INNOVATIVE ASPHALT CONSTRUCTION: CASE STUDIES ON CAPE TOWN INTERNATIONAL AIRPORT AND KROMBOOM PARKWAY

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ABSTRACT

The main taxiways at Cape Town International Airport and sections of Kromboom Parkway (M5) were identified to be in urgent need of rehabilitation. Thick asphalt base layers were selected for providing the appropriate pavement rehabilitation structure in both projects. The aggressive wheel loading and environmental conditions (especially on the Taxiway contract) necessitated a superior asphalt construction methodology for these upper structural layers.

Due to the extremely high tyre pressures of the aircraft wheel loads (1200kPa) in the Taxiway Contract, special emphasis was placed on deformation resistance within the asphalt mixes. The selected asphalt mixes were therefore chosen to be inherently stiff and harsh (very flaky fine aggregate, no sand content, high VMA) and special stiffening additives (Gilsonite) and stiff base bitumen binders were selected to ensure maximum resistance to deformation. In addition hereto the filler/binder ratio of the mix (1.6) and the Voids-in-Mix (5% to 5.5%) were set to further enhance the rutting resistance of the selected mixes. The resultant harsh mixes as well as the paving climatic conditions (night time occupations and resultant cold ambient and road temperatures) required a maximised compaction effort

In addition to the high asphalt densities (93% to 94% of MTRD i.e. RICE density), permeability on joints and special joint preparation and sealing specifications were also specified to ensure ultimate durability and low future maintenance of these taxiway areas.

Due to the high riding quality requirement (on the M5 rehabilitation project) as well as other special long term functional requirements (including impermeable joint sealing requirements), a special set of “best practice” asphalt construction techniques was developed in co-operation with the Contractor (Blitz Asphalt), the supplier (Much Asphalt) and the Institute of Transport Technology at the University of Stellenbosch to ensure the following key construction aspects were effectively and consistently obtained:

- **Maximised Riding Quality** through consistent mix supply, pro-active paving operation scheduling and “best-practice-paving-method” application,
- **Consistent densities** through active “paving train-length”, asphalt temperature and rolling effort management;

- **Adequate longitudinal joint sealing** results through dedicated, rigid adherence to “Best-Practice-Rolling-Methods” and special developed joint preparation methodologies.

Rigid adherence to best practice rolling and innovative state-of-the-art asphalt paving and joint construction methods ensured the adherence to the rigid construction specifications through-out both of these contracts. Riding quality and performance testing (on the completed in-situ layers) confirmed the superior quality of the constructed pavement layers. The construction methods that were developed and the “best practices”, as applied through out these two contracts, are laid-out and discussed in this paper.

INTRODUCTION

Hot mix asphalt construction is a well-established industry which enables the cost-effective, all-weather surfacing of the majority of roads, airport runways and taxiways and various industrial surfaces worldwide. With asphalt surfacing and base layers constituting an estimated 20% to 30% of new or reconstructed road structure costs and an estimated 40% to 60% of rehabilitated road structure costs, it is an essential cost component of road building - hence the importance of maximising product value through sound design and construction practice.

The authors have witnessed and investigated, during their careers, various asphalt construction projects which failed prematurely due to a lack of best practice construction procedures. When these two major asphalt rehabilitation projects, which are the subjects of this paper (consisting of both thick base layer and surfacing layer construction), came up for construction, the authors and design engineers decided that this is the ideal opportunity to innovatively define and apply current best practice construction technology and to monitor and report back on the benefits, importance and success of the various procedures followed.

The first case study - the investigation and design of the asphalt mixes for the rehabilitation of the main taxiways at Cape Town International Airport, was initiated because the existing taxiway structures had provided in excess of 30 years of service and some of the sections had exceeded their design life and were in a severe condition including failures.

The design and construction of asphalt mixes for the rehabilitation of Kromboom Parkway, a two-lane double carriageway inter-urban freeway in Cape Town, constituted the second case study.

APPLIED BEST PRACTICE ASPHALT CONSTRUCTION PROCEDURES

The fundamental rule of asphalt construction is to have a continuous, non-stop/start, paving and rolling action in order to obtain superior riding quality and consistent mix densification. The rolling effort also needs to be well controlled to ensure that the optimum compaction effort and technique is applied at maximum mix temperatures. It is further essential that compaction effort requirements, especially those of harsh deformation resistant upper asphalt layers, be adequately defined and verified. The authors argued that all continuous graded mixes that fall within reasonable volumetric tolerances (Marshall VIM < 6%, VMA < 18) are compactable, but that the effort needs to be defined (preferable at tender stage to enable contractors to tender accordingly).

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Supply Procedures

The following key best-practice asphalt supply principles were utilised on both projects:

- Asphalt supply had to be continuous and dedicated to the project, especially for the wearing coarse layers;
- Temperatures ex plant had to be within a narrow range of 150 ºC to 165 ºC (10 ºC higher for the 40/50 Pen. binder wearing course used on the CTI Airport rehabilitation contract).
- Hauling truck movements were meticulously monitored to ensure minimum time wastage and continuous supply on site;
- Tarpaulins were used consistently (both cold night times and hot summer days) and kept on right until tipping into the paver hoppers started; pieces of crust (cooled asphalt) or spillage behind the paver's hopper were meticulously removed.

Paving Procedures

- The basic paving fundamentals were rigidly applied through strict engineer's site supervision and paving operator control (continuous level planning and smoothing thickness control, active supply feed smoothing and truck bumping prevention, functional tamping bars, and other basics).
- The paving speed was adjusted continuously and smoothly to ensure that the paver stayed just ahead of the rolling effort.
- Temperatures of greater than 130 ^{o}C in wearing course layers and greater than 120^{o}C in BTB layers (bitumen treated base i.e. asphalt base) were defined as the minimum "behind-paver" temperatures allowable; where conditions justified it, as in the case of thick lower base layers which compact easier due to lower VIM and good heat retention, this was relaxed.

Rolling Procedures

The required compaction effort was verified beforehand on trial sections:

- The thick lower BTB layers (100 mm on Kromboom Parkway and 135mm on CTI Airport contract) required only 2 rollers (vibratory and static rollers used).
- The upper BTB layers (50mm on Kromboom Parkway and 135mm, gilsonite stiffened on CTI Airport contract) required a full three roller team (pneumatic included);
- The 40 mm to 50mm thin stiff wearing course mix (see high number of gyrations to obtain field density) which was placed mostly during cold night-time operations,

especially the layer with 40/50 Pen.binder placed at the CTI Airport contract, required slower paving. Also a heavy 27ton double vibrating drum roller, a 17ton static breakdown roller and in the case of the CTI Airport contract two pneumatic rollers (the smaller one was dedicated to joint finishing) were required.

All the essential fundamentals of consistent and efficient rolling were rigidly applied and supervised (rolling pattern, minimum water on roller wheels, calibrated nuclear gauge density monitoring and smooth directional changes). The rolling zone was kept to an essential minimum with all the rollers functioning within a 40m rolling zone on the CTI Airport rehabilitation contract and within a 60m zone on the Kromboom Parkway rehabilitation contract. The rolling zone was controlled by the speed of the paver and 90% of the rolling effort was applied within the 135^{o}C to 90^{o}C temperature zone.

Joint Construction Procedures

Premature failures of asphalt joints can reduce pavement lives by an estimated 20% to 50%. Based on the thorough research and findings of Kandhal and Mallick[5] as well as other fundamentals and field trials carried out by the design engineers on various other asphalt paving projects the following basic principles were considered in defining a best-practice longitudinal joint construction technique suitable for these projects:

- Cracking and ravelling, the two main distress conditions at joints, are caused by relative low density and/or surface irregularities at the joints. Field densities of at least 91 % of MTRD (Rice) density are required at joints and in situ permeability (Marvell test) of less than 3 λ/h is preferable; this was accordingly specified for these contracts.
- Trafficked joints, especially those falling in wheel track areas, to be ideally constructed as hot tandem-paved joints where logistically feasible; if not possible or economically justifiable than the joints needs to be designed to be situated at the least detrimental position and/or to receive special joint sealing treatment.
- The low-density zone along the unconfined edge(s) of the paving strip generally extents for 200mm to 400mm from the edge (depending on layer thicknesses, base roughness, roller finishing and other factors)
- The permeability in this low-density zone, especially on the vertical interface, is generally 10 times higher than on the layer itself (Marvell permeabilities[6] of 30 l/h to 250 l/h typically measured on untreated joints – note that the Marvell test apparatus measures the flow of water into the surfacing layer under a pressure head of 380 mm through a surface base of 175 mm diameter.)
- Treating of joints in order to obtain well sealed, densified and bonded interfaces must address the removal of the uncompacted cold-side edge, special compaction of the hot-side edge and sealing of the interface with sealing additives and /or suitable raking techniques.
- Consequential asphalt layers required stepped edges and straddled joints (at least 150mm offsets to ensure discontinuous joints and to reduce water infiltration).

Figure 1 depicts the final cold joint constructed method adopted on both projects to obtain the specified density and permeability requirements. Similar (slightly modified to suit logistics) techniques were used on the tranverse construction joints with equivalent success.

On the CTI Airport contract, the two most trafficked areas (8m on both sides of the taxiway centerlines) were constructed with hot tandem-paved joints in both the base layers and wearing course layers. The two pavers run in tandem (2x4m strips) with approximately 10m following distances and rolling was only allowed in the zone behind the second paver to ensure the hot joint bonding integrity. Hot tandem-paved joint were logistically unattainable on the Kromboom Parkway contract and most joints were positioned out of the wheel tracks to minimise traffic related joint deterioration.

RESULTS OF APPLIED BEST PRACTICE ASPHALT CONSTRUCTION PROCEDURES

Cape Town International Airport

Asphalt layer densities were generally found to be within specifications throughout the main contract. However on two occasions, on a subsequent contract, asphalt densities in the thin wearing course layer could not be obtained due to the full roller team not being available during cold windy night time operations (these failed sections were part of additional work done at the end of the original contract during an embargo winter period, July to August, when asphalt paving (especially at night) was not “allowed”).

The average section densities obtained in the harsh, stiff wearing course mix varied from 93.2% to 94.3% MTRD (93% minimum specification) with outstandingly consistent inter-lot standard deviations of 0.2% to 0.5% recorded. Marvell permeability values were consistently below 1 l/h with maximum values of 3 l/h recorded. The upper and lower BTB layers produced even more consistent results and no “out-of-specification” rejected sections were measured. The average densities in the Gilsonite stiffened upper BTB layer was 94.5% MRTD and those in the lower softer BTB layer was 95.5% MTRD. On various occasions the rollers had to be removed from the thick BTB layers before completion of the established rolling effort due to the densities becoming too high (> 96% MRTD).

Density and permeability measurements carried out on all the hot tandem-paved joints confirmed the superior nature of these joints. ITS (Indirect Tensile Strength) tests performed on cores taken from these joint interfaces, as well as extensive core density and Marvell permeability measurements, show that no discernible differences can be detected between the hot “joint” and the rest of the asphalt layer.

Cold constructed joints were consistently tested with both cored sample (hot side of joint) and nuclear gauge density (across joint) measurements as well as Marvell penetration testing (tested across joint). Density results showed average section densities of 91.8 % MTRD with inter-lot standard deviations of 1%. Marvell penetration testing confirmed the superior nature of the special joint sealing techniques employed. Permeability values on all accepted areas ranged between 3 λ/h and 15 λ/h before the application of the horizontal surface “Viaseal” (thick rubber-bitumen tack coat) and were all below 3 λ/h (mostly below 1 λ/h) after the “Viaseal” was applied. See Figure 2 for illustration of completed longitudinal joints.

The constructed layers have been exposed to traffic for approximately 24 months at the time of compilation of this paper and no rutting, joint cracking or other defects had been detected.

Kromboom Parkway

Similar asphalt density and joint construction results, as reported for the CTI Airport contract, were recorded. The high consistency of wearing course field densities confirmed the thorough rolling effort. The average section densities were generally 0.7% to 1.5%

above the minimum specification of 92% MTRD with inter-lot standard deviations of 0.3% to 0.6%.

The riding quality of the completed surfacing increased significantly, confirming the effectiveness of the applied " best practice" procedures followed. The riding quality index increased from an estimated PSI level of 2.9, prior to rehabilitation, to a level of 4.7 after completion.

No wheeltrack rutting or any joint deterioration was detected on the asphalt layers to date (after 2 years, or approximately 15% into the design life). See Figure 3 for general view of the completed road surface.

CONCLUSIONS AND RECOMMENDATIONS

It was concluded from this study that the necessary fundamental technology and best practice asphalt construction techniques are available in the worldwide body-of-knowledge on asphalt production and construction. Innovative and rigid application thereof may render much higher quality products than alternative, highly technical, mix design studies and design technique modifications.

The authors and design engineers involved concluded that this practical asphalt mix construction optimisation study was extremely successful due to:

- Knowledge optimisation through partnering constituted between the industry, various academic and research institutes, the design engineers, the asphalt suppliers and the paving contractors;
- Asphalt design methodology taking full account of construction criteria and aspects (construction trials to define compaction efforts);

It was further concluded that:

- High quality asphalt related contract specifications should contain adequate (and in some cases even detailed) best practice construction procedures;
- Asphalt suppliers and related industry shareholders must ensure that the best practice construction fundamentals are rigidly employed. This will enhance the ability of asphalt to cost-effectively compete with rival products, especially in the high performance areas where it competes with concrete and paving block base and surfacing layers.

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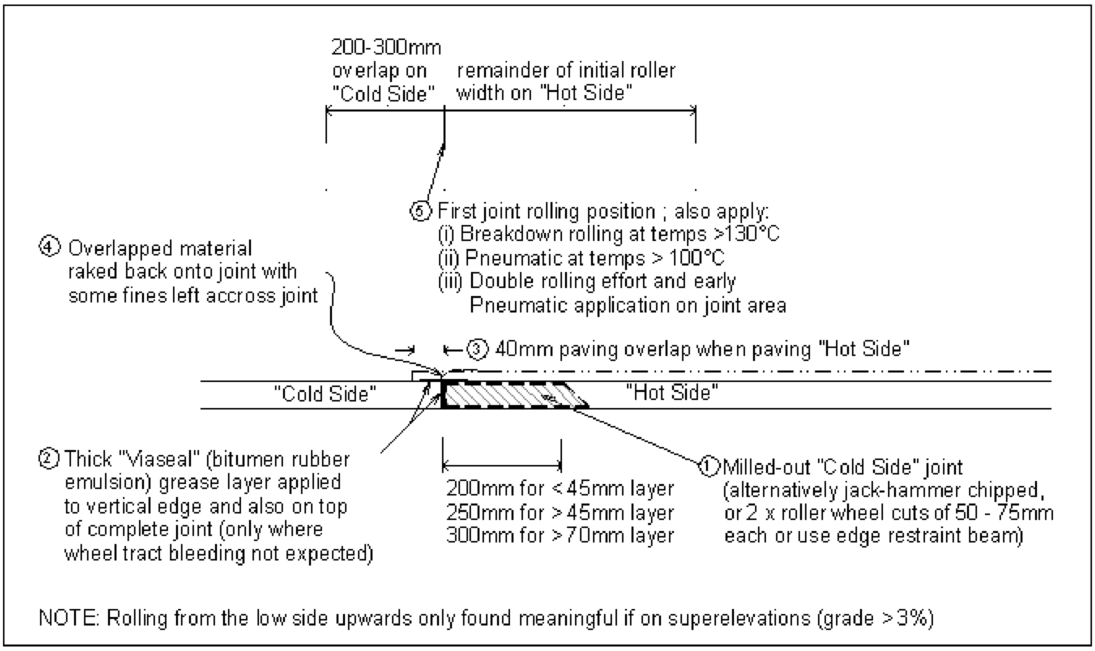

Figure 1: Cold Joint Construction Technique

Figure 2: CTI Airport Taxiways Longitudinal Joint Surface Sealing