8th International Symposium on Heavy Vehicle Weights and Dimensions

TOWARDS THE APPLICATION OF STRESS-IN-MOTION (SIM) RESULTS IN PAVEMENT DESIGN AND INFRASTRUCTURE PROTECTION

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and
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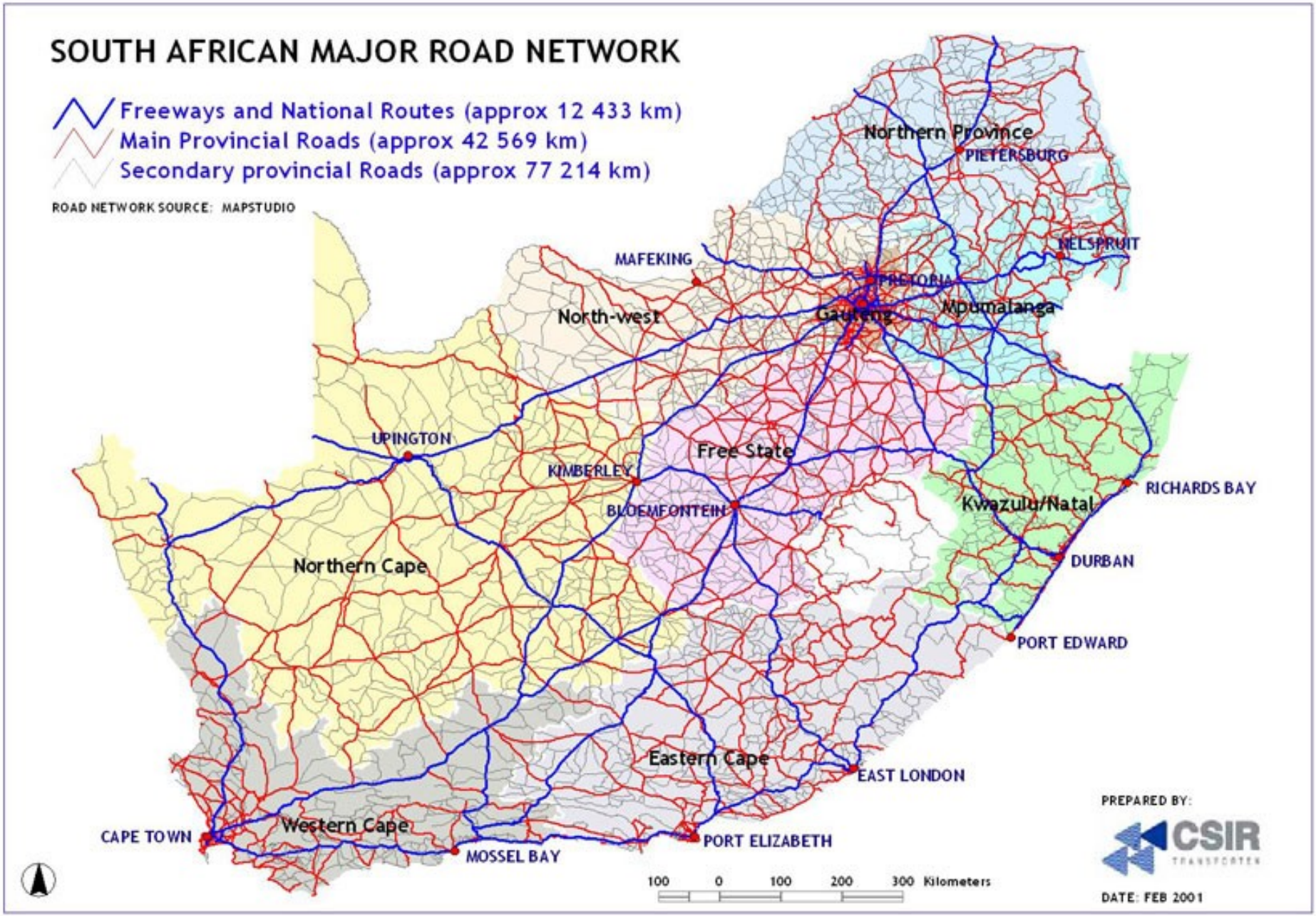
CSIR TRANSPORTEK

Layout of Presentation

- Introduction;
- Stress-In-Motion (SIM) system;
- Pavement Modeling using 3 loading cases;
- Concept of Normalised Contact Stress (NCP);
- Conclusions and recommendations.

Introduction

- Protection of road infrastructure – major challenge to RA's;
- Africa: Inter - regional traffic – as much as 70 % over loading;
- World wide: Road user charges - complex;
- Current tensions: Road Authorities vs private sector interests.
- CHALLENGE TO US "TECHNOCRATS" FOR SOLUTIONS !


SOUTH AFRICAN MAJOR ROAD NETWORK
Freeways and National Routes (approx 12 433 km)
Main Provincial Roads (approx 42 569 km)
Secondary provincial Roads (approx 77 214 km)
ROAD NETWORK SOURCE: MAPSTUDIO
Northern Province
PIETERSBURG
NELSPRUIT
MAFEKING
PRETORIA
North-west
Gauteng
Mpumalanga
UPINGTON
Free State
KIMBERLEY
BLOEMFONTEIN
RICHARDS BAY
Kwazulu/Natal
DURBAN
Northern Cape
PORT EDWARD
Eastern Cape
EAST LONDON
CAPE TOWN
Western Cape
PORT ELIZABETH
MOSSEL BAY
100 0 100 200 300 Kilometers
PREPARED BY:
CSIR
TRANSPORTEK
DATE: FEB 2001

Stress-In-Motion (SIM) system

- Description;
- Calibration and data acquisition;
- Typical Data and outputs;
  - Normalised Contact Pressure (NCP);
  - Effect of tyre speed;
  - Pavement response-top down cracking;

Figure 1: Single SIM pad configuration (used under Heavy Vehicle Simulator (HVS) with single test tyre)

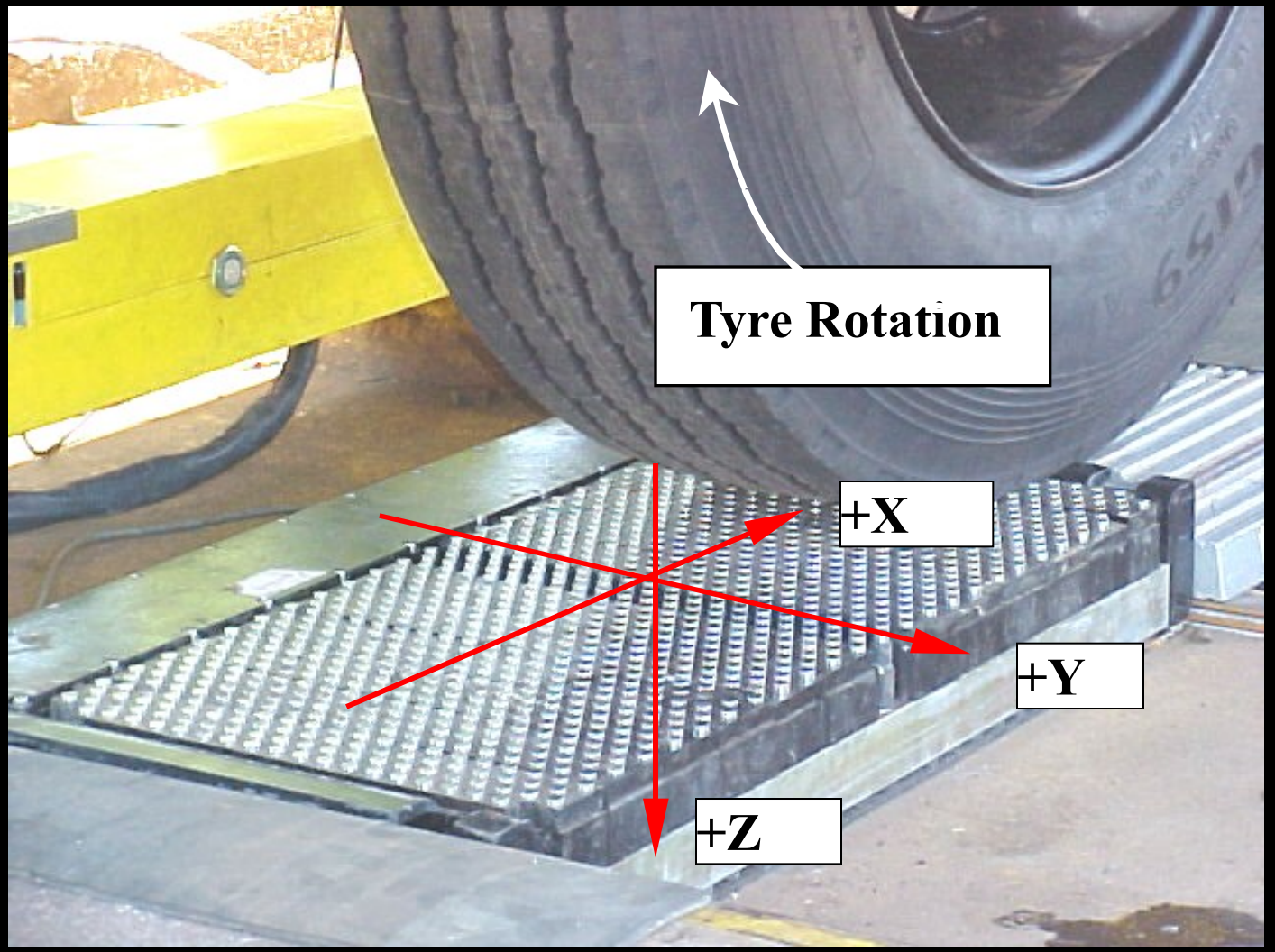
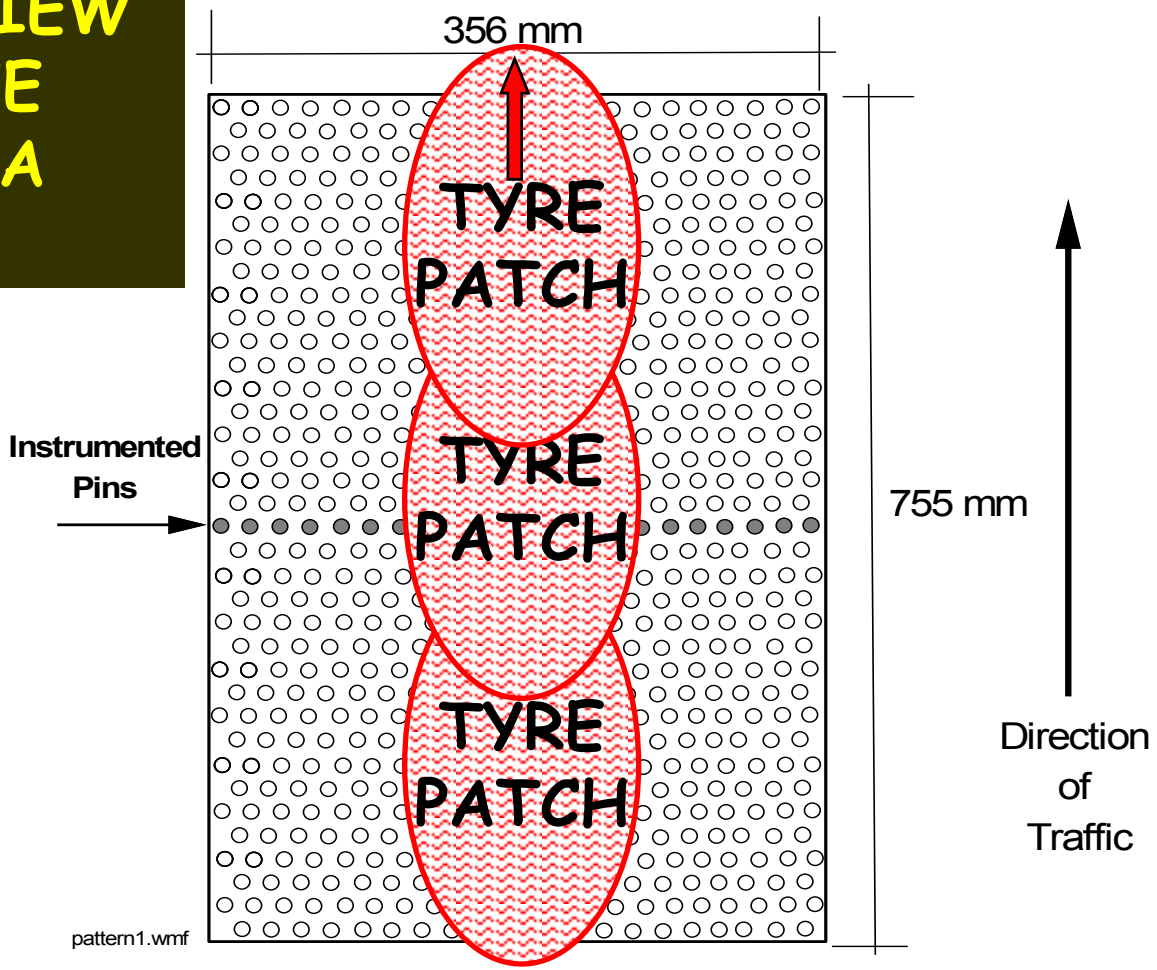
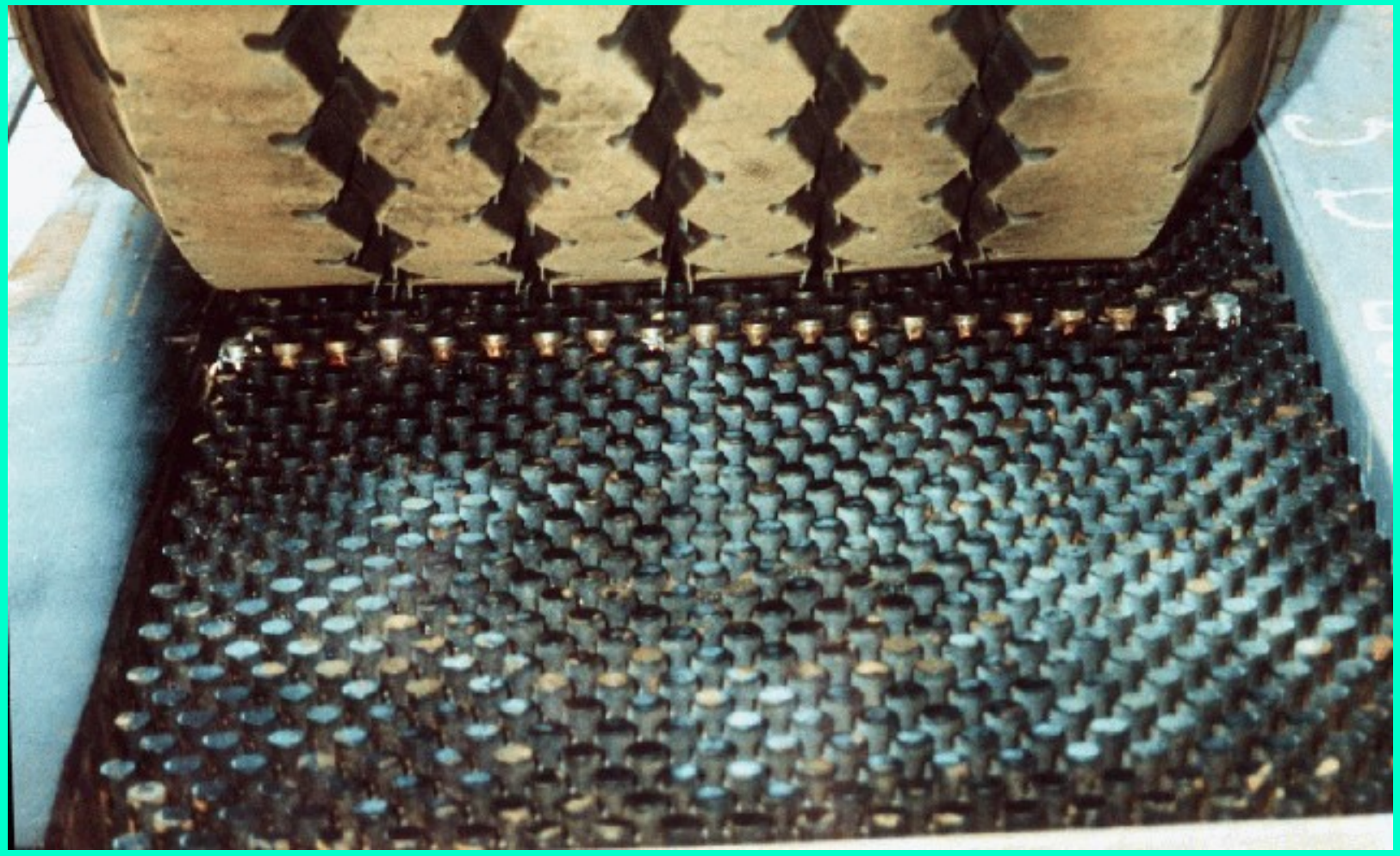


Figure 4: SAE sign convention used during SIM measurements. X-Longitudinal, Y-Lateral and Z -Vertical loads/stresses

TOP VIEW OF THE VRSPTA MK II

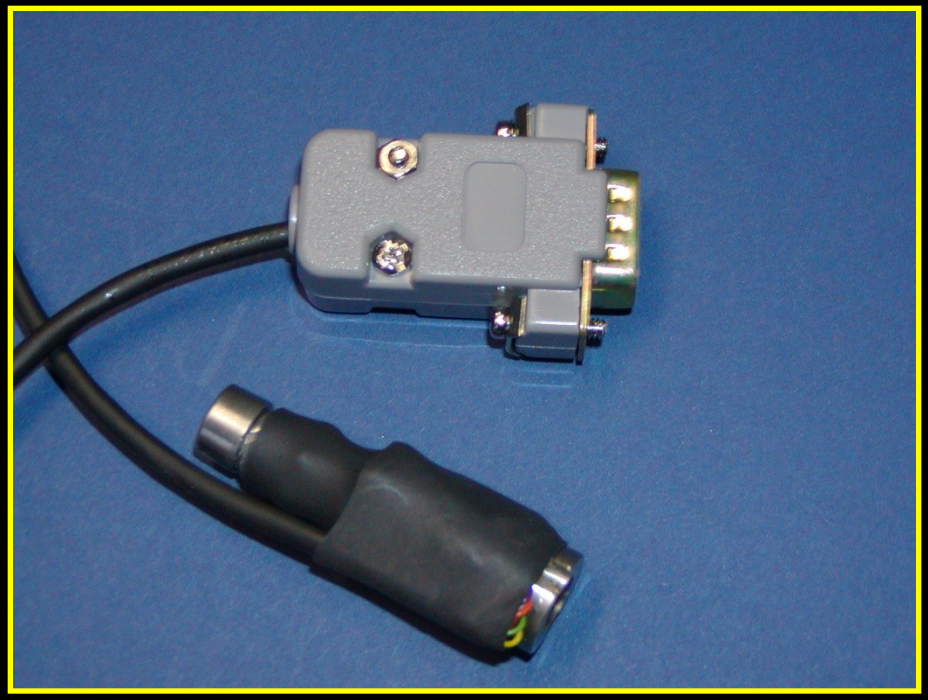




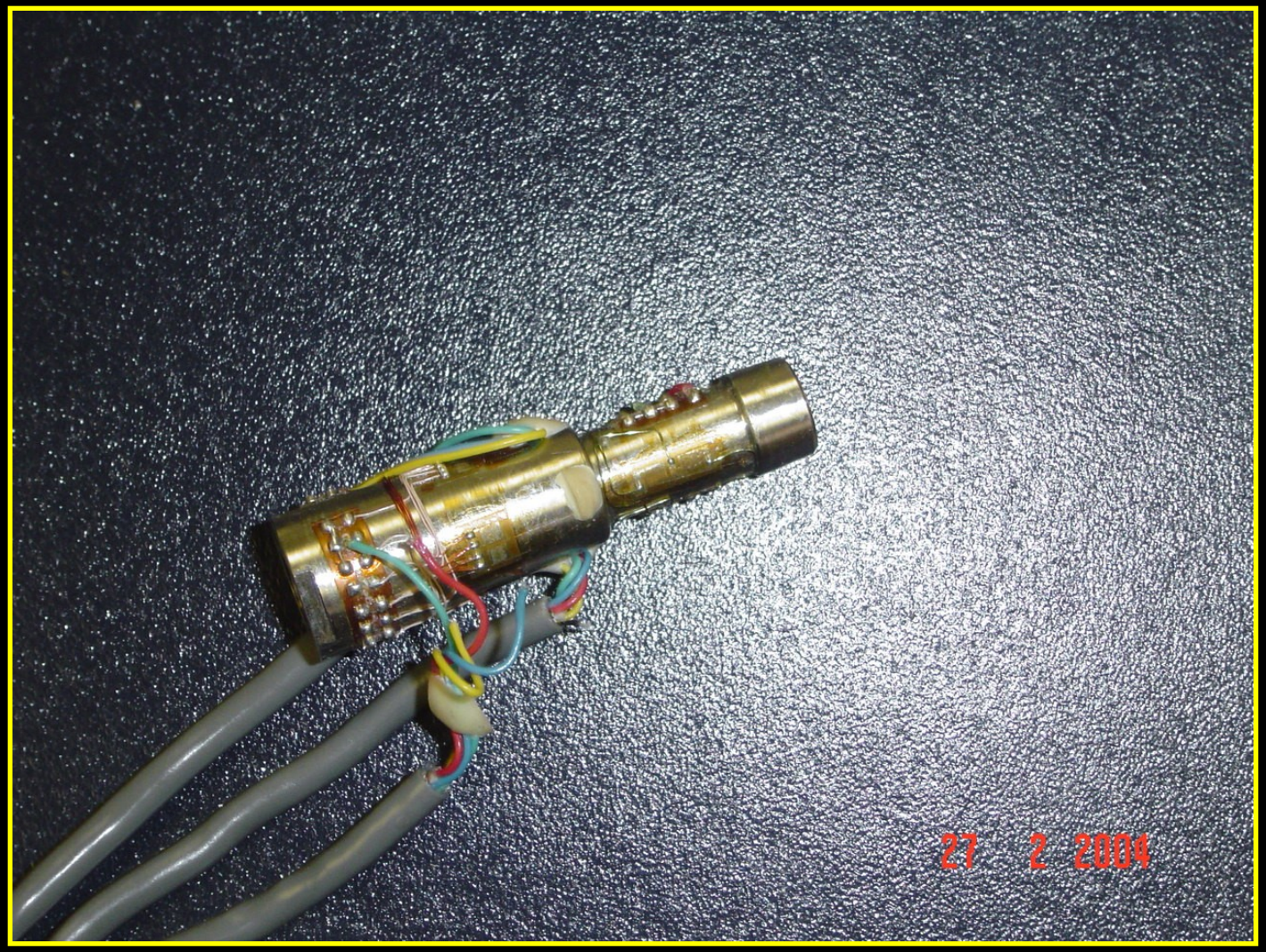
425 /65 R22.5 HVS TYRE ON SIM SYSTEM:

EXAMPLE OF FOOTPRINT TO FOLLOW…..

5-Axial Load Cell:
[+/- X; +/- Y; Z]



SIM Measuring Pins- 3-Axial

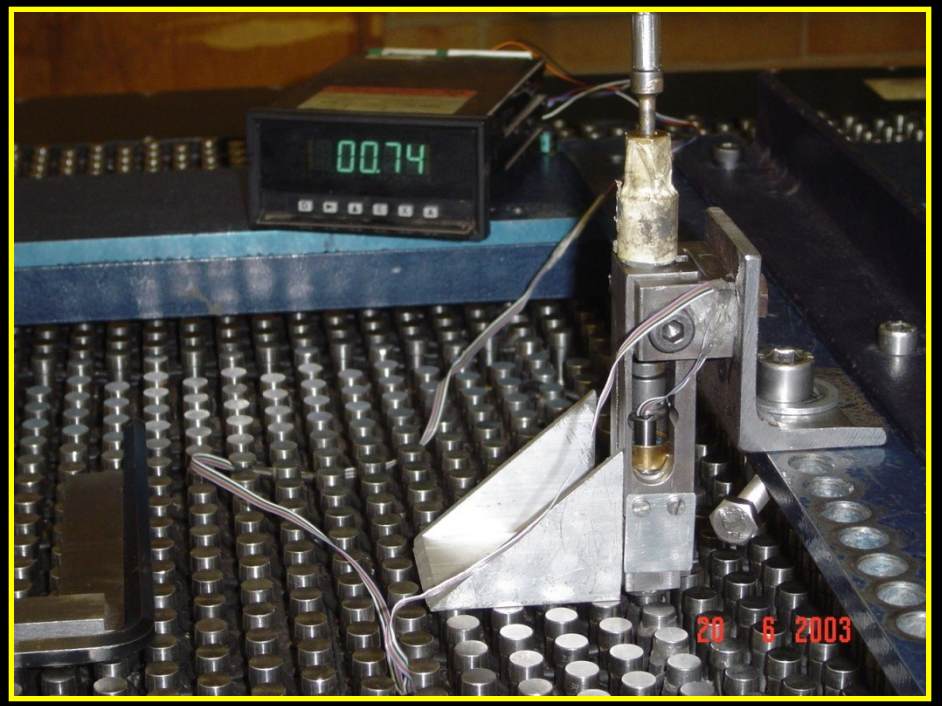


Laboratory Calibration Issues

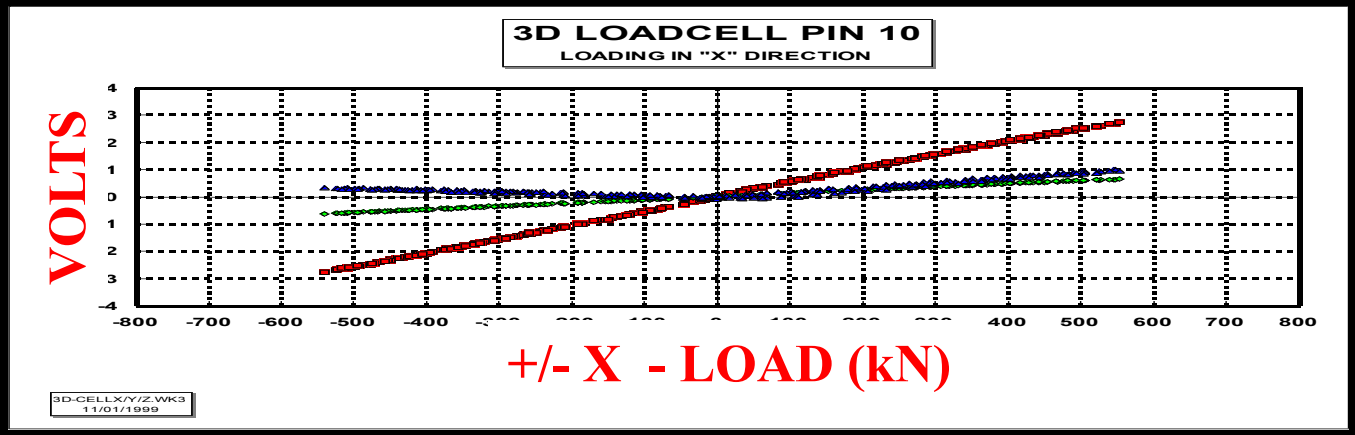
“Pin by Pin ” calibration- Jig A

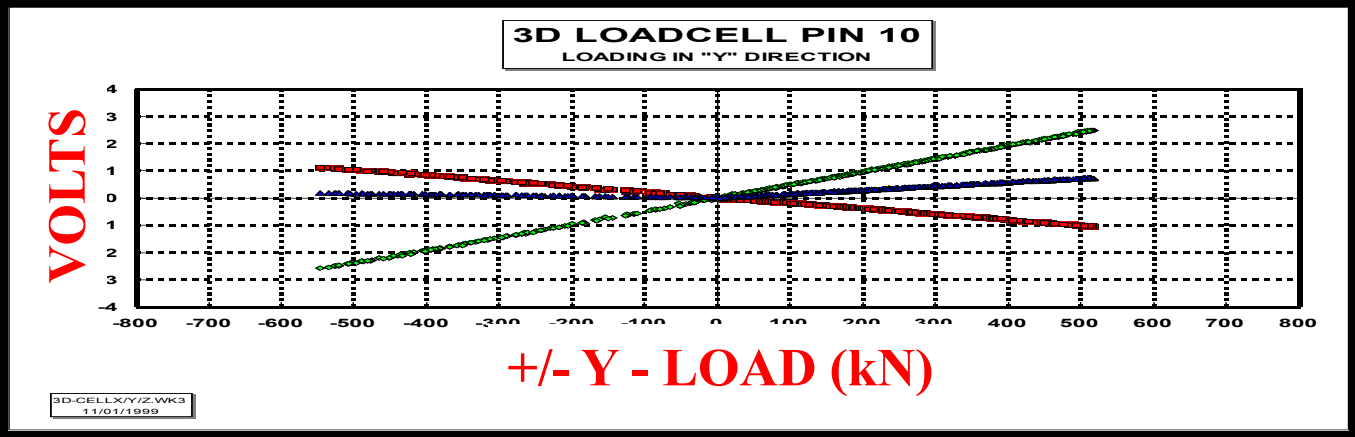
Laboratory Calibration Issues

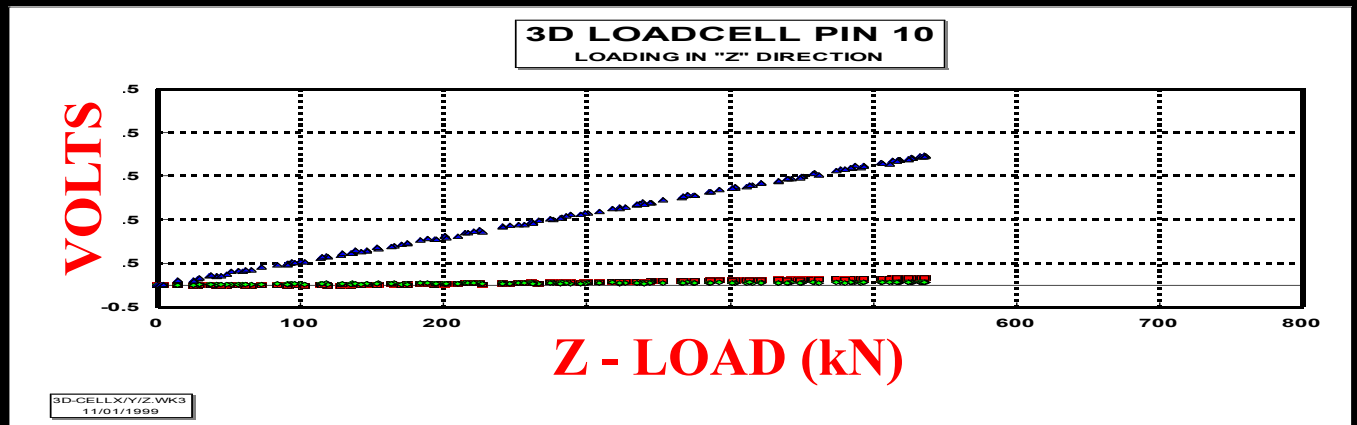
"In-Situ" calibration - Jig B



Typical Pin Calibration data

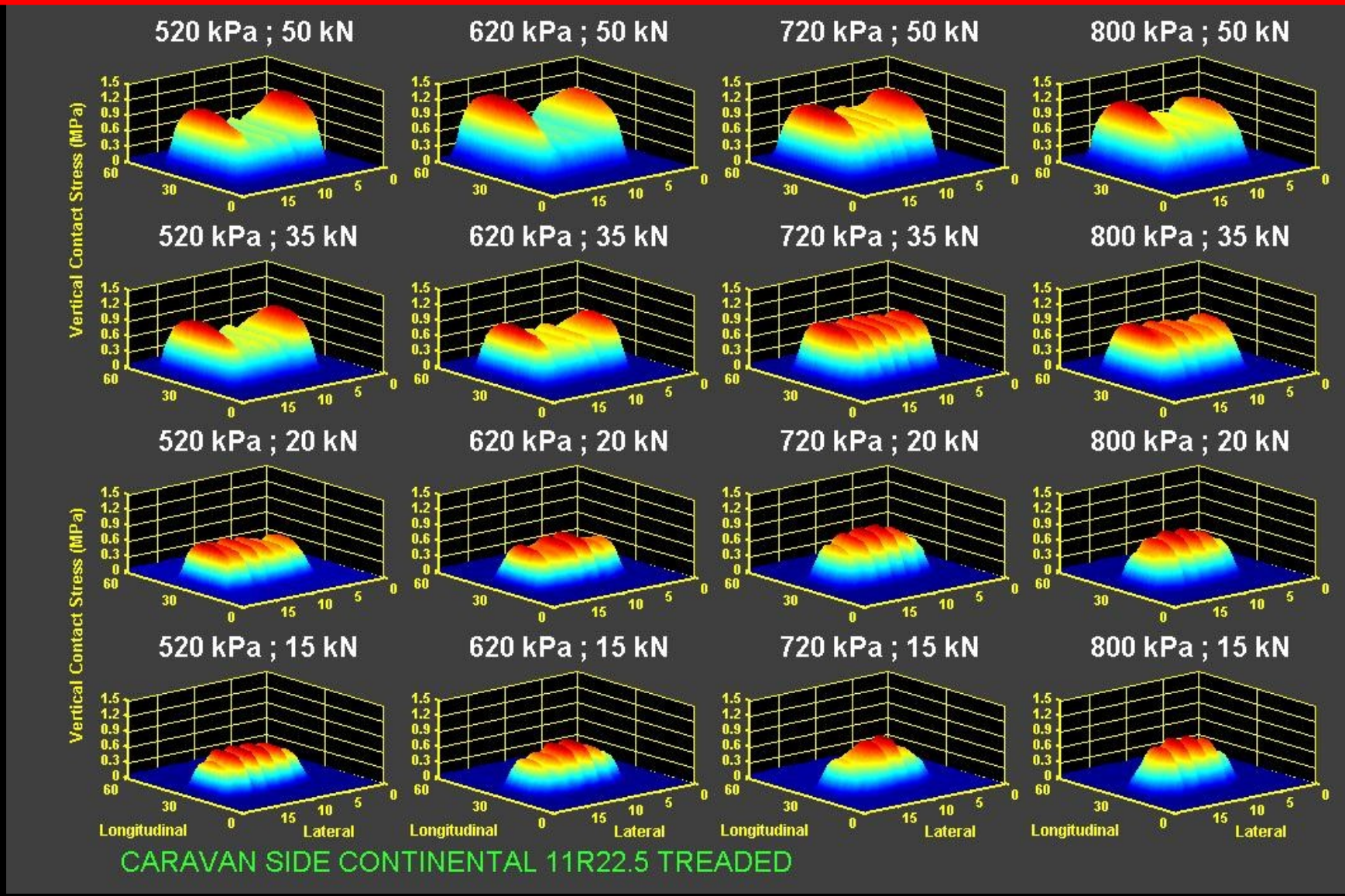






315/80 R22.5 HVS TYRE ON SIM MK II

HVS 04 SIM MEASUREMENTS OF 11R22.5 TYRE



Z - LOAD

INFLATION PRESSURE

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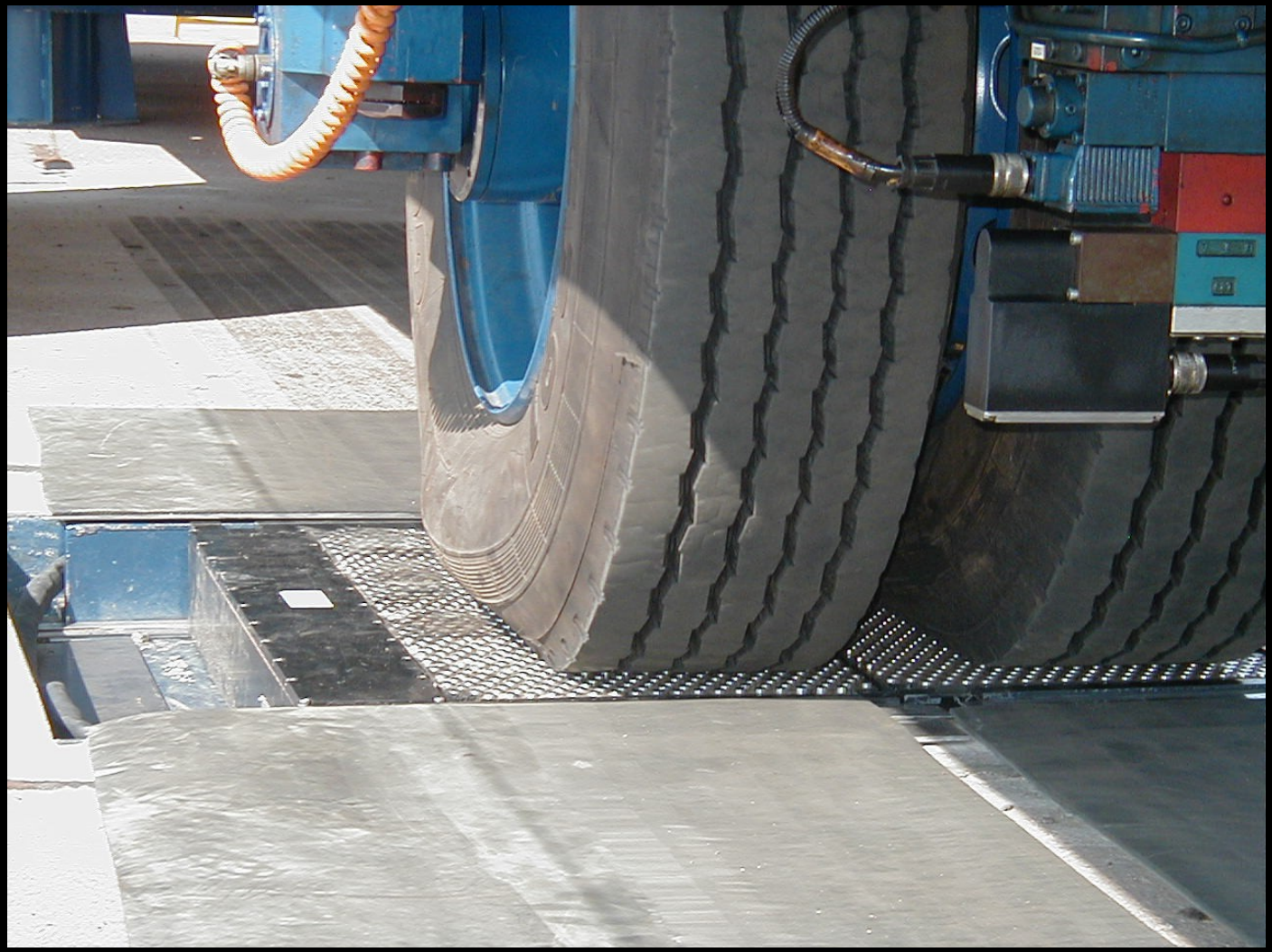


Figure 2: Twin (or dual) SIM pad configuration (used under Heavy Vehicle Simulator (HVS) with dual test tyres)

Figure 2: Quad (full) SIM pad configuration at a typical weighbridge site on National Road 3 (N3), near Heidelberg in Gauteng.

In operation: Quad (full) SIM pad configuration at a typical weighbridge site on National Road 3 (N3), near Heidelberg in Gauteng.

In operation – SIM N3-TCC

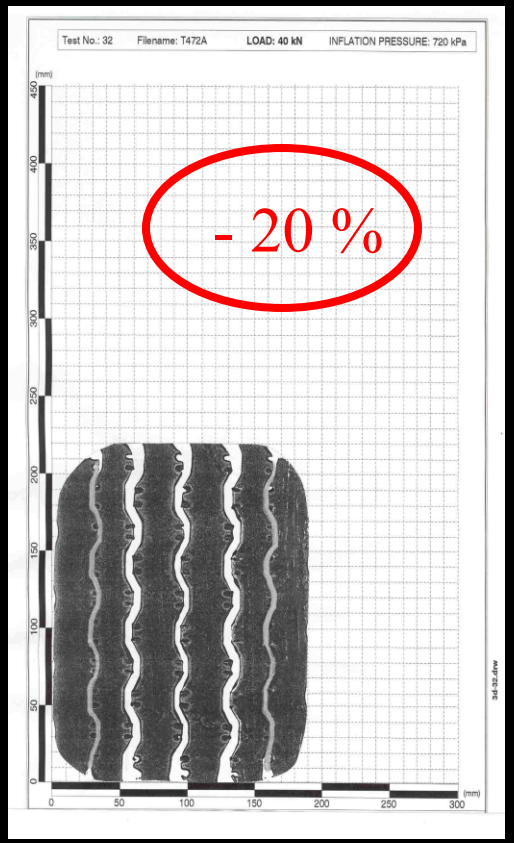
In operation: SIM N3-TCC

Table 1 Example of loading cases

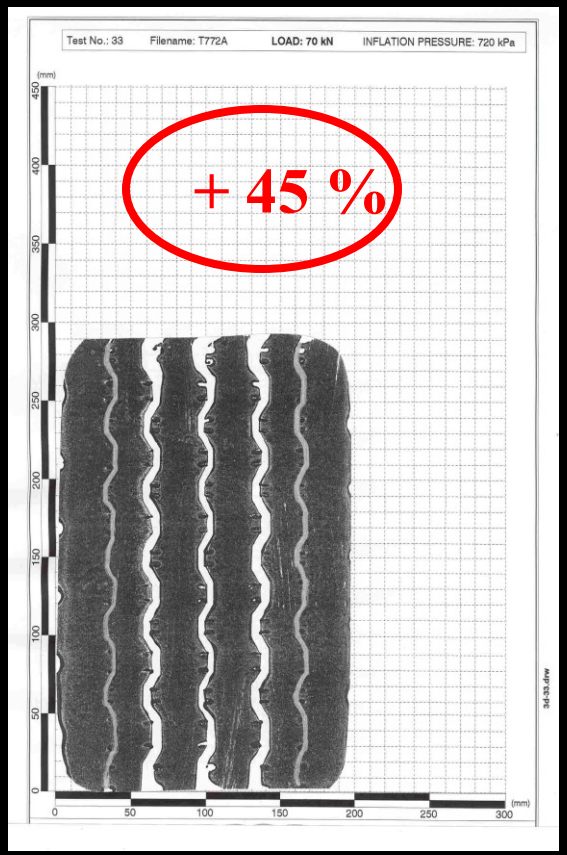
Case	Cold Inflation Pressure (kPa)	Single tyre Loading (kN)	% of rated loading @ 720 kPa[1]	Comments
1	720	20	- 20	Under-loaded
2	720	35	+ 45	Overloaded
3	720	50	+ 107	Extremely overloaded

[1] For this test tyre the rated load at 720 kPa = 24 kN

(a) Case 1: 20 kN, 720 kPa



(b) Case 2: 35 kN, 720 kPa,



(c) Case 1: 50 kN, 720 kPa

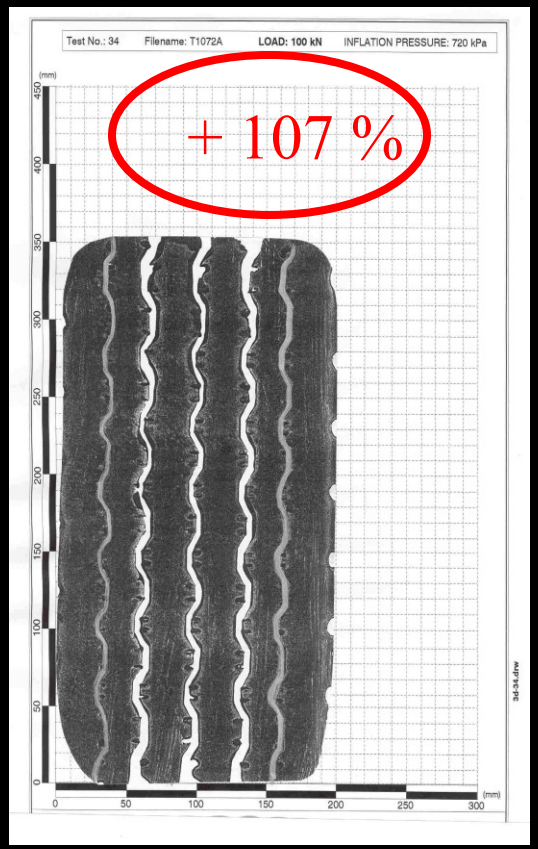
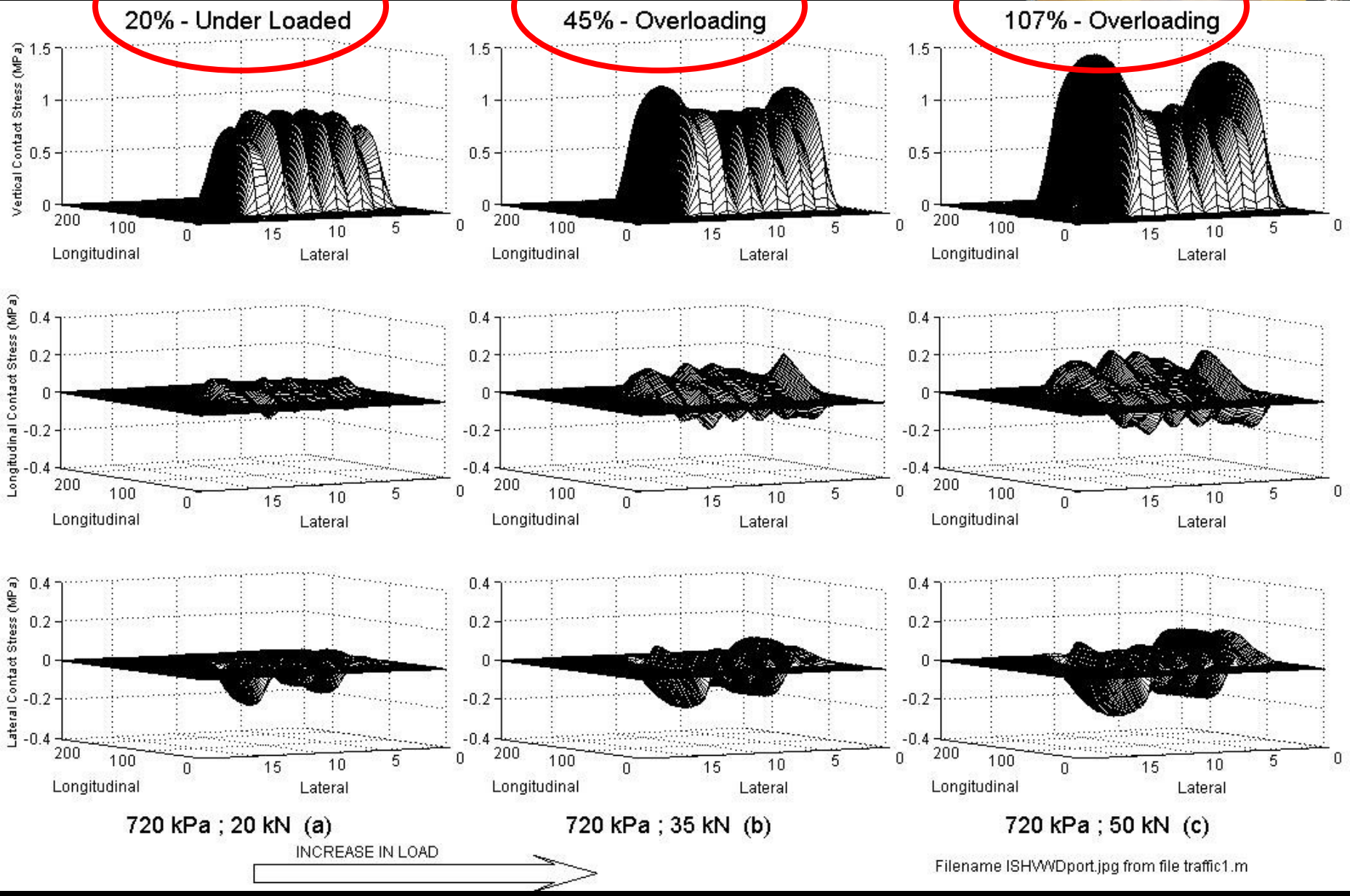
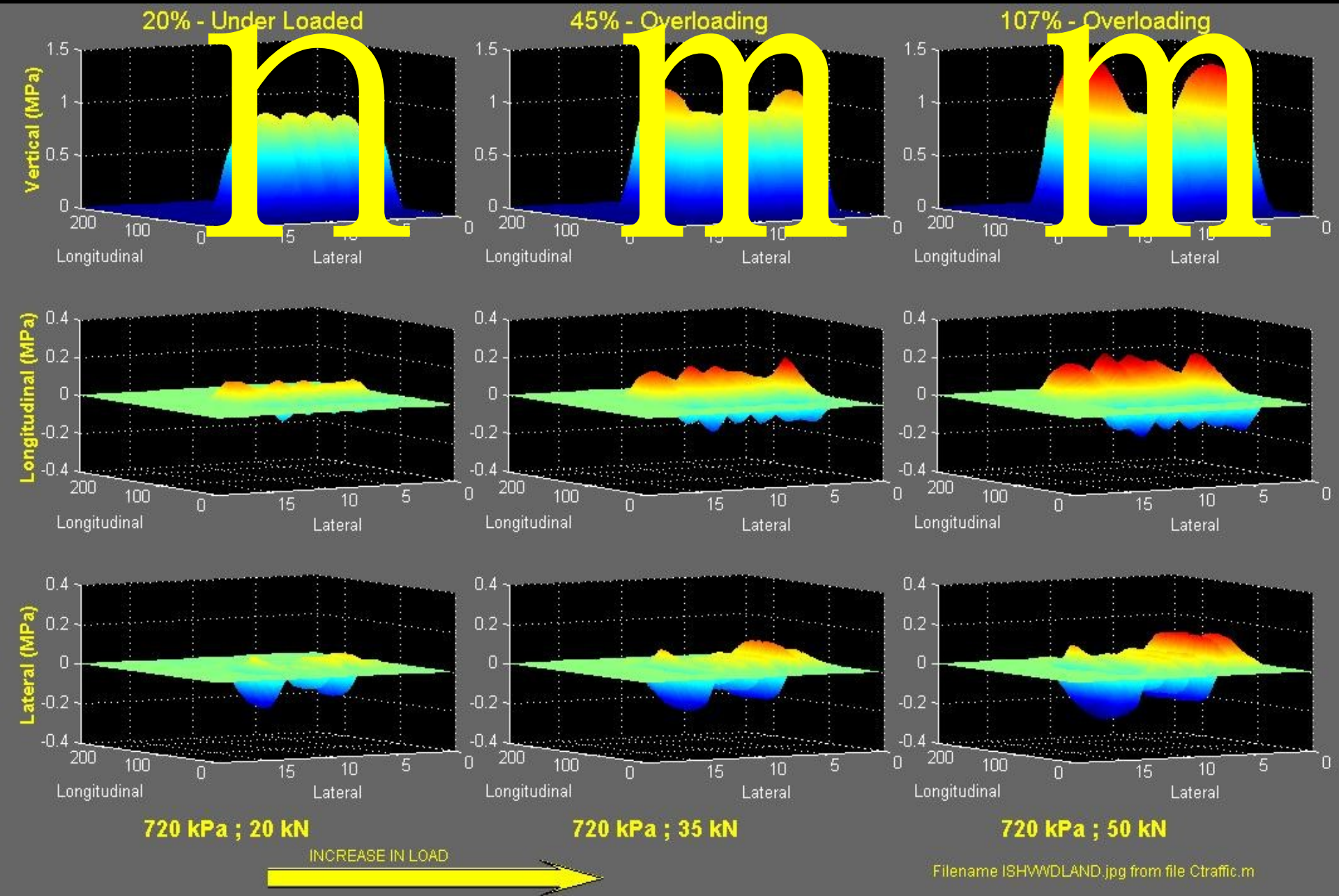


Figure 6: Static Tyre Foot Prints

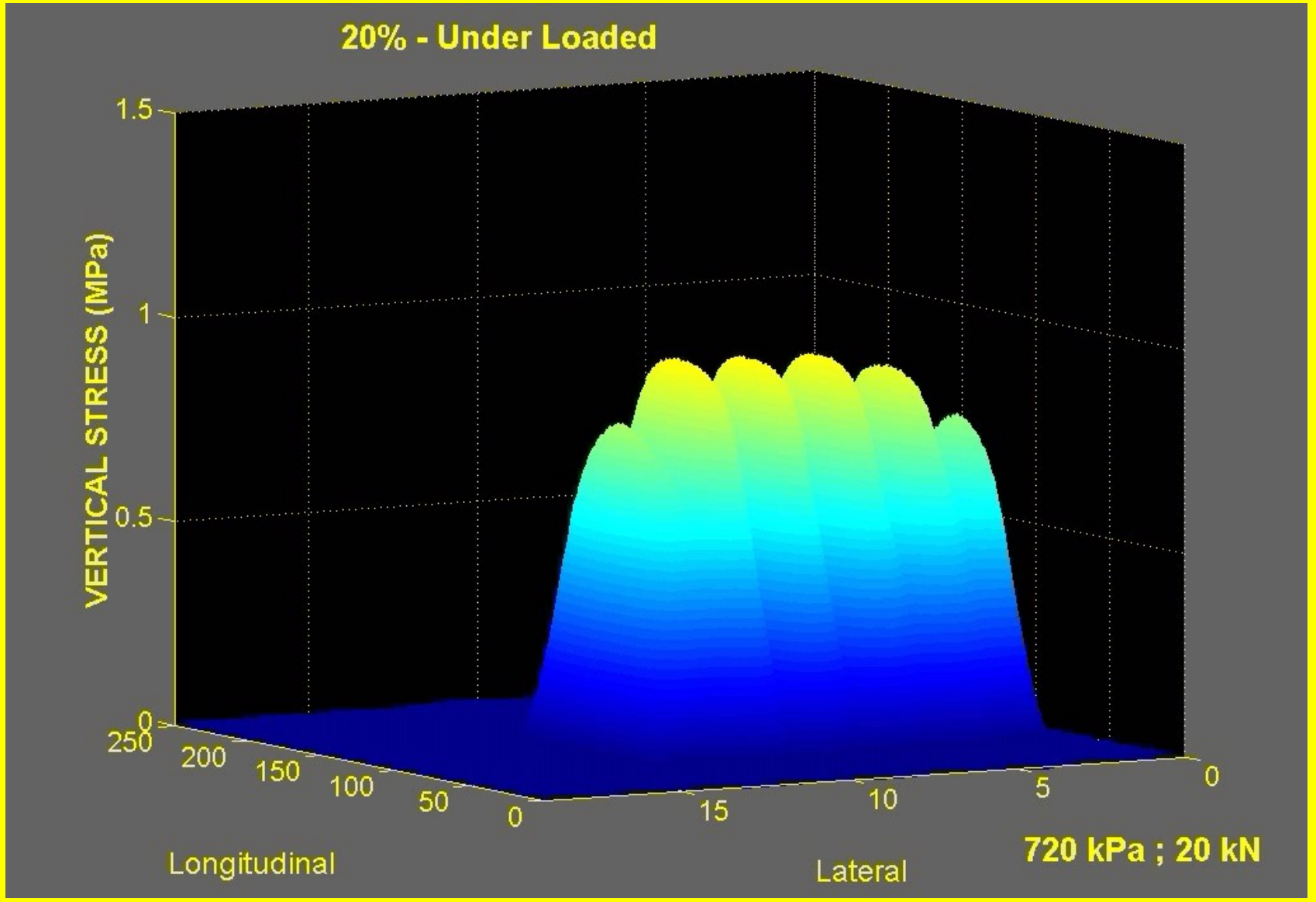


Filename ISHVWDport.jpg from file traffic1.m

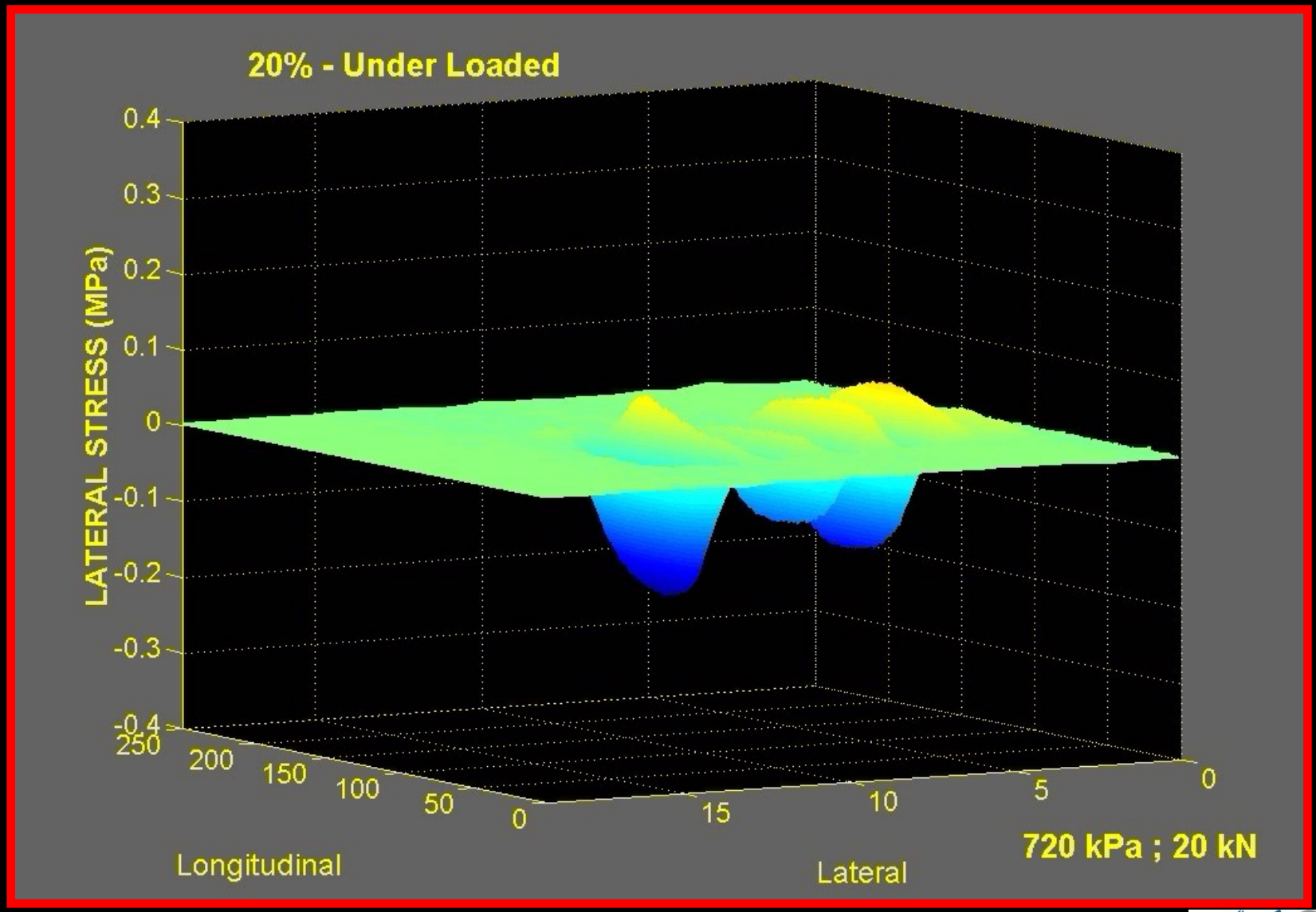
SIM DATA USED FOR ANALYSIS



SIM DATA : VERTICAL STRESSD (Z)



SIM DATA : LATERAL STRESS (Y)



SIM DATA: LONGITUDINAL STRESS (X)

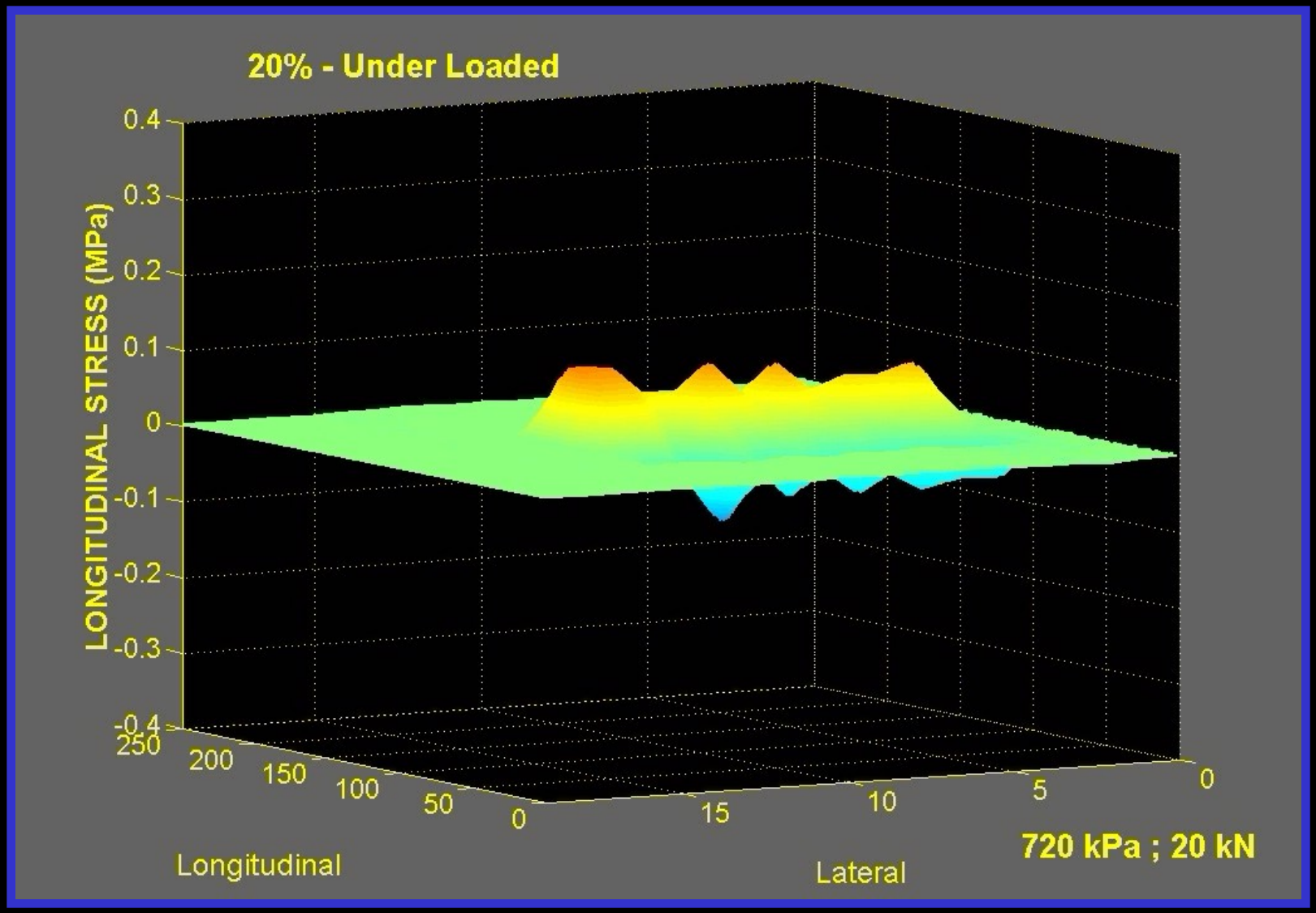


Table 2: Maximum Stresses

Loading Case	Max Vert Stress: Z (kPa)	Max Lat Stress: Y (kPa)	Max Long Stress: X(kPa)
1 (n-shape)	953	191	102
2 (m-shape)	1189	209	185
3 (m-shape)	1486	261	210

NORMALISED CONTACT PRESSURE (NCP)

$$NCP = \frac{\text{Maximum Contact Stress @ load P}}{\text{Inflation Pressure (rated tyre load)}}$$

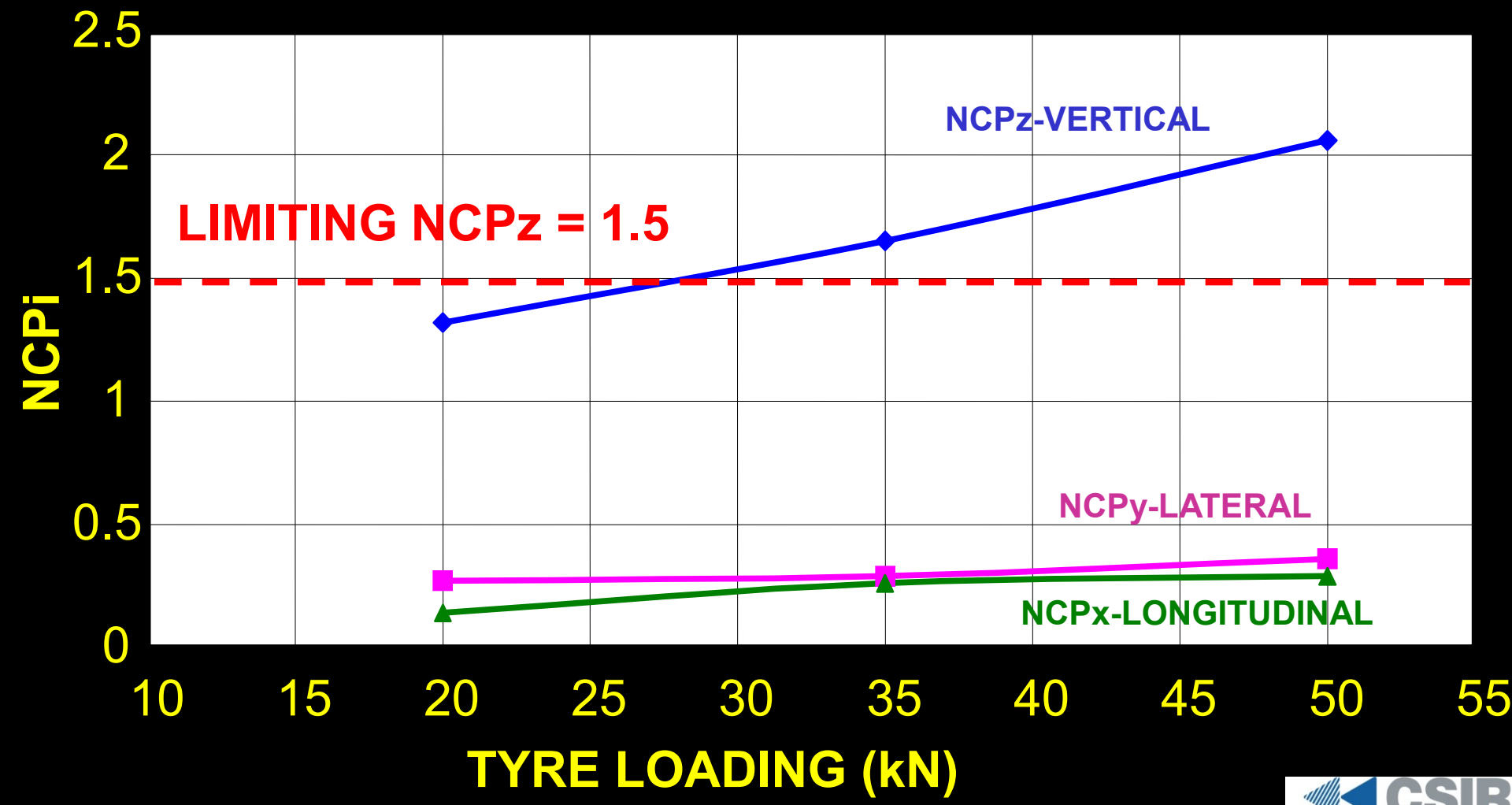
NCPz - Vertical Stress;
NCPx - Long. Stress;
NCPy - Lateral Stress;

Performance Based Standard ?

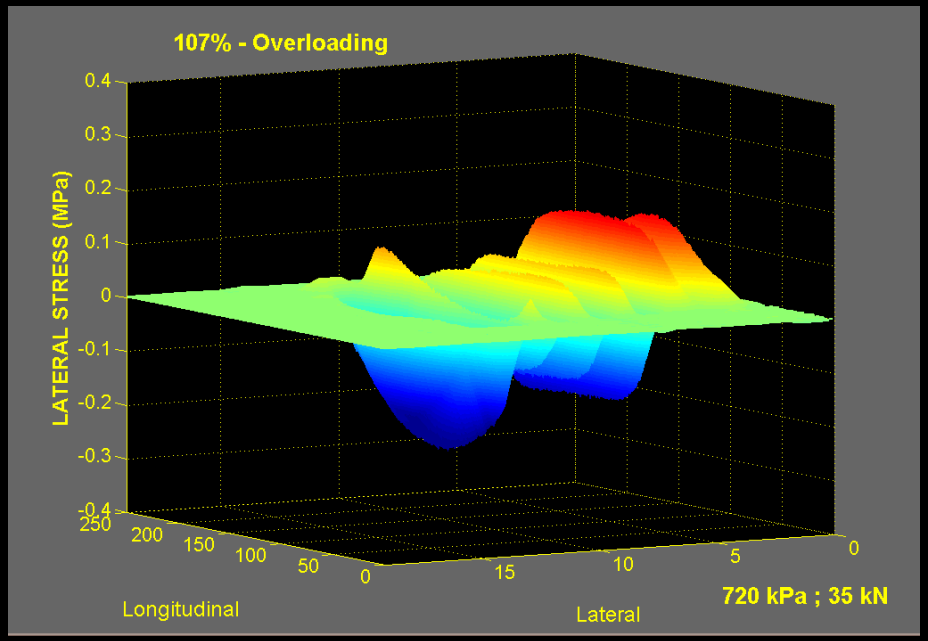
Table 3: NCPs

Load Case	NCP_Z	NCP_Y	NCP_X
1 (n-shape)	1.32	0.27	0.14
2 (m-shape)	1.65	0.29	0.26
3 (m-shape)	2.06	0.36	0.29

NCPs cont.

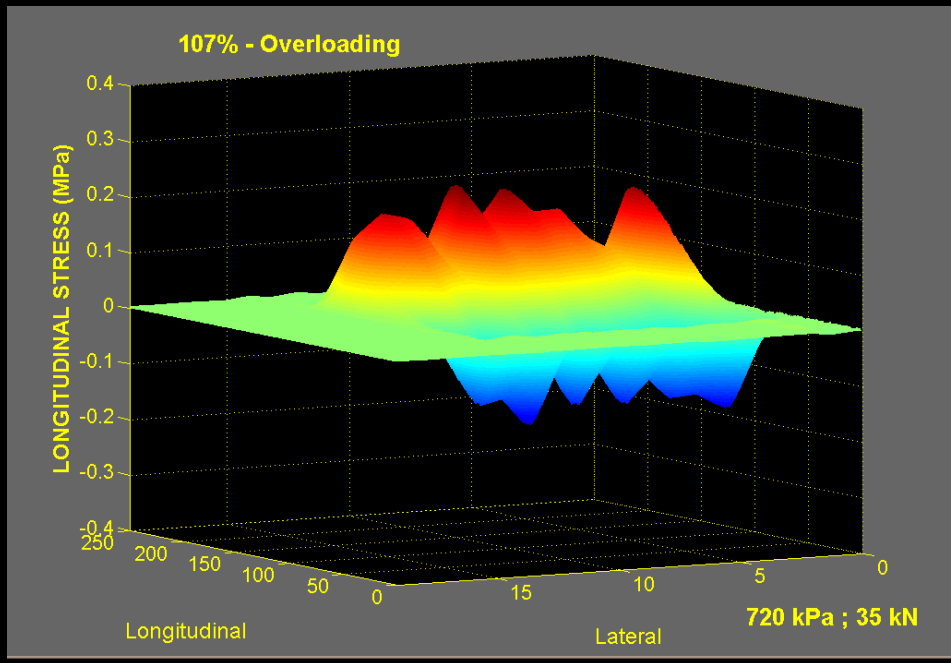

NORMALISED CONTACT PRESSURE (NCP)- FREE ROLLING TYRE
NCPi
2.5
2
1.5
1
0.5
0
LIMITING NCPz = 1.5
NCPz-VERTICAL
NCPy-LATERAL
NCPx-LONGITUDINAL
10
15
20
25
30
35
40
45
50
55
TYRE LOADING (kN)

Interface shear stresses (x,y)



Lateral (X)shear stresses

Long. (Y) shear stresses



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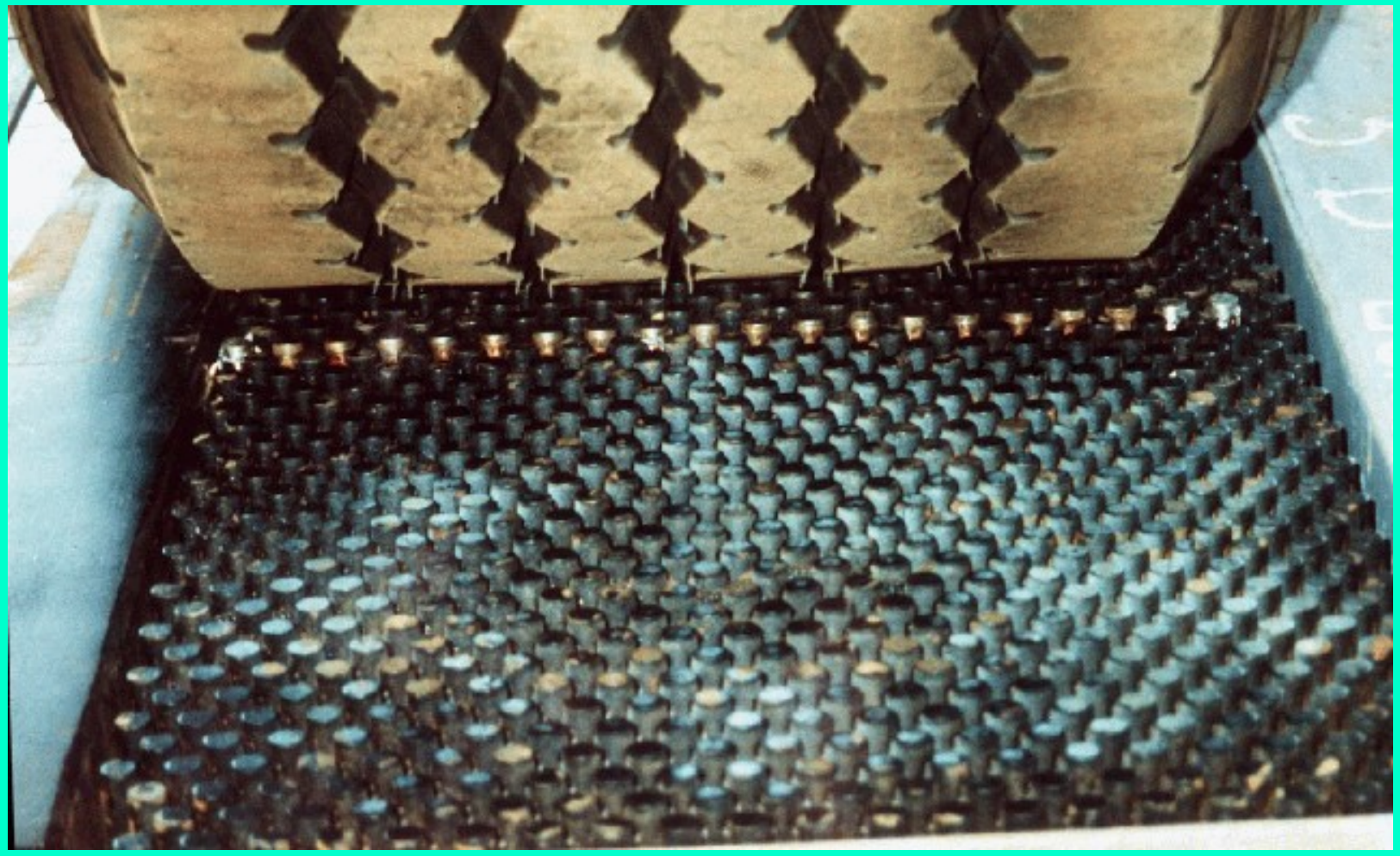
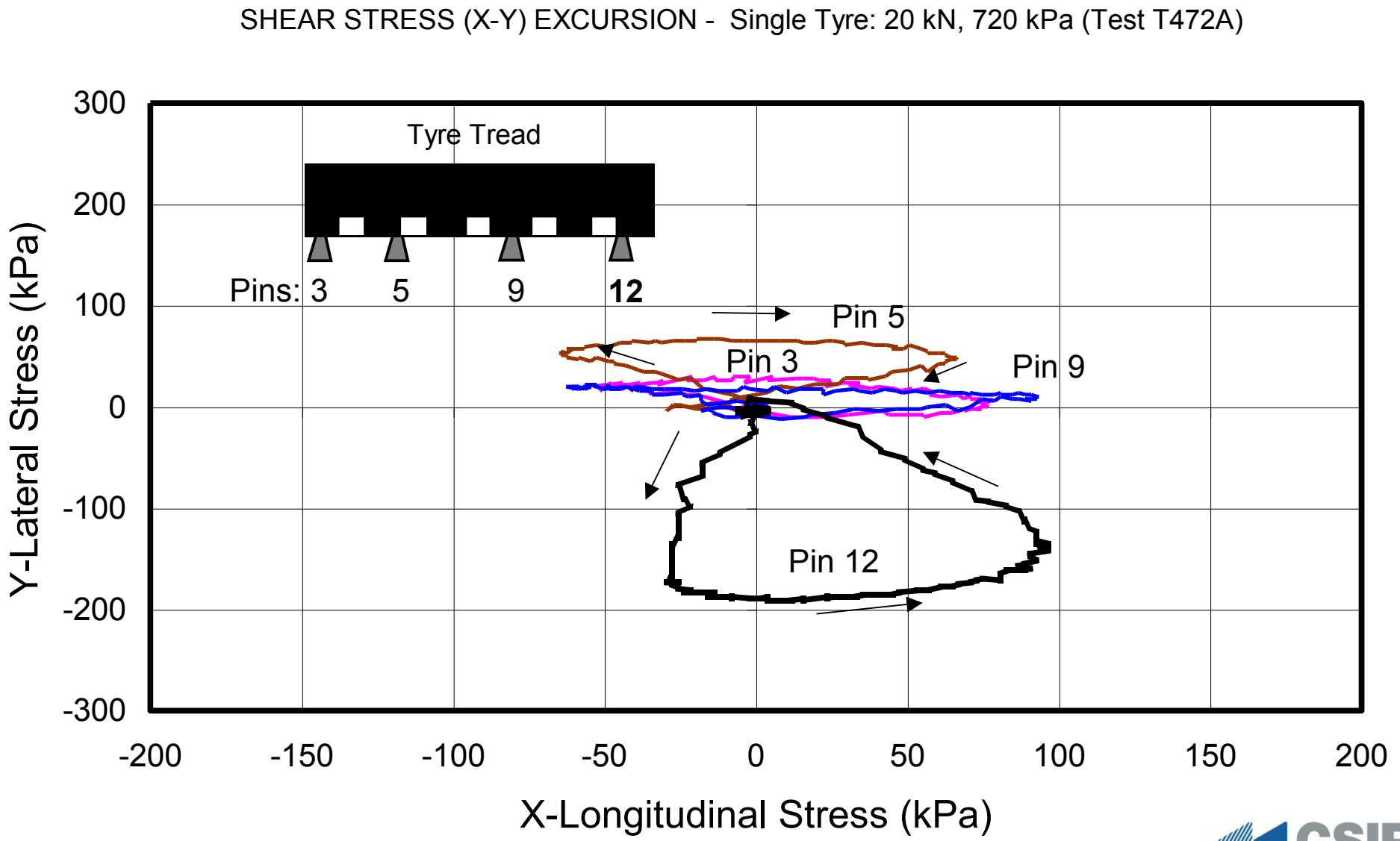


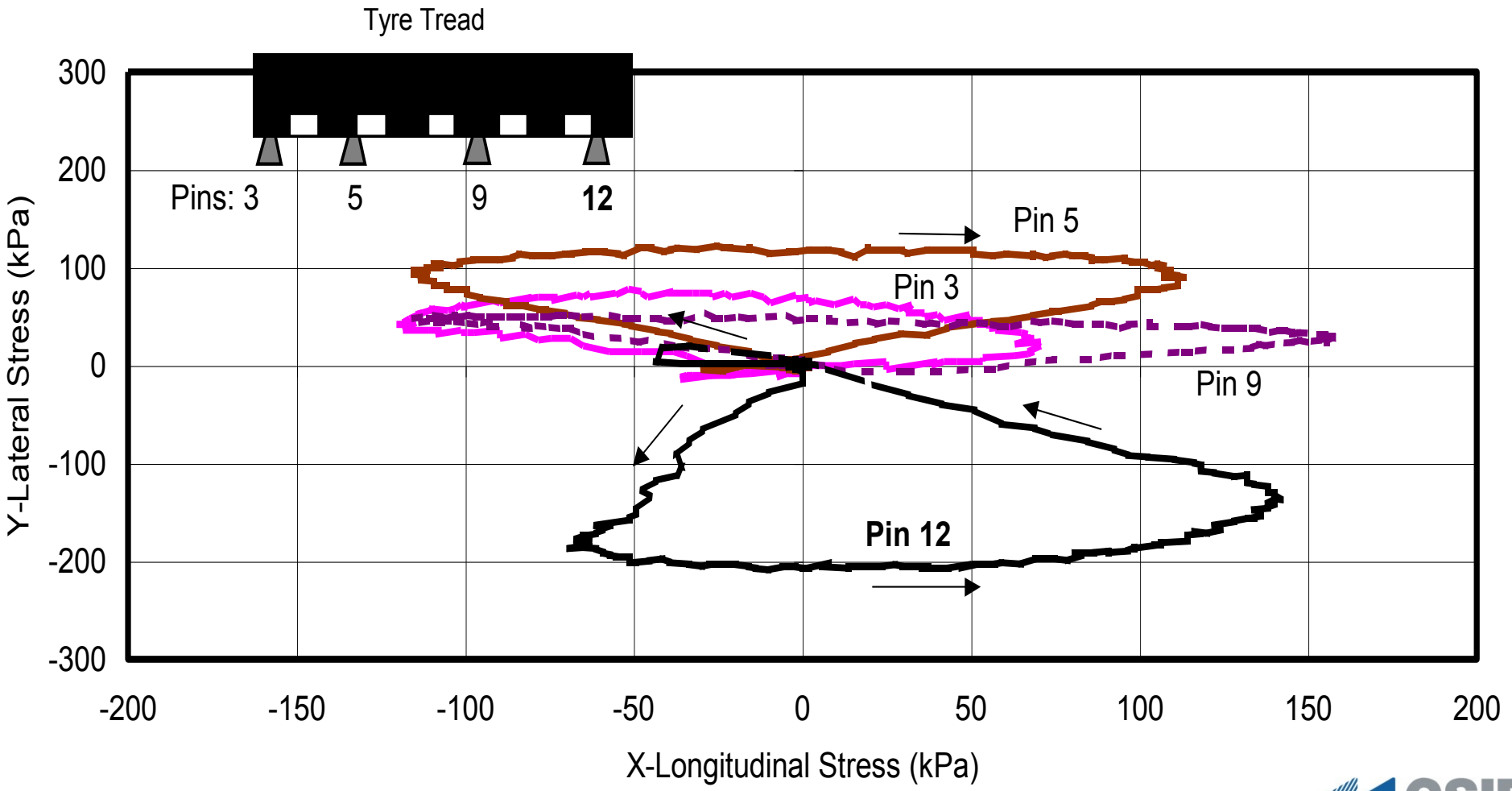
425 /65 R22.5 HVS TIRE ON SIM SYSTEM:

EXAMPLE OF FOOTPRINT TO FOLLOW…..

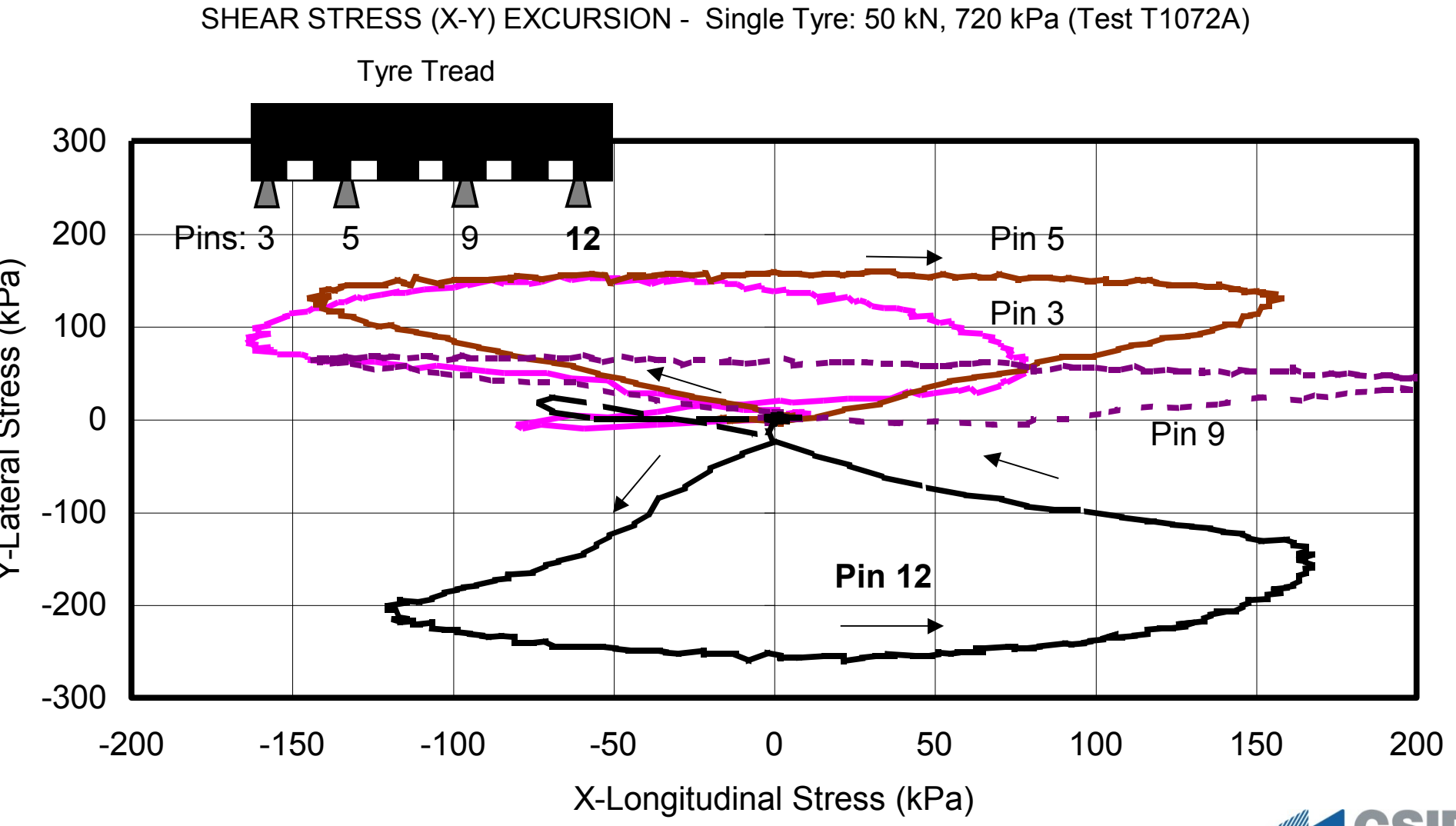
LATERAL (X-Y) STRESS EXCURSIONS



LATERAL (X-Y) STRESS EXCURSIONS



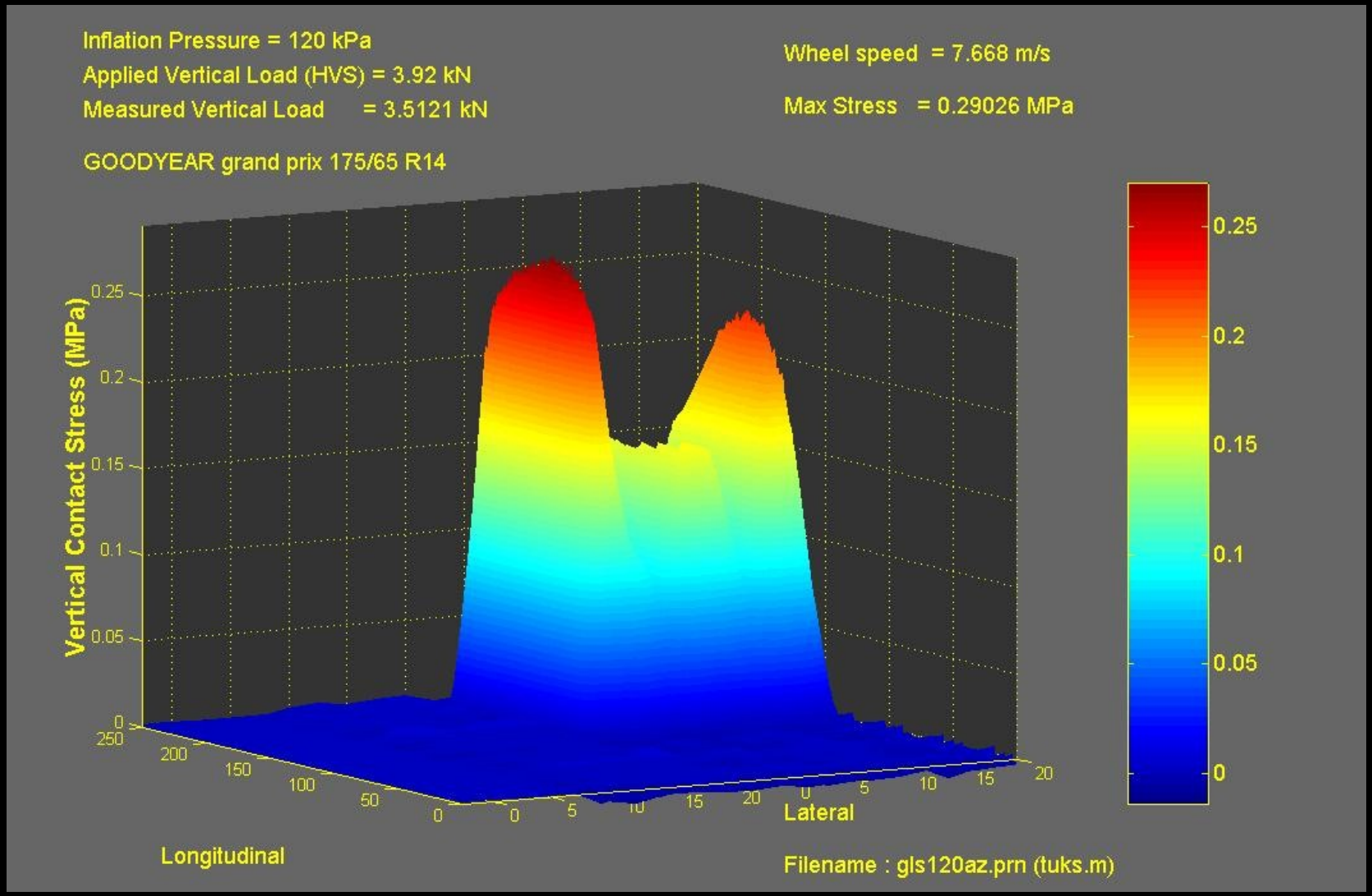
LATERAL (X-Y) STRESS EXCURSIONS



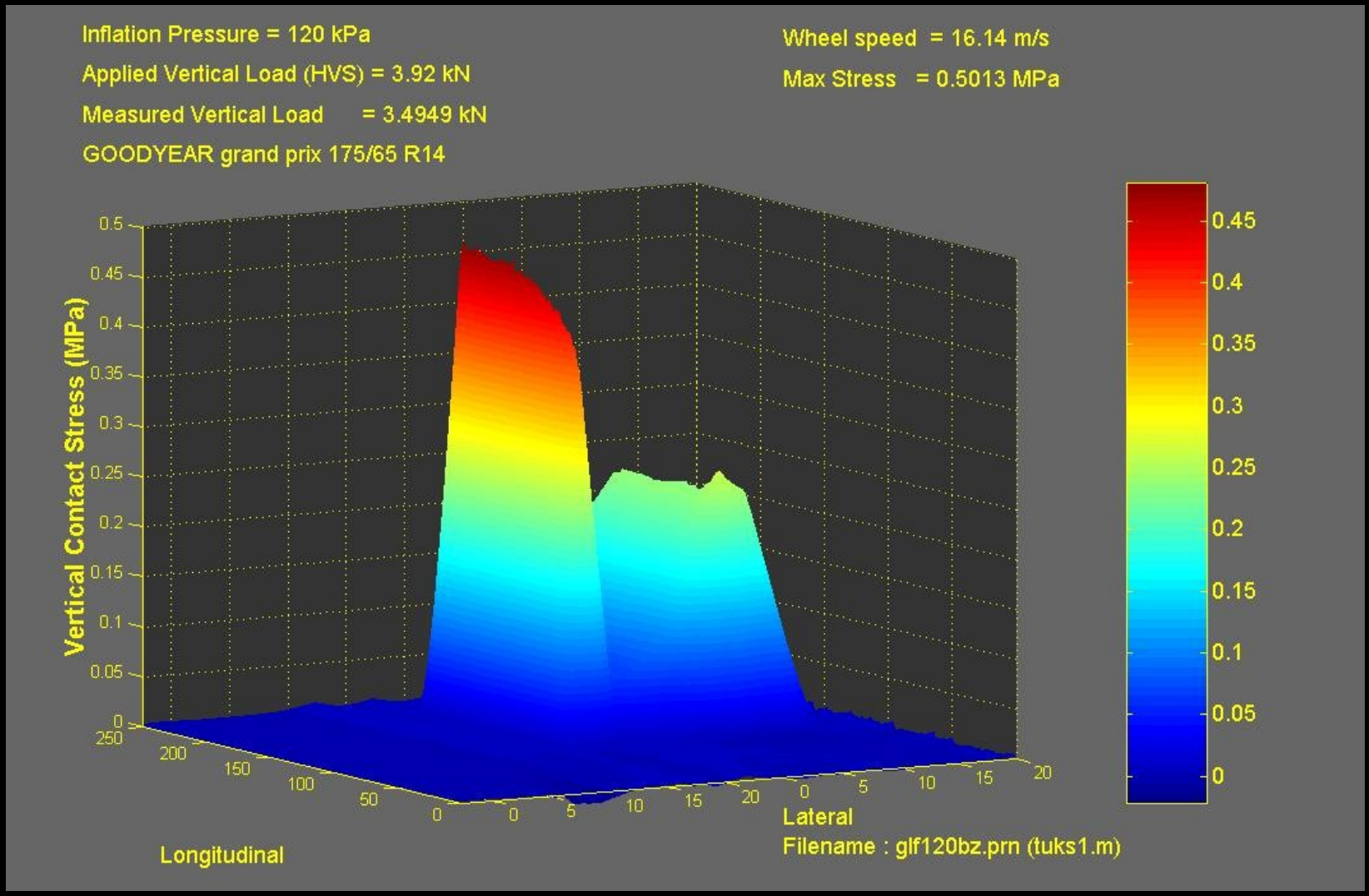
Effects of Tyre Speed on contact stress

- Not studied in detail with *SIM*;
- Preliminary work done in 1996 on *car* tyres;
- Changes in *shape of stress* regime expected;
- Axle lift may result in *smaller* contact patch (6 % @ 100 km/h);
- Some pavement response parameters *decrease* with increased speed.

Effect of Tyre Speed: 27.6 km/h

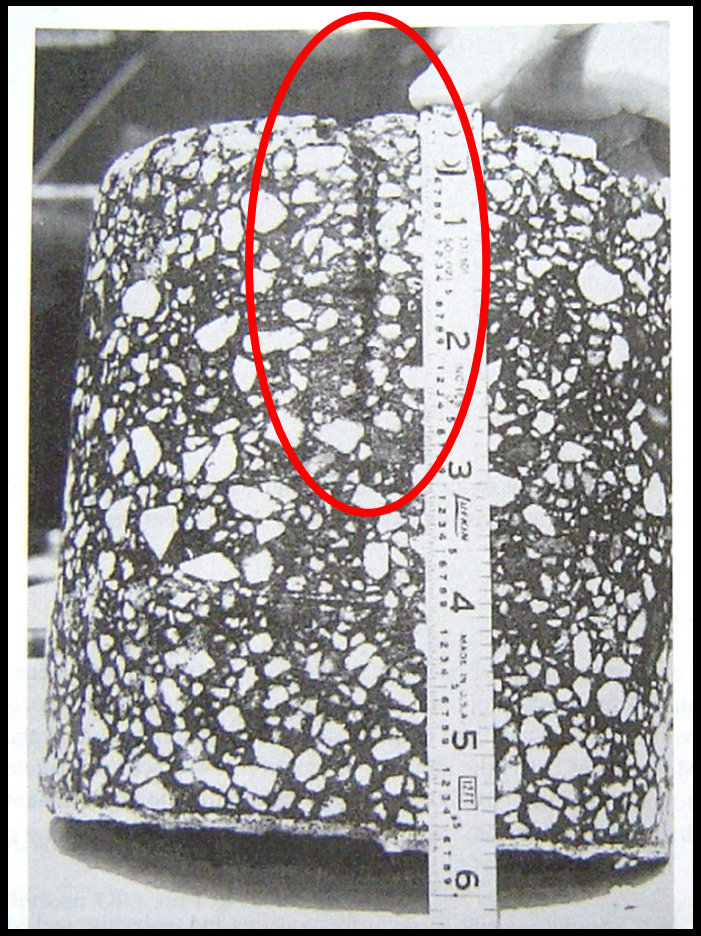


Effect of Tyre Speed: 58.1 km/h

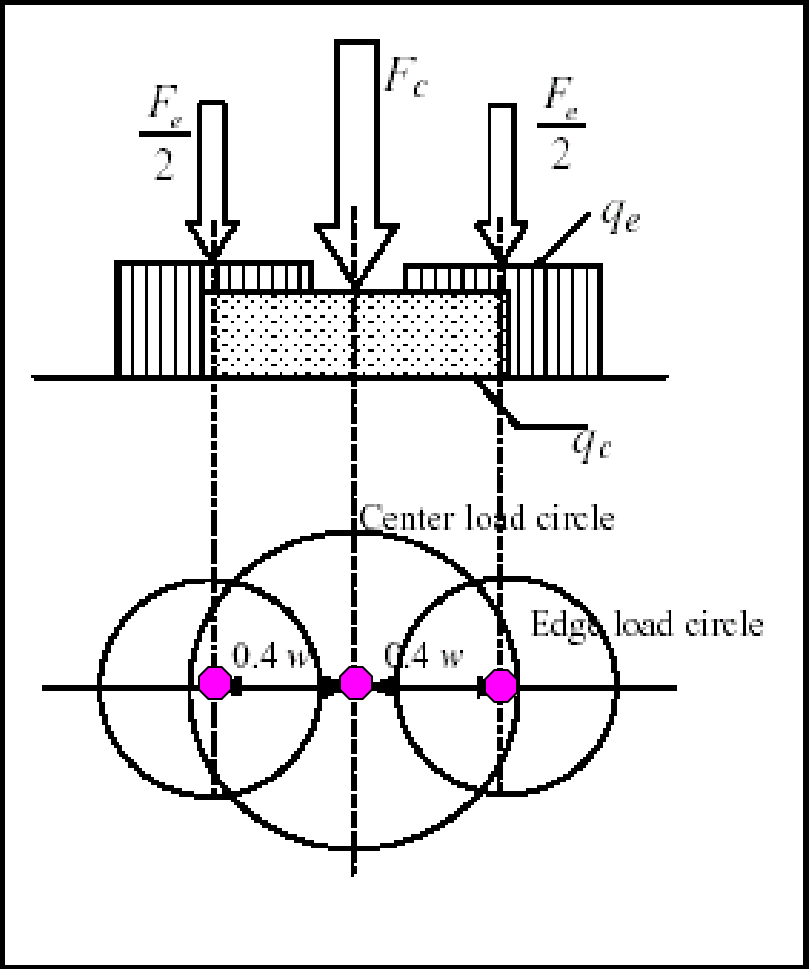


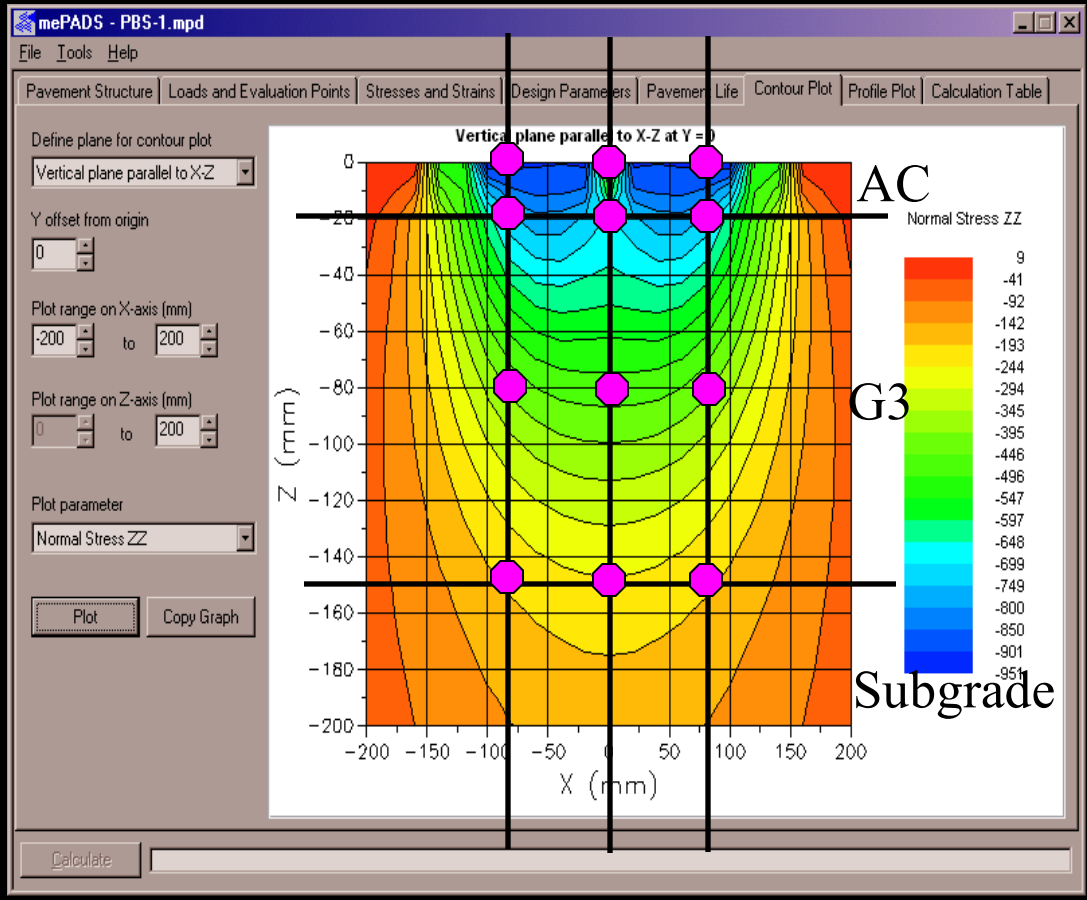
Top Down Cracking in ("thick") AC layers

- MAJOR REASON:Non-Traffic associated- shrinkage, temperature, construction, etc.;
- Traffic associated- tyres and stresses – but <u>not</u> solely responsible for this type of cracking;
- Working <u>conjointly</u> - most probable scenario;

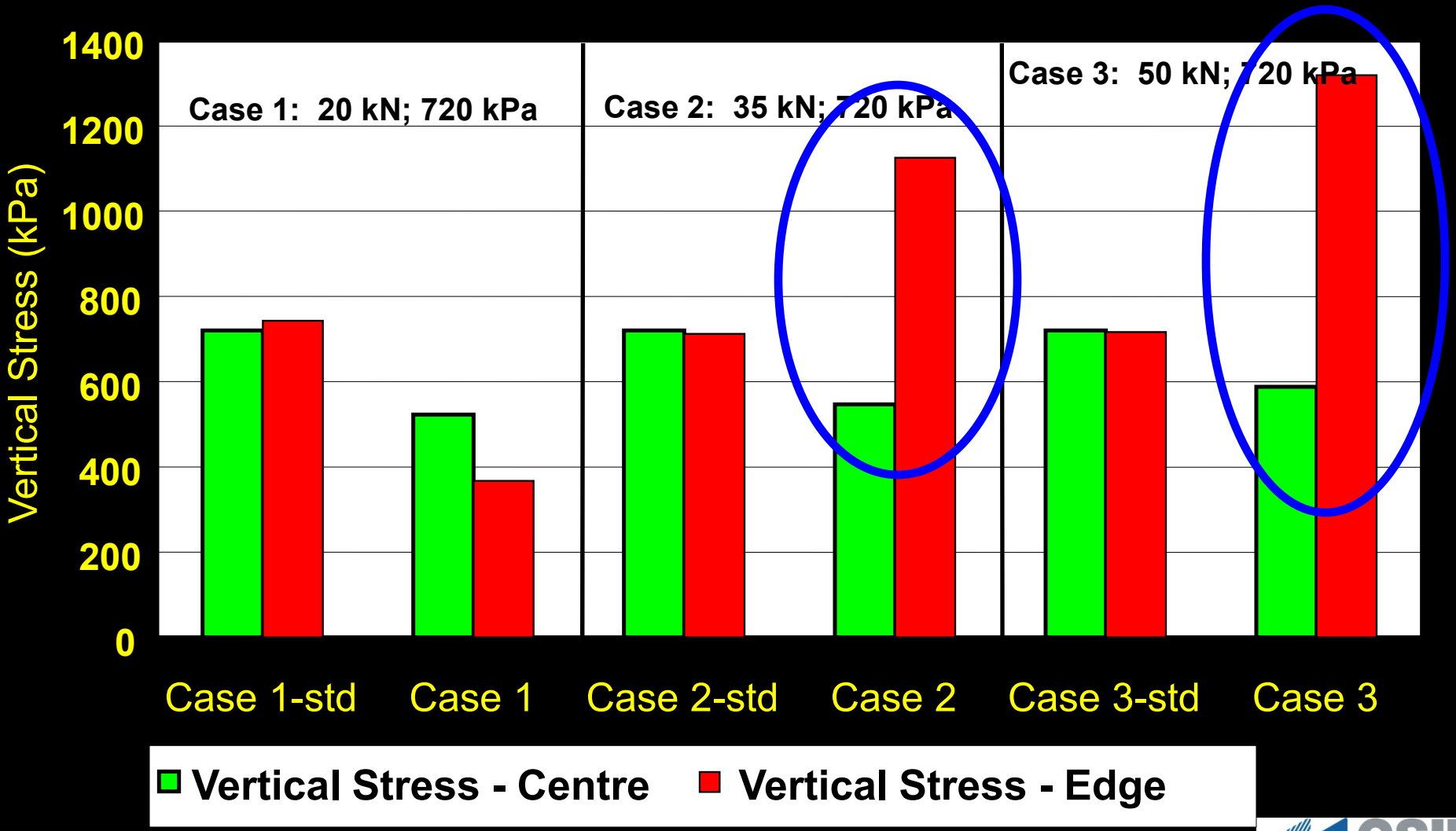


Circular load - Tyre Model (Blab, 2001)

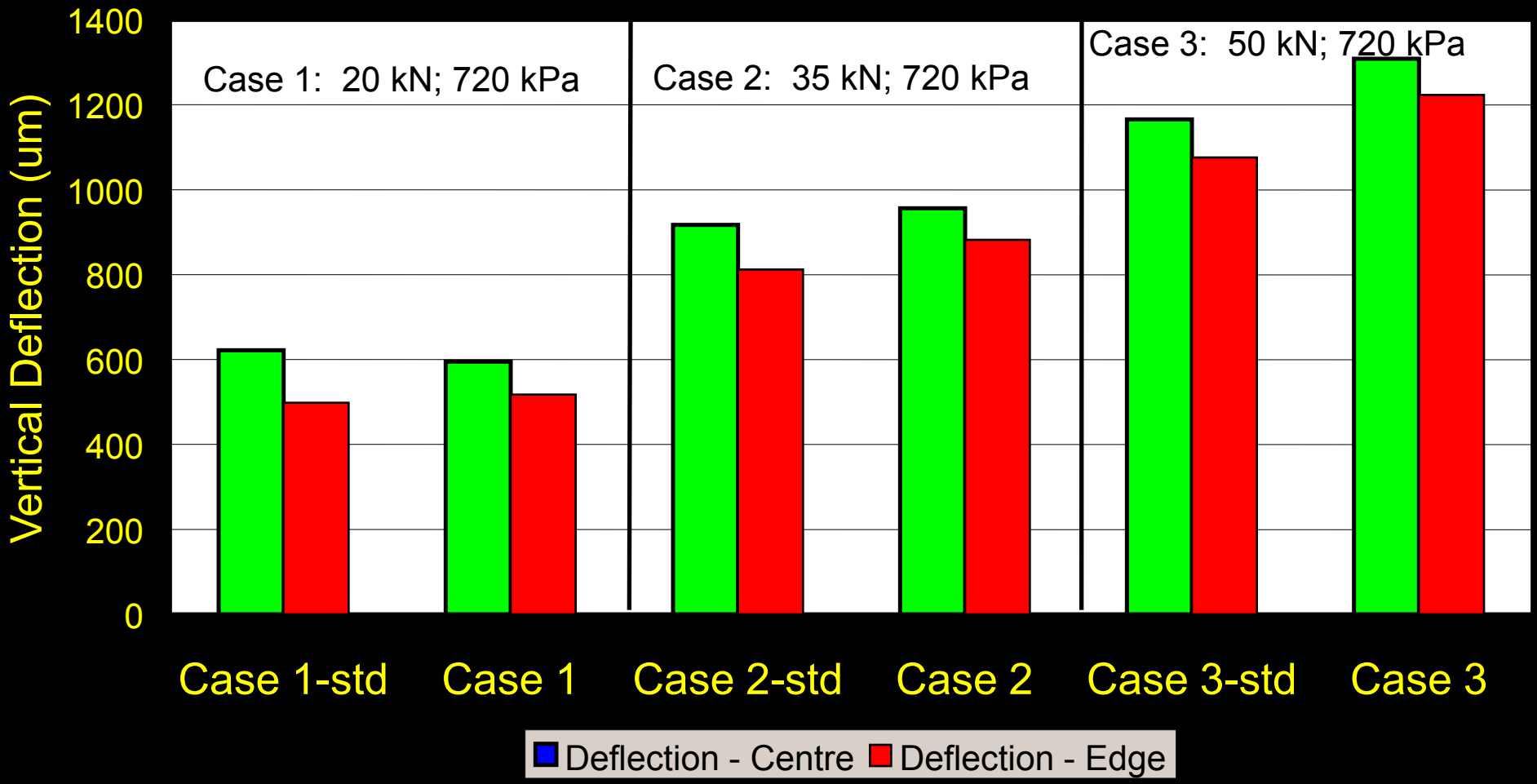




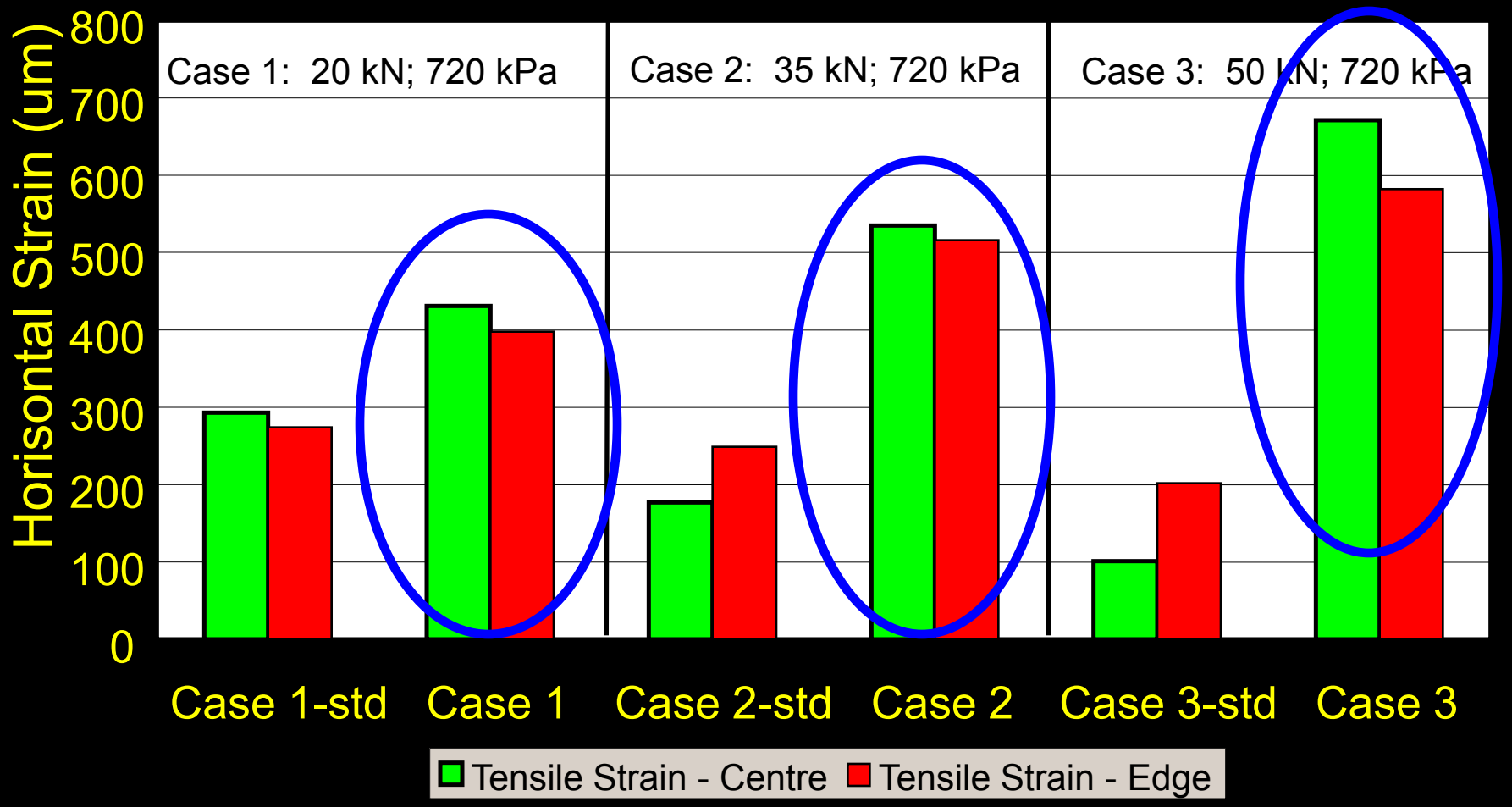
VERTICAL STRESS: TYRE CENTRE AND EDGE



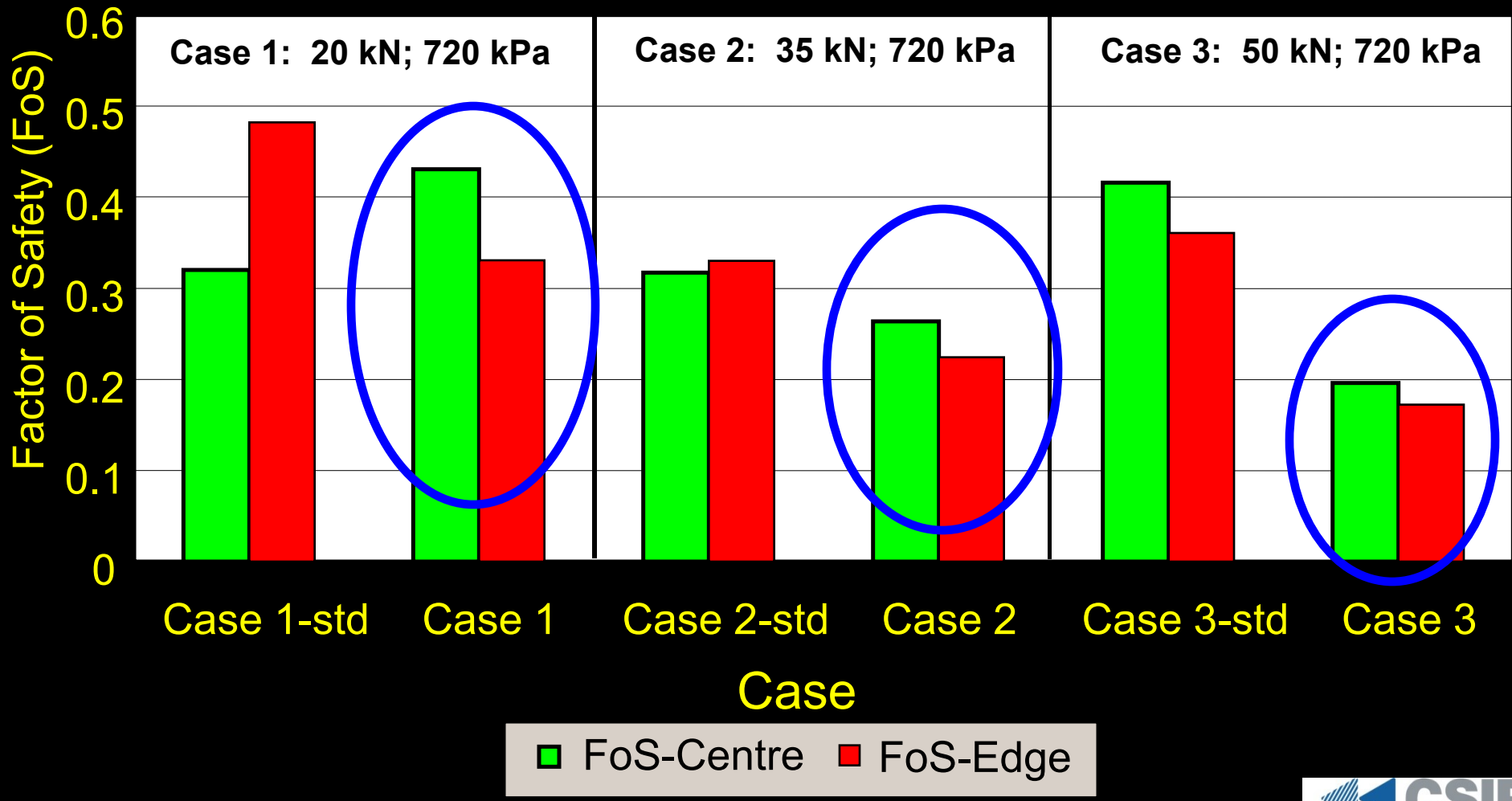
VERTICAL ELASTIC DEFLECTION ON SURFACE: TYRE CENTRE AND EDGE



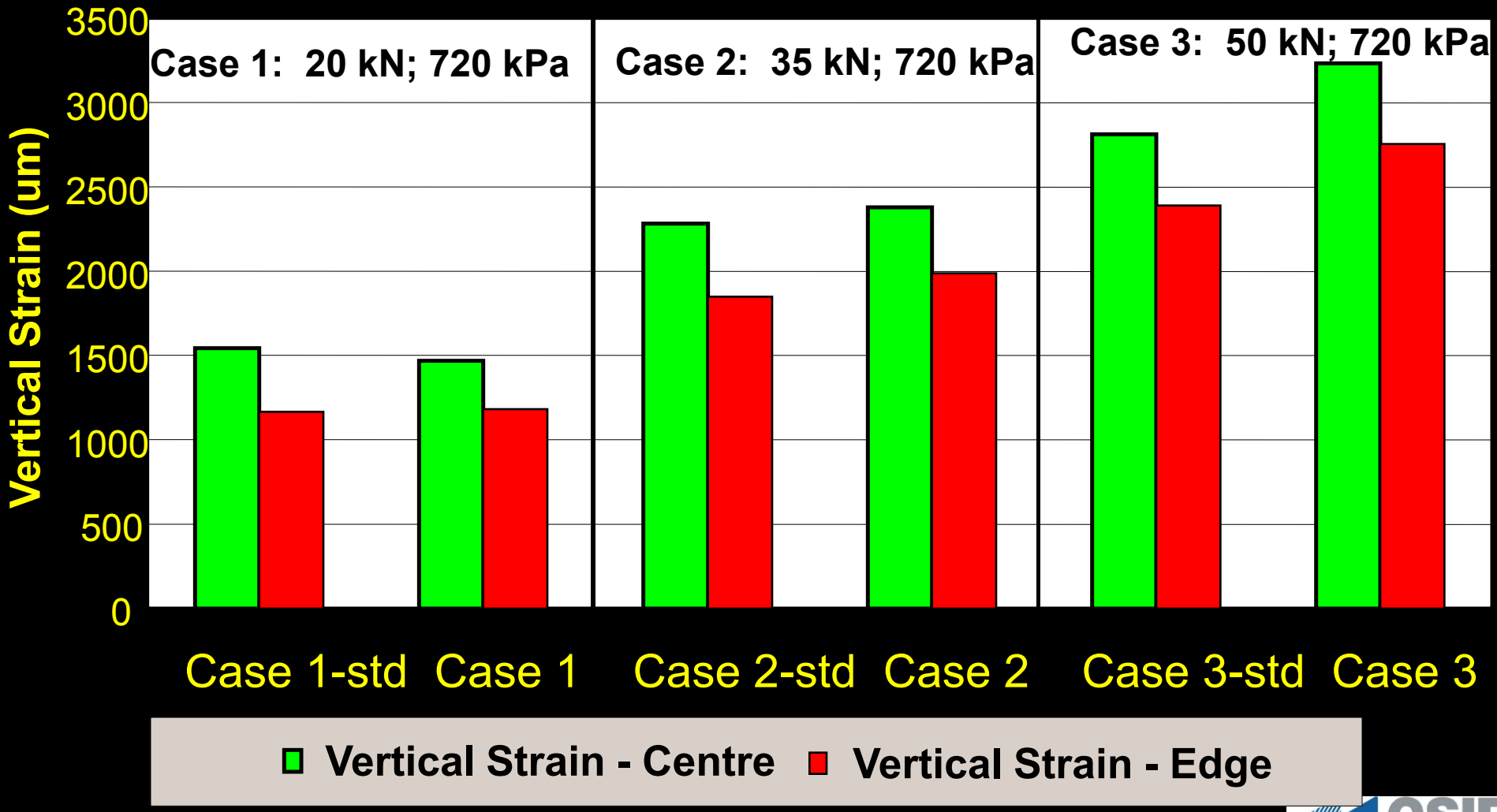
HORISONTAL STRAIN BOTTOM OF 20 mm ASPHALT SURFACING: TYRE CENTRE AND EDGE



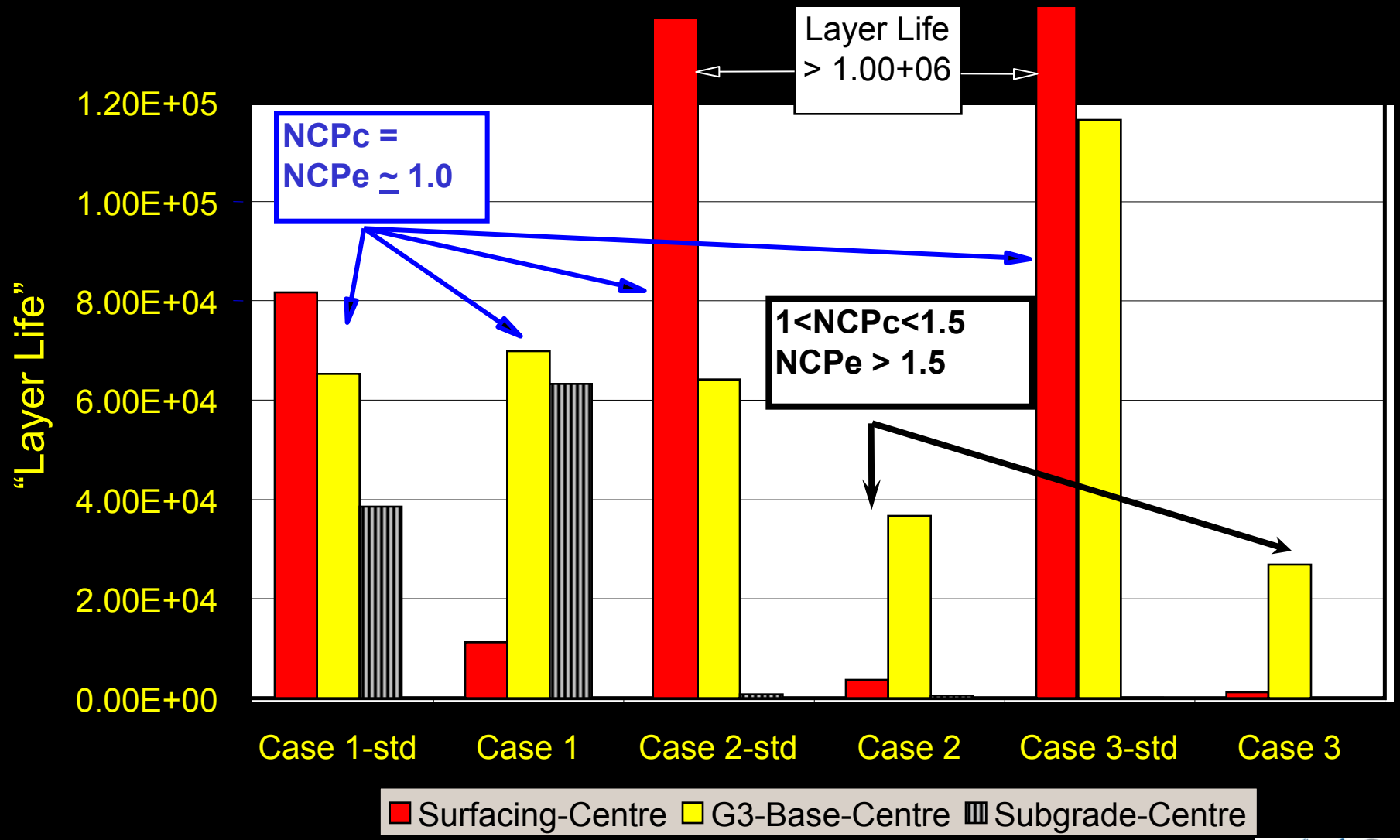
FACTOR OF SAFETY (FoS) - GRANULAR BASE TYRE CENTRE AND EDGE



VERTICAL STRAIN ON TOP OF SUBGRADE: TYRE CENTRE AND EDGE



PAVEMENT LIFE : MECHANISTIC – EMPIRICAL: CRITICAL LAYER APPROACH (*me-PADS*)



PERFORMANCE BASED STANDARD (PBS)

NCPz (for Vertical Stress) ≤ 1.5

….for rated tyre loading on thinly surfaced pavements.. ?

IN SUMMARY…….

- Use of SIM technology demonstrated;
- Tyre contact stress shapes: Vertical: typically “n-shapes and “m”-shapes;
- X-Y Shear excursion plots- useful concept ?;
- Three-circle modeling in MLLE analyses;
- NCP useful concept recommended for PBS;

RECOMMENDATIONS…..

- Continued R & D with SIM:
  - Higher speeds;
  - Braking and acceleration (down hill);
- Analysis of a wider range of pavement types;
- Improved modeling (tyre contact patch non-uniform & non-circular);
- NCPz, NCPx, NCPy to be further investigated for PBS applications.


Thank you