Modified Dry-bound Macadam (MDBM) - a Logical step towards Water-wise base-course construction.

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***Abstract*— Climate change have an enormous impact on the livelihood of communities and also impact on the road-building industry, as water for road construction and the compaction of the upper crushed stone base layers will become scarcer and scarcer. Therefore, construction methodologies, approaches and design philosophies which require less compaction effort, or no water in the upper pavement layers must be further pursued, especially in a rural and social economic context.**

Water bound Macadam proved to be an economical base type on a number of roads in Southern Africa in the past. Lower long term maintenance costs, good draining properties and very high resistance to shear failure under adverse environmental conditions are key attributes in the long term pavement performance. Drastic water shortages and drought conditions calls for seriously revisiting the Dry-Bound Macadam technique.

Dry-bound Macadam is not a well- known construction method. It utilizes a single sized larger coarse aggregate fraction and a binary smaller sand/crusher dust fraction with hardly any fines which is easily locked in place without the aid of heavy plant equipment, with or/-out the aid of additional compaction water. Literature on the topic is relatively scarce and does not differentiate a lot of detail between the construction methodologies between, Water-bound macadam, Slurry Bound Macadam and Dry-bound Macadam.

The Modified Dry Bound Macadam (MDBM) was refined and developed on this project. The incorporation of a smaller single sized stone to accommodate 50mm construction lifts, using only the available moisture in the fine crusher dust/ river-sand mix. Smaller plants were successfully introduced to achieve excellent compaction in confined conditions. Appropriate penetration slurries and seals were also used to accommodate the site challenges faced in the Abel Erasmus Pass, slope/wash-away repair contract. (SANRAL Contract R036-060-2015/1)

Keywords—Coarse Aggregate; penetration slurries; Modified Dry-Bound MacAdam; stage construction; training; evaluation panels;

I. INTRODUCTION

Climate change is expected to have a considerable impact on the social-economic environment in South Africa with a significant impact on existing and future transport infrastructure. The need for improved water preservation and water wise construction technologies must not be underestimated as construction water will become a scarce resource. The future availability of potable compaction and slushing water during the construction and rehabilitation of flood damaged roads might soon be a “sought after” phenomena.

A slip / wash-away occurred during the January 2012 floods on the Abel Erasmus Pass (R36-4) between Orighstad and the Strijdom Tunnel, between kilometres 60 and 61 (Fig. 1). This called for a 14m high slope stabilization reconstruction, which fall outside the scope of this paper. However, the construction of and Bitumen Stabilized Material (BSM) sub-base support layer, as well as a Coarse Aggregate Base, with labour intensive methods and the minimum use of added moisture are the key aspects of this paper, as the limited smaller pavement repair of the upper pavement provided an ideal opportunity to further investigate, develop and implement this technique in a rural context.

The adopted pavement design philosophy was adapted to support the road geometry as well as for the use of local labour in a very confined and restricted construction environment within the pass. The technique of slurry Penetrated Water bound Macadam has proved to be feasible from a construction point of view, forming the basis of a practical self-draining construction base and lane. This was proven in the Southbroom Experiment (Section N2/20) [1].

Fig. 1 Locality map of the Abel Erasmus pass on the R36-4.

II. GEOLOGY

According to the 2430 Pilgrims Rest 1:250 000 geological map, the Abel Erasmus Pass section under repair and rehabilitation is underlain by dolomite and chert of the Transvaal Supergroup, Chuniespoort Group and the Malmani Subgroup [2].

The road construction aggregate for the sub base (BSM), Coarse Aggregate (Modified Dry bound Macadam-MDBM) and Surfacing seals and slurries were sourced from commercial sources at Tzaneen. Achaean granitoid intrusions, associated with the Pietersburg and Giyani greenstone, as well as the Northeastern Kaapvaal Craton, of Neoarchaean age (2800-2500 Ma) are known as the Duivelskloof Leucogranite and Turfloop Granite bodies, which are mined for concrete and road aggregates in Polokwane (Pietersburg) and Tzaneen (Fig. 2).

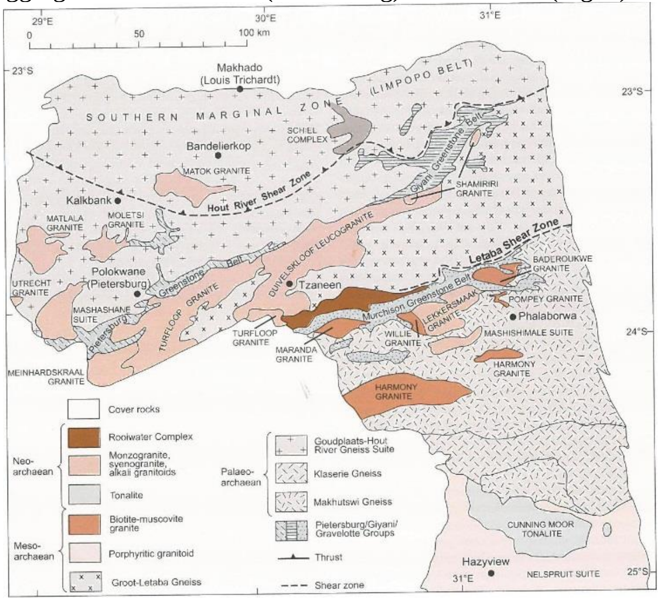

Fig.2 Map of the northern and eastern sector of the Kaapvaal Craton showing the various granitoid occurrences in the vicinity of Tzaneen [3].

The Turfloop Granite is of the dominant variety, which varies between light grey and pinkish grey in colour and is medium to coarse grained, with rare porphyritic phases. Plagioclase, quartz, orthoclase/microcline, biotite and some muscovite make up the bulk of the rock. Magnetite, ilmenite and sphene are minor constituents. The presence of epidote and chlorite can be ascribed to subsolidus alteration. Small enclaves of mafic material and grey gneiss are common.

The contacts of Duivelskloof Leucogranite and surrounding granitoid gneisses and the Turfloop Granite is not well defined. The Leucogranite is an off-white, medium grained rock, which can locally grade into a pegmatoidal variety. The rock has a massive appearance, although it becomes somewhat finer grained and relatively richer in darker minerals closer to the contact with the greenstone belt. The main constituents of the rock is sodium plagioclase, quartz, orthoclase, microperthitic microcline and muscovite. The leucogranite varies in composition from a syenogranite to a monzogranite and is more aluminum rich (peraluminious) in character.

III. OBJECTIVES

The R36 is a lower volume route situated in a rural area, which includes the Abel Erasmus pass. The repair section of this project is a considerable distance from commercial asphalt plants situated in the city of Mbombela (Nelspruit) and Polokwane (Pietersburg).

The engineering geological and resulting geotechnical behaviour of many rocks, and resulting performance is in most instances dominated by the historic tectonic environment during the Archaean Kaapvaal Craton tectonic evolution, which is never considered in the final pavement and surfacing design criteria.

The material from the Tzaneen Crushers superficially appeared as good fresh granite of mixed origin, and is generally considered to be a very useful aggregate on the outside surface alone. The objectives of the project were:

- Employ water saving technologies for base construction;
- Use of locally available aggregate;
- Use of local labour for job creation;
- Use of smaller plants to promote more environmentally friendly construction practices (fuel emissions);
- Stage construction of more regular and thinner surfacing seals;

IV. METHODOLOGY

At the onset of the project, the local construction materials were sampled and submitted for laboratory testing and analysis. At the same time, training of the local labour commenced on this construction technique, using small test panel sections. When the laboratory results became available (Table. 1 and Table 2), a final pavement design and method specification were done.

TABLE I. COARSE AND FINE AGGREGATE FIELD MOISTURE AND DENSITY

Description	Moisture Content (%)	Density (kg/m^3)
DBM Coarse Aggregate	1.3	2849
River sand	7.5	2743
Red Fine in-situ sand	2.9	2795

TABLE II. DBM AND FINE AGGREGATE SIEVE GRADINGS

Sieve Analysis (mm)	Final DBM grading	River sand component	Red Fine sand component
37.5	100		
26.5	86		
19.0	80		
13.2	65	100	100
4.75	34	97	99
2.0	25	86	93
0.425	14	49	64
0.075	4	9	45

Construction of training and test panels comprises pits of 5 m by 3m within the in-situ red dolomitic soil. Each test panel was 200 mm deep. The bottom in-situ material of each test panel was thoroughly compacted with a pedestrian roller, using static and vibrating mode.

The best methodology, which was determined experimentally, comprised a mixture of all three fractions. The volumetric ratios were 66% coarse aggregate and 34% fine aggregate. The fine best fine aggregate blend comprised 67% river sand and 33% red soil. If the fractions were introduced separately into the test panel it was extremely difficult to transport or vibrate the fine aggregate into the open pores of the coarse aggregate without using flushing water.

No additional water was used during the construction of any of the test panels. The test panels were constructed in individual lifts of 50 mm. The natural moisture content (3% to 5%) as reflected in Table. 1 proofed to be adequate to ensure good compaction and the weighted moisture content of the final DBM layer was 2.88% (Fig. 3).

Fig.3 Various DBM test panels with and without penetration slurry for training and evaluation purposes.

The thickness of the Bitumen Stabilised Base (BSM) of the various test panels were obtained through a design which required a rise with a thickness of 150 mm, and were placed using two lifts of 75 mm each. All mixing was performed in a concrete mixer and compacted with a pedestrian roller.

V. CONSTRUCTION ON THE R36 PASS SECTION

The extent of the flood water damage (total wash away) within the Abel Erasmus pass was approximately 300 m by 5 m. The first step to repair the damage of this section of the R36 was to construct a seek and pile wall, but due to geotechnical and integrity challenges of the dolomitic bedrock at depth, it was decided that a rock anchoring option would be more suitable to stabilize the high fill. The backfill was completed in stages with additional geo-fabrick reinforcement according to the geotechnical design.

The BSM layer of the repair section covered started at 350 mm to 375 mm below the final road level, depending on cross fall and grade. The thickness of the impervious BSM layer was 150 mm thick.

The final step was to construct the coarse aggregate base as a drainage layer, with a thickness of 200 mm. This layer was constructed with optimum moisture content (OMC) of 6.5%, as per the OMC laboratory determination (Fig. 4). It was achieved with two lifts of 100 mm (Fig. 5), making use of a sit-on roller (static and vibrating mode) of two tons (Fig. 6). In order to create haulage and traffic accommodation a penetration slurry was applied.

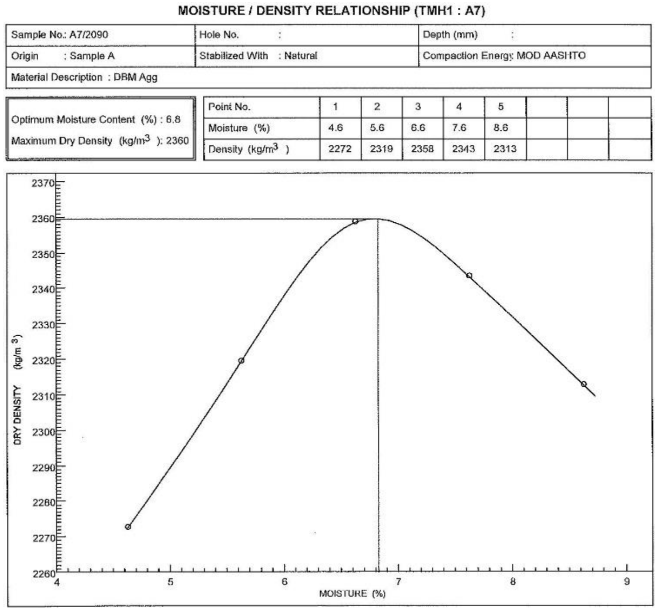

Fig.4 Optimum moisture content OMC curve for the coarse aggregate base on the R36 as determined by SGS MATROLAB.

Fig.5 Final coarse aggregate prior to placement of the penetration slurry.

Fig.6 Final placement of the composite Macadam layer, showing the combination of labour and two ton sit-on roller.

VI. CONCLUSIONS

In conclusion the construction method proved to be successful if measured against the objectives due to the following reasons:

- It was possible to train unskilled labour to master the technique;
- Labour and smaller plants combined seamlessly during the construction phase(s), resulting in lower carbon footprint;
- This construction technique is not more time consuming that that of conventional construction techniques;
- According to laboratory results, the use of different sizes of aggregate simulates a G1 grade material;
- This technique has the potential to achieve a construction water saving of up to 60%;
- Due to the fact that no warm asphalt is needed, it reduces the risk of burn injuries by labourers and reduce the associated construction and health risk;
- This method is more susceptible to more frequent thinner surfacing, more sustainable for job creation and smaller contractors, while addressing the potential damage of asphalt due to higher ultra-violet radiation as a result of climate change [4].

VII. RECOMMENDATIONS

Stage construction in future coarse aggregate base construction utilizing no to limited additional moisture must be considered as an alternative design option where feasible, especially in arid and desert environments. It is also recommended that the pavement surveillance (riding quality and deflection measurements) as well as laboratory testing is conducted on a regular basis. This will finalize a method specification and or performance specification for Modified Dry Bound Macadam (MDBM) layers.

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