Technical Presentation:

Follow up on HVS testing of Roller Compacted Concrete and Ultra-thin reinforced concrete test sections

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Objectives

- UTRCP
  - Previous round of HVS testing done 2010/11
  - Light structure Design traffic < 1 million E80s
  - Cycles to failure varied between 2.3m (in the dry state) to 360 000 (in the wet state)
  - Weak support (initial deflections = 0.6mm)
    - (increased to over 1.8mm during the wet cycles)
    - Basic 2 layer system: 50mm UTRCP on top of 150mm Imported base on top of a prepared roadbed
- Objectives of this series of testing
- Determine if the UTRCP system can be improved and used for higher order roads such as collector and provincial roads (1-3million E80s, or even possible 3-10m)

UTRCP: Structural Design evaluation

- Due to serious early failures on certain projects the CSIR investigated mechanistically why certain sections had premature failures
- Used CNCPave to evaluate the stress conditions under a well supported UTRCP structure
- Test the stresses against MOR
- Analyze the results

History: The Roodekrans Experiment (2007)

Roodekrans experimental section layout Sections 1 to 7

Section	1	2	3	4	5	6	7
Surfacing	75 mm SFRC	75 mm SFRC	75 mm SFRC	50 mm CRCP	75 mm CRCP	100 mm CRCP	100 mm butt jointed concrete
Leveling layer			25 mm ETB	50 mm ETB	25 mm ETB		
Support	140 mm foam concrete	125 mm stabilized subbase					
	In situ compacted gravel						

Table 1. Summary of selected in place material properties for the various test sections.

LAYER	MATERIAL PROPERTY	Layer Thickness and Material type						
		75 mm SFRC, foam; stab	75 mm SFRC, ETB	50 mm; 75 mm CRCP, ETB	100 mm CRCP, ETB	100 mm JCP, stab	100 mm JCP, AC	140 mm JCP; dowel
Concrete	Compressive strength 28 days [MPa]	22.5 to 28	28	31 to 42	32 to 39.5	32 to 37	34 to 37	34 to 37
Base / Subbase	Average UCS [kPa]	1 950						
	PI	Non Plastic						
	Average Stiffness [MPa]	750						
Subgrade	Average CBR [%]	75						
	PI	6						
	Grading Modulus	2.5						
	Density [kg/m^3]	2 143						
	Average Stiffness [MPa]	180						
	Classification	A1 - a(0) and A2 - 4(0)						

Table 2. Summarized deflection response data for the various test sections.

RESPONSE PARAMETER	75 mm SFRC, foam; stab	75 mm SFRC, ETB	50 mm; 75 mm CRCP, ETB	100 mm CRCP, ETB	100 mm JCP, stab	100 mm JCP, AC	140 mm JCP; dowel
Average surface deflection range (FWD) [mm]	0.52 to 0.61	0.75	0.55 to 0.63	0.48	0.50	0.59	0.51 to 0.69

Mechanistic evaluation

Pavement structure

3 layers - concrete surfacing, stabilized base, subgrade

Stiffness concrete

28 GPa

Stiffness of base

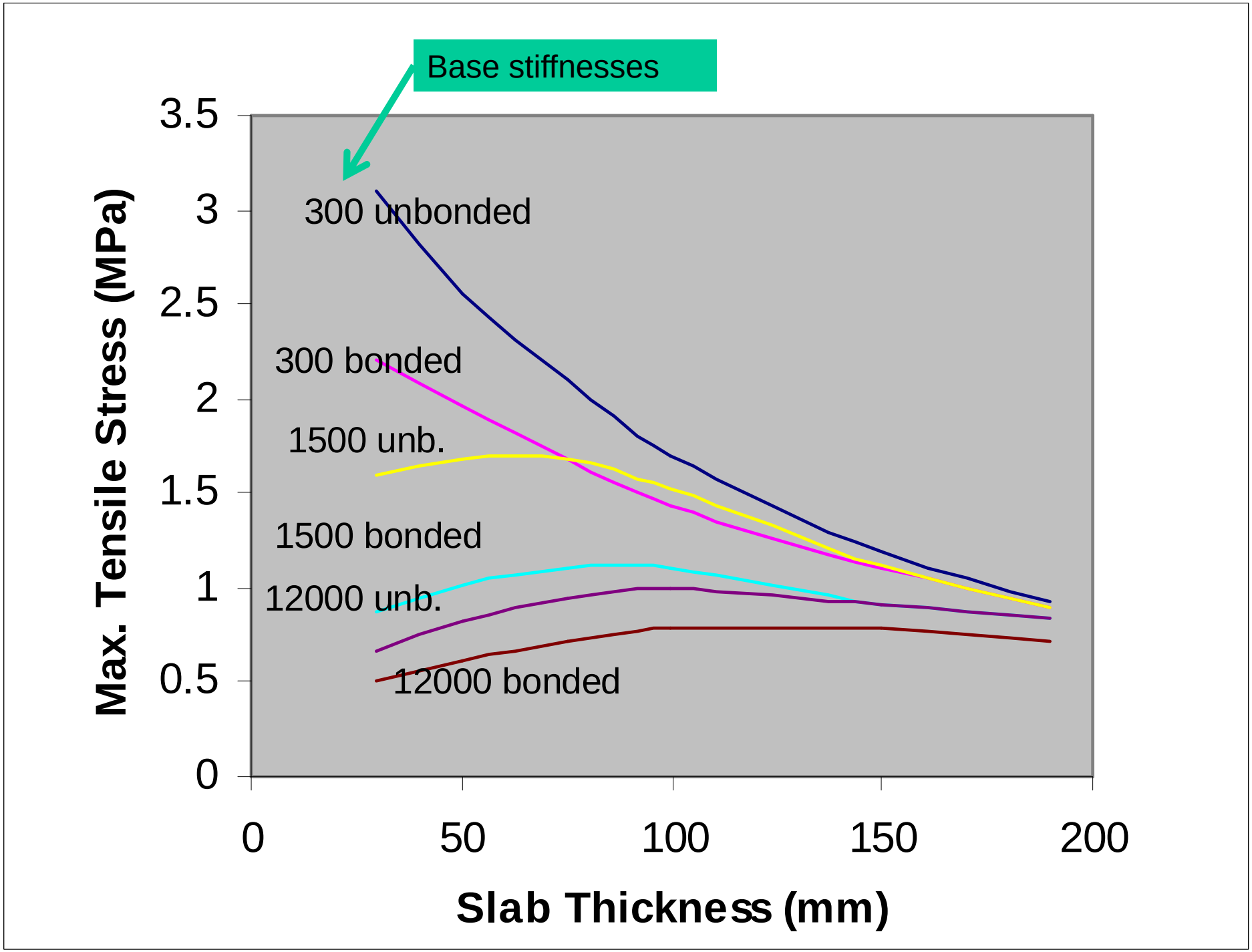
1000 MPa

Stiffness of subgrade support

Between 140 MPa and 70 MPa

Focus on tensile strain of the concrete

Indicate potential for cracking


Base stiffnesses
3.5
3
2.5
2
1.5
1
0.5
0
Max. Tensile Stress (MPa)
300 unbonded
300 bonded
1500 unb.
1500 bonded
12000 unb.
12000 bonded
0
50
100
150
200
Slab Thickness (mm)

Mamelodi Investigation Example of early failures

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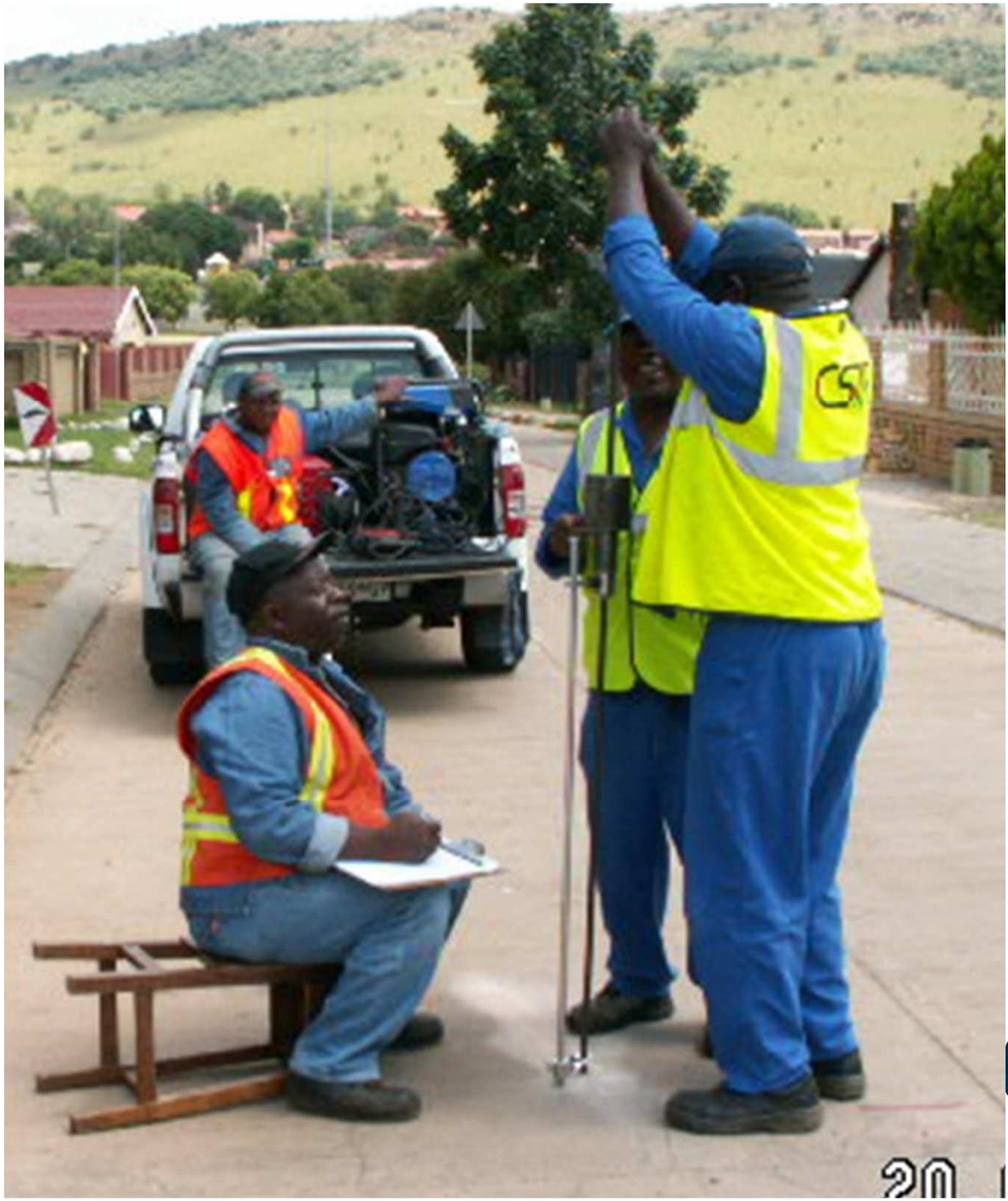
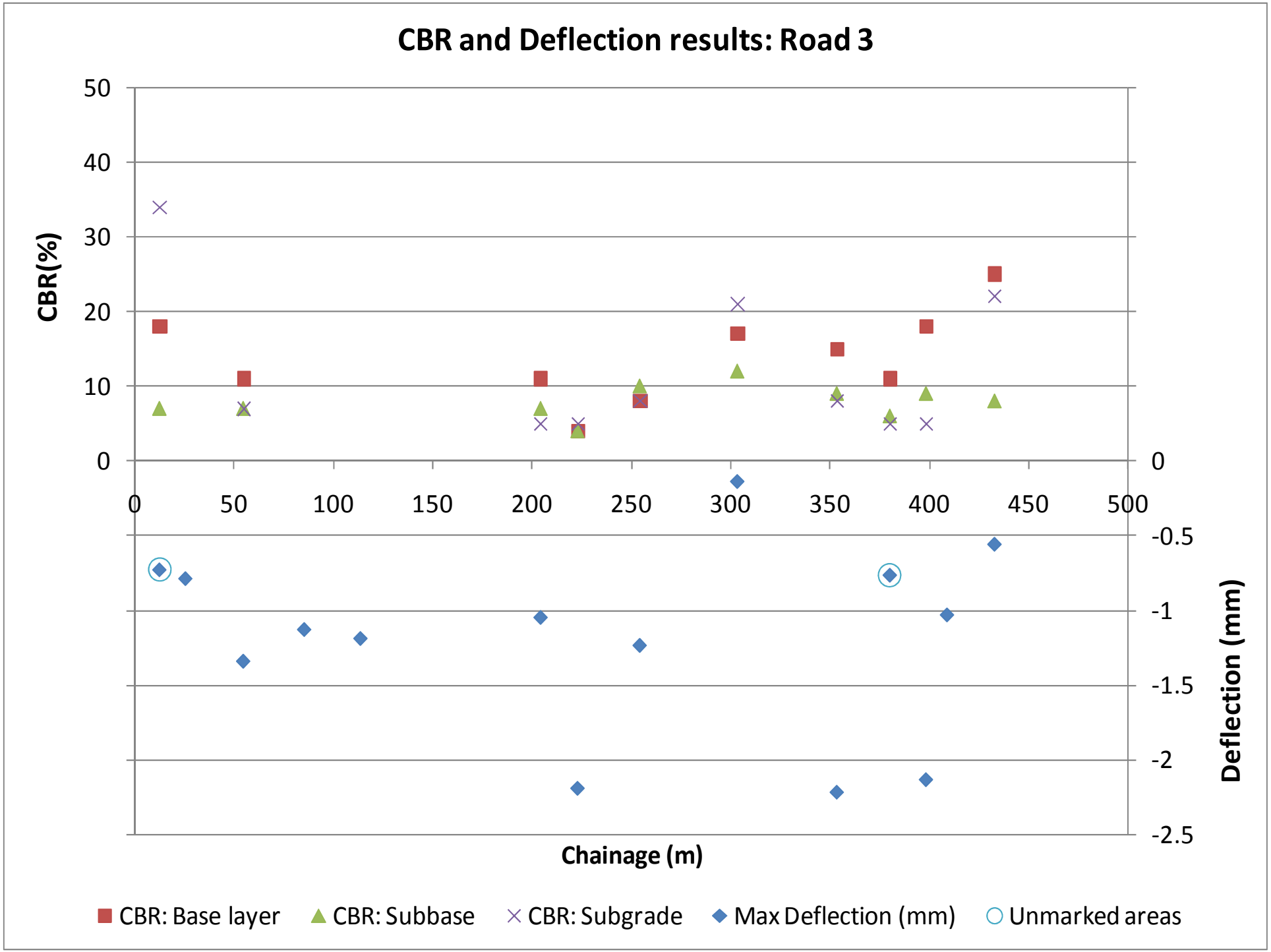



CBR and Deflection results: Road 3
CBR(%)
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500
Chainage (m)
0
-0.5
-1
-1.5
-2
-2.5
Deflection (mm)
CBR: Base layer
CBR: Subbase
CBR: Subgrade
Max Deflection (mm)
Unmarked areas

Summary of Ave deflections and CBR data

Road #	RSD Deflections		DCP CBR derived results					
	(mm)	std	Base	std	Subbase	std	Subgrade	std
1	1.01	0.21	18.7	8.9	15.5	9.6	12.9	7.70
2	1.00	0.30	46.0	41.0	16.0	11.6	14.9	20.55
3	1.15	0.59	13.2	6.1	8.4	2.6	12.1	9.59
4	0.95	0.18	12.8	3.7	12.0	2.4	11.0	2.00
5	0.84	0.47	9.8	2.6	6.5	2.5	10.3	0.50
6	1.35	0.47	13.8	4.3	7.8	1.9	6.0	2.45
Ave	1.05	0.37	19.02	11.08	11.0	5.11	11.2	7.13

Compare to Roodekrans: < 0.6mm

Compare to Roodekrans: CBR = 75

PROJECT 2 - SOSHANGUVE BUS ROUTE

Construction process

PROJECT 1 - SOSHANGUVE BUS ROUTE

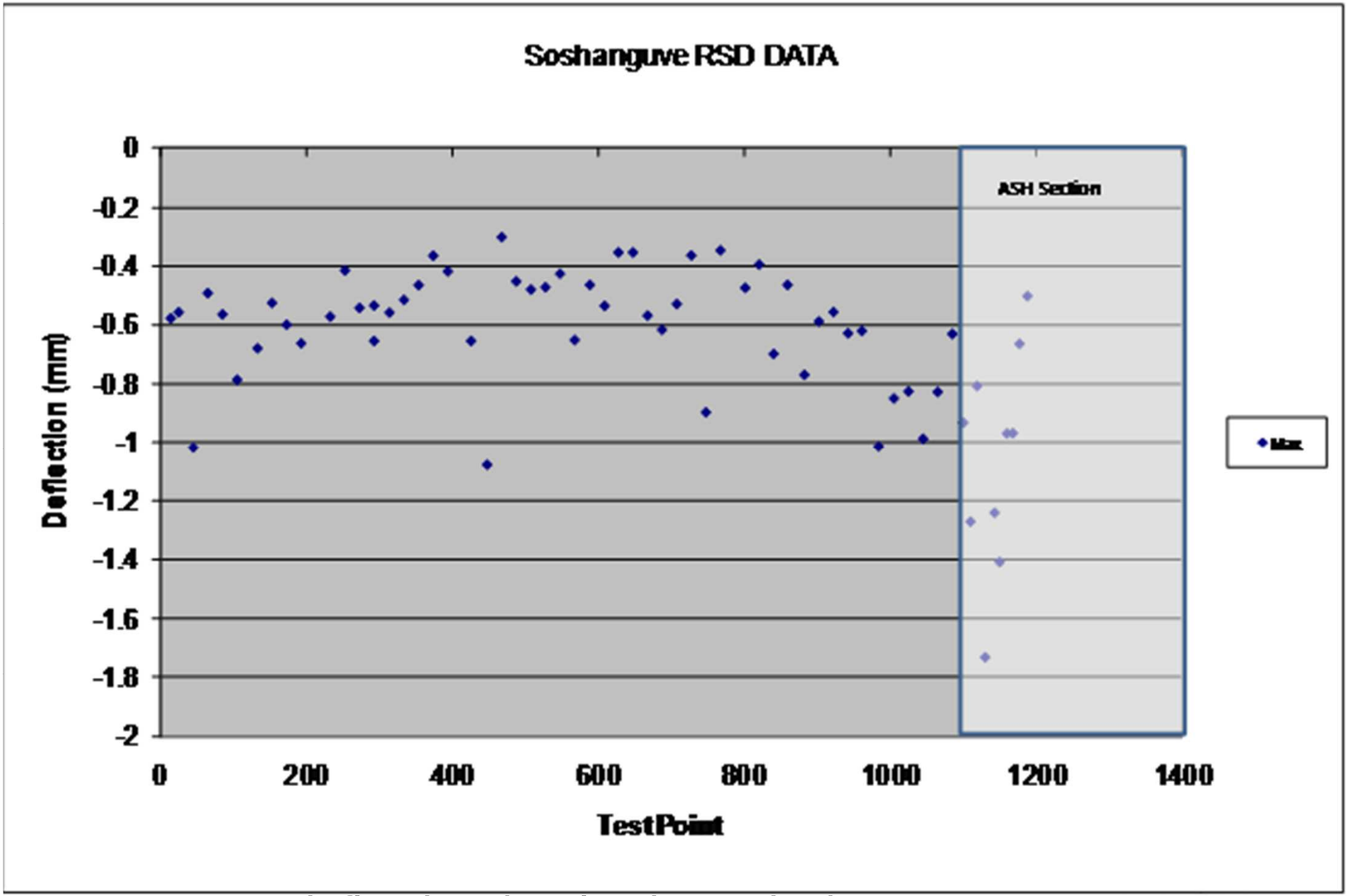
Earthworks and shaping of in-situ layer

Competed UTRCP road with side drain

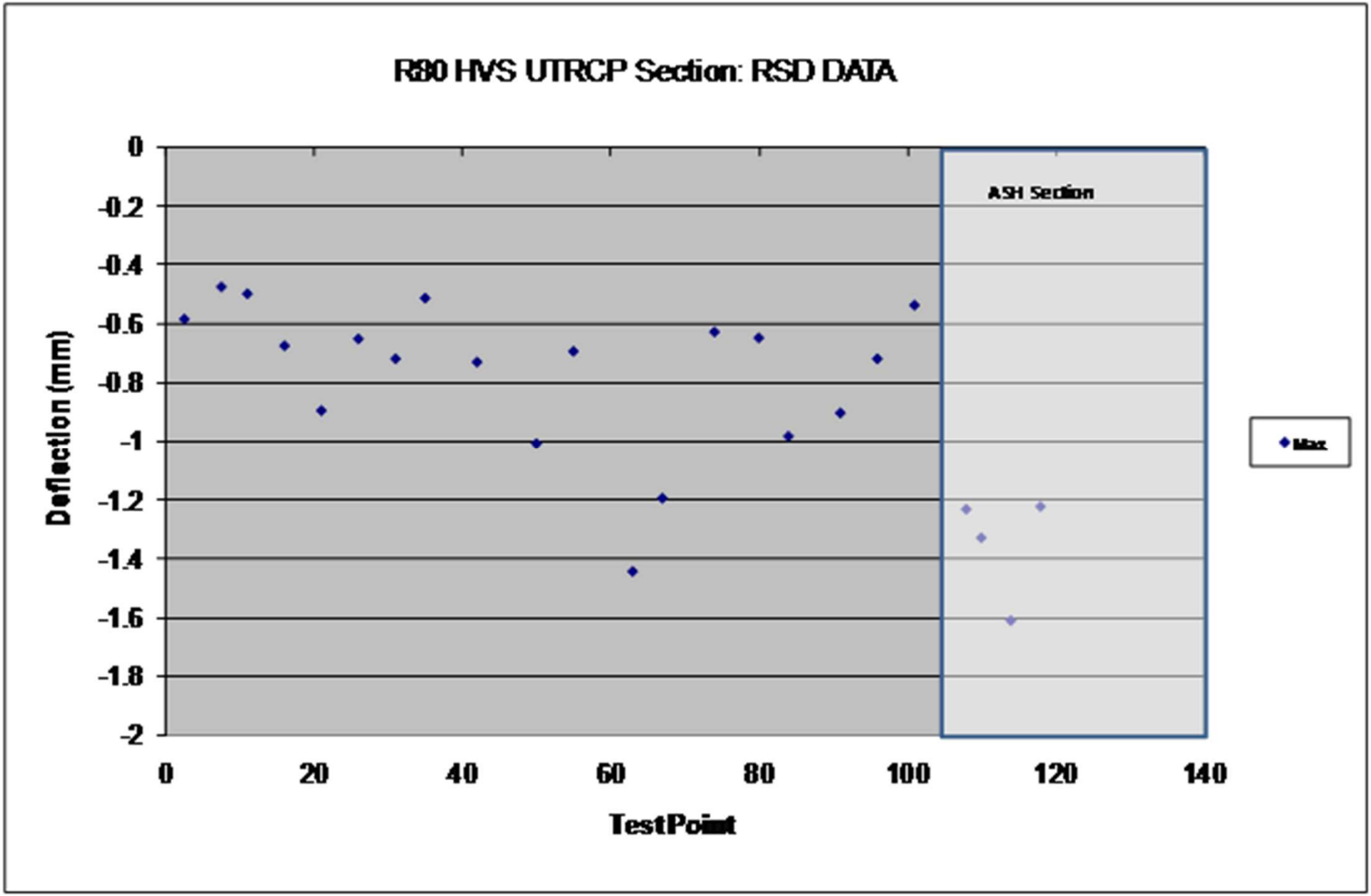
PROJECT - SOSHANGUVE BUS ROUTE

Completed road

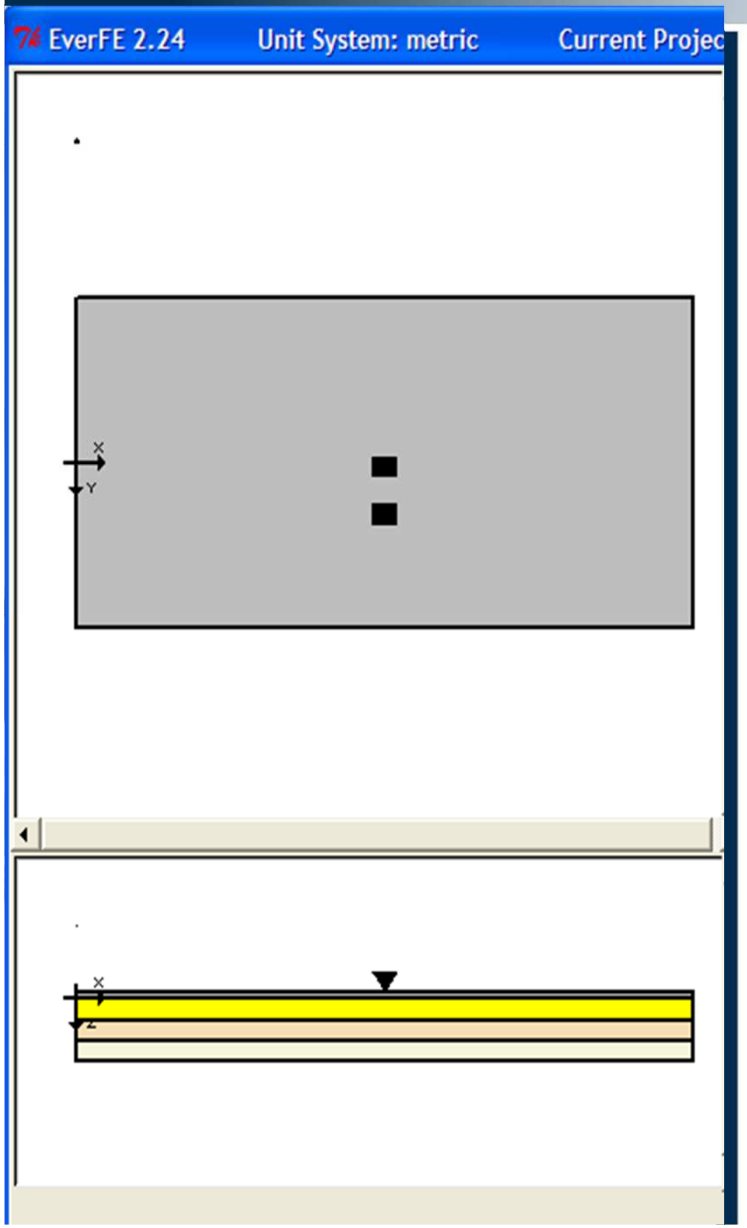
Comparison: Soshanguve & R80 HVS UTRCP sites



Ave deflection (excl ash section) = 0.59mm


R80 HVS UTRCP Section: RSD DATA
ASH Section
Max
Deflection (mm)
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
0
20
40
60
80
100
120
140
TestPoint

Analysis



- Analysis performed using EverFE 2.24 and cncPave 404,
- Assumed material properties 30-40 MPa concrete:
  - MOR = 4.0 MPa, f_t = 2.0 MPa
  - E = 30 GPa, Poisson's ratio 0.2
  - Coef. of thermal expansion: 12 10^{-6} /ºC
  - Pavement surface temperature : 40 ºC
  - Temperature differential: 4 ºC

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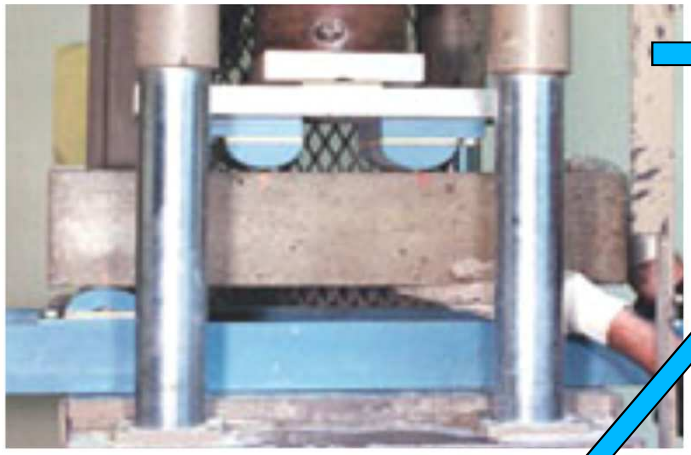
Modulus of Rupture (MOR)



- MOR = Flexural strength of concrete
- Because it's a specialised test the compressive strength are used (f_c)
- MOR = $k\sqrt{f_c}$
  - K = spring stiffness (MPa/mm):

    stress on SG/deflection ≈ 0.74
- Thus for a 30MPa concrete MOR = 4 MPa

SG is modelled as a dense liquid (winkler spring)

- Westergaard 1926 -

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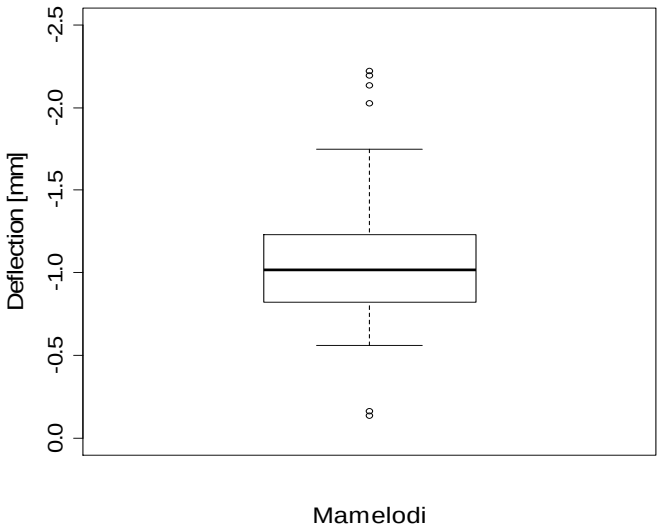
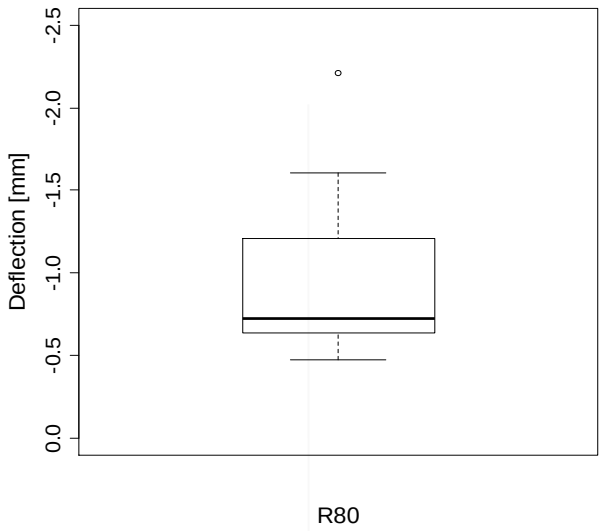
Deflection survey: Average Deflections



Mamelodi: 1.0 mm



HVS: 0.7mm

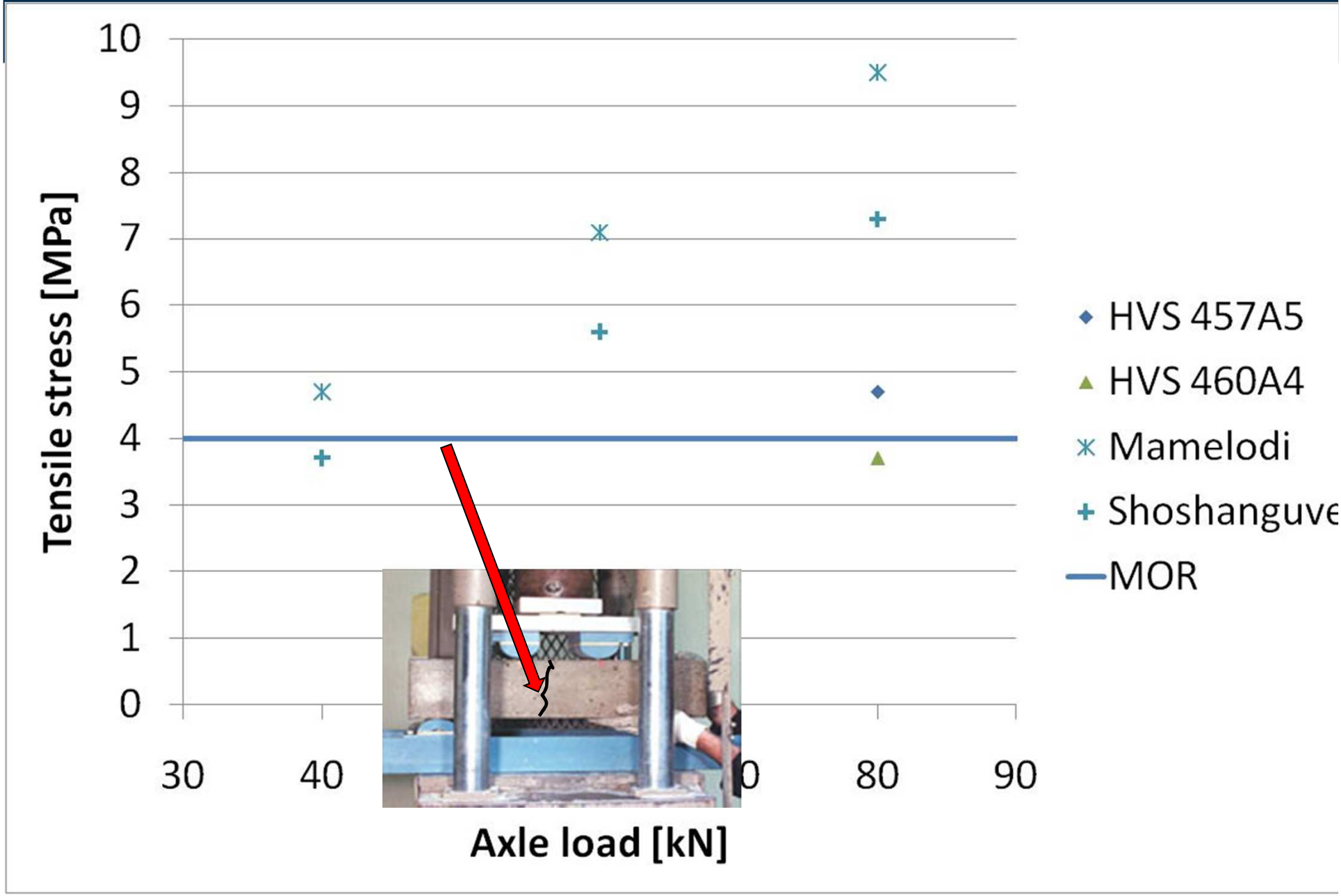
Shoshanguve 0.6 mm

Matching measured deflections Mamelodi

Layer	Thickness	Modulus [MPa]	Poisson's ratio
Concrete slab	50	30 000	0.2
Granular	150	70	0.35
Granular	150	60	0.35
Granular	150	50	0.35
Subgrade	∞	varied	N/A

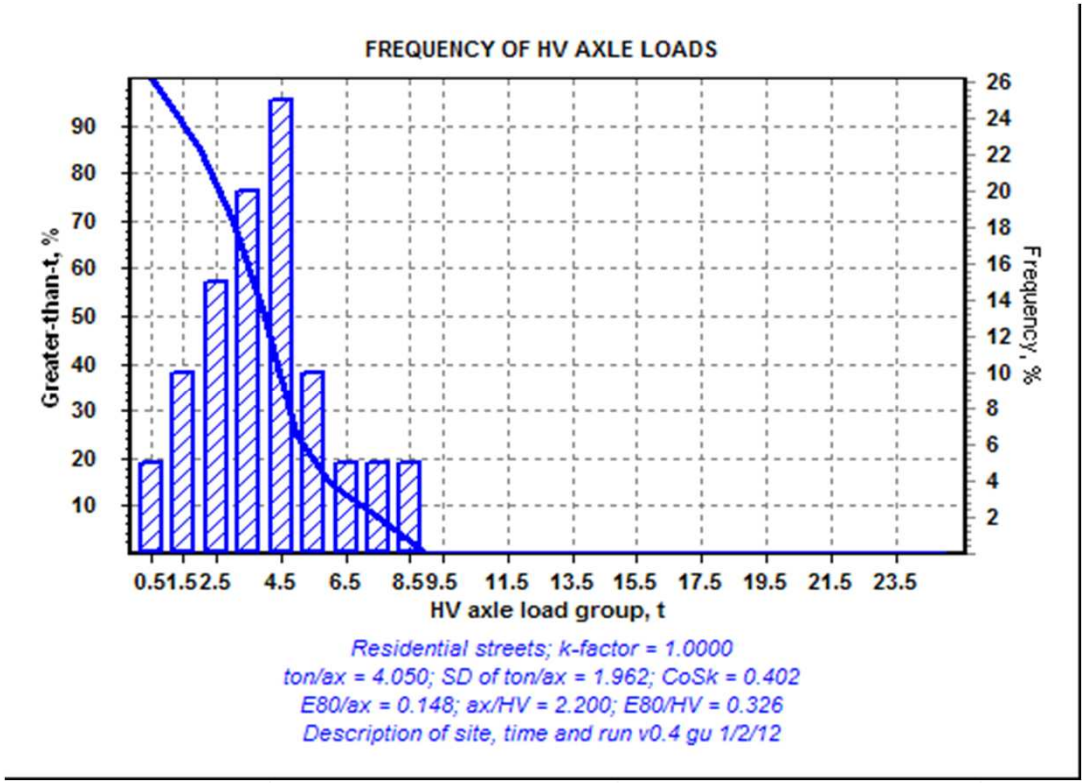
Subgrade modulus [MPa]	Spring stiffness (k) [MPa/mm]	Deflection [mm]	Maximum tensile stress [MPa]
50	0.258	0.659	7.62
40	0.206	0.696	7.68
20	0.103	0.859	7.90
10	0.052	1.13	8.17
5	0.026	1.58	8.46

Comparing stresses at different sections



cncPave Analysis of the Mamelodi structure

Loading according to cncPave Urban load Spectra



Pavement Model as above with a SG moduli of 15 Mpa (to get to the ave surface deflection of 1mm with a 80kN load)

cncPave Analysis of the Mamelodi structure

cncPave decision criteria UTRCP

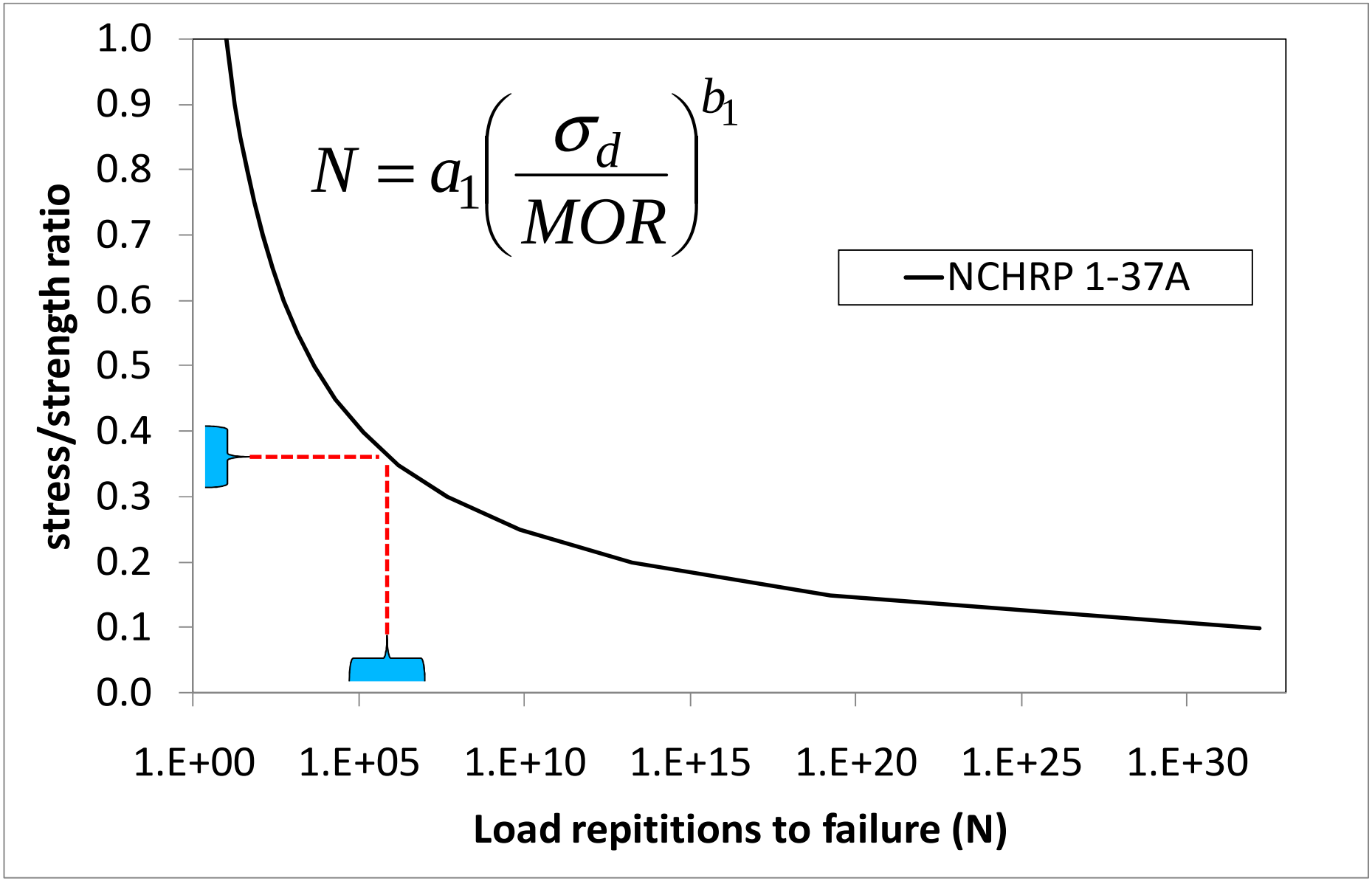
Decision variable	Good	Acceptable	Excessive
% shattered concrete	below 0.2 %	0.2 % to 0.5 %	over 0.5 %
% pumping	below 2 %	2 % to 5 %	over 5 %
Crack spacing	0.3 m - 0.5 m	0.2 m to 0.7 m	below 0.2 m or over 0.7 m

The results from the analysis indicate:

- There is a 50% probability that the surface area with shattered concrete will be excessive after 7 years, and
- a 80% probability that shattering will be excessive after 10 years.

- Analysis in agreement with what was observed: an unacceptably short life for a concrete pavement, which are typically designed to last past 20 years.

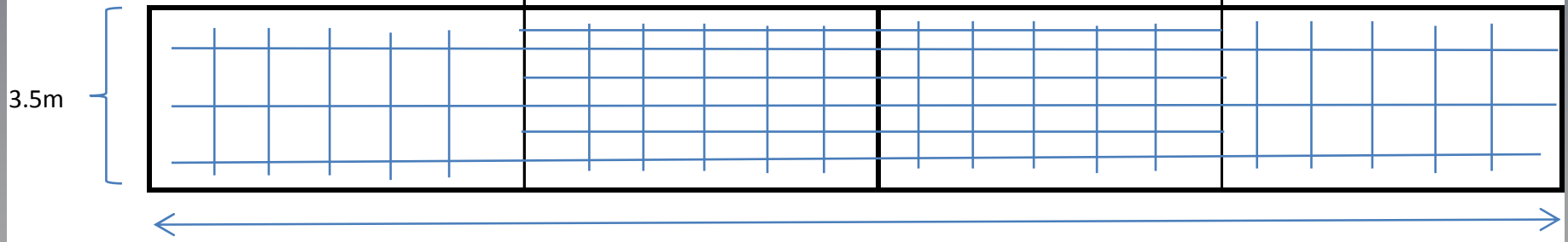
Design approach: Transfer function of the new American Mechanistic Empirical Pavement Design Guide (MEPG 2004)



Latest testing on UTRCP

- CSIR has tested an improved version of the original 50 mm UTRCP with extra steel, additional thickness and strengthened support with success
  - Design traffic 3–10 million standards 80 kN axle loads
  - Suitable for medium traffic provincial roads

Design Traffic	ES 10: 3 - 10 million E80s		ES 1: 0.3 - 1million E80s
Ref 193 mesh (200mm x200mm X 5.6mm diameter)		Ref 289 mesh (100mm x 200mm x 5.6mm diameter)	Ref 193 mesh (200x200 x 5.6mm dia)



75mm	UTRCP (30MPa)	
150mm	C3 (parent G4) (1.5 - 3 MPa, 97% MOD AASHTO)	G4 (min CBR 80, 98% MOD AASHTO)
150mm	C4 (Parent G6) (UCS 0.75 - 1.5MPa, 95% MOD AASHTO)	G6 (min CBR 25, 95% MOD AASHTO)
150mm	G6 (min CBR 25, 95% MOD AASHTO)	
	G9 Roadbed prep 93% MOD AASHTO	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HVS05
SECTION : 472AA
DATE : 6 MAY 2014
N : 2,592,842
CRACKS : ALL OVER SECTION
WET/DRY : WET
POINTS : 0 — 16
TIME : 10H00
LOAD : 100 KN
PAINT : YELLOW CHALK
SECTION FAILED "AFTER CLEANING"