GB5® HIGH MODULUS ASPHALT

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ABSTRACT

With ever increasing volumes of traffic on South African roads, and particular that of heavy vehicles, the road building industry has recognized the need for specialised asphalt mixes to address the rutting and fatigue problems experienced currently.

GB5 is a cost effective asphalt base mix, designed for high performance and long life, similar to stiff grade bitumen mixes (EME's). This mix can be produced with most of the aggregate and bitumen road grade types available in South Africa that is currently being used in the production of hot mix asphalt. Usage of this mix will allow for reduced pavement thickness, increased longevity and decreased rutting.

The GB5 alternative controls the volumetric properties by optimizing the combination of fine and coarse aggregates, resulting in an interactive network of particles in the mix to obtain a high stiffness modulus; at the same time uses modified bitumen, instead of high binder contents to obtain good fatigue properties.

GB5 has already proven itself in France, where it was developed, under heavy traffic (more than 500 000 tons paved) where legal axle loading limits are significantly higher than those in South Africa. The extensive trials done in eThekwini Metro in KZN have shown that the GB5 technology has now successfully been transferred to South Africa.

BACKGROUND

The need for asphalt base and surfacing mixes that can perform well without premature rutting or cracking under extreme loading led to research worldwide into stiffer, stronger layers. The idea of a perpetual road where only the wearing course becomes a sacrificial layer that can be rehabilitated or replaced became the goal. In the USA the road authorities embarked on their Superpave concept and spend a lot of time and money to research new designs and test methods based on performance of the binders and mixes.

In Europe the French developed the EME (Enrobé à Module Élevé). EME mixes are produced using hard paving grade bitumen (10/20 Penetration Grade) applied at a high binder content (approx. 6%). Compared to conventional asphalt bases with unmodified

binders, high modulus asphalt is characterised by high stiffness, high durability, superior resistance to permanent deformation and good fatigue resistance. The EME technology was successfully transferred to South Africa and resulted in publishing Sabita Manual 33.

This has led to the development and use of high modulus mixes, one being GB5. This product was developed by Eiffage, a large multi-faceted French company based in Lyon, and it is being used successfully in France. Here in South Africa, Francois Olard, Eiffage Travaux Public's R&I Director, presented an informative paper at CAPSA 2011. After a thorough investigation by Much Asphalt, who saw the potential for the use of GB5 on heavily stressed roads and bus routes, reached agreement with Eiffage to introduce GB5 into South Africa.

eThekwini Municipality's Road Provision Branch, which has a well-established policy of introducing innovations in pavement materials and design systems, were approached by Much Asphalt to consider a trial using GB5. At a meeting held on 3 March 2014, a decision was taken to proceed with a plant trial mix, utilising a short section on Brighton Road on the Bluff, which was already earmarked for an overlay. It was also agreed that, should these trials be successful, consideration would be given to utilise GB5 on a larger rehabilitation project. Subsequently more than 10000 tons of GB5 were laid on Solomon Mahlangu Road (the extension of the M7 to the old Bluff Road), a very heavy trafficked road feeding the container terminals at Durban Harbour.

The information provided in this paper is specific to the experience gained in the manufacture, paving, and compaction of GB5; it includes summaries and comments on the various tests that were carried out during the course of these trials.

The paper concludes with recommendations for GB5 to be considered on both city and rural roads that carry large proportions of heavy traffic, for instance on the Bus Rapid Transport (BRT) lanes that forms part of various Metro's Public Transport plans.

TYPICAL GB5 MIX COMPOSITION & CHARACTERISTICS

Very basically GB5 consists of a stone skeleton type mix that utilises a modified binder. The aggregate grading requirements are strictly controlled, as the aggregate packing together with the modified binder, are the main contributors to the mix's typically high modulus of over 16 000 MPa. The modified binder comprises 35/50 penetration grade bitumen modified with SBS (Styrene-Butadiene-Styrene). It was found that the locally produced bitumen could be used to manufacture binder to the required specification.

Eiffage undertook the laboratory mix design in their laboratories in Lyon, France, using aggregates and binder provided by Much Asphalt. A useful environmental and cost saving measure was the inclusion of 20% of reclaimed asphalt (RA) in the mix.

The following components were recommended in the laboratory mix design:

Coarse aggregate (<14).	53%
RA (Reclaimed Asphalt)	20%
Fine aggregate: (Crusher Dust)	22%
Filler	5%
Optimum binder content	5.0%
Voids at optimum binder content	3.5%

TRIAL SECTIONS

The trials followed the well-tried format used in the WMA trials, also done in Durban with the eThekwini Metro, using several stages to reduce the level of risk to eThekwini Municipality and Much Asphalt, as well as to Aqua Transport, who were commissioned to carry out the traffic accommodation, preparation, and paving. At the completion of each stage a meeting was held with representatives of all three parties involved and the decision was taken whether there was sufficient confidence to proceed with the next step or if further information or changes to the process was required.

The most pertinent of these stages, in consecutive order were:

- Laboratory mix design. As already mentioned the laboratory mix design was undertaken by Eiffage in France, using aggregates, RA and binder supplied by Much Asphalt. This stage was approved on 3 March 2014.

- Plant mix design and paving. This important step was to carry out full-scale manufacturing of the mix in order to gain experience with the mix through the mixing plant and to gain confidence in the quality and variability of the local aggregates and modified binder. As already alluded to, the plant mix design was paved on Brighton Road on the Bluff, the work being carried out on 7 April 2014. This stage was approved after a comprehensive review and discussion of the results on 16 April 2014.

- The main trial on Solomon Mahlangu Drive commenced on 30 May, the paving of GB5 being completed on 2nd of September 2014. In all approximately 10750 tons of GB5 was paved during this period.

Discussions to assess the test results, preparation work and paving were held at frequent intervals throughout the course of the trials. During the initial stages regular pre-trial meetings were held in the morning before the paving commenced as a means of maintaining good communication between the various parties. It is worthwhile recording the high level of supervision that was maintained during both the plant mix trial and the main trial, with a dedicated supervisory and monitoring team comprising members from eThekwini Road Provision, Aqua Transport, and Much Asphalt. The team consisted of those with extensive experience in asphalt manufacture, paving and compaction, as well as less experienced technicians who monitored temperatures, number of roller passes and

compaction using a nuclear gauge. The primary aim of this team was to assist in gathering useful information on the manufacture, paving and compaction of GB5 while maintaining progress and a high standard of workmanship under restricted working hours. An on-going challenge was to accommodate the large volumes of traffic on Solomon Mahlangu Drive, especially during peaks in the morning and afternoon.

PLANT TRIAL MIX

The trial commenced with preparation work, which included milling of the existing surface as well as cutting keys across driveways to accommodate a 70 mm thick GB5 layer.

Mixing of the GB5 was carried out at Much Asphalt's Coedmore plant in Durban, the plant mix trial was successfully completed on 7 April 2014.

This being the first time that GB5 has been paved in South Africa, it was possible to gather very useful information regarding the full-scale mixing and paving of this product.

The RA was prepared using a power screen. Carefully attention was paid to the uniformity of the screened material, with samples for sieve analysis and recovered binder properties being taken at intervals during the course of the screening process. Samples of the other aggregates used in the mix were taken for analysis as delivery from the quarry took place. Particular attention was paid to ensure the uniformity of the crusher dust fraction; the grading of crusher dust supplied by commercial quarries is notoriously variable and could affect the mix's grading. It was necessary to slightly boost the quantity of filler that could be obtained from the aggregates and RA; this was achieved by introducing 4% of filler.

The modified binder was produced by Emergeco using 35/50 penetration grade bitumen from SAPREF, modified with 3% SBS. At Much Asphalt's Coedmore plant the binder was stored in an oil-heated tank that was reserved for use on this trial.

A mixing temperature of 165^{o}C and a binder content of 5.0% were targeted and approximately 200 tons was produced. As mentioned previously in this paper both the mixing process as well as the paving and compaction were supervised and monitored closely, the aim being to extract as much experience and confidence as possible from the trial. The mixing process in Much Asphalt's batch-type plant went smoothly, with the mixing temperatures close to the target temperature being achieved.

One of the main findings of the trial was that the use of a PTR (pneumatic tyre roller) was not required or desirable for GB5. Compaction could best be achieved using around 2 or 3 passes with a 12-ton 3-point steel wheeled static roller followed by a 10-ton double drummed vibratory roller. Finishing was achieved using a 4-ton double drummed roller. This roller combination produced a well-textured surface. A summary of the monitoring and test results is shown in Table 1.

Table 1 Summary of paving trial test results

Test	Average	Standard deviation
Mix temperature at weighbridge	168	6.05
Mix temperature at the paver	148	6.08
Binder content (%)	5.0	0.18
Filler content (%)	8.4	0.34
Void content (%)	2.8	0.28
Field compaction (% of voidless density)	97.1	1.41

It can be seen that the average mixing temperature was slightly higher than the targeted temperature and the mix was generally paved at around 148^{o}C. An average of 5.0% binder content was achieved, however the filler content is slightly higher than that obtained in the original laboratory mix design. This probably resulted in the lower void content of the mix, with a similar level of void contents being reached in the compacted layer.

Besides these routine tests, more advanced testing was carried out by SRT. This included rut resistance testing using the MMLS, as well as a Modified Lottman test to check the mix's susceptibility to moisture. The MMLS yielded a rut depth of 1.1 mm, indicating excellent rut resistance, and the Modified Lottman value (TSR) was found to be 92%, well over the minimum 80% requirement and an indication of the mix's low susceptibility to moisture ingress.

Samples were also submitted to the CSIR for testing, the results of which are summarised in Table 2.

Table 2 Summary of tests carried out by the CSIR

TEST	RESULTS ACHIEVED	REQUIREMENTS
Dynamic Modulus (Stiffness)	18 – 20 GPa	>14GPa **(16GPa revised)**
Resistance to Deformation RSST-C	3@55°, <0.5 @ 25°C **	<1 @55°C
Fatigue (4pt Bending Beam)	250 – 280 micro strain	>250 **(260 revised)**
Voids after 45 Gyrations	4.8 – 5.8	<6

From this summary it is evident that the stiffness of the mix exceeded the 14 GPa that is typical for GB5 mixes. The results showed that resistance to deformation at 55^{o}C using the CSIR's RSST-CH method was on the low side. It may however be necessary to reconsider the requirements for stone skeleton type mixes such as GB5, especially considering the excellent rut resistance found in the MMLS testing. The Hamburg Wheel Tracking Test will be used in future to determine resistance to deformation.

Emergeco, the binder supplier, carried out the more advanced testing of the modified binder, while Much Asphalt carried out routine Softening Point and Viscosity checks. After appraising these results and discussing the positive experience gained with paving and

compacting the GB5, the Client agreed to the further use of GB5 on Solomon Mahlangu Drive.

FULL-SCALE USE OF GB5 ON SOLOMON MAHLANGU DRIVE

Solomon Mahlangu Drive is a major arterial road, besides providing access to commuters travelling between the City of Durban and the residential suburbs of the Bluff and Wentworth, it also serves the adjacent light industries. Large volumes of laden heavies to and from the harbour's container depots use this route.

Over the years the condition of Solomon Mahlangu Drive has deteriorated under this heavy traffic loading, exhibiting cracks and localised rutting, mostly in the slip lanes at the intersections as well as in other areas where there is a concentration of slow moving or stationary heavies. It was therefore included in eThekwini Municipality's road rehabilitation programme with the investigation and design being carried out by the Road Provision Branch.

This seemed a good opportunity to evaluate GB5, which exhibits much higher stiffness properties than the asphalt mixes routinely being used in base layers, under the actual heavy traffic loading conditions that prevail along Solomon Mahlangu Drive.

The project consists of a divided 4-lane dual carriageway facility with signalised intersections at the crossroads. Besides the main traffic lanes there are passing lanes and several slip lanes.

The design included the milling of the existing lanes to a depth of 110 mm, inlaying with 70 mm asphalt base (GB5) and 40 mm SMA asphalt surfacing. In isolated areas, such as in some of the slip and turning lanes, where the concentrated heavy loadings have resulted in higher levels of deflection, the work included the installation of GlasGrid to assist in loading spreading as well as to retard crack propagation. The geo-grid is most effective when it is installed between smooth asphalt surfaces making it was necessary to mill slightly deeper so that a 20 mm layer of finely graded asphalt could be paved on top of the rough milled surface. The layer of GB5 was then paved on top of this levelling course.

With approval for the use of GB5 in the base layer having been given, preparation work commenced with the first loads of this product being paved on 29th May 2014. The large traffic volumes that had to be accommodated presented major on-going challenges, particularly with working hours being restricted to cope with the morning and afternoon peaks and getting the mix to the paver.

Valuable experience with both the mixing and paving of GB5 had been gained on Brighton Road. As with the Brighton Road trial, the mixing at Much Asphalt's Coedmore plant, as well as the preparation work and paving operations were closely supervised and monitored. One of the focuses of the laboratory was the variability of the aggregate supplied by Afrisam and Lafarge Quarries, and regular checks were carried out on these

materials as the stockpiles at the plant were replenished. The quality of the RA was continually monitored as changes in the grading and well as binder content could affect the mix uniformity and quality. The same paving and compaction equipment was used as on the Brighton Road trial.

At the paving site the monitoring team established a routine to check the number of passes of the two primary rollers, namely the static roller and the 10-ton double drum vibratory roller, which were required to achieve 96% of voidless density (MTRD), using a nuclear gauge. This level of compaction, when measured using the Troxler was found to be “safe” when compared to the results of laboratory tests carried out on core samples; the nuclear device tended to indicate percentage compaction levels around 2% lower than that found in the core test results. Temperatures of the mix as it was being tipped into the paver hopper, and again at intervals behind the paver, were measured and recorded.

Compaction of the 70 mm thick layer was generally achieved after 3 passes of the static roller and the large vibratory roller, respectively. There was usually some movement (tenderness) in the surface approaching the completion of the static roller passes, however the mix settled down and movement stopped during the 10-ton vibratory roller passes. The 4-ton double drum vibratory roller was then used for final finishing. Based on the experience gained during the Brighton Road trial, a PTR was not included in the compaction train.

Installation of the GlasGrid was easily accomplished once the site team became accustomed to the procedure. A Fine mix was paved as a levelling course, the layer was allowed to cool to less than 50^{o}C before the geo-grid was unrolled onto the surface. Several passes of a PTR were used to ensure that the geo-grid was firmly adhered to the asphalt surface. The tack coat was applied once this operation had been completed. The summary in Table 3 includes measurements recorded during the monitoring process as well as results of tests carried out in Much Asphalt’s laboratory at the Coedmore plant.

Table 3 Temperature measurements, field compaction and laboratory results

Test	Average	Standard deviation
Mix temperature at weighbridge	167	4.05
Mix temperature at the paver	145	6.2
Binder content (%)	5.0	0.10
Filler content (%)	8.2	0.35
Void content (%)	3.8	0.41
Field compaction (% of voidless density)	95.8	2.1

The result obtained were similar to the plant mix trial on Brighton Road, with slightly higher void contents being achieved on laboratory compacted samples as well as from field compaction tests.

Due to the good surface texture of the GB5 it was agreed to pave a section where the GB5 would serve as a surfacing layer. This section, on the westbound carriageway between the intersection of Solomon Mahlangu Drive and the Umhlatuzana Canal Bridge was paved to the full layer thickness of 110 mm; the GB5 therefore serves as both base and surfacing. An average texture depth of 0.8mm was obtained. The typical surface texture after approximately two years of trafficking is shown in the photograph below.

Typical surface texture of GB5

It was also agreed to include a section of continuously graded asphalt base mix (Mix B) using A-P1 modified binder. The comparison of the relative performance of GB5 and the A-P1 mixes under heavy traffic will obviously become apparent in the LTPP surveys.

PRACTICAL EXPERIENCE GAINED

The trials enabled a wealth of experience to be gained in the manufacture, paving and compaction of GB5, while the test results provide useful information on GB5's properties.

Quality and uniformity of the aggregates supplied by local commercial sources was found to be satisfactory to produce GB5 within its tight grading requirements without additional screening being required; it was however found necessary to monitor the gradation of the aggregates regularly, particularly those of the crusher dust. Sampling and testing was undertaken during each new delivery to the asphalt plant. Selection of sufficient quantities of RA with generally similar qualities in terms of grading and binder content was necessary. Screening to obtain a uniform sized product was undertaken otherwise the gradings would have been too variable.

Penetration grade (35/50pen) bitumen produced by SAPREF was successfully modified off-site to meet GB5 design requirements.

The trials verified the laboratory mix design carried out in Eiffage's laboratory in Lyon, with similar results being achieved in both laboratory and full-scale mixes.

Besides the information provided by the laboratory, the dedicated monitoring team recorded aspects such as mix temperatures at the weighbridge and during delivery of the mix to the paver. These, together with the results of the more advanced testing by SRT and the CSIR, could be used to compile a practical project specification for other projects.

No problems directly attributable to GB5 were encountered during the mixing process using Much Asphalt's Coedmore batch-type asphalt plant. The mix required the addition of 4% of bag-house filler. This required the erection of a silo to store the filler obtained from other mixes.

Paving of GB5 was straightforward and very similar to the techniques used for other conventionally used asphalt mixes. The compaction method that was developed early in the trials was to use a 12-ton 3-point steel-wheeled roller, followed by a 10-ton double drum vibratory roller, with a 4-ton double drum vibratory roller carrying out the final compaction and finishing. It was found that around 3 passes of each of the former rollers was sufficient to raise the level of compaction to 96% of voidless density. It was noted that after the initial break down rolling using the 3-point roller, compaction increased gradually, and there were even further small increases in compaction when the smaller 4-ton roller was used. No sudden stiffening up as the layer cooled and compaction increased was evident, it was not necessary to take special care that the layer did not become too stiff before the compaction and finishing had been completed.

Construction of the GB5

The trial section carried out using GB5 in a 110 mm layer where it acts both as base and surfacing proved successful and is currently performing well after more than two years of trafficking.

Subsequently a further 1250 tons were paved on South Coast Road in November 2014. Two trial sections has also been done on SANRAL projects. In May 2016, 870 tons were paved on the N3 Northbound from Pietermaritzburg up Townhill towards Hilton from the Much Pietermaritzburg Plant and in June 2016, 350 tons were paved on the N2 Southbound between EB Cloete Interchange (Spaghetti Junction) and the M7 / Edwin Swales Intersection. On the N2 rutting values of 1.41mm (MMLS) and 2.2mm (Hamburg Wheeltracking) were obtained.
Much Asphalt submitted an application to Agrément South Africa (CSIR) for a “fit for purpose” certification.

CONCLUSION AND RECOMMENDATIONS

Experience gained from these extensive trials show GB5 to be a high modulus base mix that can be used advantageously in situations where the pavement carries high axle loadings, such as busy freeways, streets and bus routes. The work described in this paper showed it to be practical to maintain the strict grading requirements using locally produced aggregates while the manufacture of the modified binder in the mix was well within the capabilities of local suppliers. The use of 35/50pen bitumen produced by local refineries in the manufacture of the modified binder has logistical and pricing advantages compared to specialized imported binders.

The use of GB5 in the surfacing layer showed great potential; testing shows it to be highly resistant to rutting with a good macro-texture.

Although it is very early in the pavement’s life, the performance to date over the full length of the project is excellent; after several seasons of hot weather there are no visual signs of rutting or cracking.

GB5 has already proved itself in France under heavy traffic where legal axle loading limits are significantly higher than those in South Africa. These extensive trials have shown that the GB5 technology has now been successfully transferred to this country.

It is therefore recommended that GB5 be considered on other projects that carry large proportions of heavy traffic, for instance on the Bus Rapid Transport (BRT) lanes that form part of the Metro’s Integrated Rapid Public Transport Network (IRPTN), where the design has to cater for abnormally high axle loads.

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