trenches and test pits were also undertaken during the mobilisation period and before layerwork construction commenced. However, despite the thorough investigations, during construction, the actual layer thicknesses encountered differed significantly from the results of the investigation and associated layerworks profiles. The contractor encountered the sandy selected subgrade layer at shallower depths than expected in areas.
- This resulted in issues such as the milling machine and the asphalt paver being used to place the BSM getting stuck in the subgrade in isolated instances. The contractor was compelled to modify their construction techniques when sand was encountered. Instead of placing 2 BSM layers with an asphalt paver, the lower layer had to be end-tipped and spread with a grader before compaction. The second layer was then placed with a paver. This resulted in lower production than anticipated as well as the contractor having to keep a grader permanently on stand-by on site in case sand in the subgrade was encountered.
- An objective of the project that was not achieved was the repairing of a fill slope embankment approaching for a road-over-rail bridge. The need to repair the embankment was identified during the design stage, however during the tender period an informal settlement encroached onto the embankment, right up to the edge of the road. Negotiations with the community to allow for temporary relocations for the embankment to be repaired failed and no work could be carried out on the embankment. To avoid the possibility of damage to dwellings caused by heavy compaction equipment during the road rehabilitation process, the stretch of road adjacent to this community was constructed using static compaction, both for the BSM and the asphalt surfacing.
- The very busy intersection of Jakes Gerwel Drive and Viking Road was programmed to be the final section of BSM work. However, towards the end of the project, as winter approached and temperatures were dropping, it was found that the BSM was ravelling faster than expected. Instead of risking ravelling in the intersection due to high volumes of turning traffic, it was decided to carry out the intersection rehabilitation using hot mix bitumen treated base (BTB) instead of BSM.
- At the start of the contract there was a lot of uncertainty about the reliability of bitumen supply in the Western Cape. In order to avoid possible "force-majeure" delays and claims and to ensure a guaranteed supply of bitumen, it was agreed to purchase the bulk of the bitumen required for the BSM in advance, with the supplier providing an advance payment guarantee as security. Bitumen containers at the storage yard were ring-fenced for this project which resulted in an uninterrupted supply of bitumen for the project.

5. PROJECT OUTCOMES

5.1. Sustainability outcomes

- In total, 24 491m^3 of reclaimed asphalt was used in the manufacture of BSM in this project. A commensurate saving on the equivalent amount of virgin materials was therefore realised.
- The production of BSM is a cold mix process, with only the bitumen, which constitutes 2% of the mix, needing to be heated to 180°C. This resulted in far less energy consumption and carbon emissions that would have been the case if the alternative of hot mix BTB was used. For hot mix asphalt, the entire volume of materials needs to be heated to above 160°C.
- By using the depot closest to the site, further savings on carbon emissions were achieved compared to the alternative of transporting virgin materials and BTB from outlying quarries and asphalt plants.

- The existing pavement was deconstructed in layers by means of a milling machine. The reclaimed asphalt was taken to stockpile at the Ndabeni Depot for later re-use. Reclaimed granular material was used in the construction of median islands and sidewalks.
- The remaining excavated, potential spoil material was diverted from landfill by being delivered to the contractor's own recycling crushing and screening plant for re-use on other projects.
- The additional 20mm BSM thickness that was placed as an armouring layer, was diverted from landfill when milled and reintroduced to the crushed stockpile for re-use as BSM.

5.2. Potential savings achieved using RA BSM

In total 24 491m^3 of BSM was produced for the rehabilitation of Jakes Gerwel Drive. The total cost of BSM contract was R24.964 million, broken down as follow:

- BSM production costs: R13.850 million
- Bitumen rise and fall: R5.816 million
- Contract price adjustment: R2.056 million
- Additional cost for drying RA: R3.242 million

The total unit cost for the production of BSM was therefore R1 019/m^3. The cost of BTB material used in the rehabilitation of the Viking Rd intersection was R1 300 per ton which converts to approximately R3 120 per m^3.

Comparison based on material production costs shows that a 100mm thick BSM layer is equivalent to a 33mm thick layer of BTB. In terms of structural strength however, 100mm of layer of BSM 1 is typically structurally equivalent to approximately 80mm of BTB. It is important to note that the pavement was designed to be opened to traffic every morning, to limit traffic disruption. A BTB layer is suitable for use in such a scenario, however a BTB layer would typically be placed on a cement stabilized subbase (in terms of pavement design requirements). A cement stabilized subbase would however require long term lane closures to allow for the layer to cure and was not considered a viable option on this busy road. A structurally sound base that could be opened to traffic immediately was therefore required.

The accepted pavement design was a 300mm thick layer of BSM 1 (constructed in two layers) which equates to a structurally equivalent BTB layer thickness of 240mm. This is however not a feasible design and for the purposes of comparison, an equivalent pavement design utilising a 200mm thick cement stabilized subbase followed by a 100mm thick BTB base is considered.

This in turn converts to 8 163m^3 BTB and 16 328m^3 of cement treated subbase. The total material cost of this option is composed of R25 470 640 for the BTB layer and R9 860 000 for the cement treated subbase, which equates to approximately R35 330 680.

Therefore, by using a recycled RA BSM instead of an equivalent asphalt pavement, a potential saving of R10.4 million was achieved. These calculations do not however consider the increased road user costs, additional preliminary and general costs and increased future maintenance costs that are associated with the asphalt base option.

6. CONCLUSION

The objectives of the investigation into the possible uses of RA at City depots were achieved in the implementation of the crushing and screening and BSM contracts. The crushing and screening process achieved as a well graded material, capable of being used in a variety of applications, including BSM.

These two contracts set the foundation for the rehabilitation of Jakes Gerwel using a 100% RA BSM. The BSM mix design was found to achieve optimum results when assessed against the BSM classification limits according to TG2[4].

The rehabilitation project proved the viability of using RA material in producing BSM by designing and constructing a pavement for the rehabilitation of Jakes Gerwel Drive that provided to be a structurally equivalent and cost-effective alternative to conventional construction. Furthermore, this construction methodology achieved the goal of minimal traffic disruptions as the use of BSM enabled the road to be opened to traffic every morning during the construction period.

Sustainability objectives were also achieved through the minimization of virgin material use through the recycling of RA, the re-use of materials on site and the diversion of potential spoil material from landfill to another recycling plant. Energy consumption and carbon emissions were also reduced compared to conventional pavement designs through the cold mix process of BSM, as opposed to the hot mix process of BTB and through the reduction in transportation of materials due to the proximity of the depot compared to commercial quarries and asphalt plants.

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