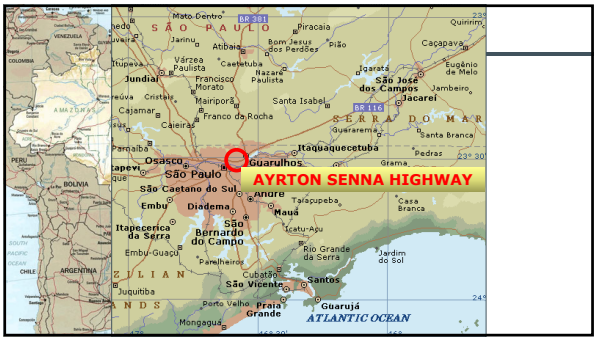
ADVANCED COLD RECYCLING

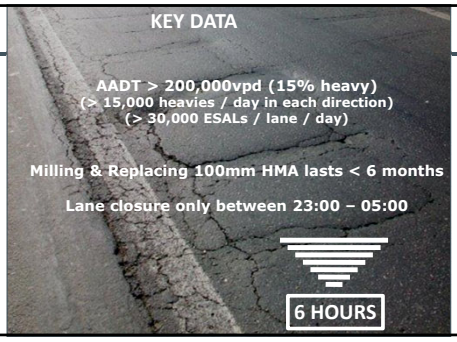
Pavement Design – Case Study

1



2

3

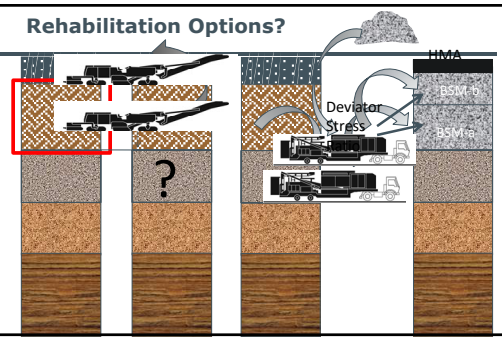


4

Results of Pavement Investigations

5

Rehabilitation Options?



6

Case Study **Tests on Existing Pavement**

Ayrton Senna - EcoPistas

Layer / material	Test Pit and chainage	Layer thickness (mm)	CBR (%) / E_{vd} (MPa)	MDD / OMC (kg/m³ / %)	In situ moisture (%)	Comments
Asphalt surfacing (capa)	TP 4 – km15+795	45	- / 112			
	TP 3 – km15+945	50	- / 82			Cracked Deformation
	TP 1 – km16+106	45	- / 18			
	TP 2 – km16+210	65	- / 118			
Asphalt base (binder)	TP 4 – km15+795	70	- / 125			
	TP 3 – km15+945	80	- / -			
	TP 1 – km16+106	80	- / 74			
	TP 2 – km16+210	70	- / 49			
Cement stabilised crushed stone base (BGTC)	TP 4 – km15+795	200	- / 238			
	TP 3 – km15+945	200	- / 63			Moist/intact
	TP 1 – km16+106	200	- / 101			Segregated
	TP 2 – km16+210	200	- / 56			Intact
Crushed stone subbase (BGS)	TP 4 – km15+795	150	118 / 54	2166 / 7.3	-	
	TP 3 – km15+945	150	117 / 40	2187 / 7.6	-	Presumed wet
	TP 1 – km16+106	150	120 / 40	2173 / 9.1	-	
	TP 2 – km16+210	150	124 / 100	2160 / 7.9	-	
Clayey sand with gravel selected subgrade (areia argilosa)	TP 4 – km15+795	185	20 / 44	1993 / 8.2	8.2	
	TP 3 – km15+945	100	21 / 40	1893 / 9.5	12.4	Wet
	TP 1 – km16+106	140	22 / 25	1985 / 7.5	10.8	
	TP 2 – km16+210	100	23 / 15	1940 / 7.5	10.8	
Sandy clay subgrade (argila arenosa)	TP 4 – km15+795	920	14 / 384	1602 / 20.9	-	
	TP 3 – km15+945	920	12 / 50	1517 / 24.6	28.0	Wet
	TP 1 – km16+106	No data	Standing water		Saturated	
	TP 2 – km16+210	895	13 / 31	15.12 / 24.5	26.2	

Recycled

Recycled

>G4

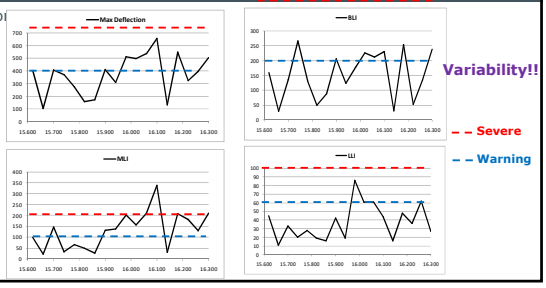
G7

G8

7

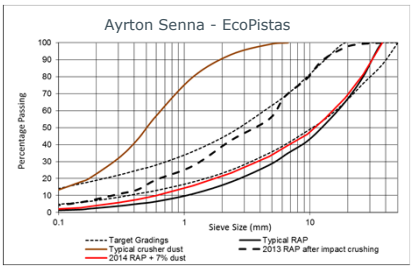
Case Study **FWD Deflection Analysis**

Ayrton



8

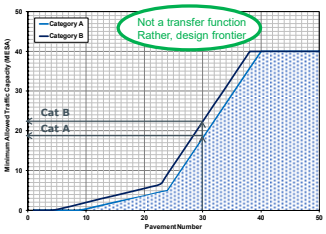
Case Study – Ayrton Senna **Gradings of Base Layer**



9

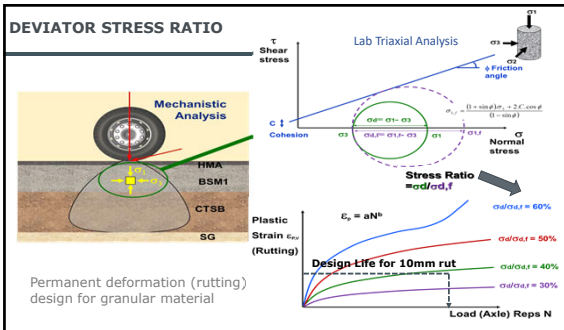
PAVEMENT NUMBER (PN)

- Pavement balance through modular ratio
- Pavement life through Frontier Curve
- Consider Category of Road
  - Cat A = 95% reliability
  - Cat B = 90% reliability



10

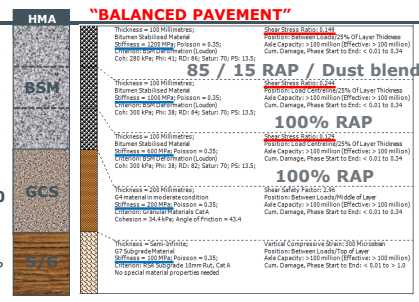
DEVIATOR STRESS RATIO



Permanent deformation (rutting) design for granular material

11

Modelling (Rubicon LET)



12

Material	Modular Ratio	Maximum stiffness (MPa)
Crushed stone	1.8 – 2.0	300 - 500
Gravel	1.5 – 1.8	150 - 300
Soil	1.2 – 1.6	50 - 150

Case Study

Selection of Modulus Values for Granular

PN

SAPEM

Material Code	Material Description	Elastic Modulus – Support Condition: Over Cemented	Elastic Modulus – Support Condition: Over Granular
G1	High quality crushed stone	250 – 1000 (450)[1]	150 – 600 (300)
G2	Crushed stone	200 – 800 (400)	100 – 400 (250)
G3	Crushed stone	200 – 800 (350)	100 – 350 (250)
G4	Natural gravel (base quality)	100 – 600 (300)	75 – 350 (225)
G5	Natural gravel	50 – 400 (250)	40 – 300 (200)
G6	Natural gravel (subbase quality)	50 – 200 (225)	30 – 200 (150)
EG4	Equivalent granular, G5/G6 parent material	–	200 – 400 (300)
EG5	Equivalent granular, G7/G8 parent material	–	100 – 300 (200)
EG6	Equivalent granular, G9/G10 parent material	–	30 – 200 (140)

13

Application	Material Code	Saturation Level	Shear Strength Parameters: Cohesion (kPa)	Shear Strength Parameters: Friction Angle (°)
Base	G1	Dry	90 – 130	53 – 57
		Moderate	75 – 100	51 – 55
		Wet	50 – 75	50 – 53
		Saturated	100 – 125	54
	G2	Moderate	50	52
		Wet	45	50
	G3	Dry	75	51
		Moderate	40	51
		Wet	20	50
	G4	Dry	75	51 – 43°
		Moderate	40	47
		Wet	20	45
Subbase Coarse Materials GM: 1.7 – 2.3 Max size: 28 – 37.5	G5/6 (BLS425< 170)	Dry	100 – 125	45 – 49
		Moderate	50 – 100	41 – 45
		Wet	10 – 50	39 – 42
	G5/6 (BLS425 > 170)	Dry	225 – 275	45 – 49
		Moderate	50 – 100	41 – 44
		Wet	25 – 35	31 – 33
Subbase Fine material GM: 1.5 – 1.6 Max size: < 14	G5/6 (BLS425 < 100)	Dry	125 – 250	43 – 45
		Moderate	40 – 50	43 – 45
		Wet	10 – 25	40 – 43
Selected Subgrade	G7 Fenicrete	Dry	75 – 100	43 – 45
		Moderate	0	41 – 43
		Wet	0	40 – 41
	G7 Sand	Dry	75 – 100	35 – 37
		Moderate	0	37 – 40
		Wet	0	35 – 37
In Situ Subgrade	G10 Fenicrete	Dry	75	45
		Moderate	0	37
		Wet		
	Silt	Dry	80 – 100	30 – 35
		Moderate	0	30 – 35
		Wet	0	30 – 35
	Clay	Dry	> 250	20 – 30
		Moderate	25 – 50	15 – 25

Actual 34

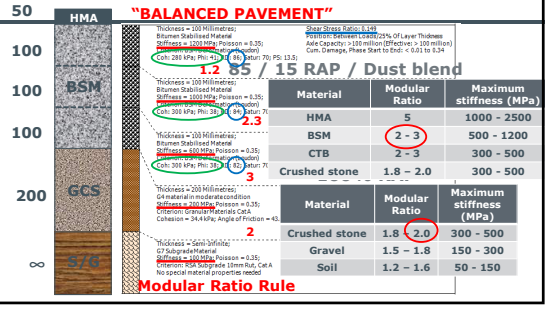
Case Study

Selection of Shear Properties for Granular Subbase

SAPEM, 2014

14

Modelling (Rubicon LET)



Material	Modular Ratio	Maximum stiffness (MPa)
HMA	5	1000 - 2500
BSM	2 - 3	500 - 1200
CTB	2 - 3	300 - 500
Crushed stone	1.8 – 2.0	300 - 500

Material	Modular Ratio	Maximum stiffness (MPa)
Crushed stone	1.8 – 2.0	300 - 500
Gravel	1.5 – 1.8	150 - 300
Soil	1.2 – 1.6	50 - 150

15

Effective Long Term Stiffness of BSM for Design

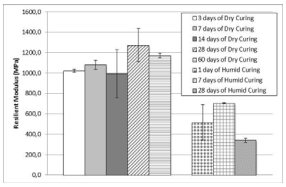
BSM Class	Supporting Layer: Cemented Subbase	Supporting Layer: Granular Subbase
BSM (RAP + GCS)	900 – 1750	700 – 1200 Actual 600/1000/1200
BSM (GCS Grade Crushed Stone)	800 – 1200	600 – 900

ELT Mr = f (aggregate type and quality, RAP %, bitumen %, support, traffic, climate)

16

Pavement Design – Case Study

BSM Modulus Values : Triaxial testing

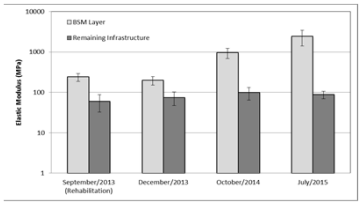


9/22/2021 17

17

Pavement Design – Case Study

BSM Modulus Values : FWD back-calcs

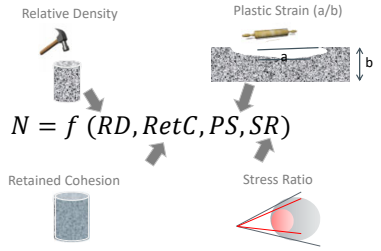


9/22/2021 18

18

Case Study

Design Function for BSM



19

Construction Sequence

23:00 Close off slow lane and shoulder

1. Mill out HMA – haul RAP to stockpile
2. Mill out CTB – remove from site
3. Proof roll with 18t PTR
   Undercut / backfill where necessary
4. Construct 1st BSM-foam layer (200mm)
5. Construct 2nd BSM-foam layer (130mm)
6. Apply 20mm HMA

05:00 Open to traffic

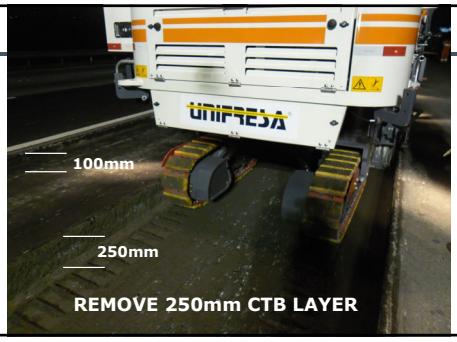
20

21

22

23

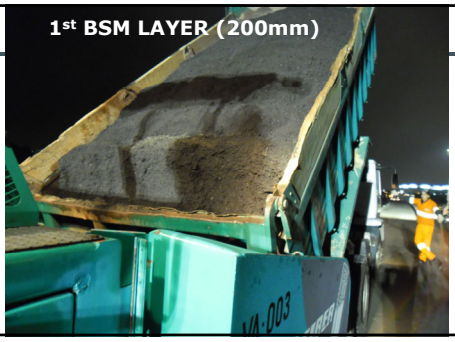
24



25

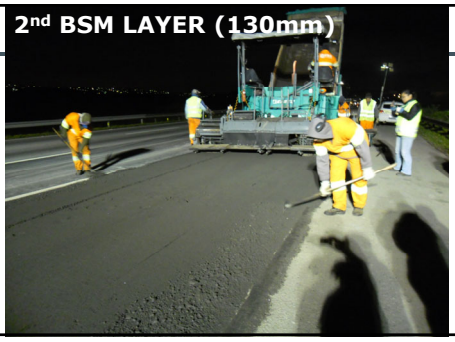
26

27



28

29



30

31

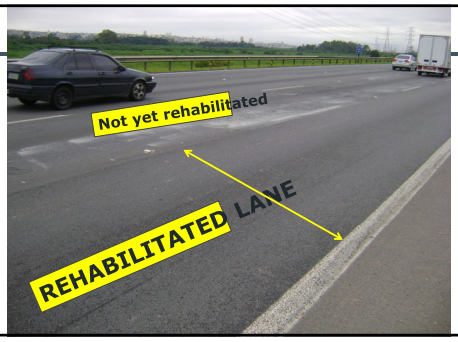
32

33

34

35

36



37

38

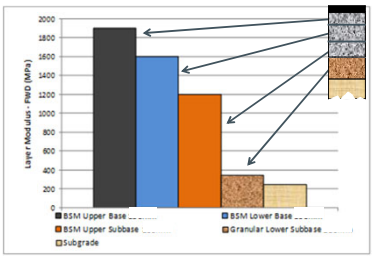
39

Analysis of FWD survey – October 2014

FWD Analysis: From km 15+650 to km 16+250						
SLOW LANE Applied Load:		8 ton axle load, 541 to 607 kPa applied pressure				
Pavement Layers		Thicknes s (mm)	Poisson' s ratio	Derived resilient modulus (M_R) (MPa)		
				Average	80th %ile (high)	80th %ile (low)
	Asphalt surfacing	50	0.4	3000	3000	3000
	BSM base	100	0.35	**1633**	**1954**	**1312**
	BSM upper subbase	200	0.35	**1192**	**1527**	**857**
	Natural lower subbase	250	0.35	346	459	253
	Subgrade support	Inf	0.35	275	309	204

40

BALANCED PAVEMENT



41

> 100 lane-km rehabilitated using this method

42

43