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Development of the slurrybound Macadam construction technique

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APPENDIX I: Draft COLTO-format specification for Slurrybound Macadam Surfaces

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PA01 SCOPE

This section covers the construction of slurry-bound and composite Macadam layers by means of labour-intensive methods.

PA02 MATERIALS

(a) Conventional Binders

The various bituminous binders specified shall comply with the relevant SABS specifications stated below:

Bitumen emulsions	SABS 309 (anionic) SABS 548 (cationic)

(b) Aggregates

Coarse and fine aggregate shall be clean and free from decomposed materials, vegetable matter and other deleterious substances and shall meet the requirements of COLTO Sections 3600 and 4300.

(i) Resistance and crushing

The aggregate crushing value (ACV) of the coarse aggregate, when determined in accordance with TMH1 method B1, shall not exceed the following values for aggregate used for:

Base and surfacing.....25

Rolled-in chippings, open graded surfacing
And stone-mastic asphalt.....21

The minimum dry 10% FACT values of the -13,2mm +9,5mm fraction shall be as follows:

Other surfacing and base.....160 kN

The wet/dry ratio shall not be less than 75%.

(ii) Shape of the aggregate

Base:

The flakiness index when determined in accordance with TMH1 method B3 shall not exceed 35 for the minus 26,5mm sieve plus 19,00mm sieve and minus 19mm plus 13,2mm sieve fractions respectively.

In addition, at least 50% by mass of the individual retained on each of the standard sieves with a square mesh size of 4,75mm and larger shall have at least one fractured face.

Surfacing and rolled-in-chippings:

The flakiness index for surfacing asphalt and rolled-in-chippings shall not exceed the values given in table 4202/5. The grades refer to the single sized crushed stone grades as defined in sub clause 4302(b).

Table 4202/5

Nominal size of aggregate (mm)	**Maximum flakiness index %**		
	Surfacing aggregate		**Rolled-in-chips (all grades)**
	Grade 1	**Grade 2**	
19,0	25	30	20
13,2	25	30	20
9,5	30	35	-
6,7	30	35	-

In additional, at least 95% of all particles shall have at least three fractured faces.

(iii) Polishing

The polished stone value of aggregate, when determined in accordance with SABS method 848, shall not be less than the following values for aggregate used for:

Continuously and open-graded surfacing
And stone-mastic asphalt surfacing.....50
Gap-graded surfacing.....45
Rolled-in chippings.....50
Macadam surfacing.....45

Aggregates with polishing values below those stated above may be approved for use by the engineer.

(iv) Adhesion

When tested in accordance with TMH1 method C5, the immersion index of a mixture of the binder and aggregate proposed for use shall not be less than 75%. The aggregate used for the text mixture shall have a grading within the actual limits for the mix concerned.

(v) Absorption

When tested in accordance with TMH1 methods B14 and B15, the water absorption of the coarse aggregate shall not exceed 1% by mass, and that of the fine aggregate shall not exceed 1,5% by mass, unless otherwise permitted.

(vii) Sand equivalent

The total fine aggregate used in all Slurrybound Macadam mixes shall have a sand equivalent of at least 50, when tested in accordance with TMH1 method B19, and the natural sand where it is permitted to be mixed with the aggregate shall have a sand equivalent of at least 30.

(viii) Design requirements

The contractor shall, by conducting the necessary tests, satisfy himself that he will be able to produce a mixture meeting the design requirements specified hereinafter, using the aggregate he proposes to supply, within the grading limits specified.

(ix) Grading

<u>General</u>

The coarse aggregate forms the skeleton that carries the whole load through direct stone-to-stone contact to the supporting layers. This structure provides high load bearing capacity. The fine aggregate or slurry provides the stability of the layer.

<u>Coarse Aggregate</u>

In general the average least dimension (ALD) of the coarse aggregate must not exceed one third of the layer thickness. In addition the grading must be such that the sufficient voids remain to be filled with filler sand or slurry. The following gradings are recommended for the various layer thicknesses.

Table 3.1

Composite Macadam: Recommended grading for selected layer thickness

Layer thickness (mm)		75	
Bottom (45mm)	Grading: Normal size(mm)	53	*Sand filler
	ALD (mm)	32	
Top (30mm)	Grading: Nominal size (mm)	19 or 16	Slurry filler
	ALD (mm)	12 or 10	

*Sand may be replaced by slurry. Costs may not be excessive for large areas. Suitable for smaller areas like bus/taxi ranks.

Table 3.2

Slurrybound Macadam: Recommended grading for various layer thicknesses

Layer thickness (mm)	50		40	30	25
Nominal size (mm)	26,5	19	19	16	13,2
ALD (MM)	16	12	12	10	7

The proposed grading envelope of the respective nominal sizes is given in table 3.3.

Table 3.3: Recommended gradings

Sieve size (mm)	**Percentage by mass passing**				
	53mm	37mm	26,5mm	19,0mm	13,2mm
75	100				
53	85 -100	100			
37,5	35 -70	85 – 100	100		
26,5	0 – 15	0 - 50	85 - 100	100	
19,0	0 - 5	0 - 25	0 - 30	85 - 100	100
13,2		0 – 5	0 – 5	0 – 30	85 - 100
9,5				0 – 5	0 – 30
4,75					0 – 5
0,075					

(x) Aggregate for slurry

The specified grading limits for the filler slurry are also a function of the layer thickness. The following gradings are recommended for the various layer thickness.

Table 3.4: Recommended grading for the slurry filler

Sieve size (mm)	Percentage passing by mass					
	Fine grade			Medium grade		
6,7 4,75 2,36 1,18 0,6 0,3 0,15 0,075	100 90 – 100 65 – 95 42 – 72 23 – 48 10 – 27 4 – 12			100 82 – 100 56 – 95 37 – 75 22 – 50 15 – 37 7 – 20 4 – 12		
Appropriate layer thickness (mm)	25	30	75 (top part)	40	50	75 (bottom part)

(xi) Fillers

Ordinary Portland cement shall comply with SABS 471 and Portland blast-furnace cement (PBFC) with the requirements of SABS 626.

Road lime shall comply with the requirements of SABS 824 (Lime for Soil Stabilization) and shall bear the SABS mark.

Only one of the above materials shall be used throughout. In order to prevent undesirable colour differences in the surface.

(xii) General

All materials shall be handled and stockpiled in a manner that will prevent contamination, segregation or damage. Cement and lime shall be used in the order in which it has been received.

The contractor shall, as often as necessary, test and control the materials produced by himself or the materials received by him from suppliers to ensure that the materials always comply with the specified requirements.

In general the contractor will not be expected to construct layers in which the nominal maximum aggregate size exceeds two-thirds of the compacted layer thickness.

PA03 COMPOSITION OF MACADAM BASE AND SURFACING MIXTURES

Surfacing Mixtures

The rates of application and mix proportions of bituminous binder, aggregates and fillers given in table 3 are nominal rates and proportions and shall only be used for tendering purposes. The rates and proportions actually used shall be determined to suite the materials used and conditions prevailing during construction and any approved variation on a nominal mix in the bitumen content or active filler content shall be the subject of an adjustment in payment for binder or active filler variations as described.

Before production or delivery of the SBM the contractor shall submit samples of the materials he proposes to use in the mix, together with his proposed mix design as determined by an approved laboratory, to the engineer so that the engineer may test the materials and confirm the use of the proposed mix if he is satisfied that it meets the specified requirements. The engineer also reserves the right to change aggregate blends in order to allow the selection of any combined aggregate grading, within the specified grading envelope(s) for the proposed mix.

As soon as the material becomes available the contractor shall produce a working mix in the plant in accordance with the design mix. The working mix shall again be tested by him for compliance with the design requirements. Samples of the working mix and the test results shall also be made available to the engineer, who will authorise the use of the working mix proportions approved for use in the trial section. Final approval of the working mix will be subject to the approval of the trail section. The composition of the approved working mix shall be maintained within the tolerances.

	Combined per 1m³ SBM	Combined per 1m³ slurry
Coarse aggregate	1m³	N/A
Slurry Aggregate	0,4m³	1m³
Netto Bitumen Binder	4%	220 ℓ
Cement *by mass of aggregate)	0,4%	1%
Water (maximum)	60 ℓ	150ℓ

Table 3: Nominal mix proportions of SBM-materials for tender purposes.

PA04 PLANT AND EQUIPMENT

The slurrybound and composite Macadam layers are constructed at very low mechanisation levels. A typical construction team of eight to ten workers need to be equipped with the following:

1 Pedestrian roller or plate compactor
2 Shovels
2 Ballast forks
4 Wheelbarrows
4 Squeegees
2 Rakes
1 x 3m straight edge (screed board)
2 Bass brooms
1 3m x 2m Hessian cloth
4 Measuring containers

Material does not require any heating and is used at ambient temperatures.

The following protective clothing needs to be provided.

- Gloves
- Overalls
- Gumboots

PA05 CONSTRUCTION

PA05.01 Slurry-bound Macadam

The Macadam ballast is spread evenly but to the required thickness. It is then levelled out with rakes, shovels and screed boards and compacted. A penetration slurry is then mixed and evenly spread over the Macadam surface by wheelbarrow, shovels and squeegees. A pedestrian type plate vibratory roller is then used to achieve penetration of the slurry until all the voids within the Macadam are filled. A final slurry is then applied in accordance with the TRH3 requirements.

A moist burlap drag shall be drawn over the final slurry to ensure an overall and even texture. The burlap will be dragged perpendicular across the centre-line of the road. Should breaking of the emulsion, segregation of the mix or formation of lumps occur during the application of slurry, the slurry operations shall be discontinued at one and any defective material removed from the road. Successive strips of slurry shall overlap transversely by not less than 25mm not more than 150mm. Any overlapping and any omitted areas shall be rectified with squeegees. The contractor shall ensure that either edge of the slurry is finished to the prescribed widths and lines. All stones dislodged in the process of applying the slurry shall be removed on the same day on which the slurry seal has been applied. All spillage of slurry or excess slurry shall be neatly removed from the road and spoiled.

Where slurry is spread by hand, the squeegee squad shall be allowed to complete the spreading of each batch onto the road, using squeegees, before the next is discharged. The slurry shall then be worked from side to side and criss-cross with the aid of squeegees so as to fill as many spaces as possible.

The finished slurry slayer shall present a smooth, dense and homogenous surface, true to level and camber on cross fall and free from tear cracks, corrugation, rutting or any other irregularity. It shall be free from depressions or elevations and when a straight edge two metres long is laid on the treated surface parallel or at right angles to the centre-line of the road, the surface shall nowhere vary from the lower edge by more than 3mm along the treated area. The outer edge of the slurry shall be formed neatly in a straight line to the widths ordered by the engineer.

The slurry shall be left open to the atmosphere to age and oxidize for a minimum period of 4 weeks, i.e. the slurry shall not be overlaid with any seal or asphalt for 4 weeks.

No slurry shall be laid when the air is less than 10˚C and in any event not during rain or when free water is standing on the surface.

PA06 LAYING TRAIL SECTIONS

Before the contractor commences with the construction of any SBM base or surfacing, he shall demonstrate, by laying a trial section of between 300m² and 600m² in area, as specified, depending on the required layer thickness, that the equipment and processes that he proposes to use, will enable him to construct the particular SBM course in accordance with the specified requirements.

The engineer may require that up to 3 different binder contents be incorporated in one such trail to verify the laboratory design phase.

Amongst others the contractor shall submit dynamic test results obtained from the testing of cores extracted from the completed trial section in locations determined by stratified random sampling methods, and/or, if specified, dynamic test results obtained from briquettes prepared from materials obtained by stratified random sampling methods at the manufacturing plant or behind the paver as directed by the engineer.

A maximum period of 10 days shall be allowed to verify dynamic creep test results unless otherwise specified in the project specifications.

Only when such a trial section has been satisfactorily laid and finished, and complies with the specified requirements, will the contractor be allowed to commence with construction of the permanent work.

If the contractor should make any alterations in the methods, processes, equipment or materials used, or if he is unable to comply consistently with the specifications, the engineer may require that further trail sections be laid at the contractor's cost before allowing the contractor to continue with the permanent work.

The intention of this clause is to avoid any experimentation by the contractor on the permanent work.

The trial sections shall be laid where indicated by the engineer. The contractor shall prepare the surface on which to lay the trial section and shall also, if required, remove the trail section after completion and restore the surfaces on which it was constructed, all at the contractor's cost.

Provision is made for payment of the first approved trial section of any particular mix type, but subsequent trial sections with the same mix type shall be at the contractor's own cost. Payment will be made for the specified area of each approved first trail section for any particular mix type.

The construction equipment and techniques as well as the mix properties applicable to the approved trail section shall not be changed without prior approval by the engineer.

PA07 PROTECTION AND MAINTENANCE

The contractor shall protect SBM base and SBM surfacing from all damage until the work is finally accepted by the engineer and he shall maintain the surfacing work until the issue of the maintenance certificate. Excepting fair wear and tear on surfacing any damage occurring to the completed base or surfacing during the maintenance period, or any defects which may develop due to faulty workmanship, shall be made good by the contractor at his own expense and to the satisfaction of the engineer.

PA08 CONSTRUCTION TOLERANCES AND FINISH REQUIREMENTS

PA08.01 Construction tolerances

The completed sections of slurrybound or composite base and surfacing shade comply with the requirement for width, thickness, cross section and smoothness stated below.

(i) Width

The average width of both asphalt base and surfacing shall be at least equal to that shown on the drawings and nowhere shall the outer edge of the layer be inside the lines shown on the drawings by more than 15mm in the case of both asphalt base and asphalt surfacing.

(ii) Thickness

The thickness tolerances referred to in clauses 8205 and 8305 shall be as follows:

D90 base	=	15mm	surfacing = 4mm
Dmax base	=	20mm	surfacing = 8mm
Dave base	=	5mm	surfacing = 2mm

Thickness shall be determined from carefully controlled levels taken before and after construction in exactly the same position and/or from cores drilled from the completed layer.

(iii) Cross section

When tested with a 3m straight-edge laid at right angles to the road centre line the surface shall not deviate from the bottom of the straight-edge by more than6mm for freeways and more than 10mm for other roads.

At any transverse section the difference in level between any two points shall not vary from their difference in level computed from the cross section shown on the drawings by more than 15mm for freeways and 20mm for other roads.

(iv) Surface regularity

The maximum value of any individual irregularity when measured with the rolling straight-edge or a 3m straight-edge laid parallel to the road centre line:

Freeways

Asphalt with rolled-in chippings…….....5mm
Stone-mastic asphalt.....6mm
Other asphalt.....4mm
Other roads.....8mm

PA08.02 Binder Content

The binder content shall be within the limits specified in the applicable statistical judgement scheme in clause 8206 or clause 8305.

APPENDIX II

SCHEDULE OF MACADAM ROADS CONSTRUCTED UNDER THE AUSPICES OF THE AUTHOR

Location	Job nr.	Road	Extent (km)	Year	Macadam type
K13 – Krugersdorp	9412	Widening of provincial road	0.5	1994	
Randfontein	9503	Taxi-rank	-	1995	SB 125
Toekomsrus	9503	Taxi-bays	-	1995	SB 125
Mohlakeng	9503	Taxi-bays	-	1995	SB 125
Doornkop (Soweto)	9513	Low volume streets	0.5	1995	SB 75
			0.5	1995	CM 100
Baragwanath Hospital	9523	Low volume streets	0.5	1995	SB 75
Zandspruit (Randburg)	9527	Low volume streets	2	1995	SB 75
Lusaka Township Mogale	9605	Low volume streets	15	1996	CM 75
Kagiso X9	9607	Low volume streets	20	1996	CM 75
Mamelodi	9612	Low volume streets	40	1996	SB 50
Dobsonville (Soweto)	9613	Sidewalks	6	1996	SB 50
Kimberley	9614	High volume streets	10	1996	CM 100
Steinkopf	9622	Low speed	5	1996	
Kwa-Thema	9624	Collector	2	1996	CM 100
Cullinan HVS-Test section	9632	Provincial	0.5	1996	CM WM
Diepsloot	9635	Access road	5	1996	CM 75
Dobsonville (Soweto)	9640	Sidewalks	3	1996	SM 50
Meadowlands	9701	Low volume street	2	1996	SM 50
Doornkop (Soweto)	9709	Low volume streets	5	1997	CM 75
Kroonstad	9712	Low volume streets	2	1997	CM 75
Tembisa	9719	Low volume streets	30	1997	CM 75
Mamelodi	9726	Low volume streets	40	1997	SM 50
Attridgeville	9733	Low volume streets	35	1997	SM 50
Kwa-Thema (Sam Ngema Street)	9818	Low volume streets	5	1998	CM 75
Attridgeville / Mamelodi	9834	Low volume streets	20	1998	SM 50
Lusaka / Township (Mogale)	9846	Low volume streets	10	1998	SM 50
Mashishing	9848	Low volume streets	5	1998	SM 50
Cullinan	9901	Low volume streets	4	1999	SM 50
Kwa-Thema (Raborife / Ndlovu)	9914	Low volume streets	2	1999	SM 50
Makapan Tower Access Road (Potgietersrus)	9915	Low volume access road	6	1999	SM Overlay (25-80m)
Kagiso	9918	Low volume streets	10	1999	SM overlays
Doornkop	0020	Low volume streets	4	2000	SM 25
Kagiso	0023	Overlays	5	2000	SM overlays
Qunu (Pres Nelson Mandela Private Road)	0028	Access road	0.3	2000	SM 50

Pilgrim's Rest	0030	Street network	4	2000	SM 15
Sasol	0109	Rehabilitation	1	2001	SM 180
Singobile	0111	Low volume streets	10	2001	SM 25
Marakele National Park	0113	Access road	16	2001	SM (20-80m)
Doornkop	0126	Link roads to K102 provincial	3	2001	SM 25
Tsakane	0127	Access road from provincial road	5	2001	CM 75
Soweto	0207	Low volume streets	10	2002	SM 25
Gansbaai	0318	Low volume streets	3	2003	SM 25
Durban	0321	Low volume streets	9	2003	SM 25
Victoria West	0326	Low volume streets	5	2003	SM 25
Umjindi	0413	Walkway	1	2004	SM 25
Soweto (Mole Street)	0416	Low volume – experimental road using spinning beam	1	2004	SM 25
Emfuleni Clinic Road	0424	Low volume street	1	2004	SM 25
Sol Plaatjies	0426	Low volume street	15	2004	SM 25
Wesselsbron	0506	Low volume street	5	2005	SM 25
Koffiefontein / Oppermansgronde	0507	Low volume – high speed	1	2005	SM 15
Randfontein / Eikepark	0527	Urban street network	5	2005	SM 25
Kagiso (Mogale)	0604	Overlays	10	2006	SM 25
			401.8km		

APPENDIX III

AWARDS FOR EXCELLENCE IN ENGINEERING

- 1995 SABITA award for outstanding achievement in asphalt technology for the development of the slurrybound Macadam.
- 1995 SAICE (Wits Branch) award for excellence in civil engineering for the development of the composite Macadam pavement.
- 1995 SAICE finalist for the national award for the most outstanding civil engineering achievement for community based projects.
- 1997 Masimanyane Award for "Process Enterprise Turnover < R 5 million".
- 1997 Masimanyane "CSIR Technological Impact Award".
- 1999 Impumelelo Innovations Award Programme- commendation for provision of road infrastructure.

APPENDIX IV: Copy of the patent: Finishing technique on macadam