



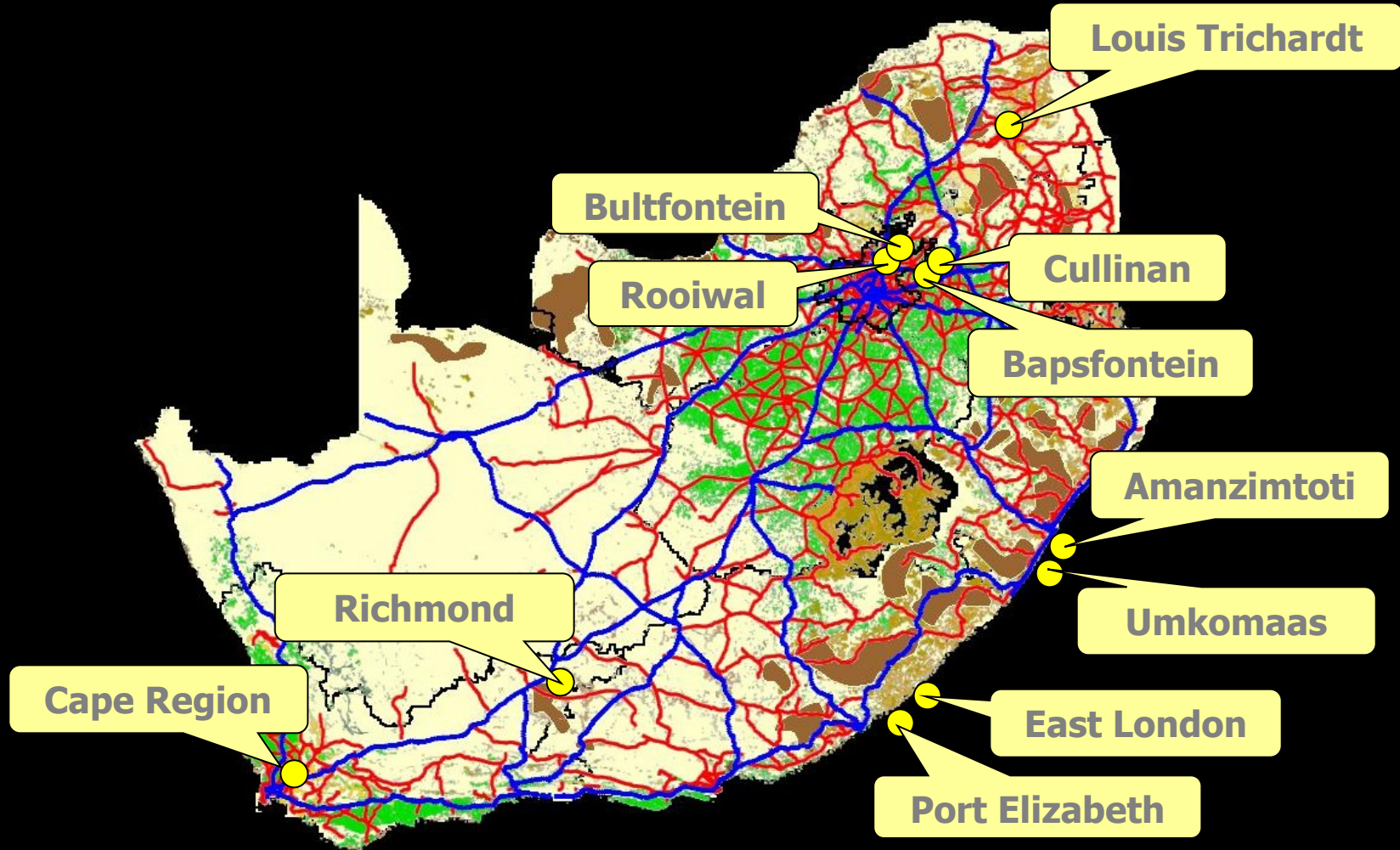
TYRE-PAVEMENT CONTACT STRESS PATTERNS FROM THE TEST TYRES OF THE GAUTRANS HEAVY VEHICLE SIMULATOR (HVS) MK IV⁺

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C FISHER, C H COETZEE
CSIR Built Environment*

3) (א) זרועות פולצות וזרועות



Some HVS tests in SA





LAYOUT OF PAPER:

- Background on test tyres of the Heavy Vehicle Simulator (HVS);
- Problem Statement – 11R22.5 vs 12R22.5 and 315/80 R22.5 tyres – are these tyres doing the same “damage” to pavements during Accelerated Pavement Testing (APT)?;
- Methodology: – Stress-In-Motion (SIM) Technology used - Test Matrices;
- Results: - Compare Contact Stresses of different tyres;

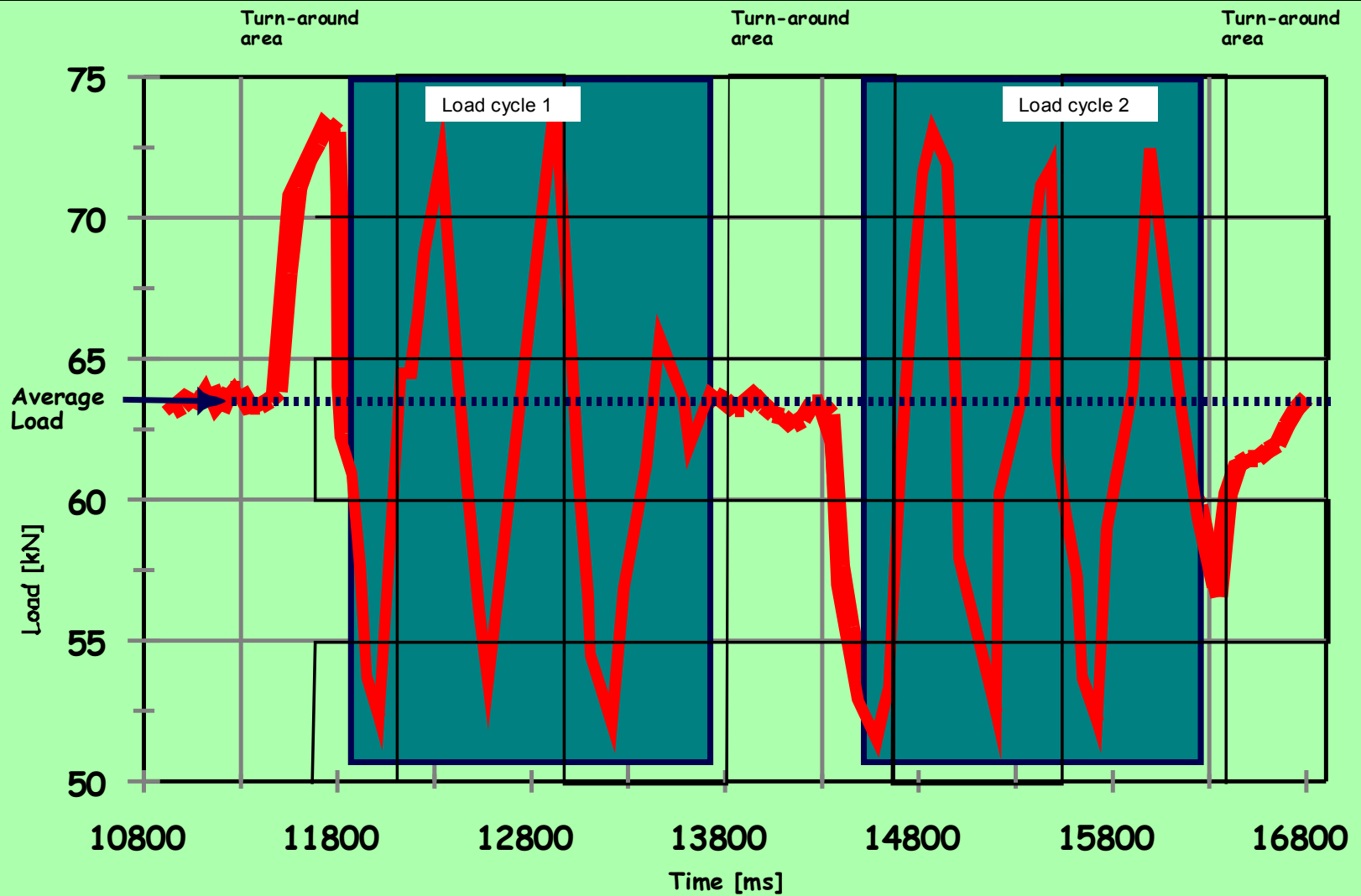
$$\frac{\{ \} \{ \} - \{ - \{ \} \{ \} (\{ \})}{\{ (\{ \{ \{ \} \}) }$$

$$\begin{aligned} \{ (\{ \{ \} \} (\{ \{ \} \} \{ \}) \} \uparrow \{ \} / \{ \} (\{ \{ \} \} (\{ \{ \} \} (\{ \}) \{ \} \{ \} \{ \}) \\) \{ \{ \{ \{ \} \} \} \{ \} \} (\{ \{ \} \}) \end{aligned}$$

Gautrans HVS Mark IV+

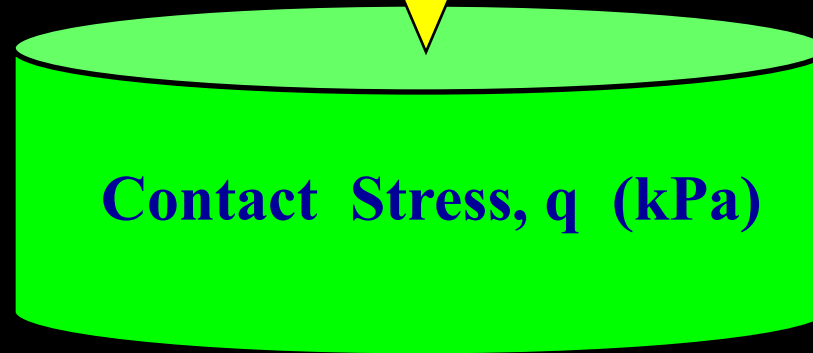


NEW HVS Mk IV +: TYPICAL DYNAMIC LOAD HISTORY



Road Pavement Design Tyre Loading: ELSYM, RUBICON

Tyre Loading, P (kN)



Contact Stress, q (kPa)

Plastic Deformation (Rutting..)



Cracking and Pumping...

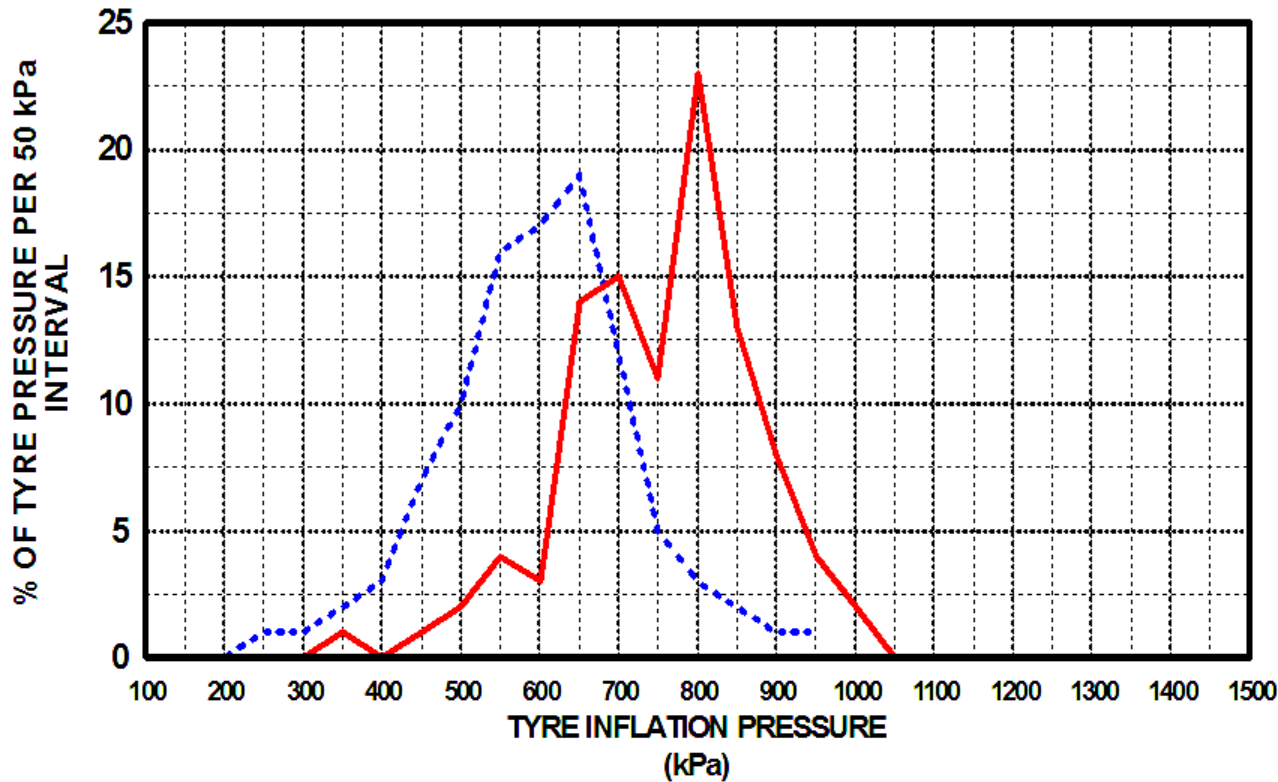


Heavy Vehicles (HVs)



Truck Tire Inflation Pressure in South Africa:

**~ 20 %
Increase
in
20 Years**



Van Vuuren (1974)

.....

Average: 620 kPa

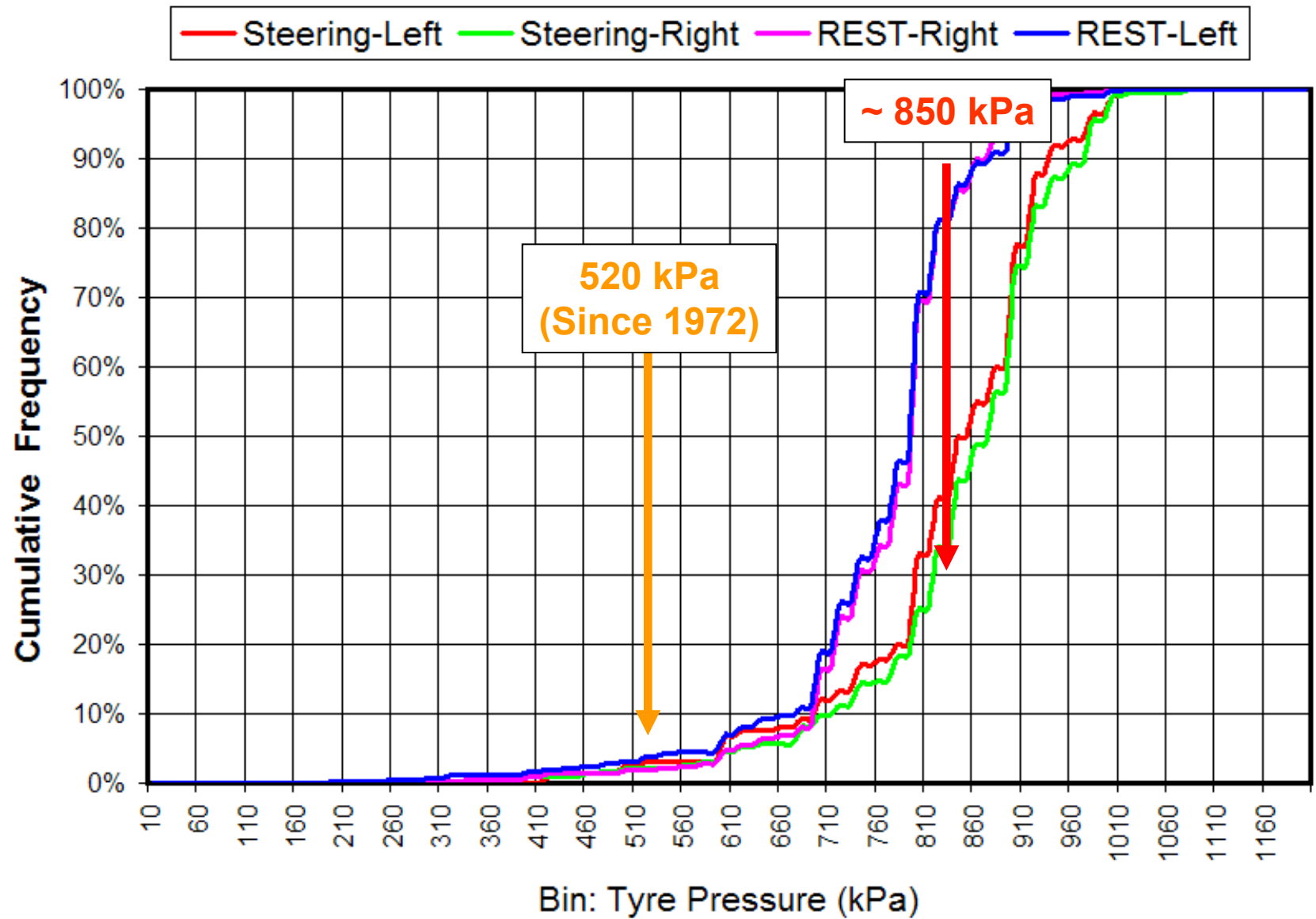
De Beer (1995)

—————

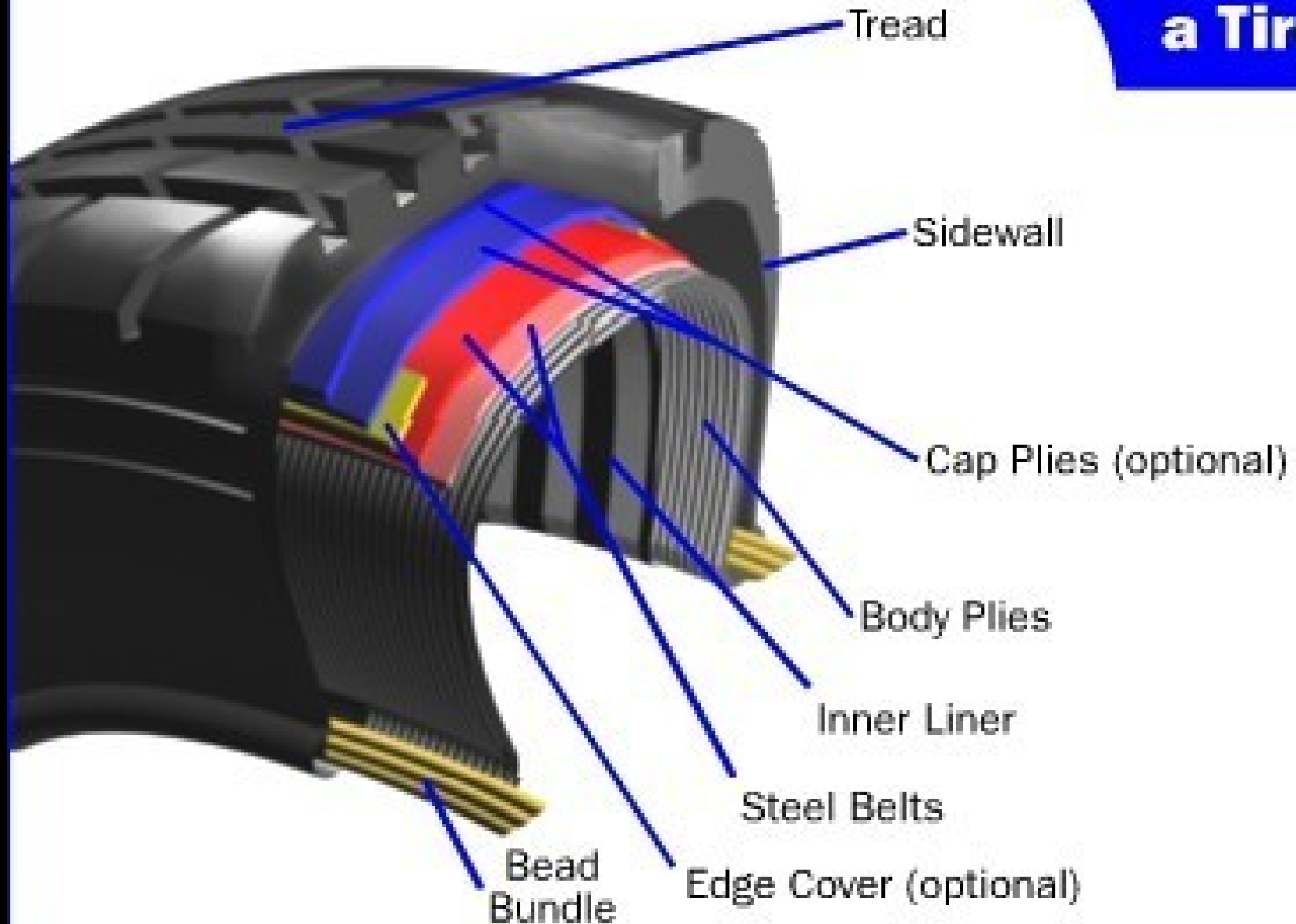
FIGURE 1

**AVERAGE MEASURED TYRE INFLATION PRESSURE DISTRIBUTIONS
OF HEAVY VEHICLES (AXLE LOADS > 7 000 kg) ON ROADS
IN THE PROVINCE OF GAUTENG, SOUTH AFRICA**

N3-TCC TYRE INFLATION PRESSURE DATA FROM MORTON ET AL, 2003

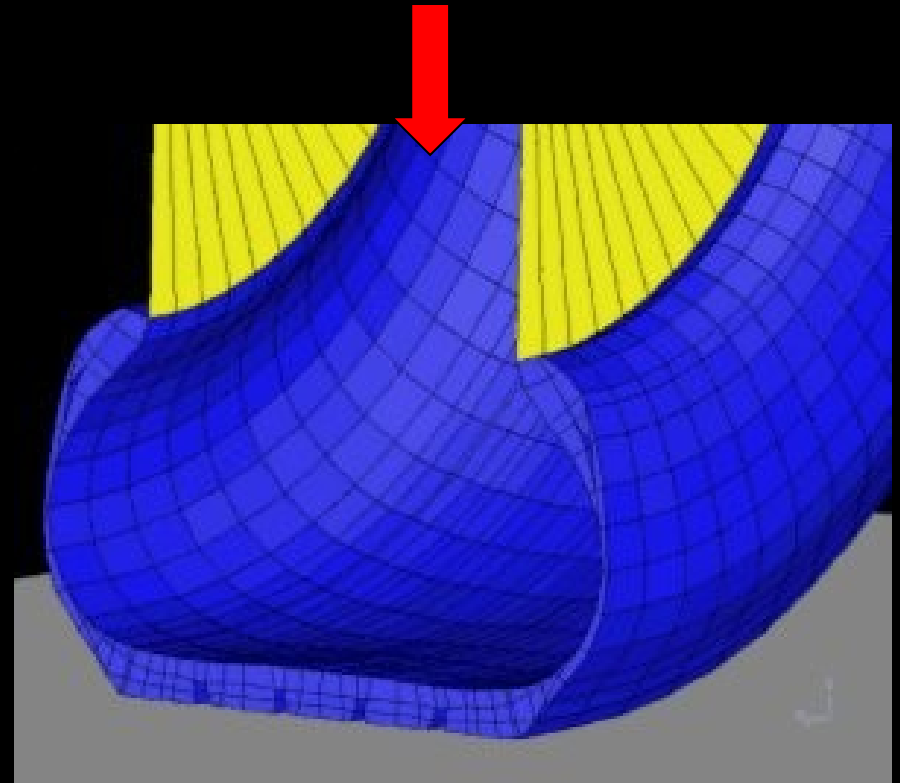
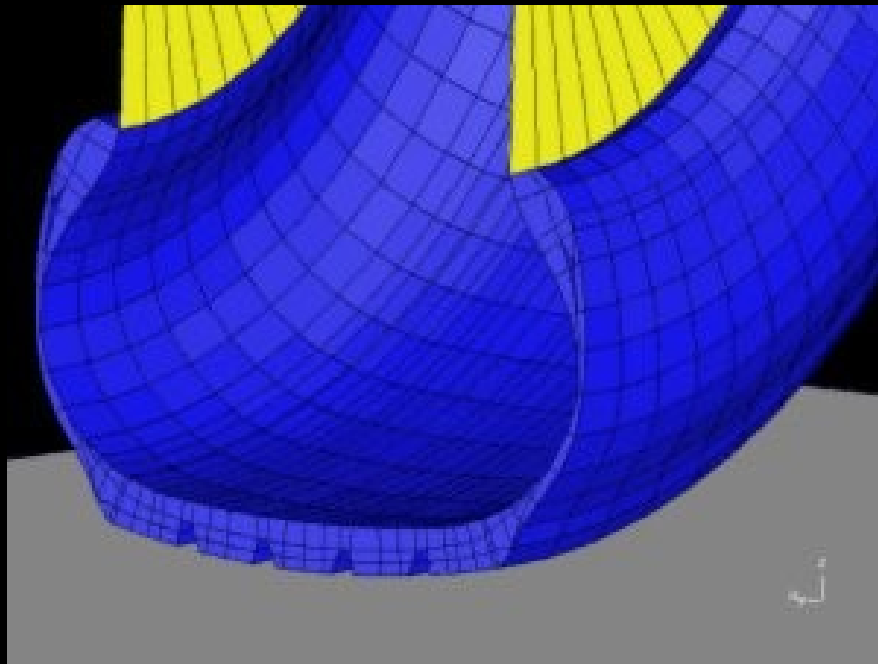


Parts of a Tire

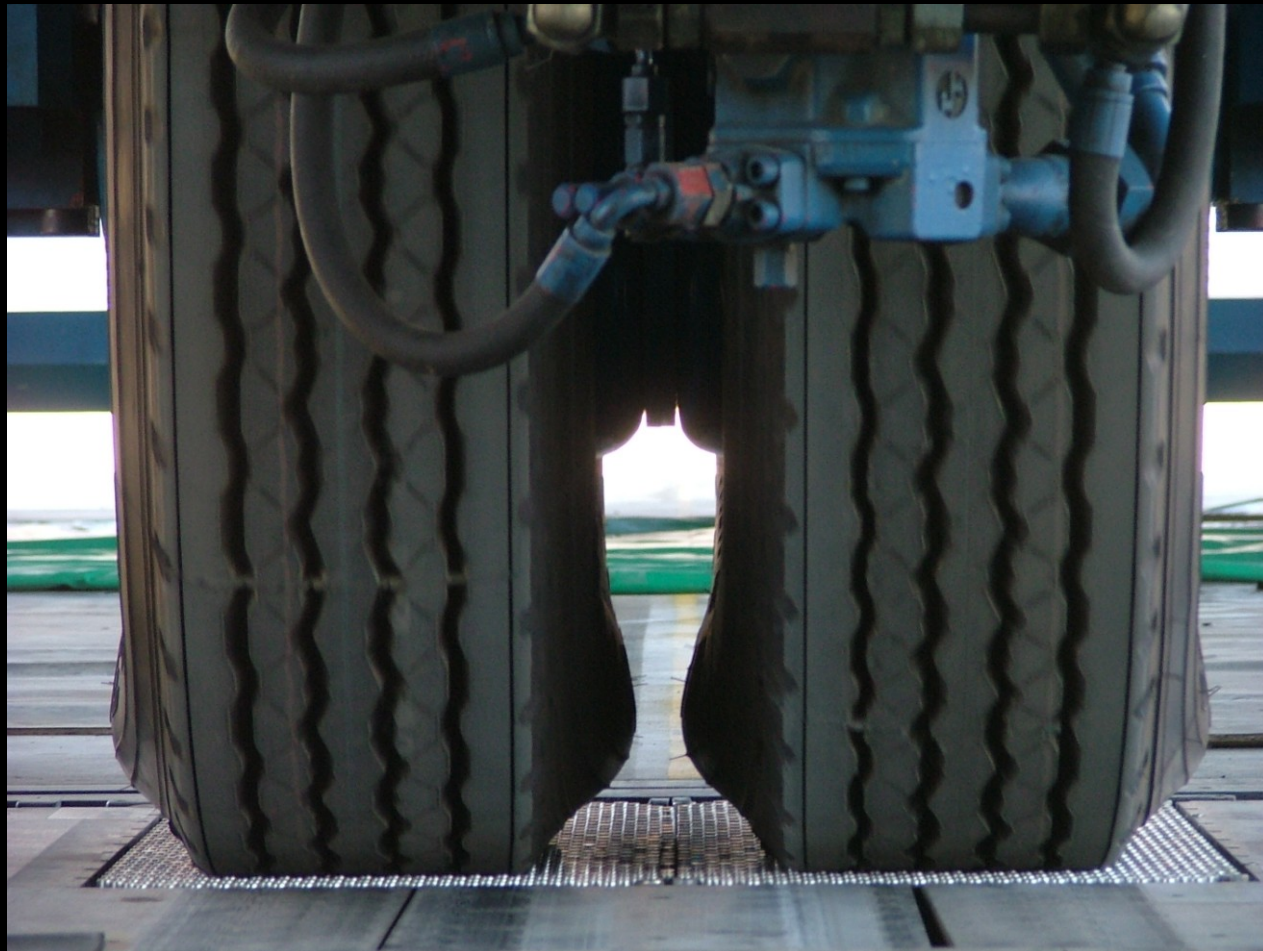


NO LOAD

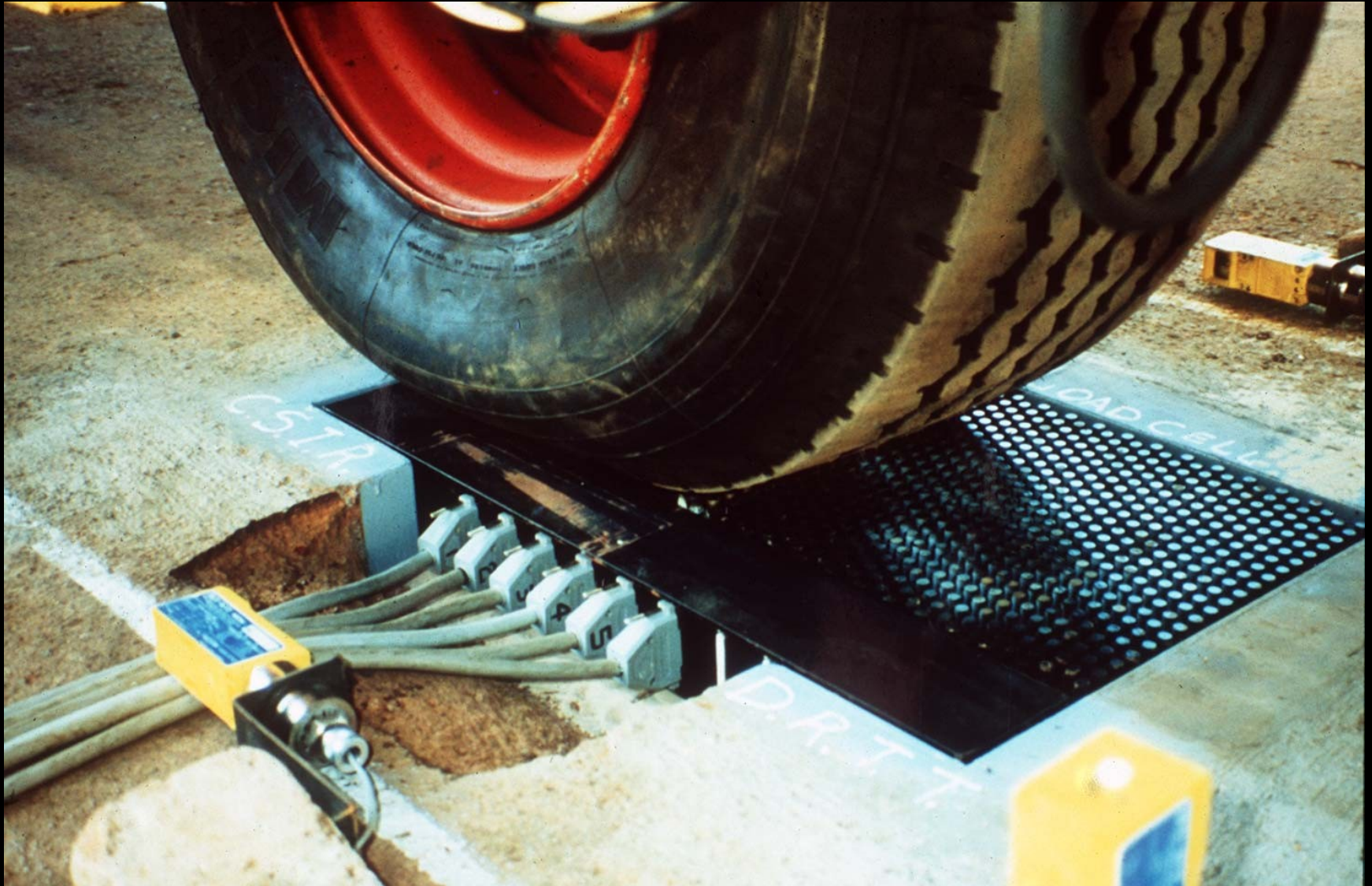
WITH
LOAD



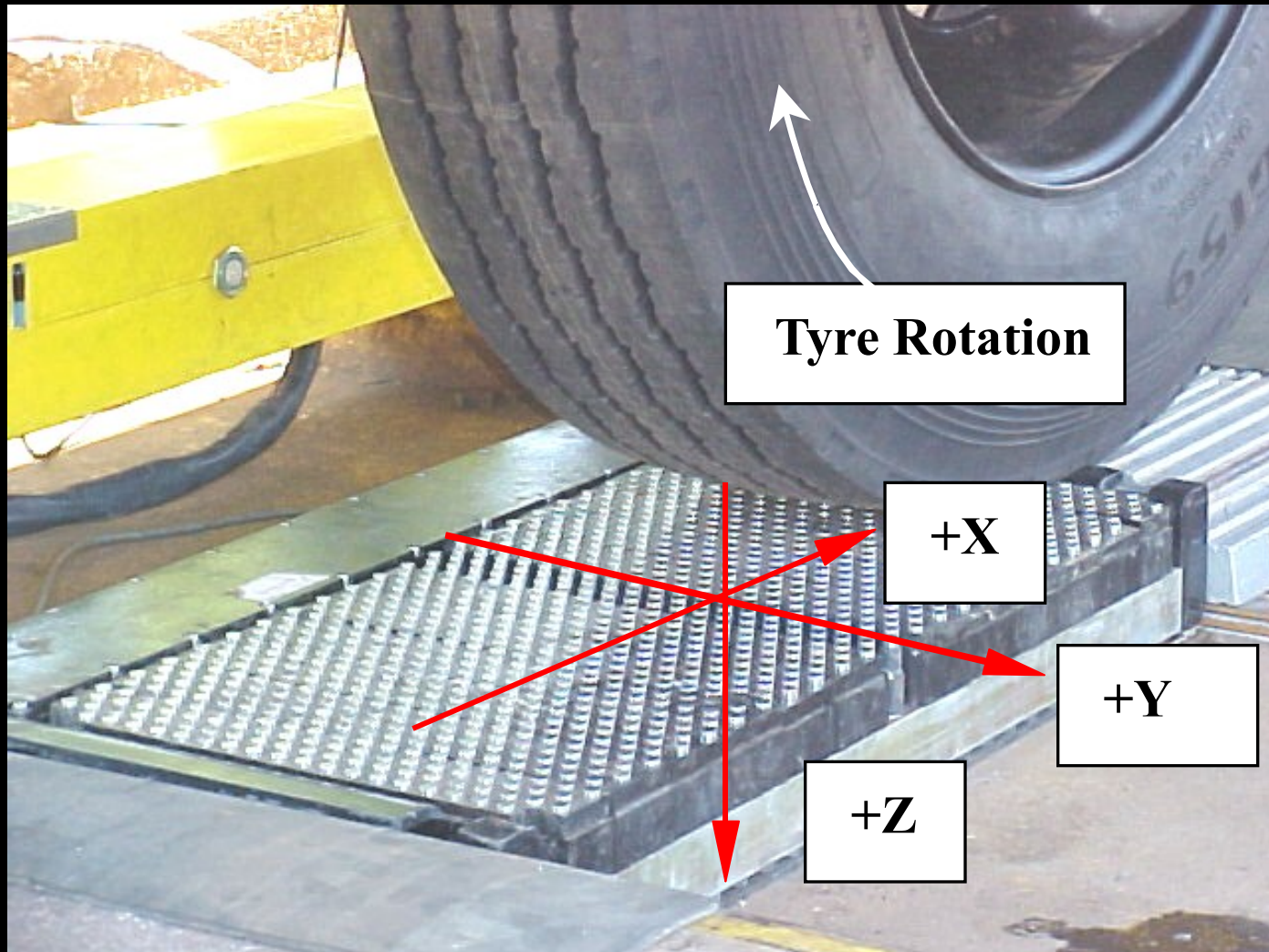
אמצעי אבטחה (X) (מסך מגן) (מ. ס. ס. ס. ס.)



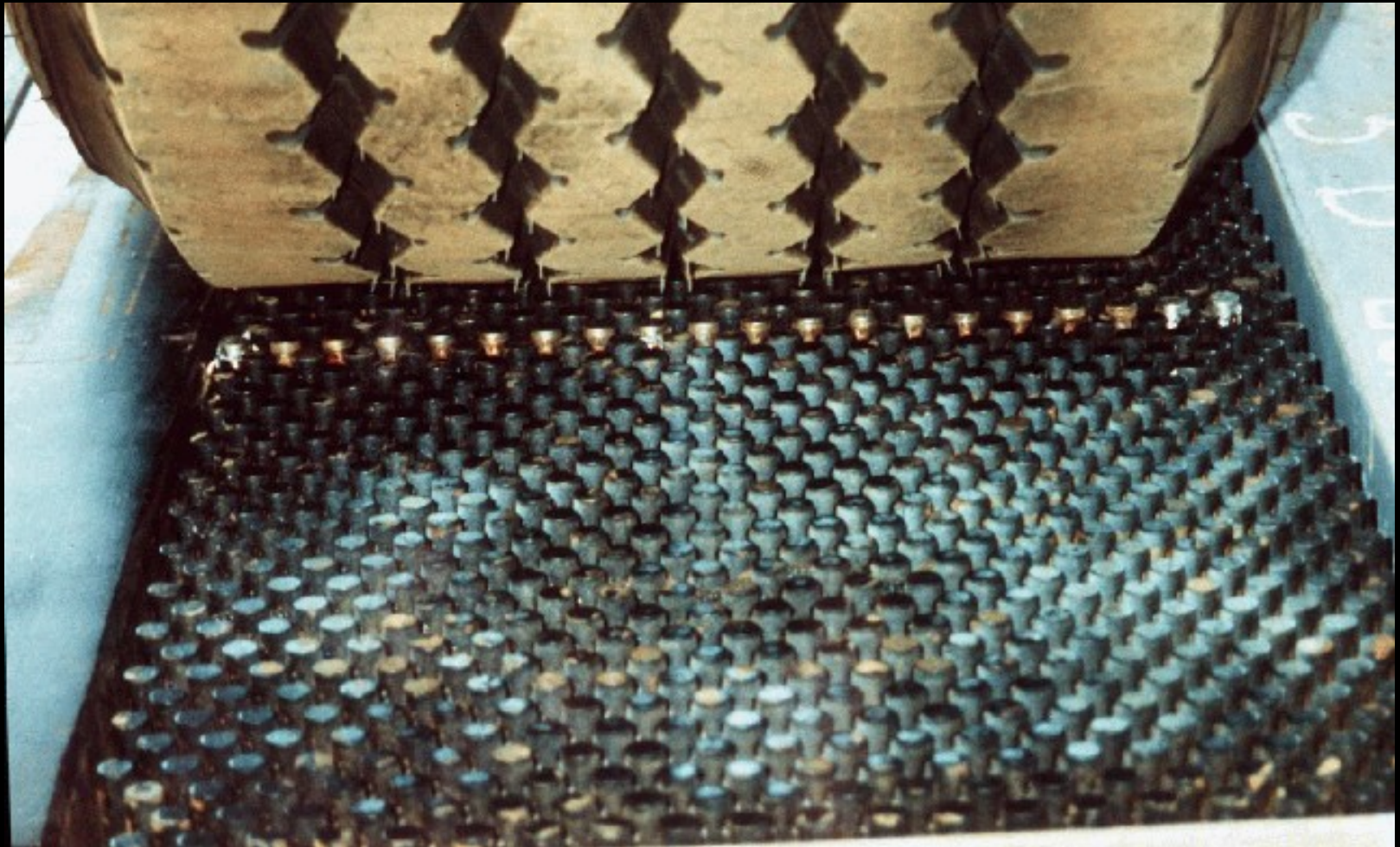
SIM MK II SYSTEM (1993-1995)



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

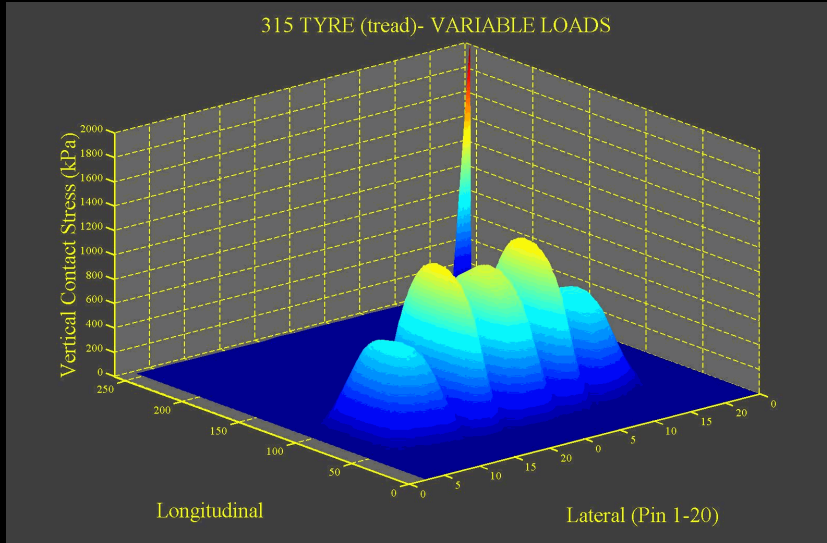


425 /65 R22.5 HVS TIRE ON SIM SYSTEM:
EXAMPLE OF FOOTPRINT TO FOLLOW.....

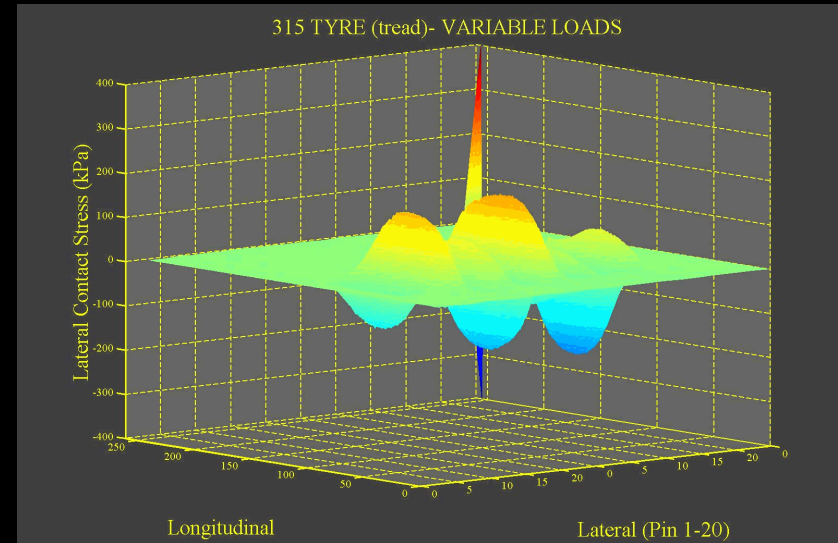


Typical SIM measured contact stress data sets:

VERTICAL (Z)



LATERAL (Y)



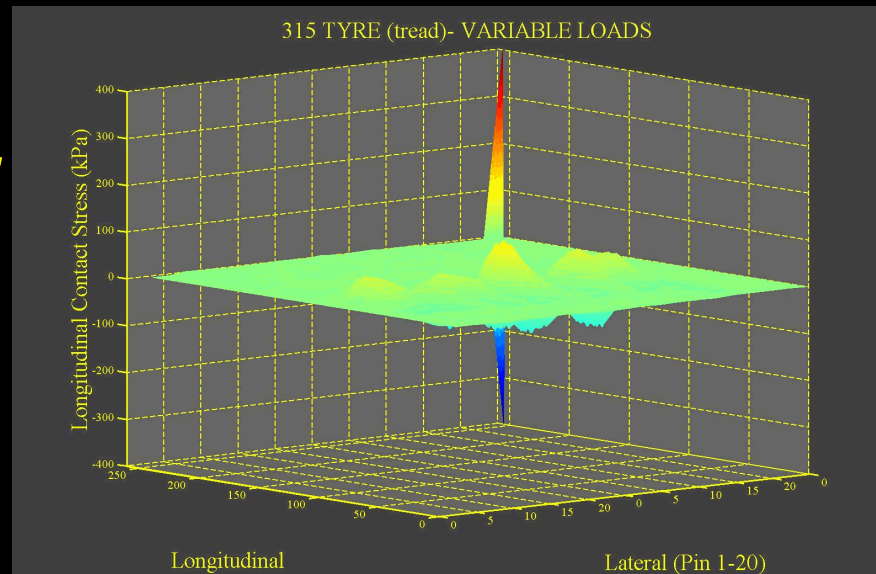
3D – Z,X,Y -

Contact Stress:

Variable loads:

315/80 R22.5

Tyre



**LONGI-
TUDINAL (X)**

Aug 2004 – Preparing of test bed.....



Aug 2004 – Steel re-inforcement.....



September 2004 – 250 mm Concrete slab.....



September 2004 – SIM test pit...



12R22.5 HVS Mk IV+ dual tyre



315/80 R22.5 HVS Mk IV+ single test tyre.



SIM-HVS TEST MATRIX – 12R22.5 TYRES

Table 1: Proposed test matrix for the SIM tests on the 12R22.5 G391 HVS test tyres

| HVS DUAL TYRE LOAD (kN) | COLD TYRE INFLATION PRESSURE ² (kPa) | | | | | |
|-------------------------------------|----------------------------------------------------|-----|-----|-----|-----|------|
| | 520 | 620 | 720 | 800 | 950 | 1000 |
| 30 | √ | √ | √ | √ | √ | ? |
| 40 | √ | √ | √ | √ | √ | ? |
| 70 | √ | √ | √ | √ | √ | ? |
| 80 | √ | √ | √ | √ | √ | ? |
| 100 | X | √ | √ | √ | X | ? |

Approximate rated load and Inflation pressure @ 81 – 95 km/h – Dual tyres:

Shaded areas: 23.9 kN @ 600 kPa to 30.0 kN @ 800 kPa

√: Intend to measure

?: Depend on safety conditions

X : Intend not to measure – safety risk

SIM-HVS TEST MATRIX – 315/80 R22.5 TYRE

Table 2: Proposed test matrix for the SIM tests on the 315/80 R22.5 HVS test tyre

| HVS SINGLE TYRE LOAD (kN) | COLD TYRE INFLATION PRESSURE (kPa) | | | | | | |
|---------------------------|------------------------------------|-----|------|-----|-----|-----|------|
| | 520 | 620 | 650* | 720 | 825 | 950 | 1000 |
| 20 | √ | √ | X | √ | √ | √ | ? |
| 30 | √ | √ | √ | √ | √ | √ | ? |
| 40 | √ | √ | X | √ | √ | √ | ? |
| 50 | √ | √ | X | √ | √ | √ | ? |
| 100 | X | √ | X | √ | √ | X | ? |

Approximate rated load and Inflation pressure @ 81 – 95 km/h – Single tyre:

Shaded areas: 31 kN @ 650 kPa to 37.5 kN @ 825 kPa

√: Intend to measure

?: Depend on safety conditions

X : Intend not to measure – safety risk

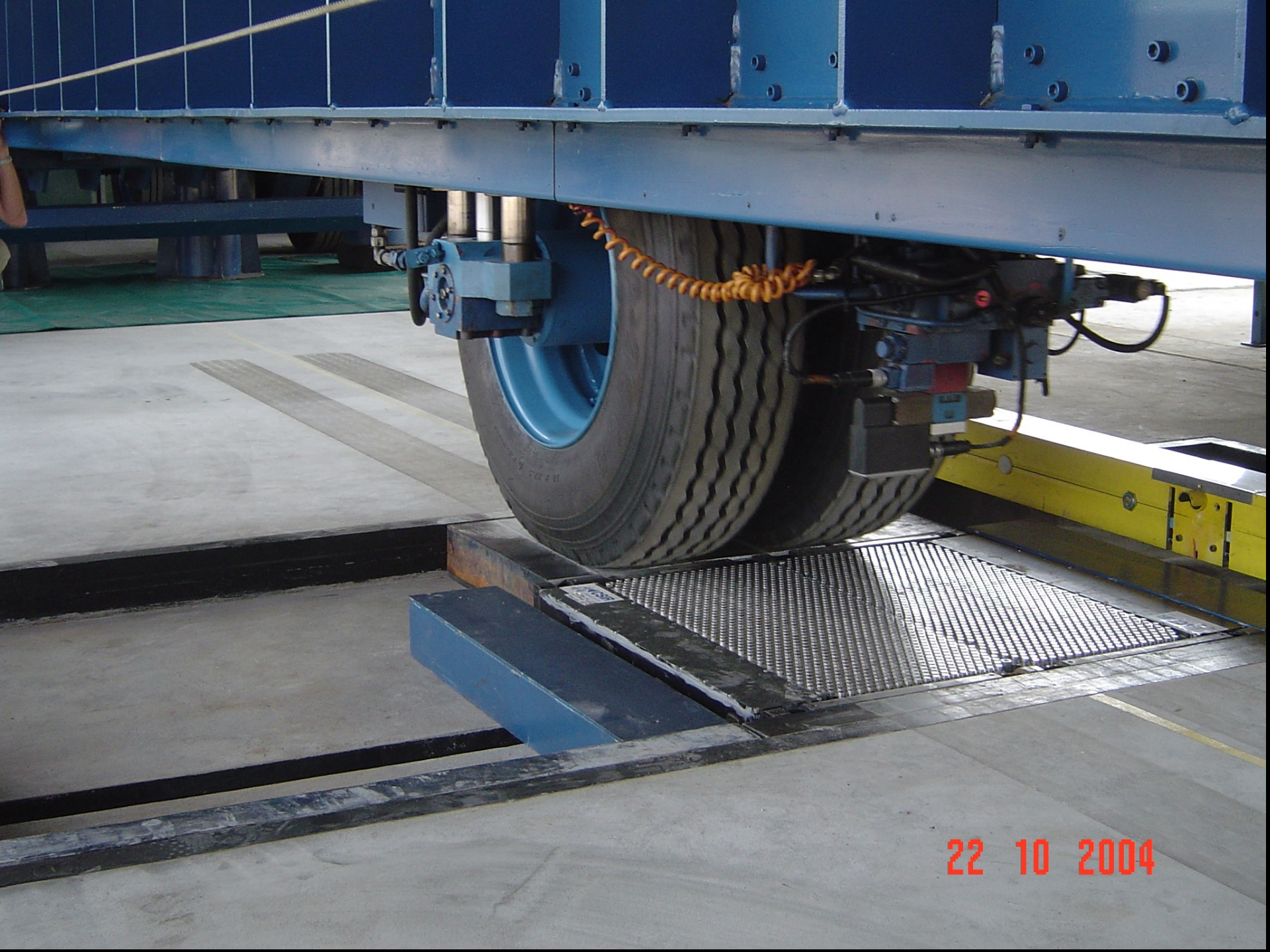
Oct 2004 - HVS in shed...



22 10 2004

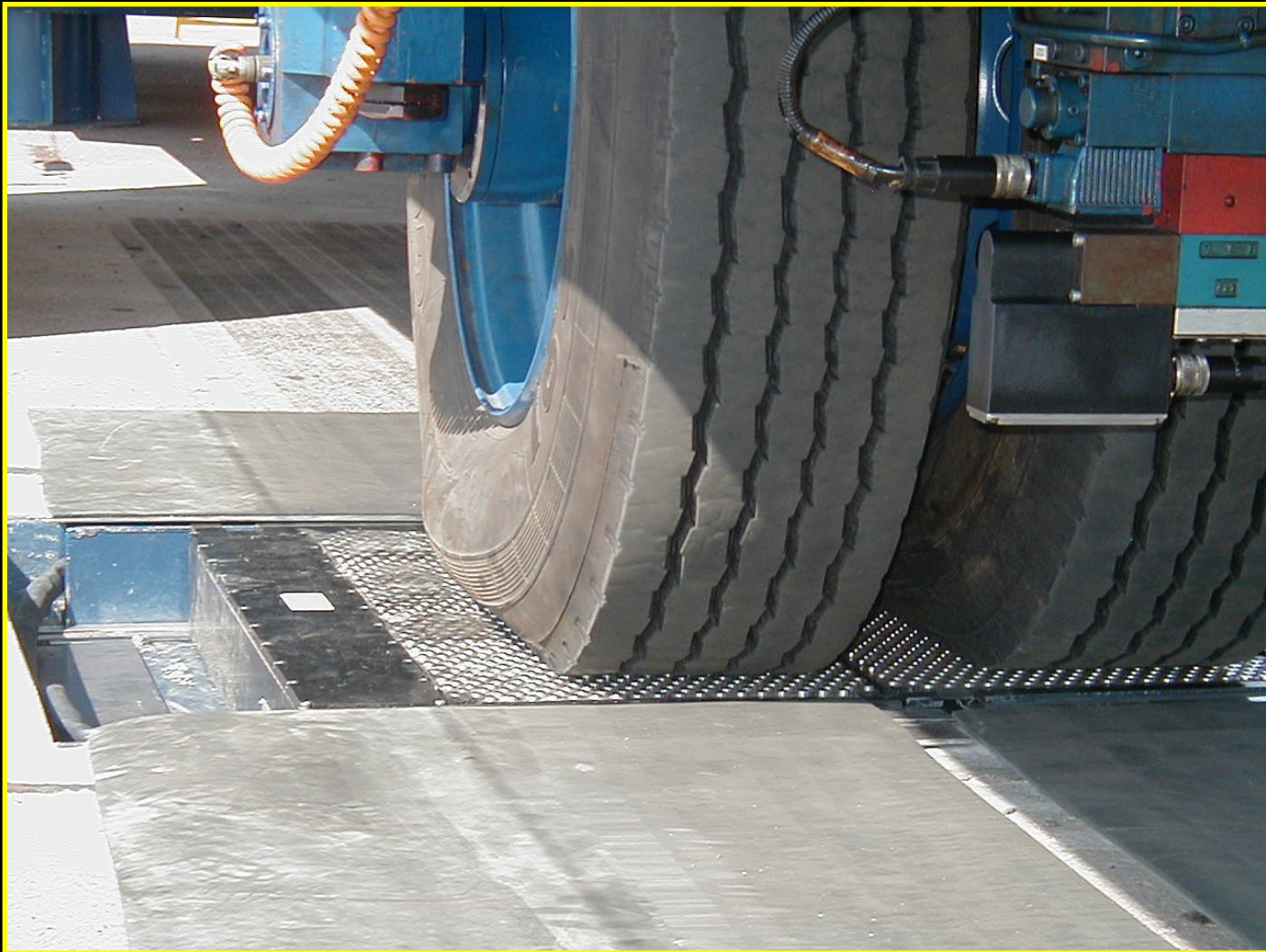
SIM in test pit





22 10 2004

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



Dual SIM pad configuration (used under Heavy Vehicle Simulator (HVS) with dual test tyres)



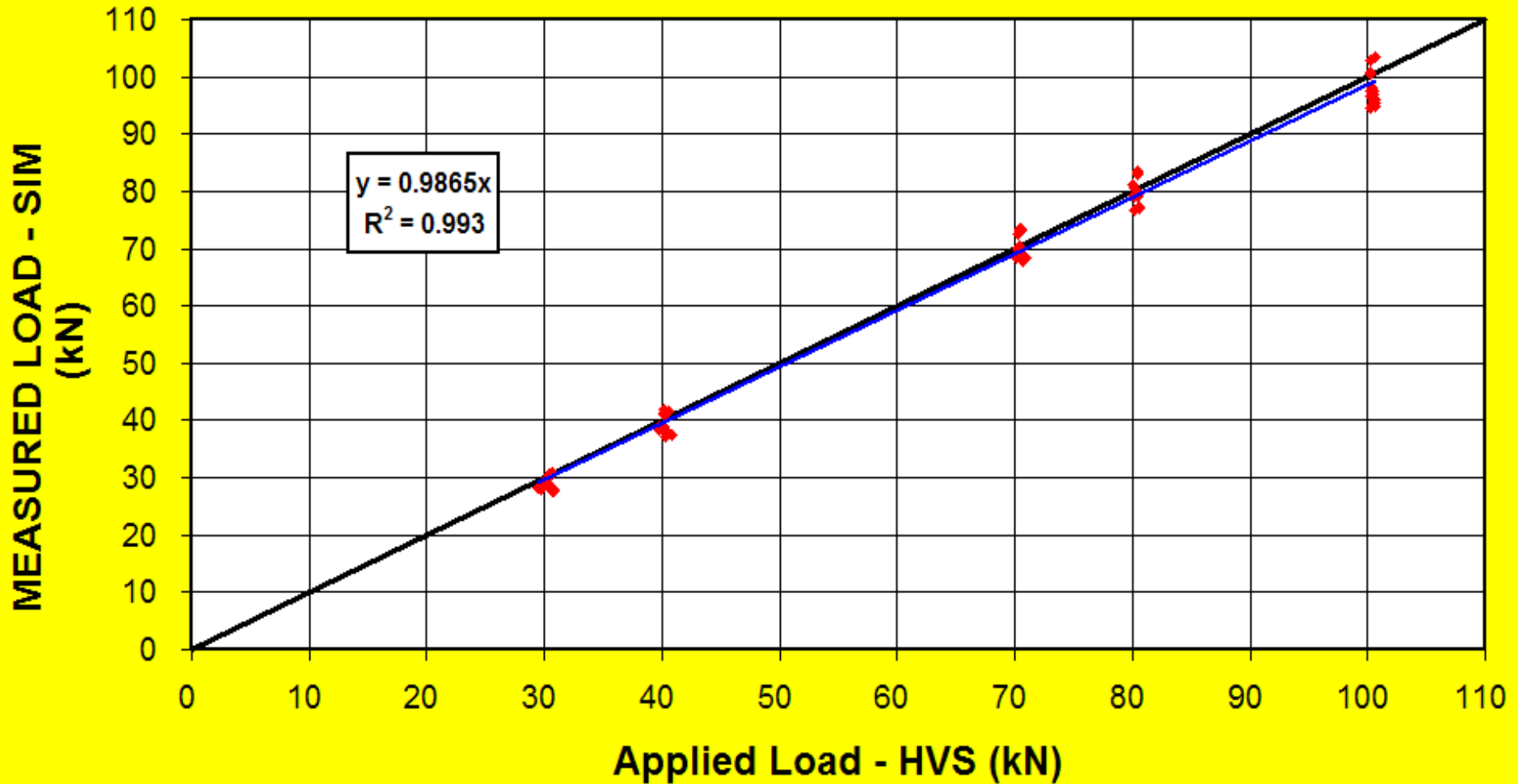
22 10 2004

LOAD COMPARISON – HVS-SIM

| | |
|---------|-------|
| MIN (%) | -4.23 |
| MAX (%) | 10.39 |
| AVE (%) | 1.78 |
| COUNT | 90 |

HVS vs SIM using Tyre 12R22.5 Gautrans HVS

◆ Dual SIM (kN) — Line of Equality — Linear (Dual SIM (kN))



Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 520 kPa

Applied Vertical Load (HVS) = 40.3 kN

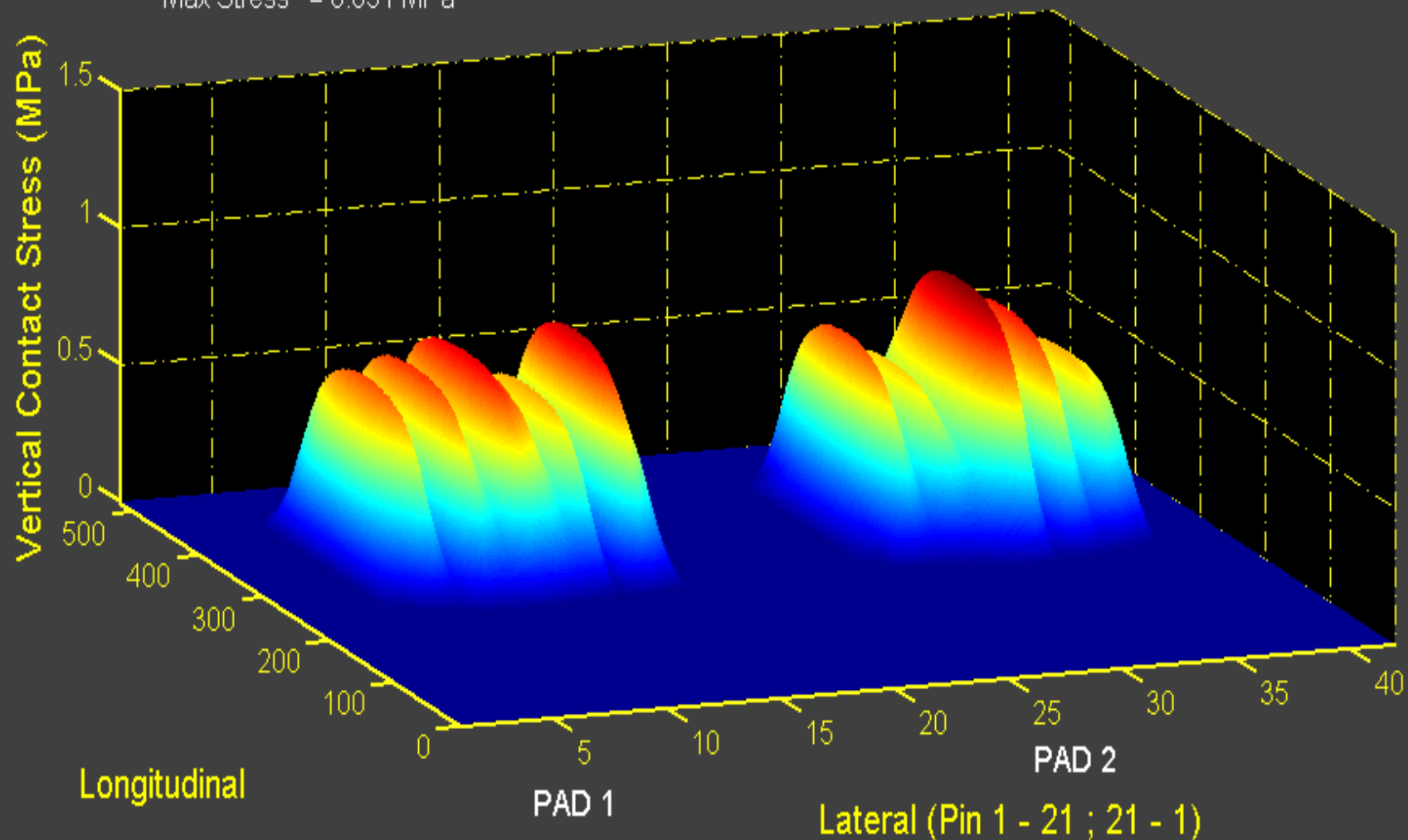
Wheel speed = 1.03 m/s

Max Stress = 0.851 MPa

Measured Vertical Total Load = 37.2 kN

Measured Vertical Load (Pad 1) = 19.6 kN

Measured Vertical Load (Pad 2) = 17.6 kN



Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 720 kPa

Applied Vertical Load (HVS) = 40.2 kN

Wheel speed = 1.02 m/s

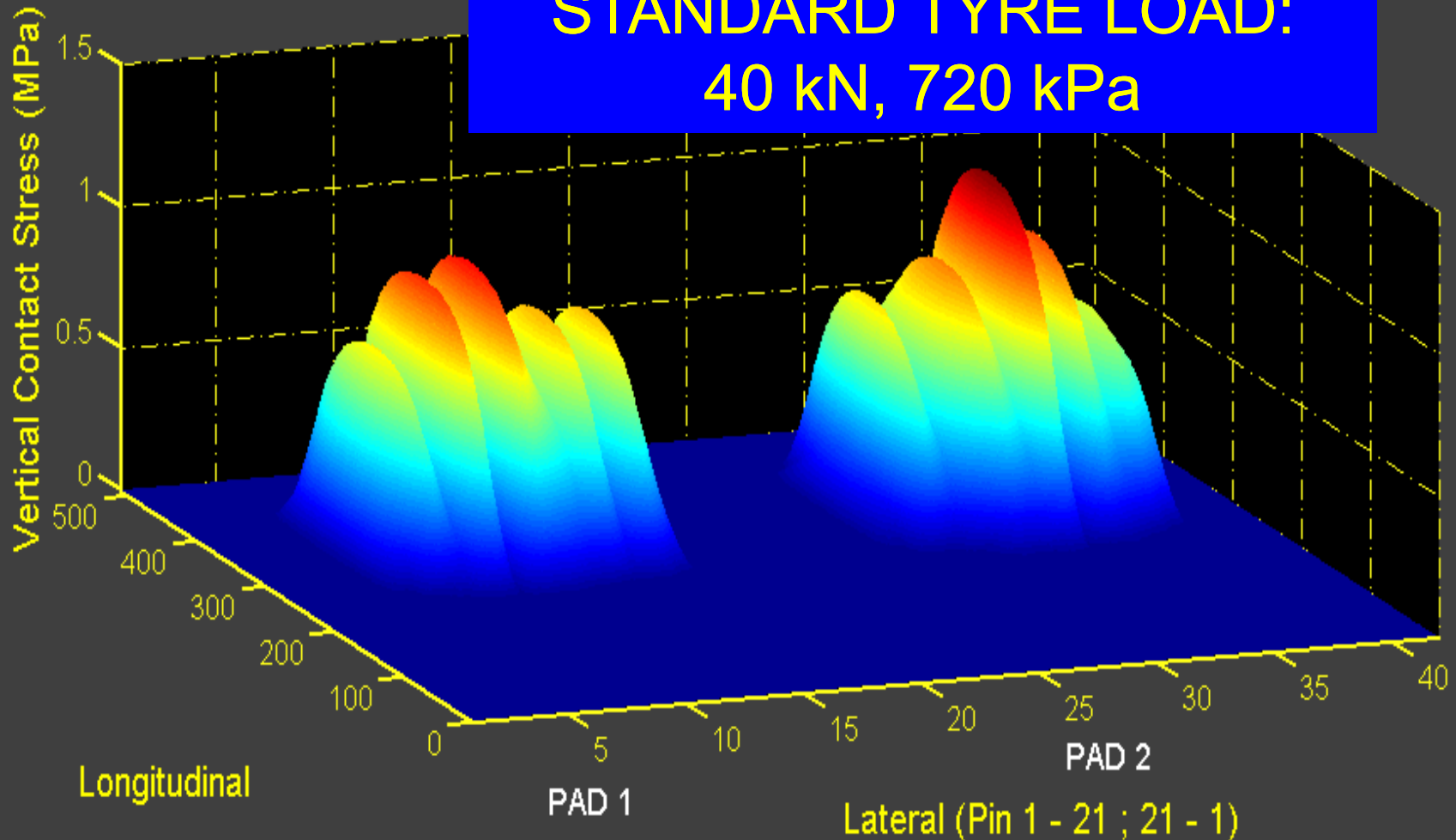
Max Stress = 1.15 MPa

Measured Vertical Total Load = 40.4 kN

Measured Vertical Load (Pad 1) = 19.8 kN

Measured Vertical Load (Pad 2) = 20.6 kN

**STANDARD TYRE LOAD:
40 kN, 720 kPa**



Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 1000 kPa

Applied Vertical Load (HVS) = 40.1 kN

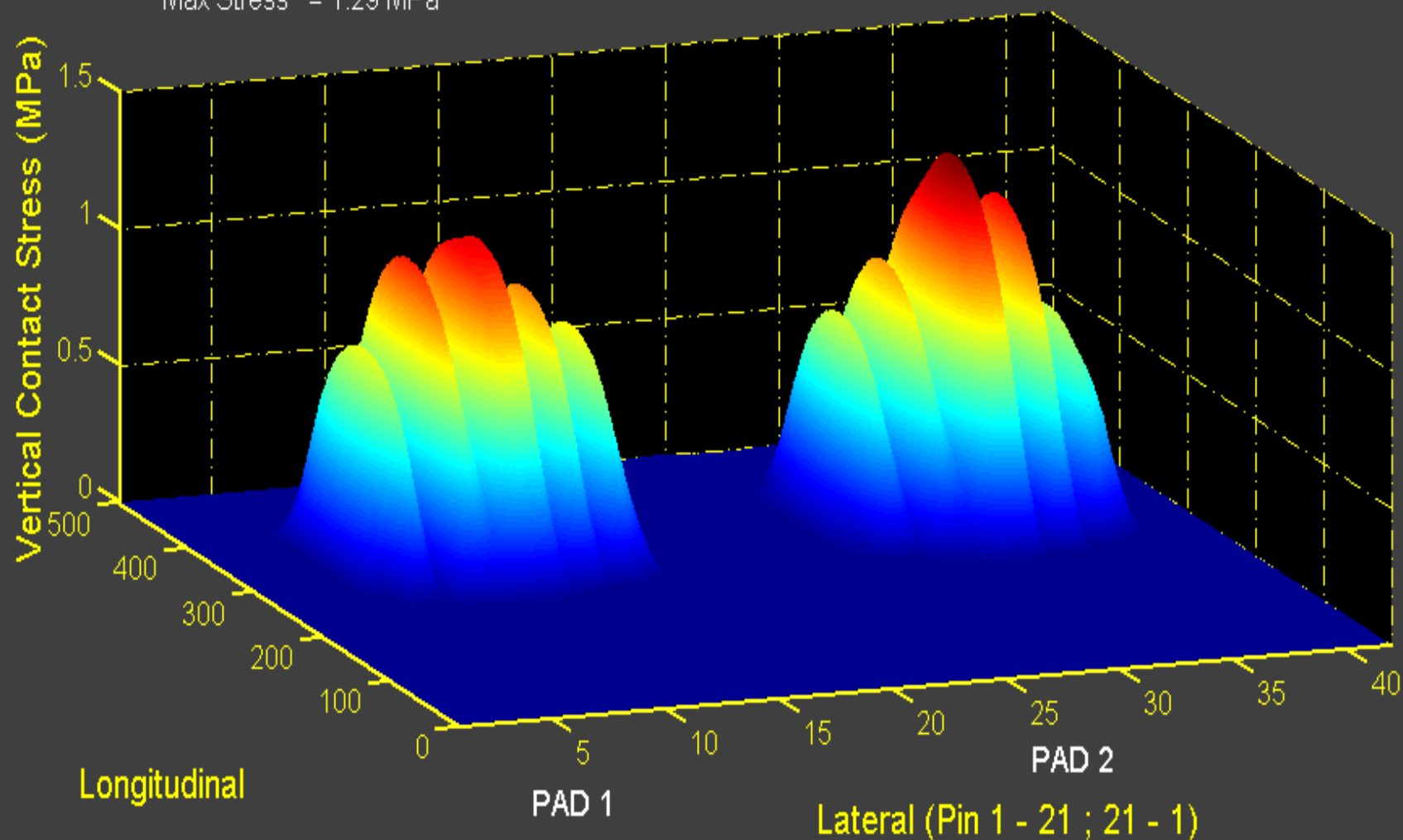
Wheel speed = 1.02 m/s

Max Stress = 1.29 MPa

Measured Vertical Total Load = 37.8 kN

Measured Vertical Load (Pad 1) = 19.3 kN

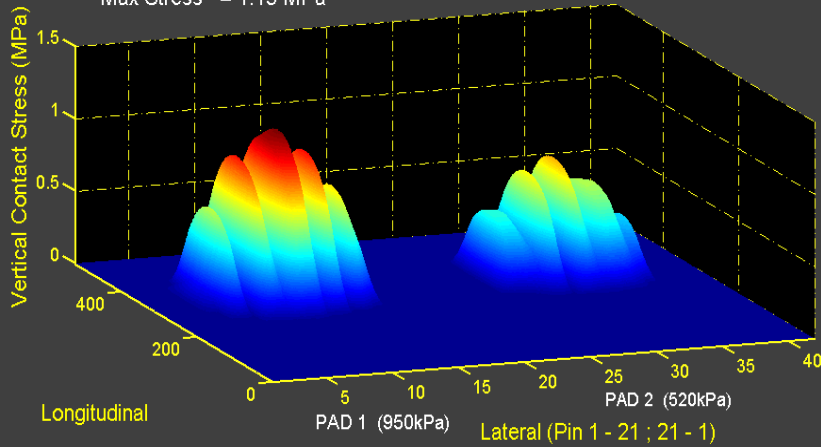
Measured Vertical Load (Pad 2) = 18.5 kN



Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 950 / 520 kPa
Applied Vertical Load (HVS) = 30.4 kN
Wheel speed = 1.02 m/s
Max Stress = 1.15 MPa

Measured Vertical Total Load = 27.8 kN
Measured Vertical Load (Pad 1) = 16.6 kN
Measured Vertical Load (Pad 2) = 11.2 kN

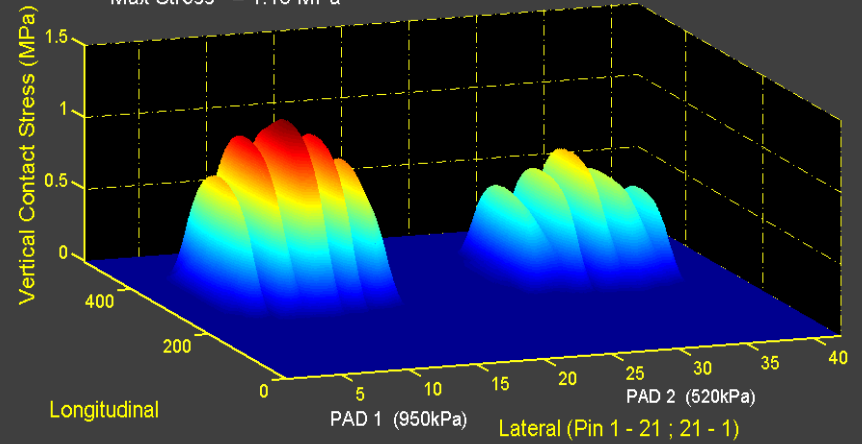


Filename : HVS149az (hvsdaulspCM.m)

Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 950 / 520 kPa
Applied Vertical Load (HVS) = 39.7 kN
Wheel speed = 1.03 m/s
Max Stress = 1.18 MPa

Measured Vertical Total Load = 37 kN
Measured Vertical Load (Pad 1) = 22.1 kN
Measured Vertical Load (Pad 2) = 14.8 kN

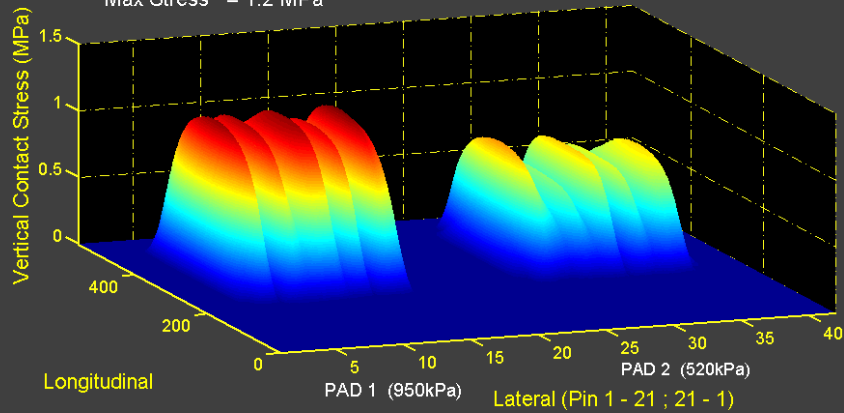


Filename : HVS152az (hvsdaulspCM.m)

Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 950 / 520 kPa
Applied Vertical Load (HVS) = 69.9 kN
Wheel speed = 1.03 m/s
Max Stress = 1.2 MPa

Measured Vertical Total Load = 68 kN
Measured Vertical Load (Pad 1) = 40.9 kN
Measured Vertical Load (Pad 2) = 27.1 kN

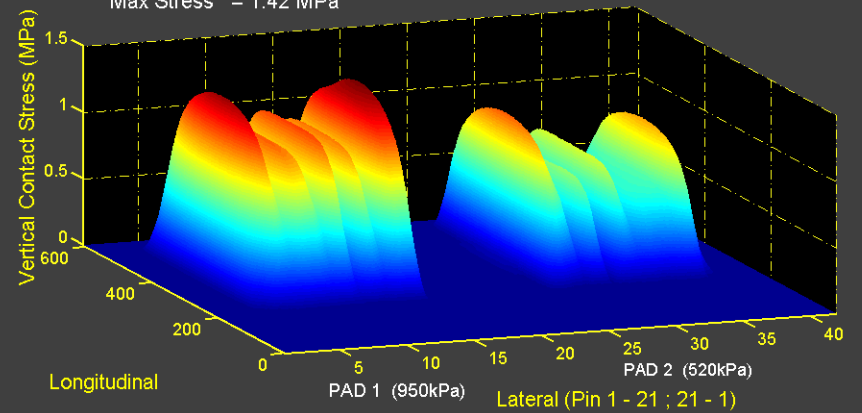


Filename : HVS155az (hvsdaulspCM.m)

Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 950 / 520 kPa
Applied Vertical Load (HVS) = 100.4 kN
Wheel speed = 1.02 m/s
Max Stress = 1.42 MPa

Measured Vertical Total Load = 99.5 kN
Measured Vertical Load (Pad 1) = 61.3 kN
Measured Vertical Load (Pad 2) = 38.2 kN



Filename : HVS161az (hvsdaulspCM.m)

Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 950 / 520 kPa

Applied Vertical Load (HVS) = 30.4 kN

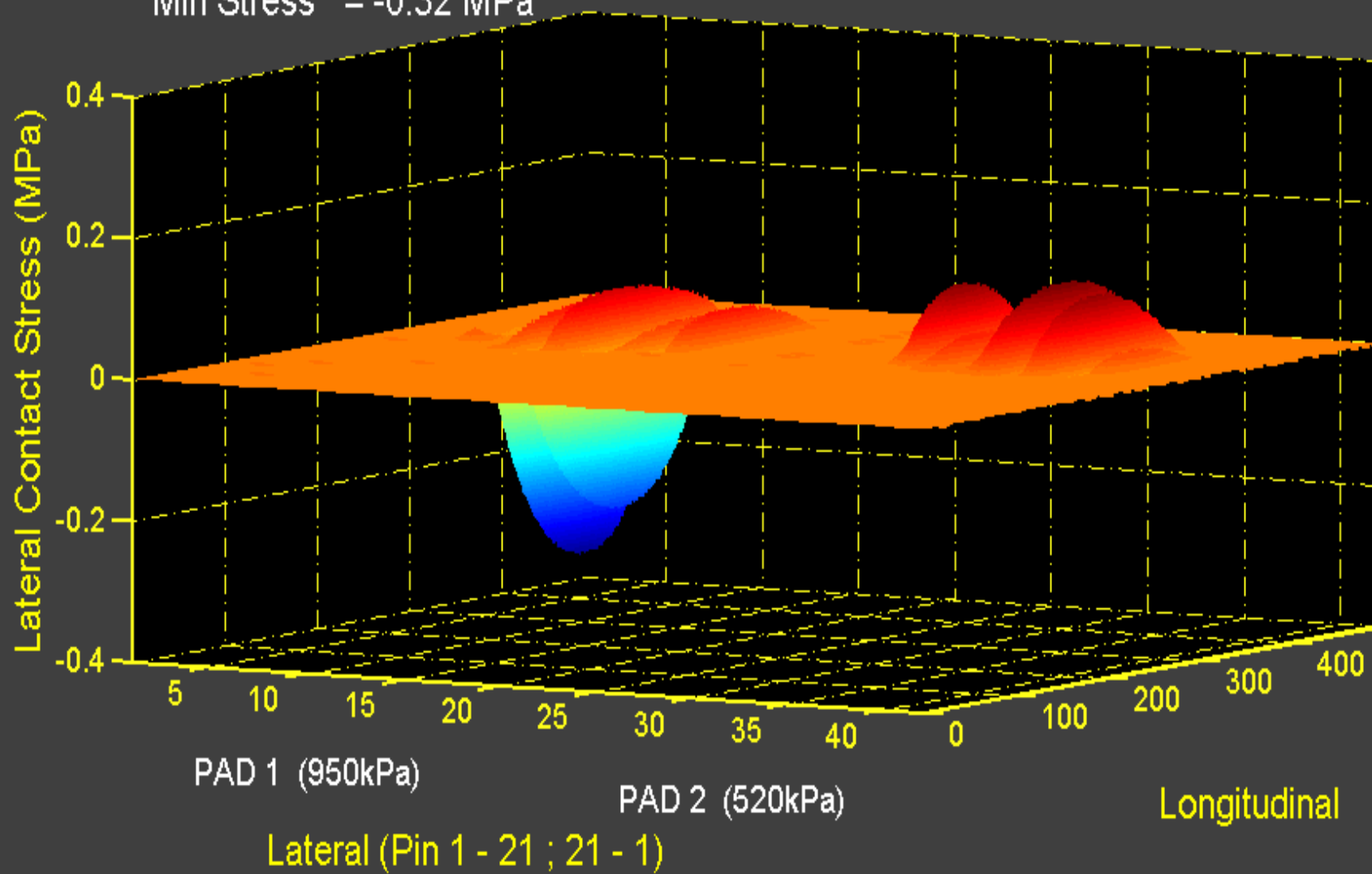
Max Stress = 0.108 MPa

Min Stress = -0.32 MPa

Wheel speed = 1.02 m/s

Measured Lateral Load (Pad 1) = -1.55 kN

Measured Lateral Load (Pad 2) = 0.298 kN



Filename : HVS149ay (hvsdaulsp.m)

Tyre Tested 12R22.5 (HP3000 P.R. 152/148L TREADED)

Inflation Pressure = 950 / 520 kPa

Applied Vertical Load (HVS) = 100.4 kN

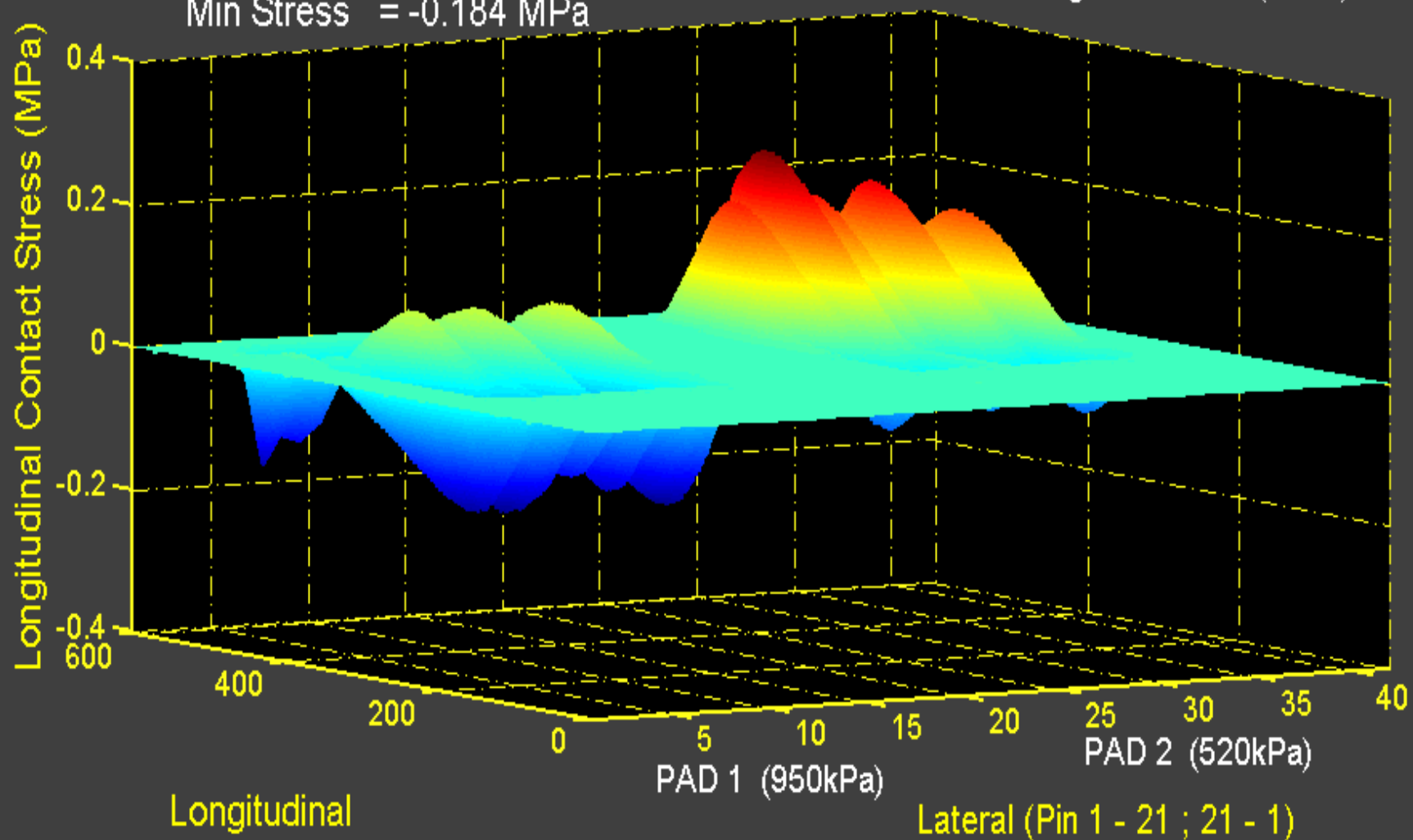
Max Stress = 0.244 MPa

Min Stress = -0.184 MPa

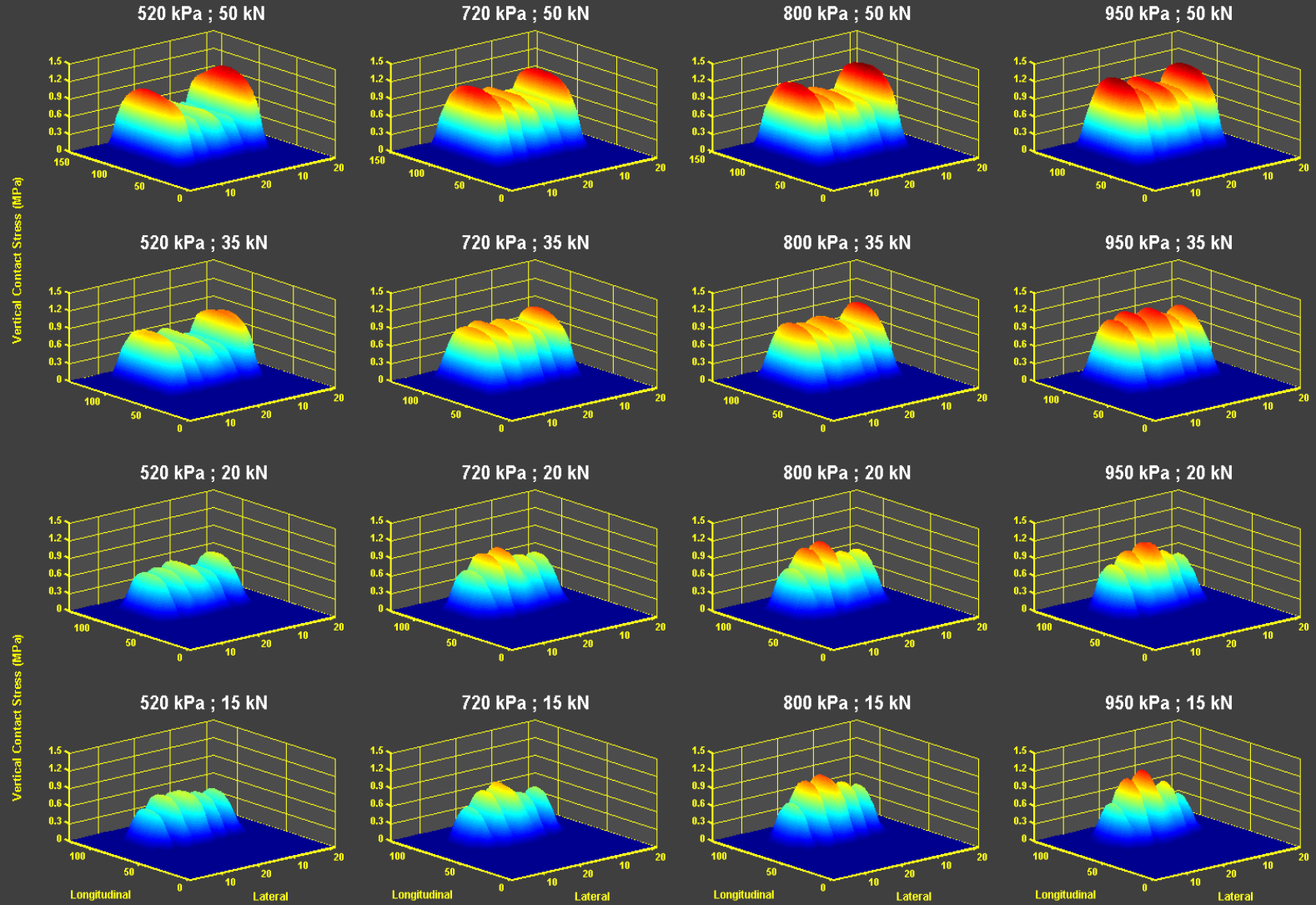
Wheel speed = 1.02 m/s

Measured Longitudinal Load (Pad 1) = -4.22 kN

Measured Longitudinal Load (Pad 2) = 3.19 kN



"FINGER PRINTING" - VERTICAL CONTACT STRESS (HVS 12R22.5)



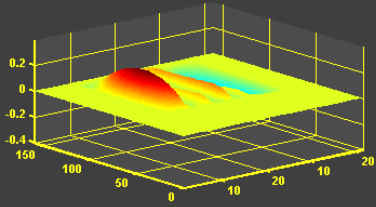
Pad 1 Tyre 12R22.5 (HP 3000) TREADED

LOAD

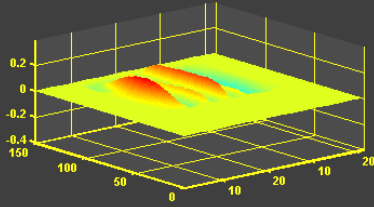
INFLATION PRESSURE

LATERAL CONTACT STRESS ACROSS TYRE WIDTH

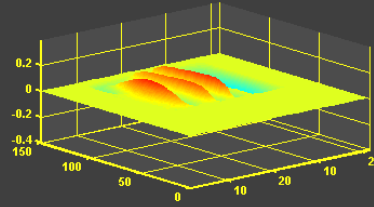
520 kPa ; 50 kN



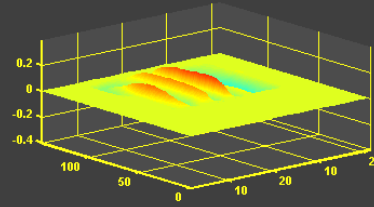
720 kPa ; 50 kN



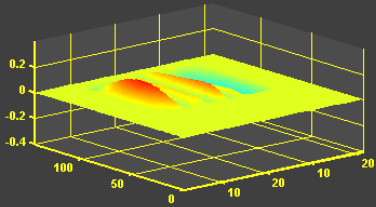
800 kPa ; 50 kN



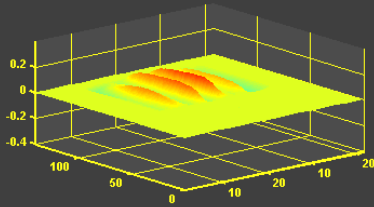
950 kPa ; 50 kN



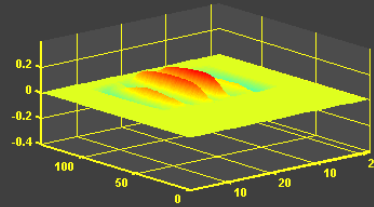
520 kPa ; 35 kN



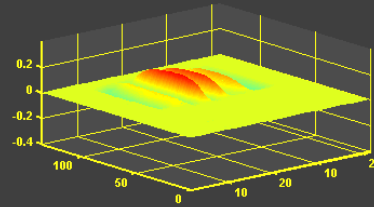
720 kPa ; 35 kN



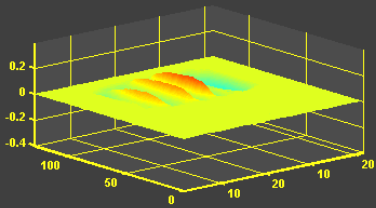
800 kPa ; 35 kN



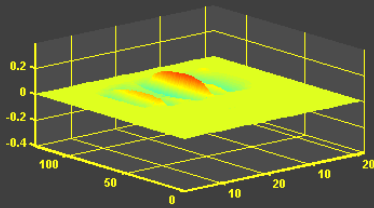
950 kPa ; 35 kN



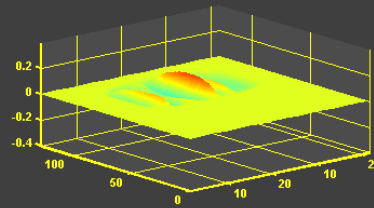
520 kPa ; 20 kN



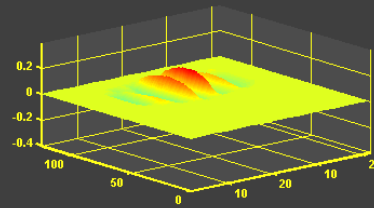
720 kPa ; 20 kN



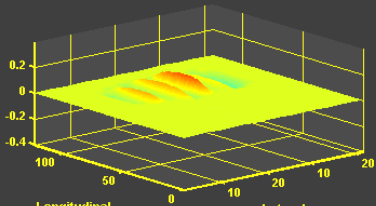
800 kPa ; 20 kN



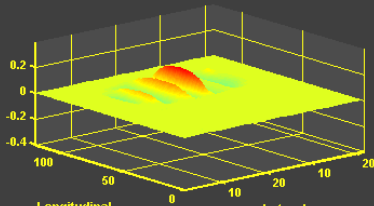
950 kPa ; 20 kN



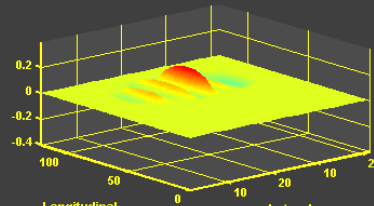
520 kPa ; 15 kN



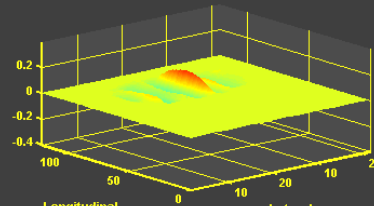
720 kPa ; 15 kN



800 kPa ; 15 kN



950 kPa ; 15 kN



Lateral Contact Stress (MPa)

Lateral Contact Stress (MPa)

Longitudinal

Lateral

Longitudinal

Lateral

Longitudinal

Lateral

Longitudinal

Lateral

Pad 1 Tyre 12R22.5 (HP 3000) TREADED

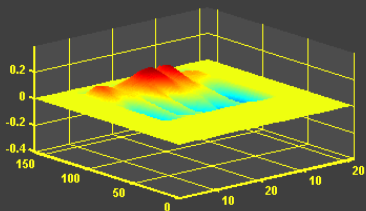
INFLATION PRESSURE

LOAD

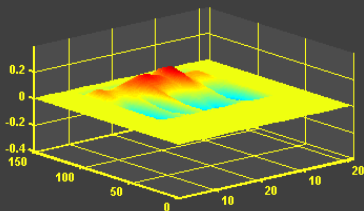
Galvani3Dsym

LONGITUDINAL CONTACT STRESS ALONG TYRE PATCH

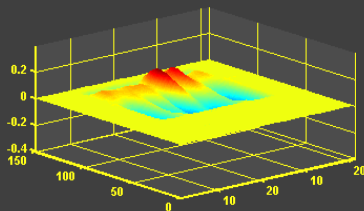
520 kPa ; 50 kN



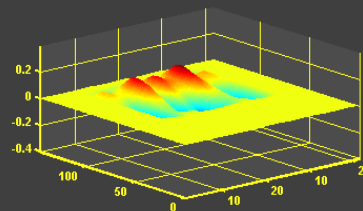
720 kPa ; 50 kN



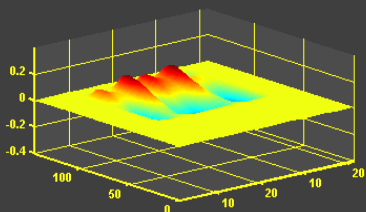
800 kPa ; 50 kN



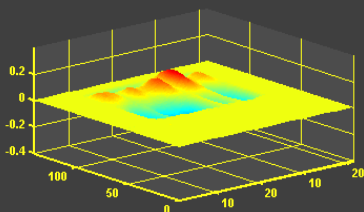
950 kPa ; 50 kN



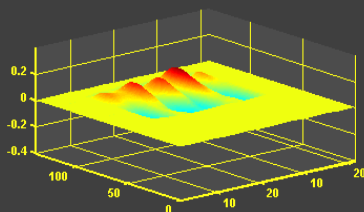
520 kPa ; 35 kN



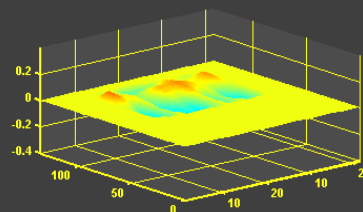
720 kPa ; 35 kN



800 kPa ; 35 kN

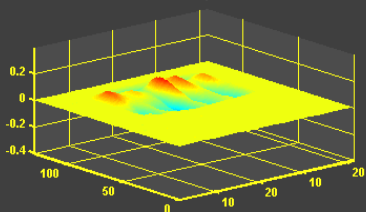


950 kPa ; 35 kN

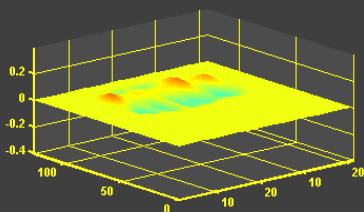


Longitudinal Contact Stress (MPa)

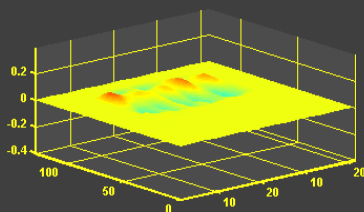
520 kPa ; 20 kN



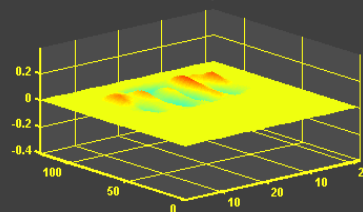
720 kPa ; 20 kN



800 kPa ; 20 kN

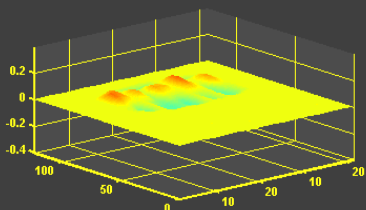


950 kPa ; 20 kN

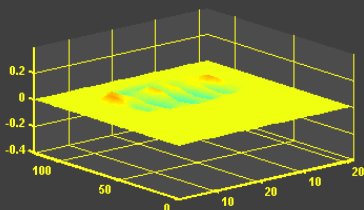


Longitudinal Contact Stress (MPa)

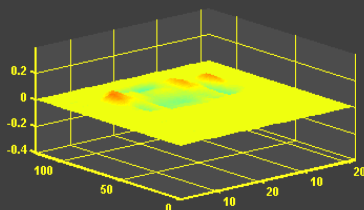
520 kPa ; 15 kN



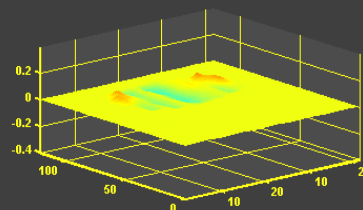
720 kPa ; 15 kN



800 kPa ; 15 kN



950 kPa ; 15 kN



Longitudinal Lateral

Longitudinal Lateral

Longitudinal Lateral

Longitudinal Lateral

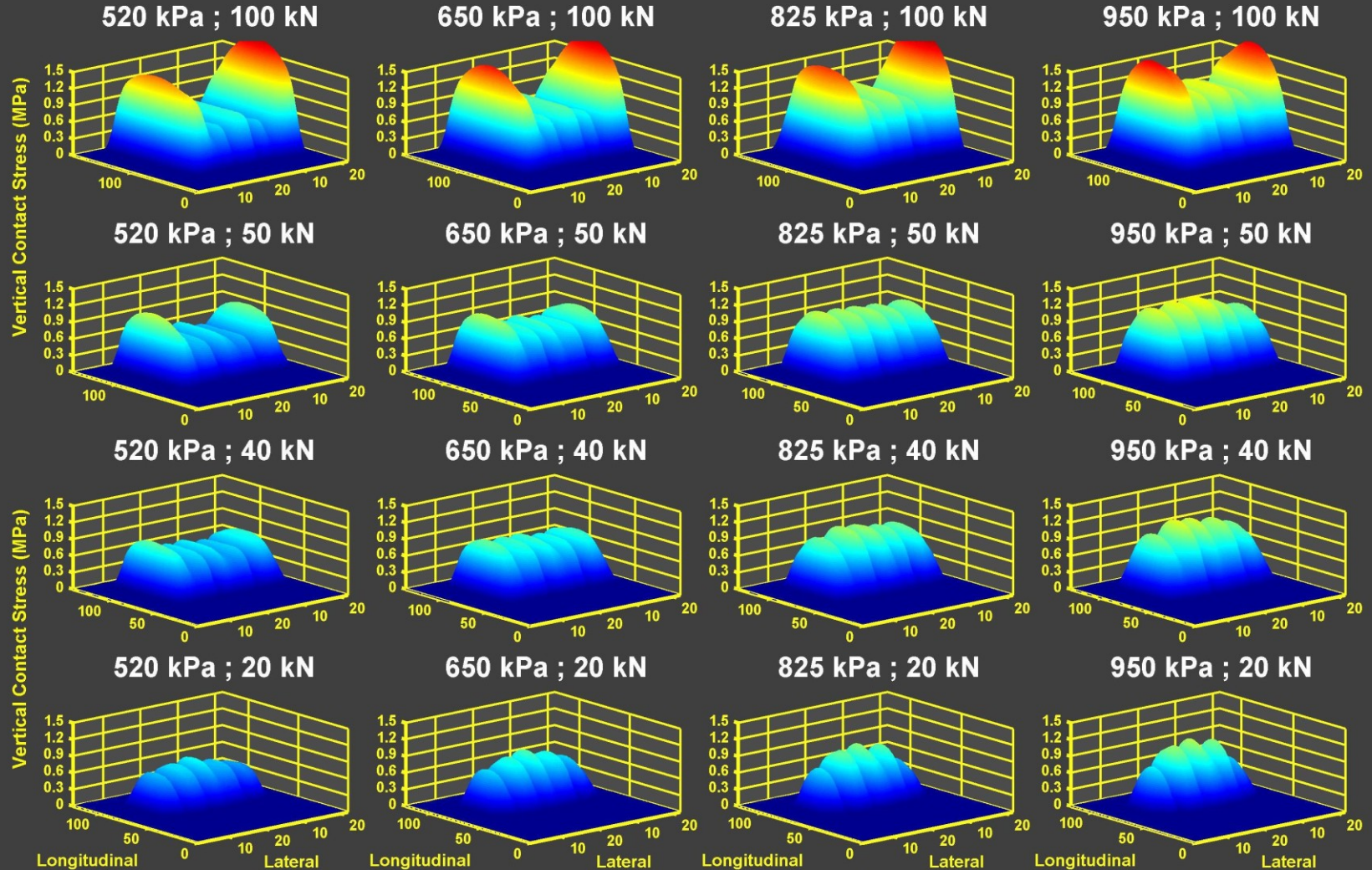
Pad 1 Tyre 12R22.5 (HP 3000) TREADED

LOAD

INFLATION PRESSURE

VERTICAL CONTACT STRESS (HVS 315/80 R22.5)

LOAD

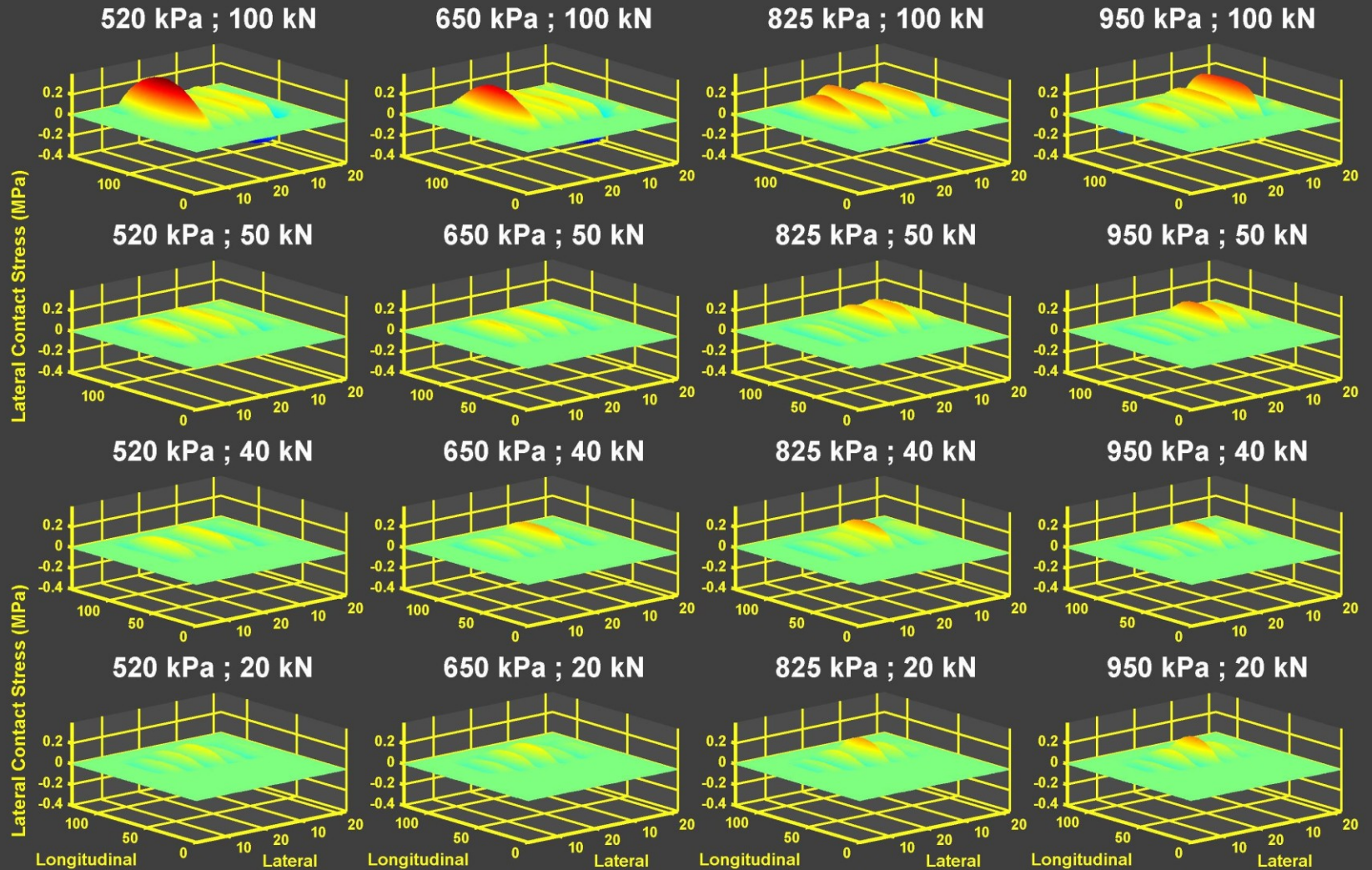


Singlez.m

Tyre 315 / 80 R22.5 TREADED

INFLATION PRESSURE

LATERAL CONTACT STRESS ACROSS TYRE WIDTH

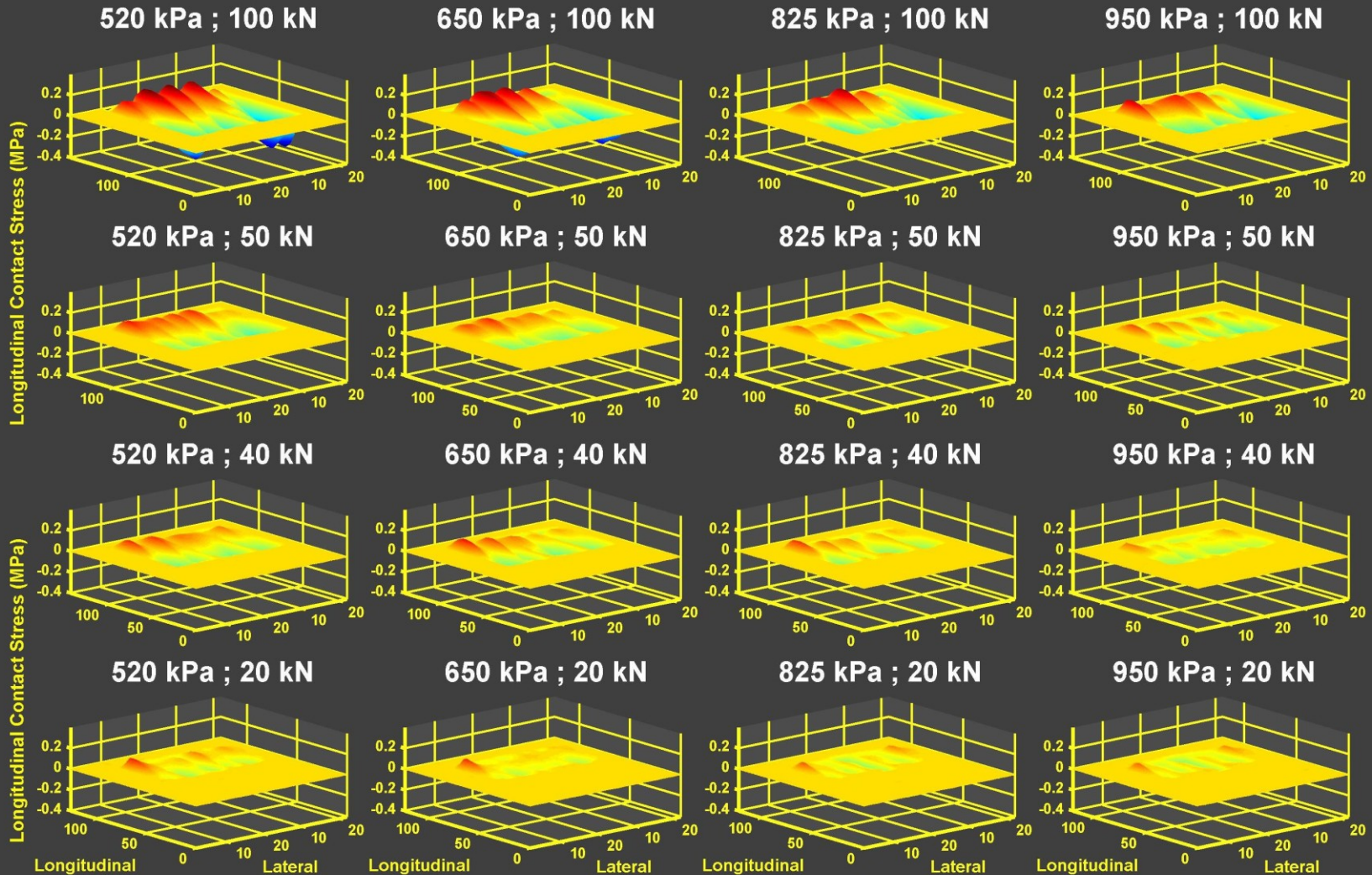


LOAD

TYRE 315 / 80R22.5 TREADED

INFLATION PRESSURE

LONGITUDINAL CONTACT STRESS ALONG TYRE PATCH



TYRE 315 / 80R22.5 TREADED

INFLATION PRESSURE

LOAD

Singlex.m

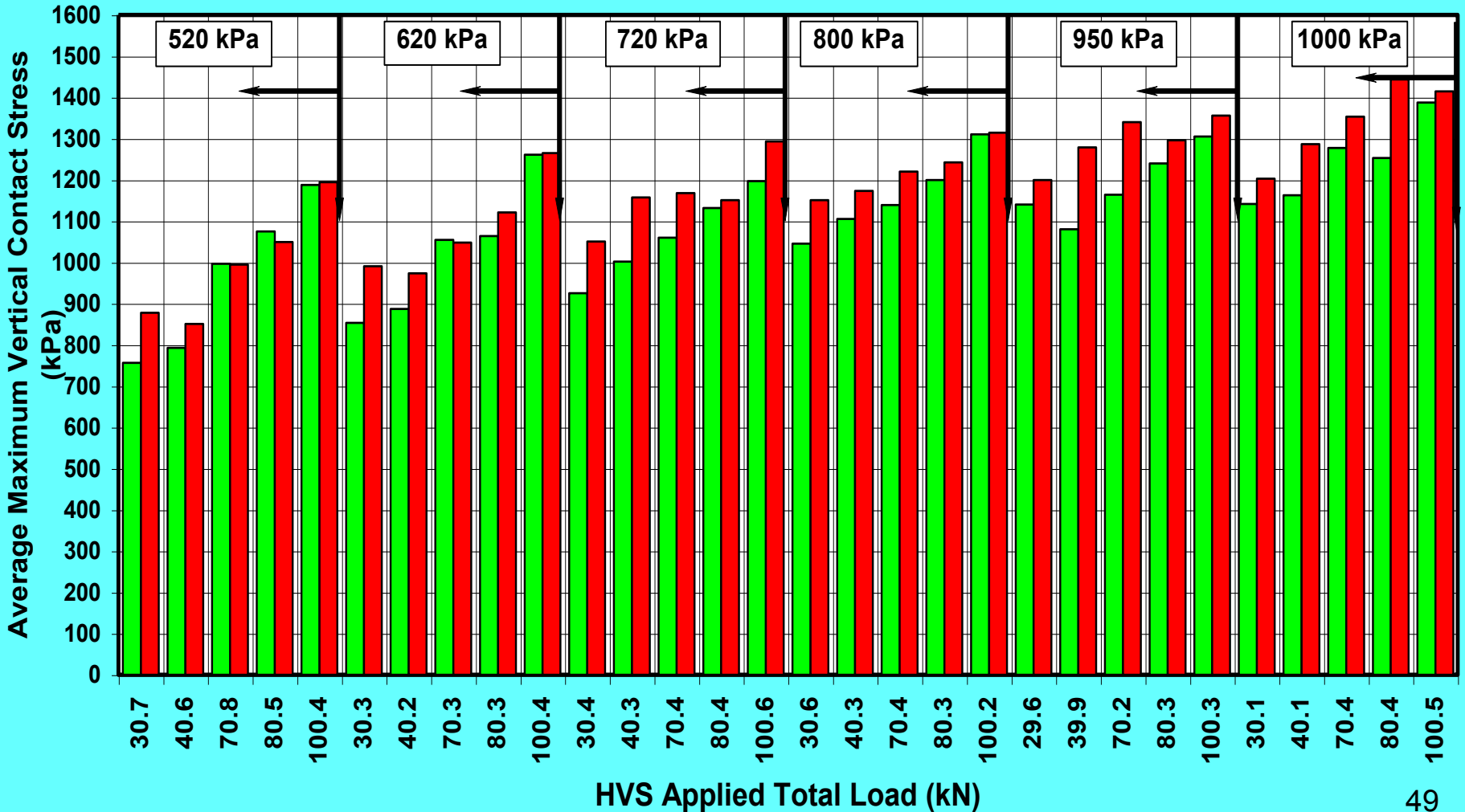
ՀԱՆՈՒՄԻ ԱՆՎՈՒՄ (Բ. ՍԵՆՆԻՍԻ)



Z-STRESS-COMPARISON – HVS-SIM

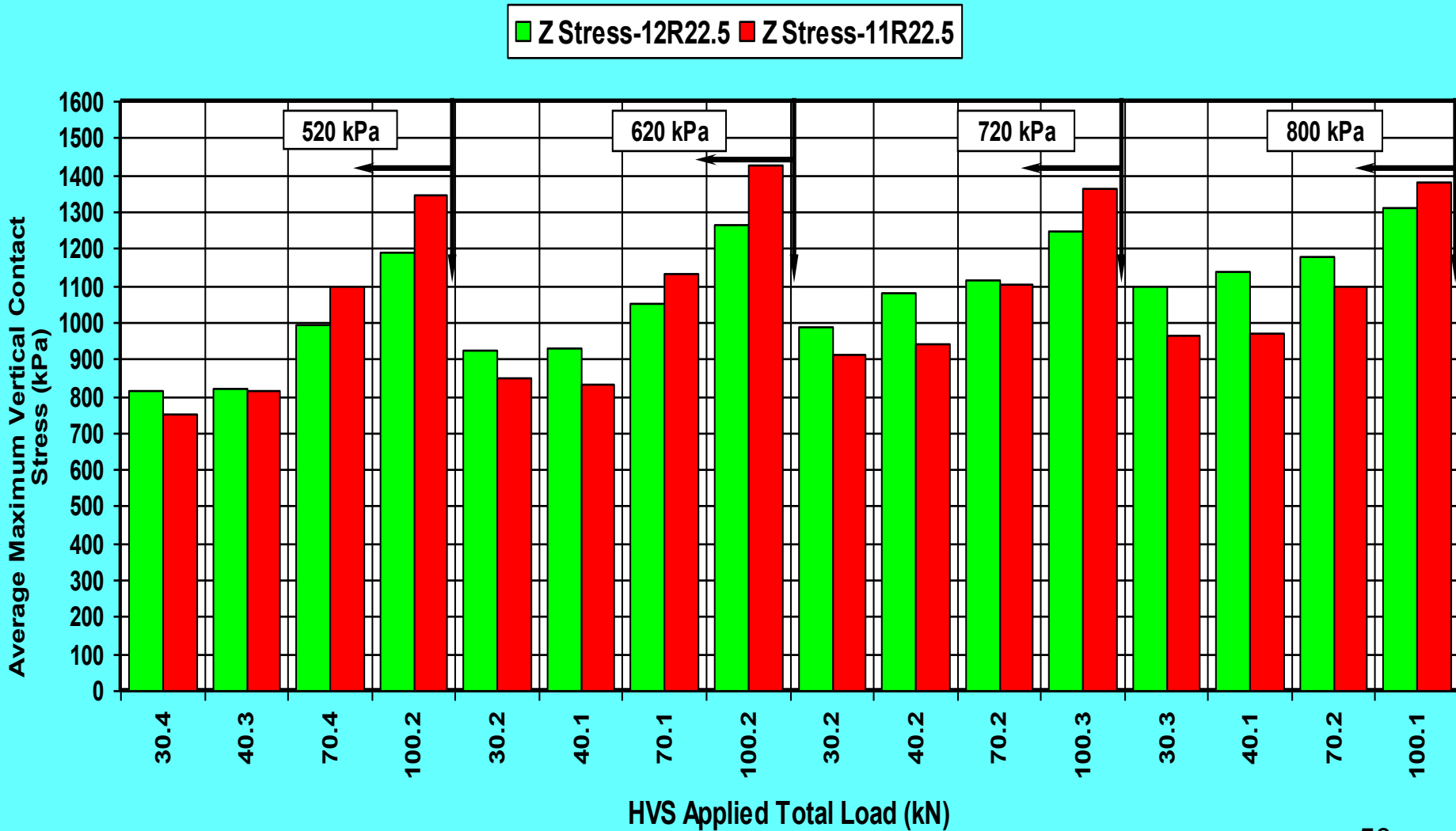
Average Maximum Vertical Contact Stresses (AMVCS) between the two HVS Mk IV⁺ test tyres: 12R22.5

■ Z Stress-Right ■ Z Stress-Left



Z-STRESS-COMPARISON – HVS-SIM

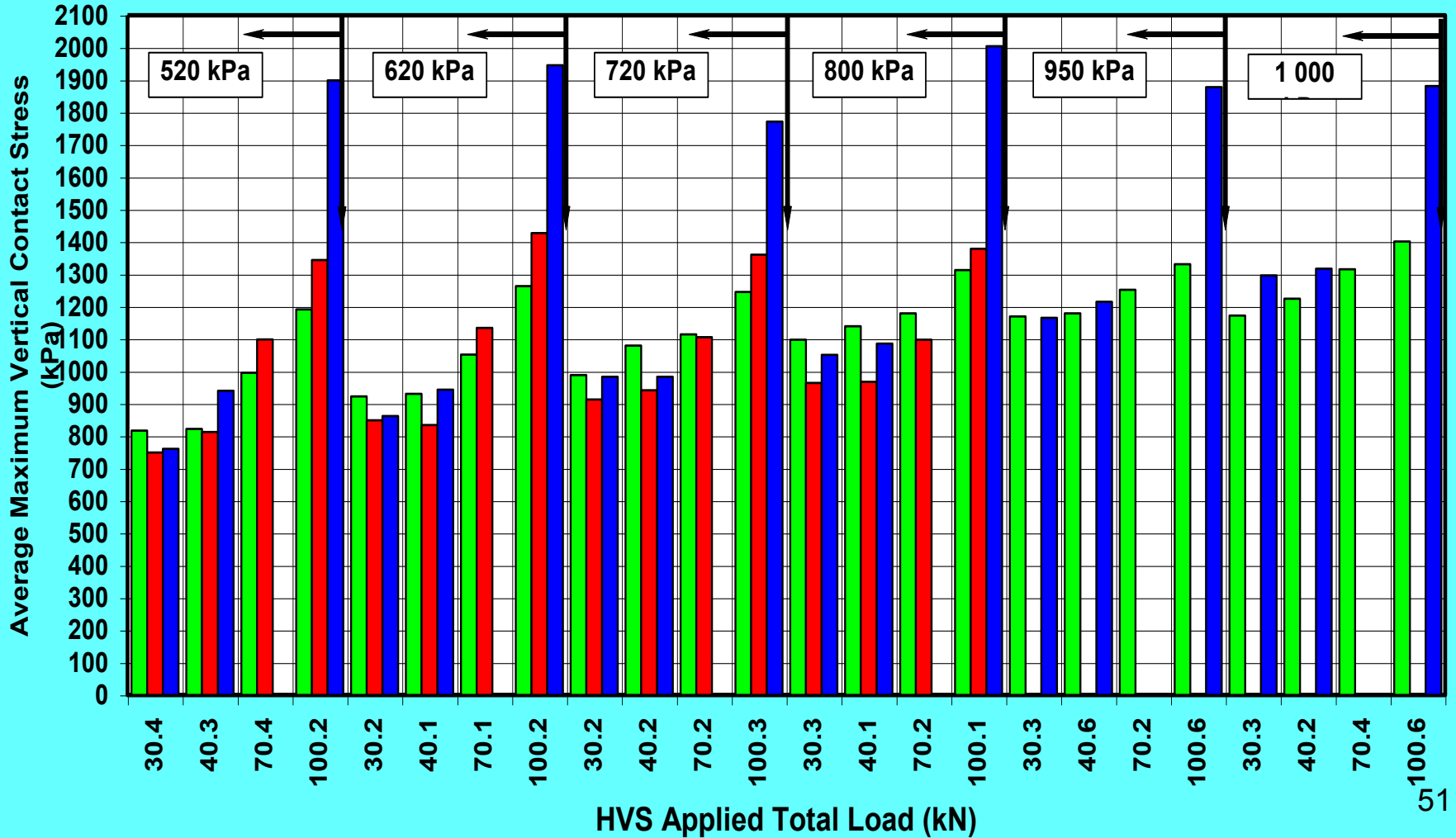
Average Maximum Vertical Contact Stresses (AMVCS) of the dual 12R22.5 and dual 11R22.5 HVS test tyres



Z-STRESS-COMPARISON – HVS-SIM

Average Maximum Vertical Contact Stresses (AMVCS) of the 11R22.5, 12R22.5 and the 315/80 R22.5 HVS test tyres

■ Z Stress-12R22.5
 ■ Z Stress-11R22.5
 ■ Z Stress-315/80 R22.5



FINDINGS (details in paper):

- Dual Loads up to 40 kN: 11R22.5 lower vertical stress than 12R22.5;
- Dual Loads > 40 kN: 11R22.5 higher (110 kPa) vertical stress than 12R22.5;
- 315/80 R22.5 tyres – comparable - but with overloading (40 to 100 kN) extremely high contact stresses !;

FINDINGS (details in paper):

- Both Inflation Pressure and Loading important on all test tyres – New Design Protocols Needed;
- Recommended to define contact stress regime before any APT/HVS testing commences !;

SATC 2005-SESSION 2B



STATISTICAL ANALYSIS OF VEHICLE LOADS MEASURED WITH THREE DIFFERENT VEHICLE WEIGHING DEVICES

*Z Q P Mkhize,
Morris De Beer*

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



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



DAW 50 SCALE - National Road 3 (N3), near Heidelberg in Gauteng



MULTI-DECK SCALE - National Road 3 (N3), near Heidelberg in Gauteng



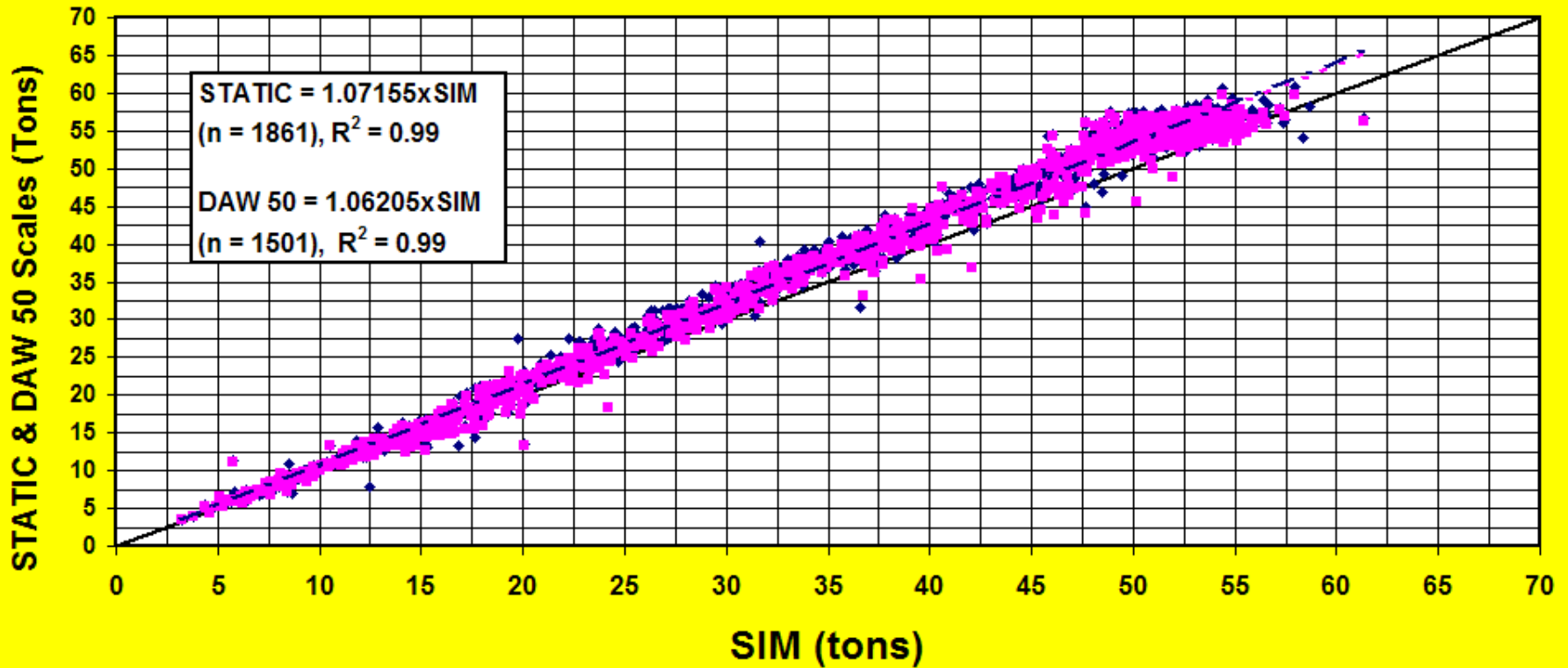
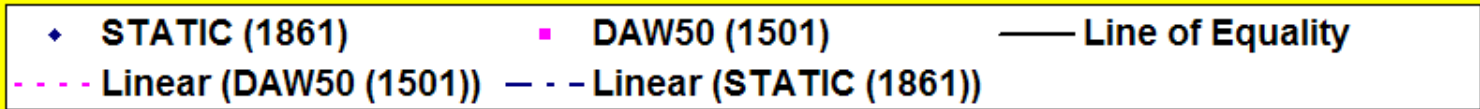
In operation – SIM N3-TCC



LOAD COMPARISON – FIELD WITH REAL TRUCKS

N3 TCC - HEIDELBERG

SIM vs MULTI-DECK STATIC AND DAW 50 at N3-TCC (Heidelberg)
(GVM/GCM) - RATINGS 1 and 2



FINDINGS ON SIM ACCURACY- 1

- For this test series the SIM Scales “under recorded” the GVM/GCM by 6 % to 7 % compared to DAW50 and Static Multi-Deck Scales - adjustment needed;
- GVM/GCM - Prediction Limits: SIM: P80: +/- 2 Tonnes to P99: +/- 4 Tonnes;
- GVM/GCM - Prediction Limits: Static/DAW50: P80: +/- 0.99 Tonnes to P99: +/- 2 Tonnes;

FINDINGS ON SIM ACCURACY-2

- Repeatability & Reproducibility: SIM: +/-1.5 Tonnes to +/- 4 Tonnes – more rigorous study needed – but current results recommended for use in interim;
- SIM very useful for both GVM/GCM, Axle Groups, Axle loads, Tyre loads and 3D Contact Stresses;

**Thank you !
....Any Q's ??**

