10TH CONFERENCE ON ASPHALT PAVEMENTS FOR SOUTHERN AFRICA

THE DEVELOPMENT & IMPLEMENTATION OF COST EFFECTIVE COLOURED BITUMINOUS SURFACINGS FOR HIGH PERFORMANCE BUS LANES : CASE STUDY ON CAPE TOWN AND OTHER IRT PROJECTS

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Abstract

This study evaluates bituminous based coloured surfacing alternatives for use on BRT bus lanes in Cape Town and other similar projects. The alternatives considered consisted of pigment coloured black binder asphalt surfacings, thin asphalt surfacing with both pigment coloured (black) binder and coloured aggregates, water-cut exposed coloured aggregate, coloured aggregate UTFC's and lastly coloured aggregate friction seals. The selection criteria evaluated include: layer durability colour quality and longevity, initial costing, constructability under interurban conditions and also maintenance practicality and durability.

The paper describes the research and development study and also the implementation of the final recommended bituminous coloured surfacing layer. The coloured aggregate and pigment coloured binder UTFC was found to be most cost-effective demarcation option.

1 INTRODUCTION

With the implementation of the Bus Rapid Transit (BRT) system in Cape Town, which included the City's requirement of having dedicated, demarcated, red coloured bus lanes, the need for a high friction, durable, rut resistant coloured surfacing as an alternative to pigmented concrete became apparent, especially on the inner city routes where rapid delivery of the new bus route and cost effectiveness were prioritized.

This paper describes the research into existing colour asphalt and surfacings used in South Africa, the development of the different options investigated for this study, the construction costs of each of the option and the durability and deformation resistance effects on the pavement structure of the preferred options.

It is the aim of this paper to provide practitioners (who may, for whatever reason be required to use coloured surfacing) with insight into the advantages and disadvantages of various options available on the market today to enable informed decision making regarding the kind of coloured surface required.

2 CURRENT INTERNATIONAL BEST PRACTICE

Worldwide best practice on colour demarcated road surfacing products shows the following options are frequently used:

- Black Binder, conventional Continuous Graded Asphalt surfacing, with coloured pigment filler (red oxide, other coloured fillers),
- Special, Colourless Binder, conventional Continuous Graded asphalt surfacing with coloured pigment filler (red oxide, other coloured fillers)
- Above conventional “coloured” asphalt surfacings with “colour-coded” aggregate for “preservation” of colour after polishing/weathering of surface binder and filler,
- Coloured Coded Aggregate chip-and-sprays where colouring is provided by naturally or artificially coloured stone chips (various options from fine glass beads to 13 mm Chips is possible). The pre-coating of larger chips, or variants of this, with “colourless” or “colour-coded” binder is challenging in Southern Africa,
- Black binder Ultra Thin Friction Courses (UTFC’s) with coloured pigment fillers and alternatively with Colour Coded Aggregates and/or colourless binders;
- Sprayed on surface colouring with road marking paint or plastic coatings or other surfacing colour solutions.
- Coloured slurries or other self-setting surface courses;
- Coloured concrete rigid pavements or block paving.

In Southern Africa, both conventional AC surface mixes with colourless binder, colour coded aggregate and colour pigments (red oxide) [as used in Durban] and also a conventional black binder AC surfacing with standard aggregate, and colour pigment filler were used before (various used in the Western Cape, e.g. Pniel). Problems with these include that mixes with non-colour coded aggregate tends with time to revert back to the original aggregate colour and mixes with colour-coded stone appears to be unaffordable on large project scale when nearby sources of coloured stone do not exist.

Globally various degrees of success with coloured “Chip-and-Spray” or so called “thin friction seals” or Sprayed-on-Colouring solutions has been experienced. The biggest setback with thin seals in the Inner City environment is tyre wear-and-tear (especially in bus lanes) which strips the aggregate off. Sprayed-on solutions on the other hand are expensive as they need frequent replacements or re-sprays due to stripping and weathering and they also seem to fill up macro-texture.

3 EXISTING COLOUR SURFACING IN SOUTH AFRICA

A desktop study was carried out to identify studies into different surfacing options as well as completed projects that used colour surfacing.

3.1 Previous City of Cape Town (CoCT) Colour surfacing Study

In a field and laboratory study carried out by PD Naidoo and Associates and HHO Infrastructure Engineer[1], for CoCT, a local cold plastic coating with two different aggregates types (Jasper and Granite) was evaluated against an international British Board of Agrément certified epoxy coating called Tyregrip with the same aggregate types in terms of macro texture, skid resistance, colour retention and abrasion. The results showed that the Tyregrip product performed better than the cold plastic product in terms of macro texture and skid resistance. Neither product met the long term colour standard because of discoloration caused by bus tyres. This apparently can be rectified by frequent washing of the surface.

3.2 Durban BRT red asphalt

Red asphalt was successfully used in Durban's BRT lanes. Both of SMA and continuously graded asphalts were used. The colour was obtained through using a reddish/pink granite aggregate available from commercial quarries in the area as well as the addition of red oxide (3% by mass, imported from the UK) to colourless bitumen binder. The availability of local colour-coded aggregate makes this a cost effective solution.

Figure 1: Red continuously graded colourless binder Asphalt on Durban BRT Route[2]

3.3 Pniel Red asphalt on the shoulders

Red asphalt was placed on the shoulders of the R44 through Pniel, near Stellenbosch in the Western Cape as a safety initiative in 2010. The mix design that was used was a Standard COLTO medium, continuously graded asphalt mix with the addition of 2.5% (by mass) red oxide. The results, as shown in the photo's below are very good in terms of colour and contrast for safety purposes. This area will however not be heavily trafficked as it is in the shoulder and conclusions on long term performance of the surface in terms of colour loss in the wheel tracks, durability and deformation resistance may be misleading. It does however appear to work well for its intended purpose of safety enhancements.

Figure 2: Red Oxide Pigment Coloured Continuously Graded AC Surfacing on Shoulders of R44

4 CAPE TOWN BUS ROUTE INVESTIGATION

4.1 Background

The majority of the outer (outside the CBD) Trunk Routes for the Cape Town BRT system were/are being constructed using pigmented, continuously reinforced concrete pavements. Initial cost efficiency studies and practical considerations called for a flexible pavement structure solution, in conjunction with concrete structures, in the CBD. Also, because of the need for rapid delivery, minimum traffic disruption, cost effectiveness and the need to gain relatively easy access to underground services and/or the placement of new underground services, it was decided to utilise the flexible asphalt pavements in the Inner City Route (Heerengracht Road, around Fountain Circle and on Hans Strijdom Road and other routes). The bus stop areas were to remain concrete due to the high shear forces of the stopping and starting actions in these areas.

The heavy, (up to 125 kN) axle loads associated with the new busses and the large number of expected bus loadings resulted in 20 year design traffic loading in excess of 50 million equivalent 80 kN axle loads. This, together with the highly channelised nature of the bus wheel loading, resulted in the need for thick asphalt structure comprising of mixes that are a highly fatigue resistant at the bottom of the structure and highly deformation resistant at the top.

The design asphalt thickness was calculated to be between 240 mm and 270 mm thick (depending on in situ condition), including 50 mm of surfacing. All asphalt layers were to be modified with A-E2 quality binder. The key issue for the surfacing was to maintain deformation resistance while still obtaining the City's short and long term colouration requirements. Friction/Texture depths were not considered the most important on these 60km/h CBD road types.

In order to achieve this, the following colouration options were investigated.

1) Special epoxy grit/chip-seal, on top of the standard AC surfacing (R222/m^2 additional cost compared to the conventional non-coloured pavement structure);

2A) Red oxide coloured asphalt surfacing (40 or 50 mm) with black binder and rolled in-chippings of red colour-coded aggregate (R140/m^2 additional);

2B) As per 2A, but replacing the course aggregate fraction (9.5 mm and 13.2 mm) with red colour-coded aggregate (R110/m2 additional).

3) Thin red oxide coloured asphalt surfacing layer of 25 mm with black binder and 100% red aggregate (9.5 mm max aggregate size mix) (R100/m^2 additional);

4) As per 2B or 3) above, but with high pressure water-cutting of the surface to achieve colour-coded aggregate exposure (red stone) instead of red-oxide colouring (R130 to R170/m^2 additional).

5) Thin UTFC (18 mm thick) 9.5 mm max aggregate size using black binder, red oxide and colour-coded red granite course stone (ex Durban) (R120/m^2 additional).

6) As per 5) above but using imported colourless binder instead of black binder (extra additional R80/m^2).

7) As per 2A, 2B, 3 or 4 above with colourless binder (extra additional R80/m^2).

8) Plastic adhesive or thin colour sprayed coatings (R70/m^2 per spray lasting 3 years)

4.2 Initial Recommendations and investigation

The investigation into the above options gave indications of possible in-situ appearance for initial elimination of unacceptable options. Options 1 and 2A were tested in trial sections but in terms of constructability and durability they were rejected and considered non-viable. Options 6 and 7 (colourless binder) were rejected due to the "small quantities" involved and the asphalt supplier's unwillingness to adjust plant for small colourless binder quantities. Trials with option 8 were prepared by contractors for CoCT but were not viable due to lack of durability and performance risks.

Originally Options 2B and 3 above were considered to be the best options and were recommended. Options 4 and 5 also investigated further.

A variety of briquettes, as shown in Table 1 below, were produced in the laboratory for the investigated options using various combinations of the following Aggregate types:

- The Reebok quarry stone (lighter coloured stone)
- Reddish aggregate from Durban
- Red Jasper stone from the Northern Cape

Jasper Stone (ex Northern Cape) initially appeared to be ideally colour-coded, however production practicalities and aggregate durability ruled it out as a viable aggregate source.

Figure 3: Red Durban Aggregate, Grey Reebok Aggregate and Red Jasper Aggregate (L to R)

Table 1: Appearance of Mix Variations from Marshall Briquettes

Mix Type	AC Mix Variations and Composition				
	Durban Aggregate	**Reebok aggregate**	**Jasper Aggregate**	**% red oxide**	**Also Water Cut**
2B(i)		100%		4%#	Yes
2B(ii)	50%	50%		4%#	Yes
2B(iii)	-	-	100%	-	No
2B(iv)	100%	-	-	-	No
2B(v)	50%	50%	-	-	No
3	9 mm stone fraction only	> 9 mm stone fraction	-	-	No
5(i)	100%			4%#	Yes
5(ii)	100%	-	-	5%#	No
5(iii)	100%	-	-	3% (using colourless binder)	No

Note: # with black bitumen binder

Based on the colour and appearance of the initial test round briquettes the original recommendations were fine tuned and it was decided to further investigate only the following two options:

- Options 2B (red aggregate, conventional AC surfacing) , using 100% ex Durban colour-coded aggregate with 4% red oxide and black binder
- Option 5, using 100% ex Durban colour-coded aggregate with 5% red oxide and black binder

Another set of briquettes was produced for these two options. Both of these options were again also put under the high pressure water cutter. Figures 4, 5 and 6 illustrate the appearance of the two preferred options (Marshall Biriquettes).

Figure 4: Option 2B(ii) from Table 1 (AC surfacing with red oxide colouring and 50% colour coded aggregate ex Durban)

Left: Top briquette is UTFC with colourless binder, 3% oxide, and colour coded stone. Lower 2 briquettes are UTFC with Black Binder, 5% oxide and colour-coded stone.

Below: Comparison between colourless and black binder UTFC's. Colourless binder is below.

Figure 5: Comparison of Options 5(ii) and 5(iii) from Table 1 (on the right, 5(iii) is below)

Left: UTFC with 5% red oxide, black binder and colour-coded aggregate

Below: UTFC with 3% red oxide, colourless binder and colour-coded aggregate

Figure 6: Option 5(ii) (left) and Option 5(iii) (right) from Table 1

The water-cutting tests were done at various pressures ranging between 300 to 500 kPa. Visually there was no major difference in appearance after the water-cutting, and the water-cutting was considered to be unsuccessful as an option for enhancing the surface colour of the mixes by initially exposing the coloured aggregates. It did however give an indication of how the surfacing would look after trafficking (i.e. once the surface binder coating had worn off) and hence an indication of colour durability. The fact that there was no major colour difference before and after water cutting was a good indication that the longevity of the colouring of the recommended options will be good.

The colour epoxy option using the imported Tyregrip Option with Jasper aggregate chippings (based on the findings of the previous CoCT study) was ruled out as a viable option for several reasons:

- It was significantly higher in price than the other options considered – R220.00 per square metre,
- It only came with a three year product guarantee,
- It has no track record in this country except for the trial section carried out in 2007 by CoCT/P D Naidoo and HHO,
- Maintaining the surface would require full reapplication every 3 to 5 years, including the cleaning and removal of the old surface prior to reapplication, thereby making this product not viable by virtue of its high the life cycle cost as well as its high initial construction costs.

The use of colourless binder (based on Durban study and testing *in-casu*) gave the most favourable colour but it was not viable because of the small quantities required for this particular project. Colourless binder is imported and the asphalt supplier needs to store it separately at their plant and ensure that their mixing plant is comprehensively cleaned before using this product to avoid any contamination, meaning that substantial production time is lost in a day if this product was to be used. This makes the costs of using colourless binder untenable. There is also very little to no track record of this material in the country and there were doubts about its performance in terms of durability and deformation resistance and also how it would react to modification with SBS (i.e. being modified to A-E2 standards). If colour-coded aggregate is not used the aggregate colour will dominate after 2 to 4 years.

4.3 Cost estimates of recommended options

The costs of the two recommended colouring options were calculated as an extra over cost to the cost of the conventional black flexible pavement structure. The additional colouring cost of Option 2B (Conventional Pigment (Oxide) Coloured AC, with 100% colour coded aggregate from Durban and 4% red oxide) is broken down as follows:

40 to 50 mm surfacing with 4% Red Oxide and Coloured Aggregate ex Durban:

• EO for Red Oxide (4%)	=	R46/m^2
• EO for imported Coloured Aggregate (95%)	=	R216/m^2
		±R262/m^2

The extra over cost of the UTFC colouring option was based on a quote from the contractor and is given below.

• UTFC 100% Colour Aggregate (ex Durban) and 4% Red Oxide	=	±R120/m^2

The addition of a coloured UTFC overlay instead of attempting to colour the full 50 mm asphalt surfacing therefore holds significant initial construction cost advantages. It also holds a further advantage in future maintenance were this 18 mm thick layer can be milled off and replaced instead of having to replace the 50 mm thick coloured asphalt surfacing. In addition UTFC's offer good friction and visible (texture difference) demarcation (for bus lanes etc) properties.

4.4 Colour durability considerations

Both mixes utilise the colour aggregate and red oxide with black binder and as can be seen in the photos, both options yield a good red/maroon colour. The advantage of the colour aggregate is that once the binder on the surface is removed through trafficking, the colour of the aggregate is exposed, which in this case would be light reddish/pink as opposed to black. It is felt that this will contribute significantly to the longevity of the colouring in both options.

It was found practically easier and less costly to remove mineral aggregate filler material from the UTFC aggregate grading and replace it with red oxide than it is to remove from the continuously graded asphalt's aggregate. Up to 5% of coloured "filler" can be added into the UTFC grading whereas only up to 3% can be added to AC surfacing mixes. This will give the UTFC option an advantage in terms of colour life over the continuously graded asphalt option.

Another advantage of the UTFC option is its open texture. If the surface is contaminated through trafficking and rubber or surfacing wear, the open texture will still allow the colour within the layer to be seen as opposed to just the contaminated/worn surface as the case would be with the continuously graded asphalt.

4.5 Durability and resistance to deformation

The UTFC is purely a functional layer that colours the surface and enhances friction properties. Because it is such a thin layer, with a stone on stone structure, deformation testing in terms of a wheel tracking test is not required. However durability testing in terms of the Cantabro test was carried out. The minimum durability criteria for the Cantabro test was set at a loss of mass of not greater than 20%. All the tests carried out on the UTFC briquettes met the required criteria.

The UTFC will also give additional protection to the asphalt below by providing a "cooling effect" preventing the upper asphalt layer from excessive temperature related deformation risks on extreme hot days under the high (12 ton) bus wheel loadings. It will also allow the mix designs of the pavement structure to be carried out conventionally to optimise the pavements durability and deformation resistance without the additional risk of having to add 4% red oxide in place of the normal filler, the effects of which on durability and deformation resistance are still to be determined.

4.6 Construction and maintenance aspects

The disadvantage of the UTFC is that it adds an additional layer to the pavement which needs to be correctly tied-in in terms of surface drainage. Also special paving equipment (self tacking power) is needed. On the project in question, the quantities are small (±150 tons) and the additional time required (additional layer) would at most be two days, which is not significant when compared to the cost savings gained by utilizing the UTFC instead of the continuously graded asphalt. UTFC construction is also common and most asphalt contractors have experience with it.

Small scale maintenance of any coloured surface e.g. service trench crossing reinstatement, remains a future problem. Production of small quantities of coloured asphalt, continuously graded or UTFC is very costly. Also, because, in this case the aggregate is imported, it may not be readily available in the small quantities required.

The best option, in terms of cost is to patch/backfill trenches or other re-instatements using conventional asphalt and paint the surface to a similar colour until there is a large enough area to make production of the coloured asphalt viable. Once off larger scale maintenance operations can take place cost effectively to reinstate the coloured asphalt surfacing.

5 CONCLUSIONS AND RECOMMENDATIONS

The study showed that the most cost effective coloured surfacing option identified for the Cape Town Inner City BRT route is an Ultra Thin Friction Course utilising a pigment coloured (red oxide) black binder and “colour-coded” aggregate imported from Durban (or similar obtained elsewhere).

The major cost advantage its holds over conventional AC surfacing is that it can be placed to 18 mm thickness, reducing the quantities of costly imported “colour-coded” aggregate (when close-by sources are not available) and pigment (red oxide) needed.

The “colour-coded” aggregate serves to preserve the longevity of the colour by exposing a coloured aggregate after traffic polishing and tyre wear. A richer, longer lasting colour can also be achieved more easily in a UTFC by ease of replacing more (up to 4%) of the mineral aggregate filler with red oxide pigment.

The UTFC does however require an additional step in the construction process, but UTFC construction is fairly commonplace now-days and this is not seen as a major disadvantage in terms of construction difficulty or the additional time required to construct it.

The durability of the UTFC in Southern Africa has been proven to be good and it helps improve the durability of the underlying pavement by providing an impermeable seal. It further offers superior friction, spray-reduction and surface texture functional and safety properties.

REFERENCES

1 PD Naidoo & Associates, HHO Africa Infrastructure Engineer, 2009. **Performance monitoring of High Friction Colour Surfacing on BRT Lanes.** City of Cape Town

2 Photo taken from the following website: **http://www.velavke.co.za/projects.htm?action=view-item&id=917**

KEY WORDS

Colour asphalt, BRT, lane demarcation