Tire technology expo 2010 & Conference - 9 to 11 February 2010, Koelnmesse, Cologne, Germany

WEDNESDAY 10 FEBRUARY:
SESSION 4 – TYROSAFE

Quantification of moving tire-road pavement contact stresses

Prof Dr Morris De Beer

CSIR Built Environment
Pretoria, South Africa
(http://www.csir.co.za)

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STRUCTURE OF PRESENTATION:

- Background – South African road situation ;
- Increase in inflation pressures over time;
- Research with Accelerated Pavement Testing (APT) Devices;
- R&D on tyre-pavement contact stresses, using *Stress-In-Motion (SIM)* technology;
- Pavement damage & Analyses in SA context;
- The way forward;
- Conclusions en Recommendations

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STRESS-IN-MOTION (SIM) TECHNOLOGY

- Since the 1990s – improvement necessary in tyre-pavement interaction model;
- "Uniform & Circular" shape not representative - studying road surface failures with HVS;
- *Stress-In-Motion (SIM)* devices developed;
  - New 3D shapes and sizes of tyre-pavement contact stress regimes measured;
  - Implementation in linear and non-linear pavement models (new challenge);

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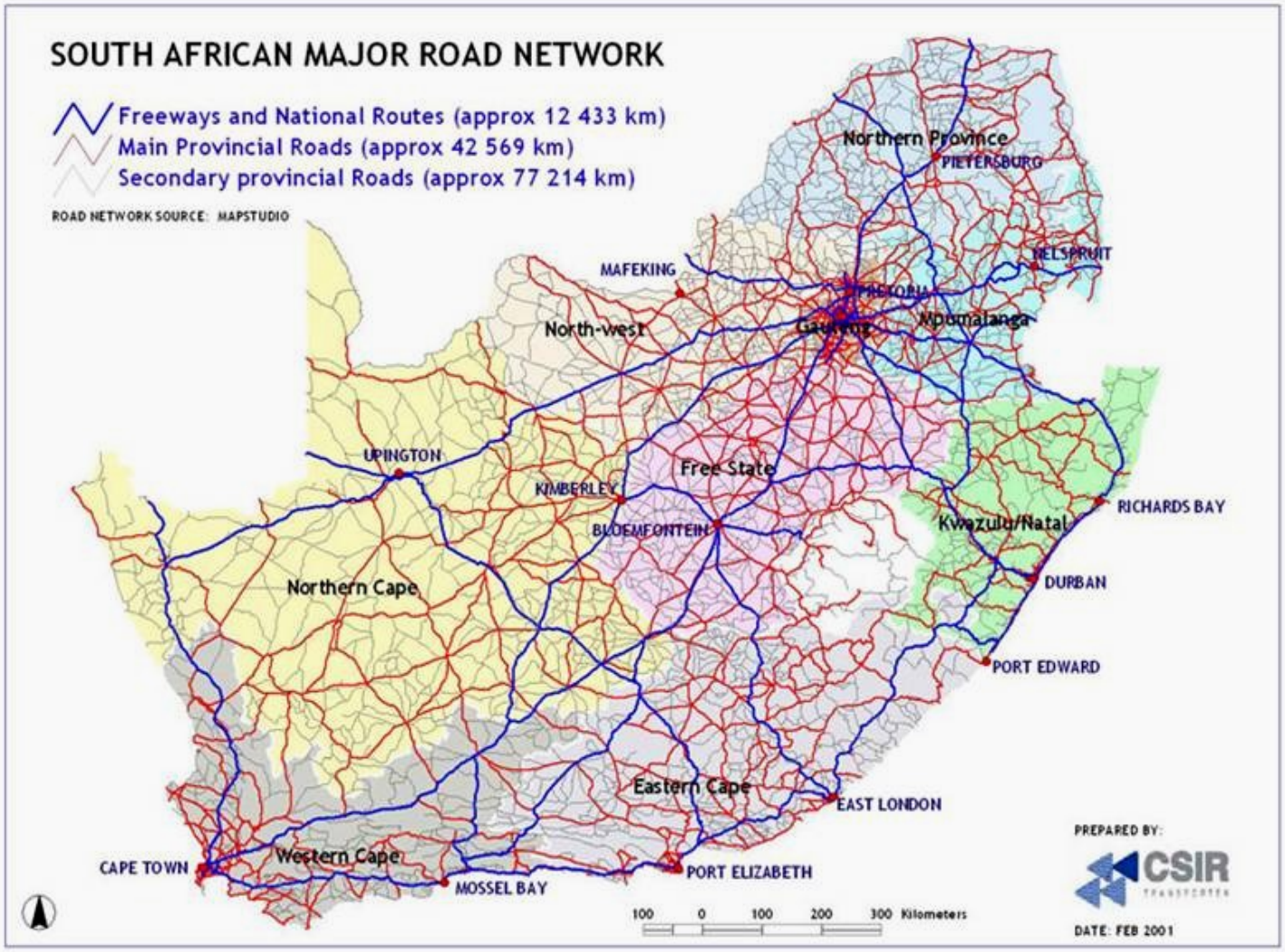
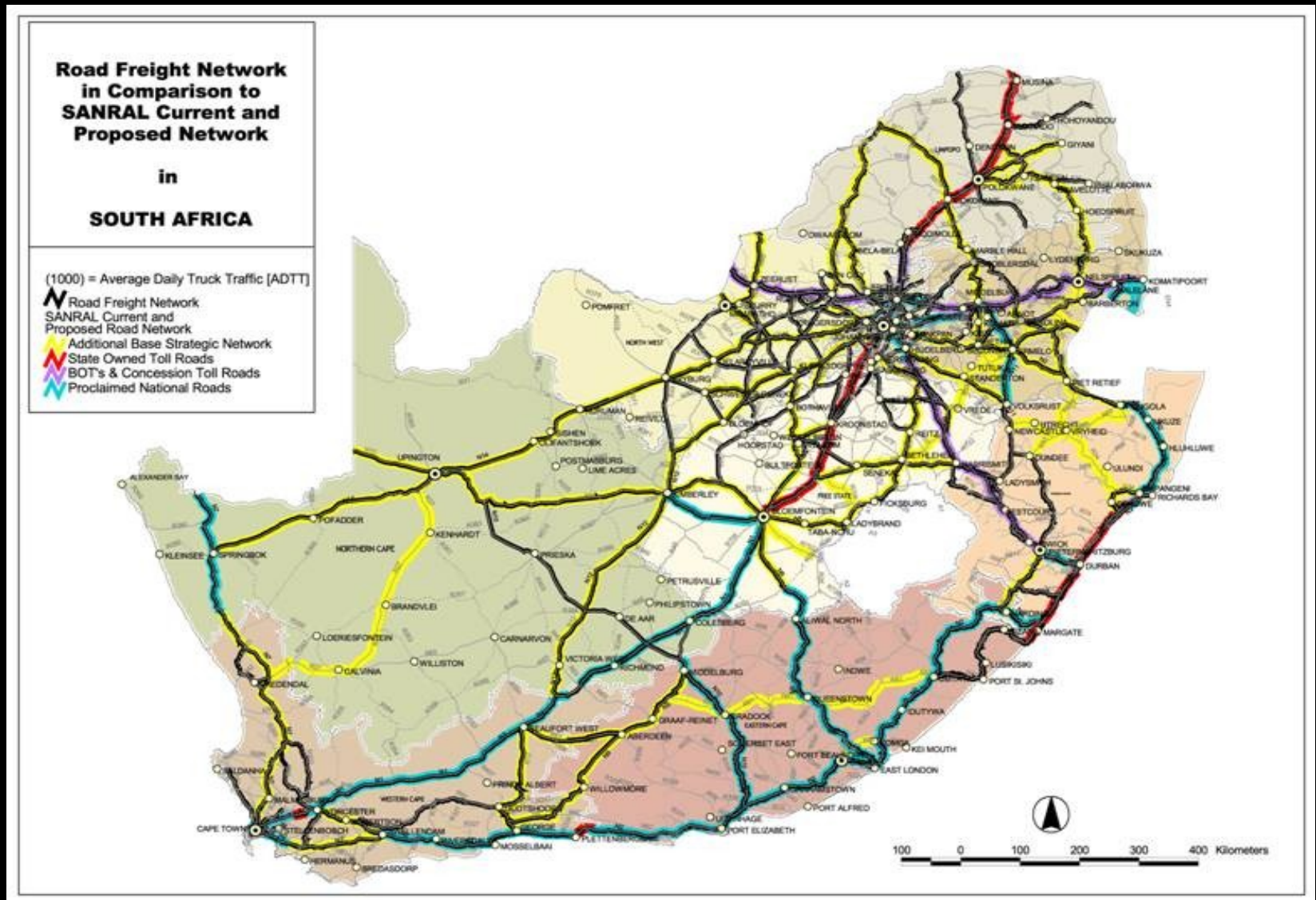
Heavy Vehicle Simulator (HVS) testing since 1975…

…PRACTICAL SOLUTIONS NEEDED !!

Total - all Roads in SA ~ 750 000 km

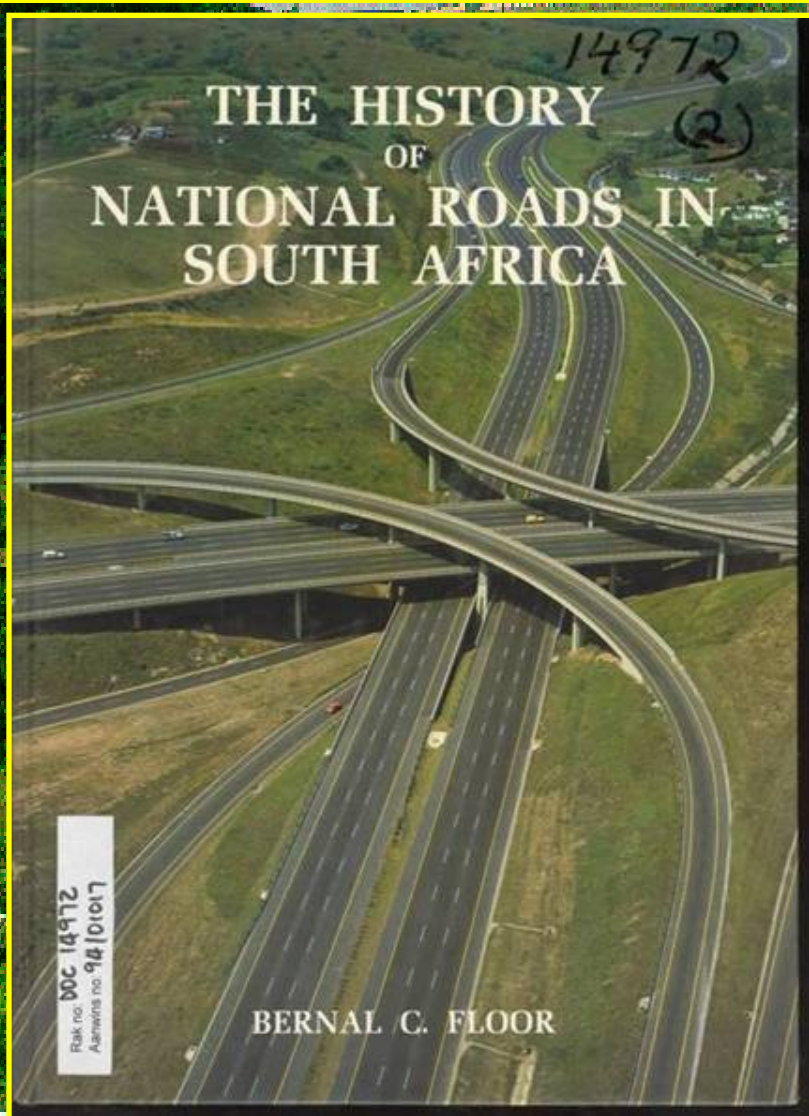


SOUTH AFRICAN MAJOR PAVED ROAD NETWORK ~ 20 000 km



Thinly Surfaced (12-50 mm) Flexible Pavements -

7 700 km National Roads in SA of Freeway/Expressway standard



Thin Asphalt Surfacings (12 mm to 50 mm) on crushed rock: Economical in dry regions - maintenance intensive

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Typical Heavy Vehicles (HVs)

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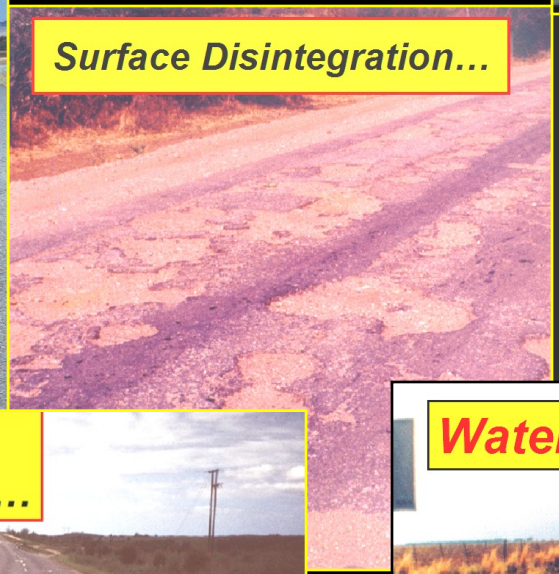
RUTTING


Longitudinal Flow of Asphalt


Fatigue Cracking and aging


Delamination..


Surface Disintegration…


POTHOLES :
Water & Loads …


Water & Safety…

Road Pavement Damage….

Tyre Types on Steering Axles - Recently:

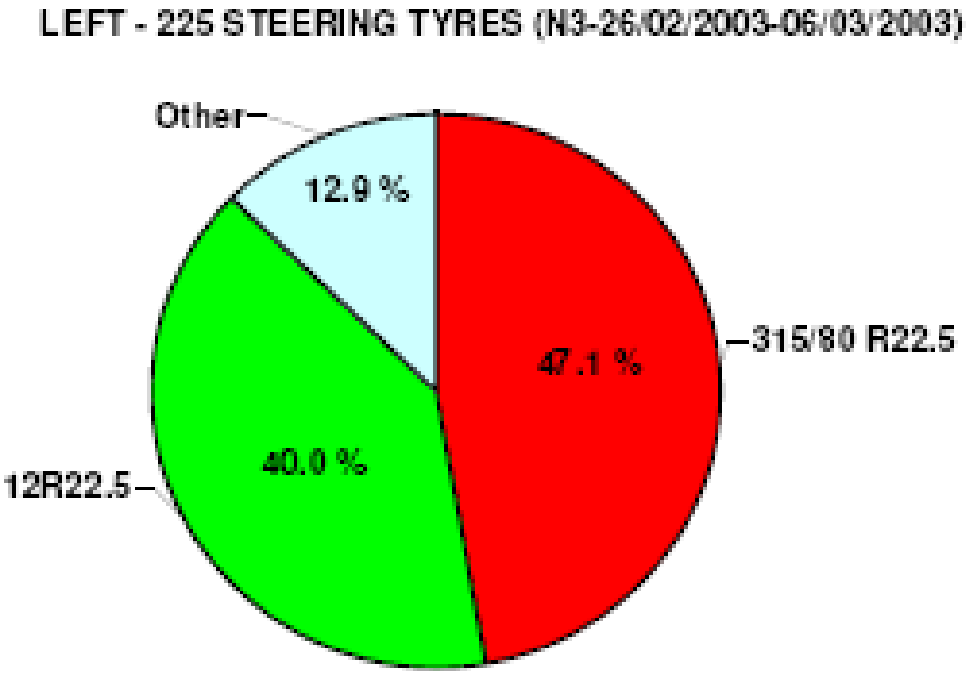


Figure 3: Distribution of left tyre type on steering axles of 225 Heavy Vehicles (HVs) on the N3-North (Heidelberg) (Tyre Data from Morton and Theyse, 2004)

Truck Tire Inflation Pressure in South Africa:

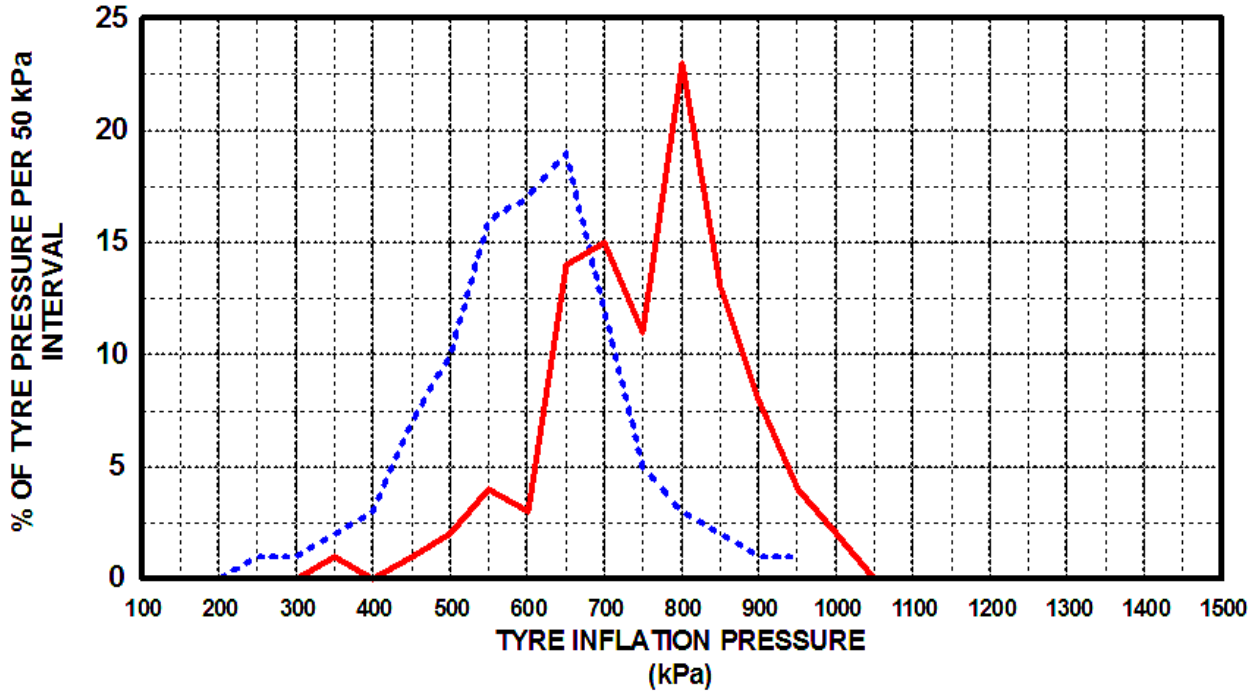


FIGURE 1

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

c:/capsaf1.wmf

~ 20 % Increase in 20 Years

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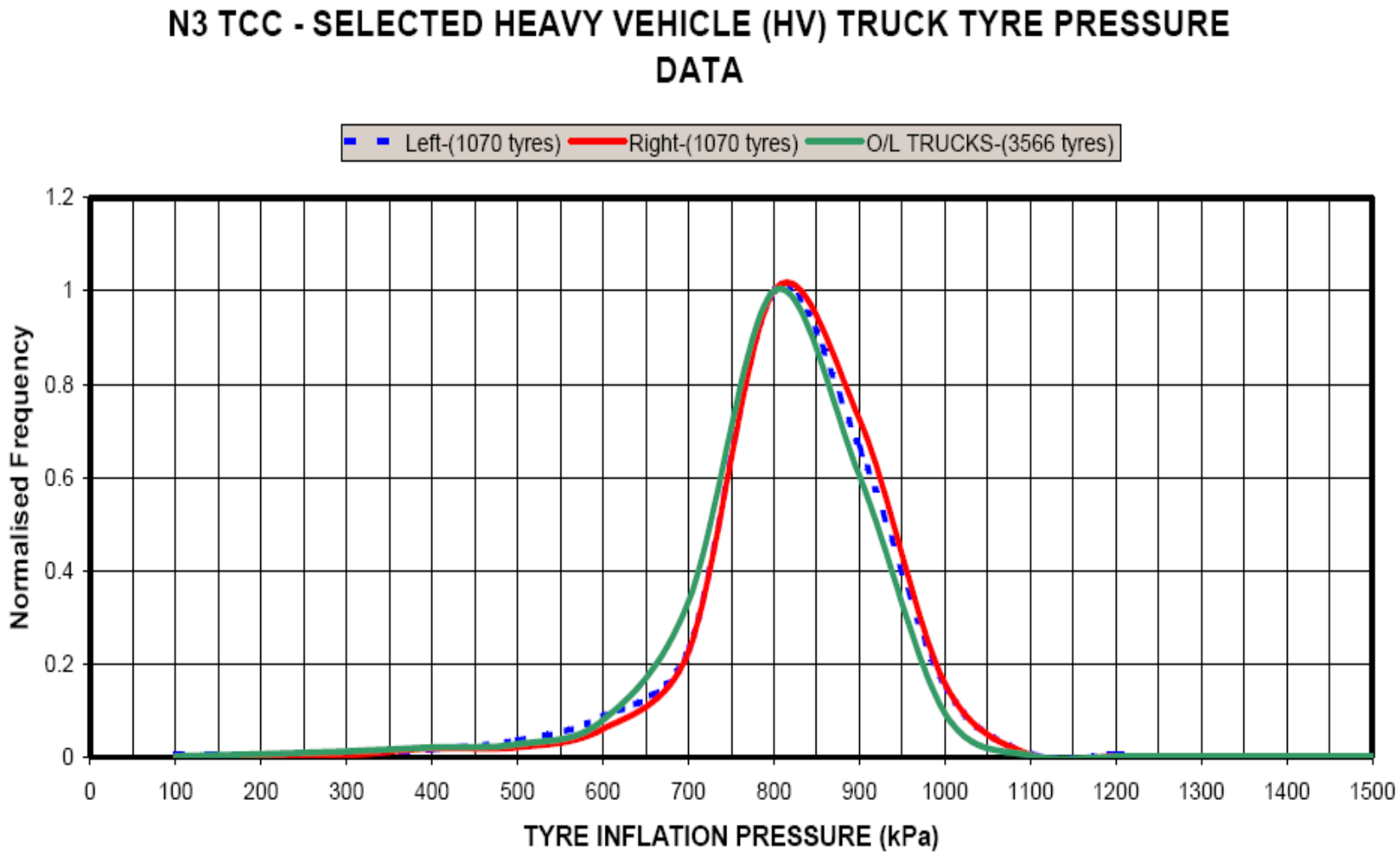
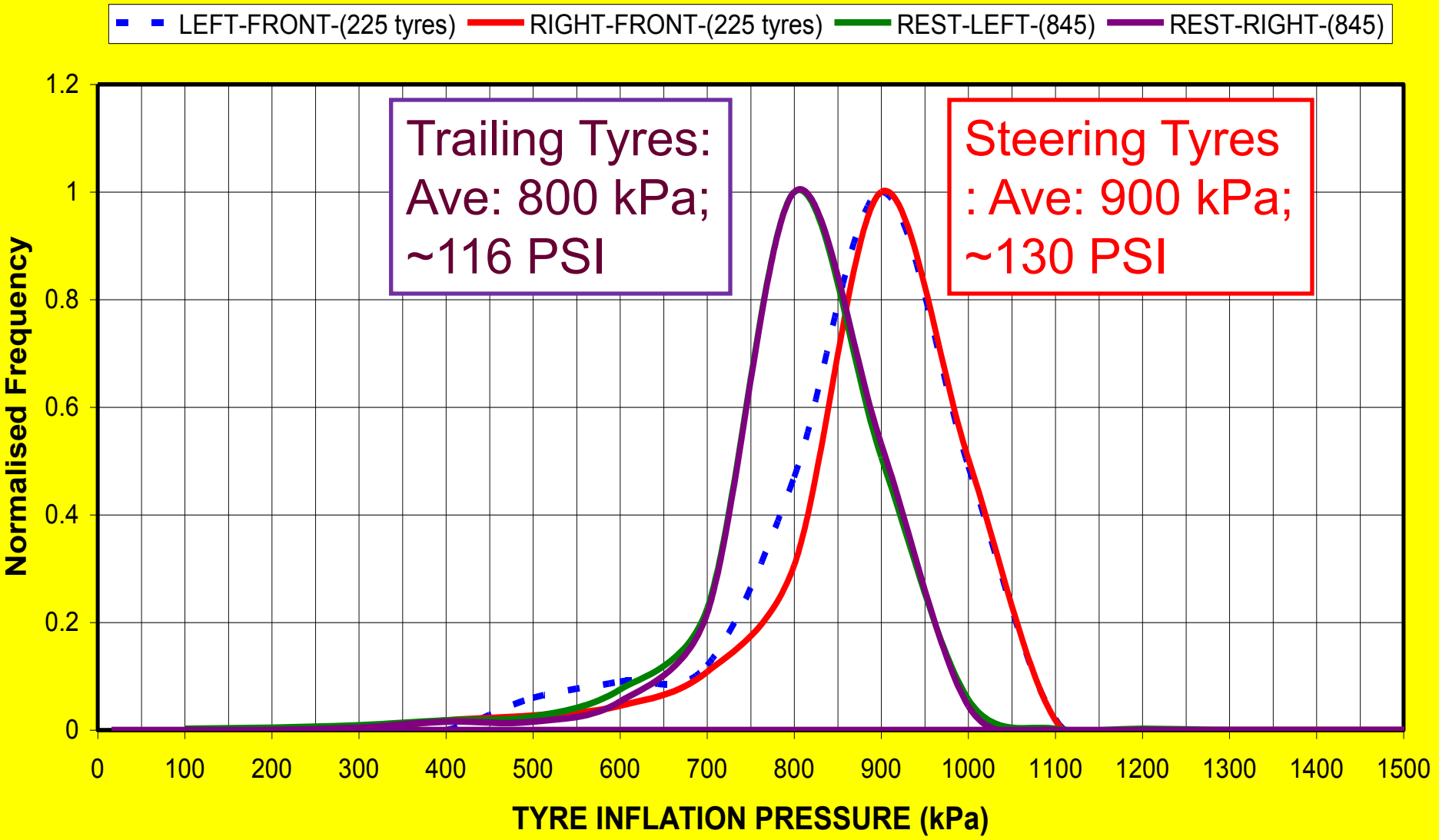
Inflation Pressure Distributions – N3 – TCC - 2003



H:\CAPSA04\[Tyre Inflation Pressure Information-MORTON-MDB-

N3 TCC - SELECTED HEAVY VEHICLE (HV) TRUCK TYRE PRESSURE DATA
(26 Feb 2003 - 06 March 2003)



H:\ICAP-2006 Summary N3 TCC-FINAL-4-B-ICAP-2006.xls TYRES-1-2 -Histogram-Paper (2)

ALL TYRES MEASURED: n = 45 227 (This Study) - N3 -TCC-2003

All Other Tyres | Axle 1 Left | Axle 1 Right

All other Tyers: 1.9 Tonne

Steering Tyres: 2.95 Tonne

Number of Tyres

0 200 400 600 800 1000 1200 1400 1600

0 20 40 60 80 100 120

0.050 0.300 0.550 0.800 1.050 1.300 1.550 1.800 2.050 2.300 2.550 2.800 3.050 3.300 3.550 3.800 4.050 4.300 4.550 4.800

Bin: Tyre Mass Weight [Tonne]

HVS Mk IV+ Test Tyres

DUAL: 12R22.5

SINGLE: 315/80 R22.5

425/65 R22.5 tyre in South Africa

Vehicle-Tyre-Pavement Interaction:

Stress-In-Motion (SIM) Technology

Stress – In – Motion (SIM) Technology

The measurement of 3D tyre/pavement contact stresses from moving vehicles

Stress – In – Motion (SIM) – SIM Mk II
Device: CSIR : '93-'95

315/80 HVS TYRE ON SIM Mk II SYSTEM

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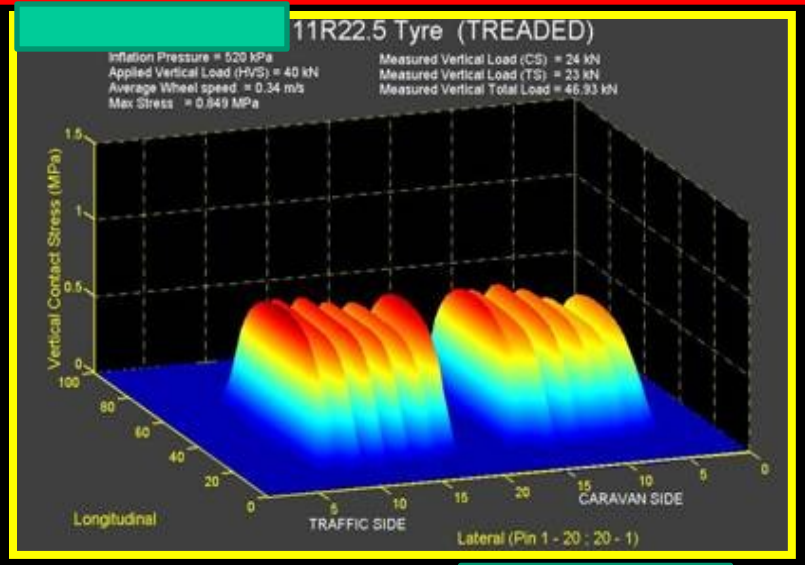
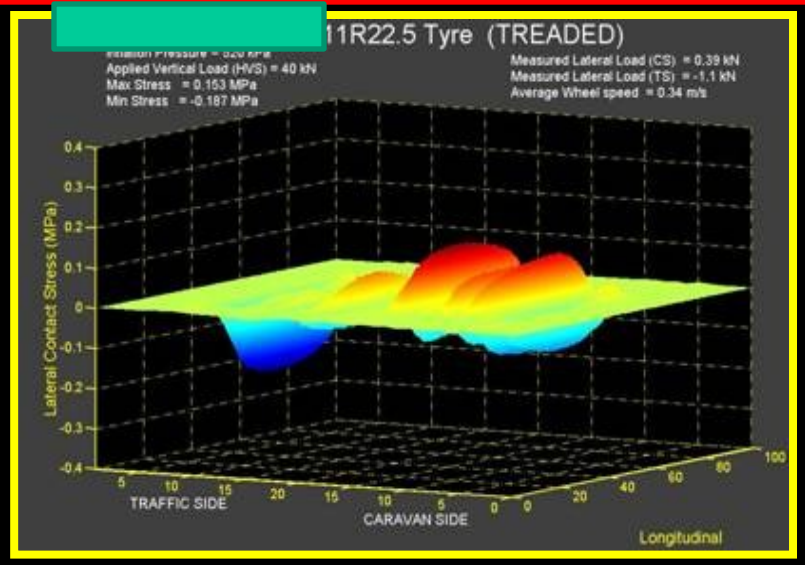
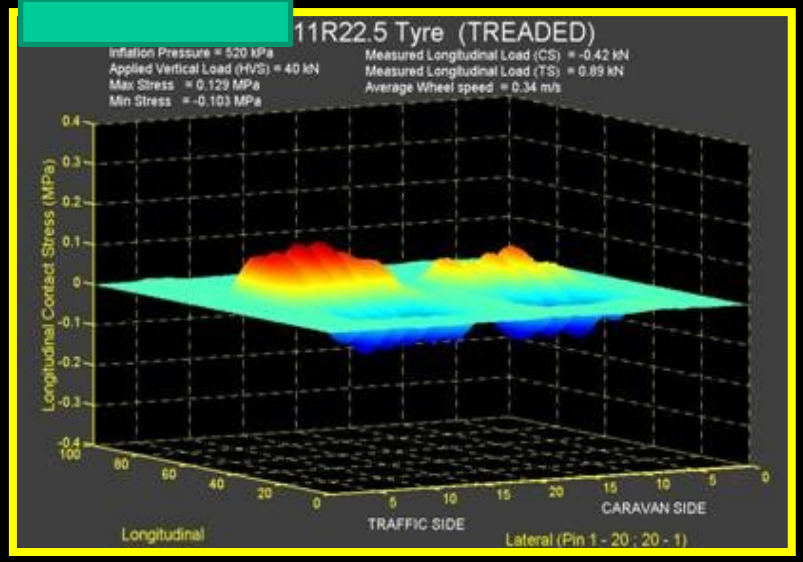
Dual Tyre: Measured 3D-Contact Stresses (Pressure)…80 kN Single Axle… (..ESAL)





Stress Ratio: 10:3:1



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Truck Tyres….

”Sectometer”

S. Eckels, 1928

The "sectometer" was leveled (Figure 4), and the height of the springs were measured with nine inch micrometer calipers (Figure 1). The

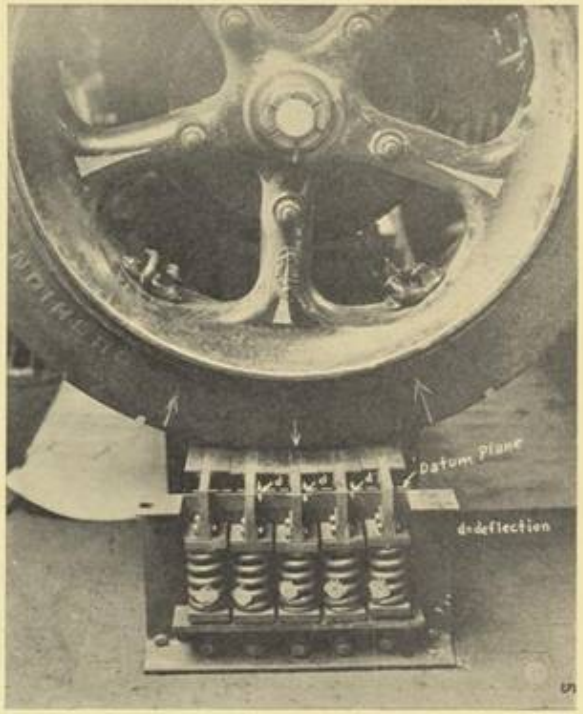
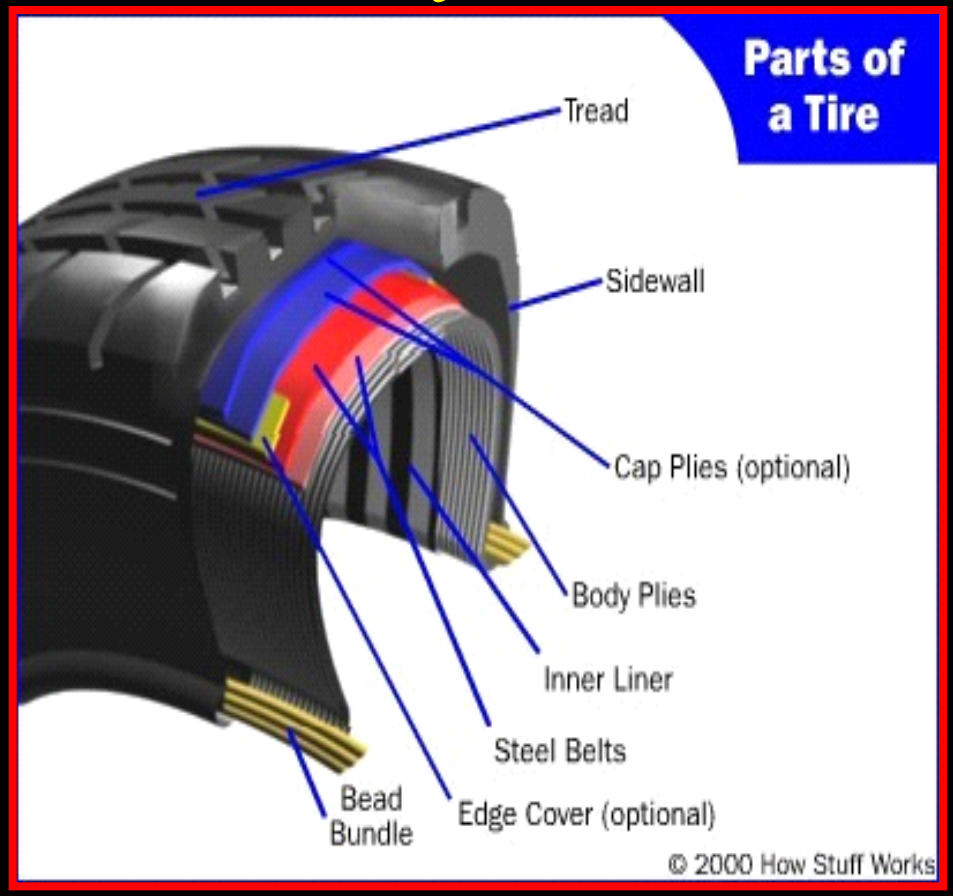


Figure 5

machine was now in position for the impression and also for the determination of the load distribution.

Modern Tyre science…



HEAVY VEHICLE SIMULATOR (HVS) - SINCE 1970s

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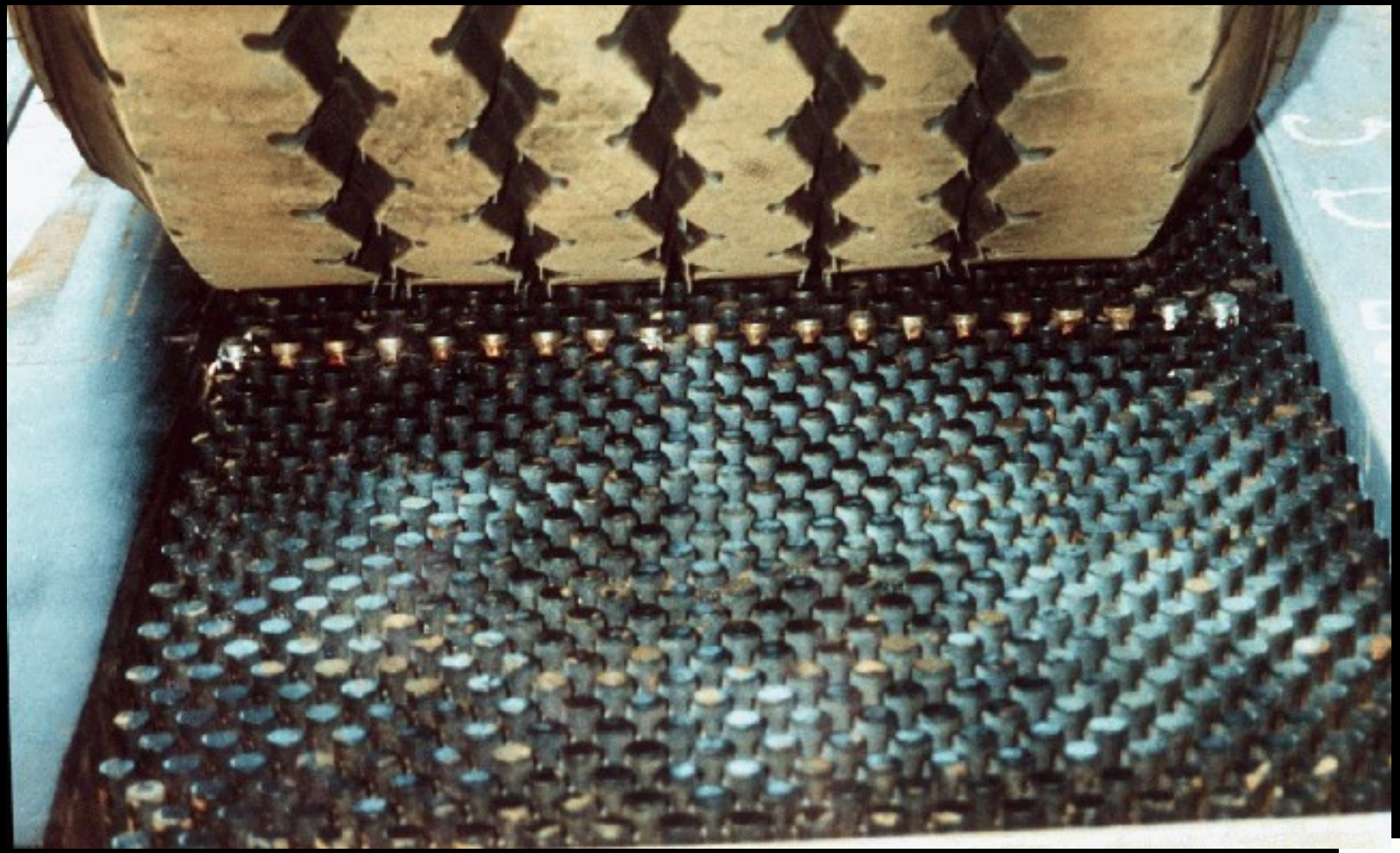
Oct 2004 - HVS – SIM Tests

SINGLE SIM PAD FOR HVS TESTING

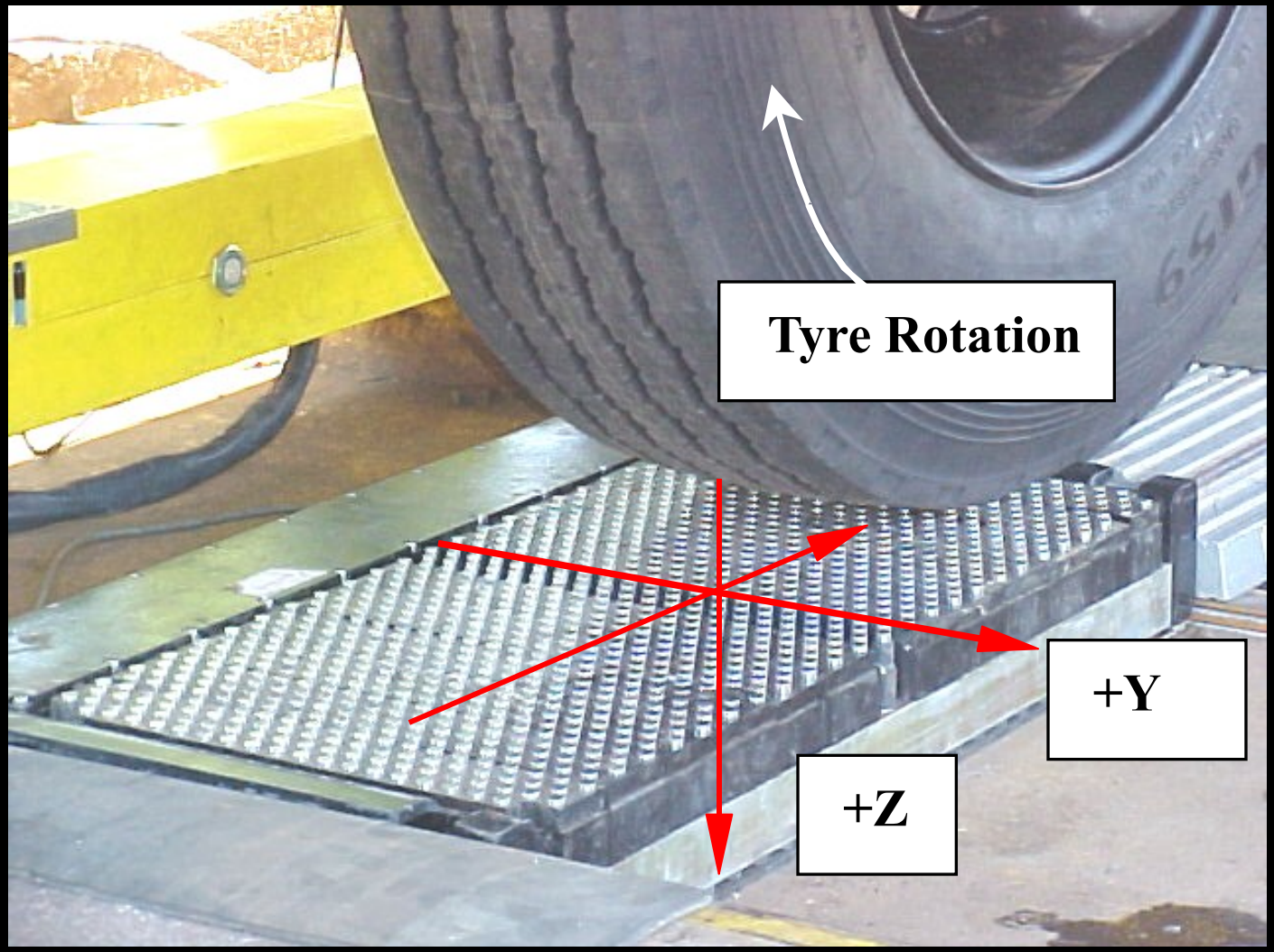
Stress – In – Motion (SIM) – SIM Mk II: CSIR : '93-'95

315/80 HVS TYRE ON SIM Mk II SYSTEM

425 /65 R22.5 HVS Tyre: Single pad SIM system (Use with HVS)



SAE sign convention : X-Longitudinal, Y-Lateral and Z -Vertical loads/stresses



TYRE-SURFACE INTERACTION
on textured surface - 3D Stress Regimes

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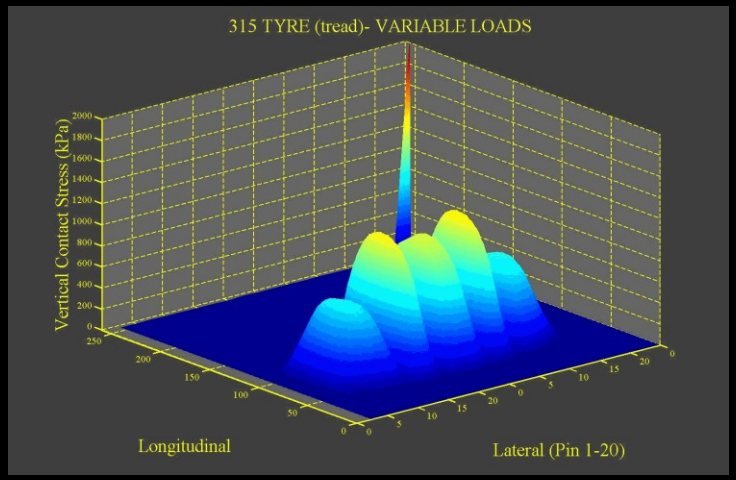
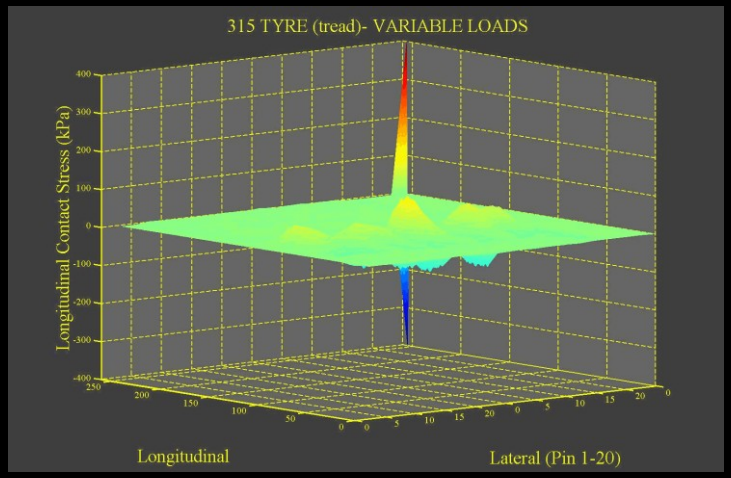
Typical SIM Data Sets: *Z, X, Y - Contact Stresses @ Variable loads: 315/80 R22.5 Tire*

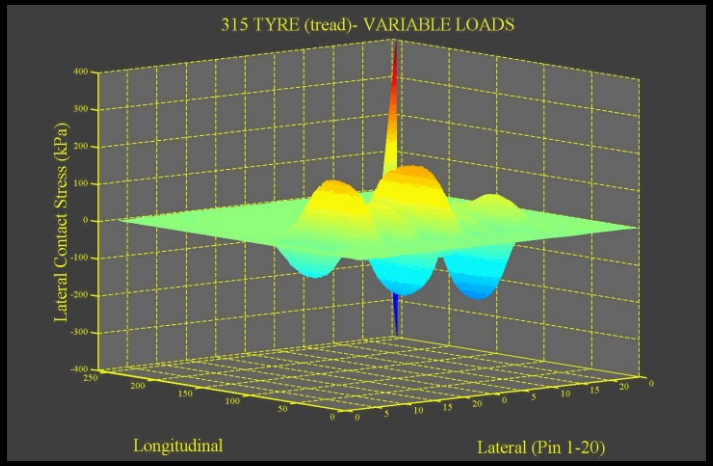
Z: Vertical Stress



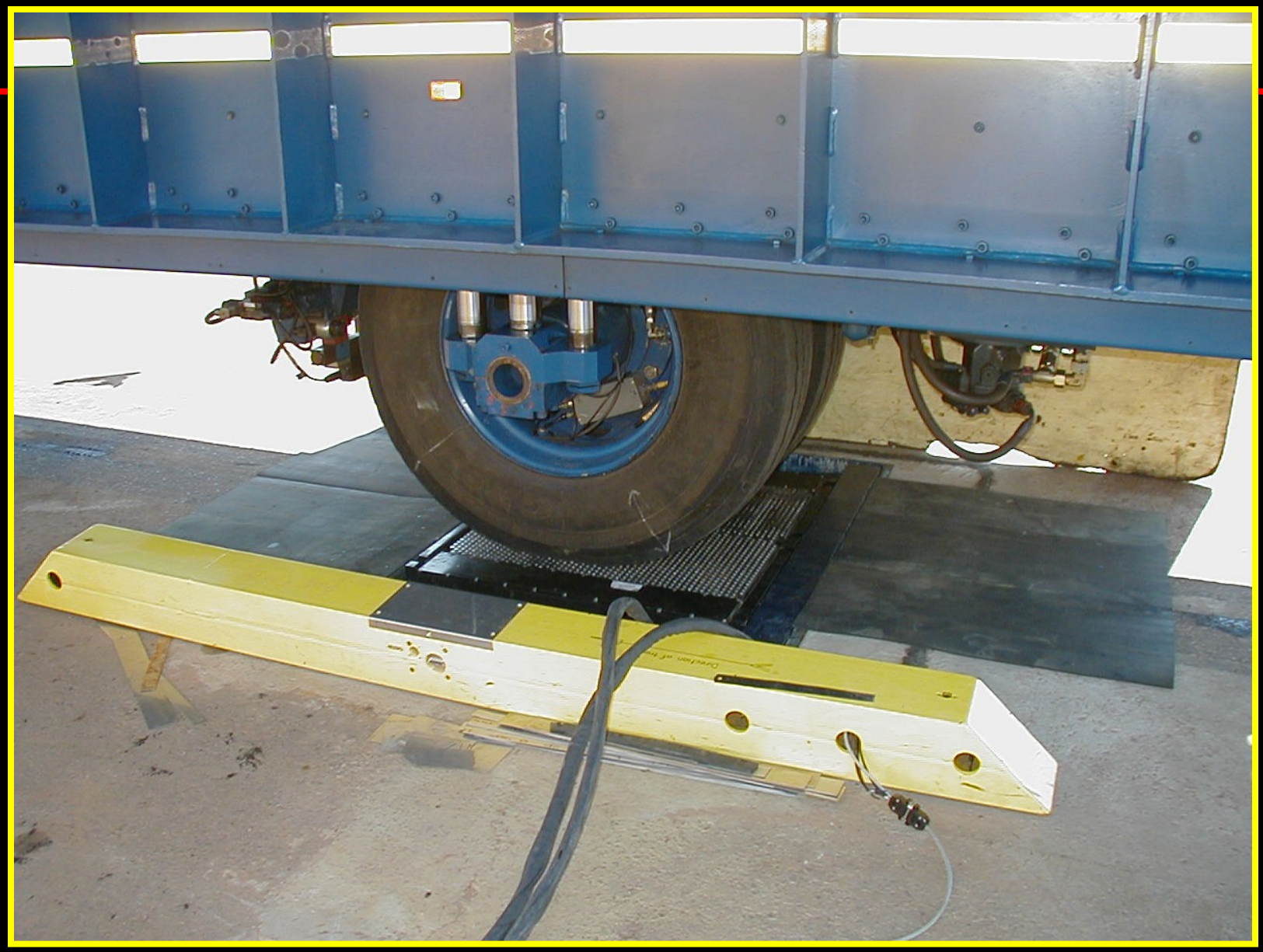
Y: Lateral Stress



X: Longitudinal Stress

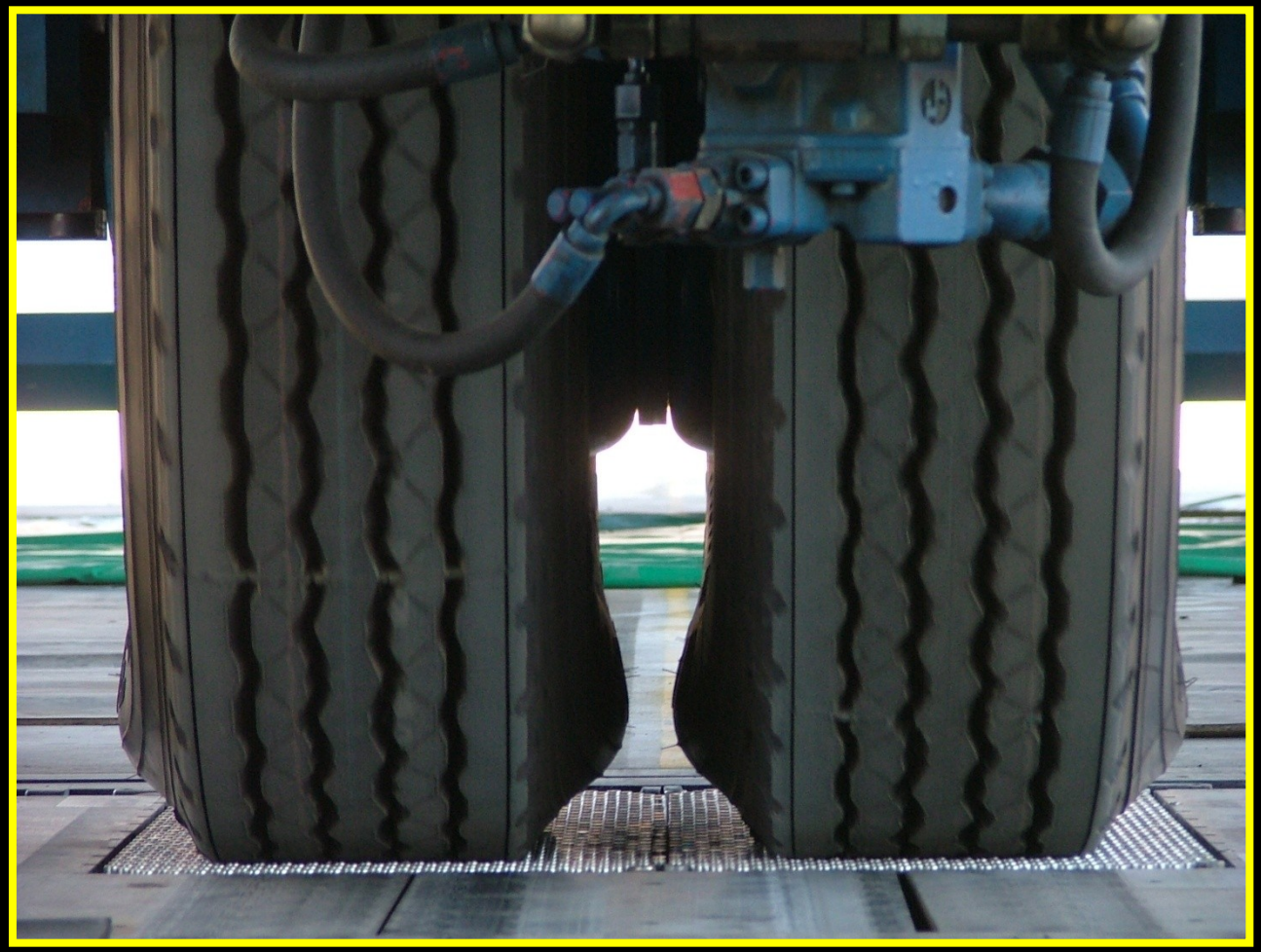


SIM TESTING USING THE HVS - DUAL LOADING..



STRESS-IN-MOTION TESTING USING THE HVS

HEAVY VEHICLE SIMULATOR (HVS) - DUAL TEST TYRES (12R22.5)

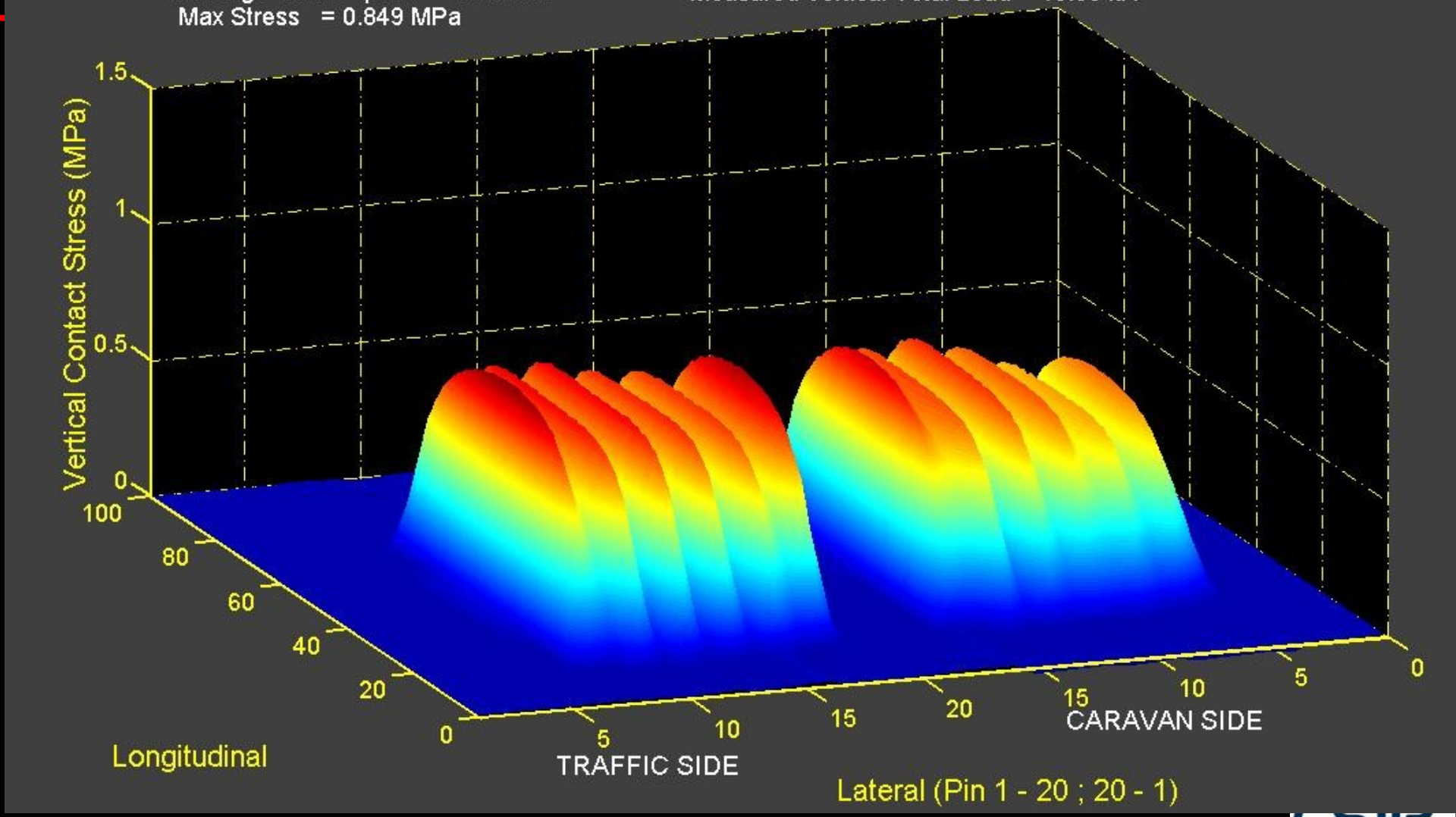


STRESS-IN-MOTION (SIM) testing using the Heavy Vehicle Simulator (HVS)- Dual Load Configuration – Twin (dual) SIM pads

11R22.5 Tyre (TREADED)

Inflation Pressure = 520 kPa
Applied Vertical Load (HVS) = 40 kN
Average Wheel speed = 0.34 m/s
Max Stress = 0.849 MPa

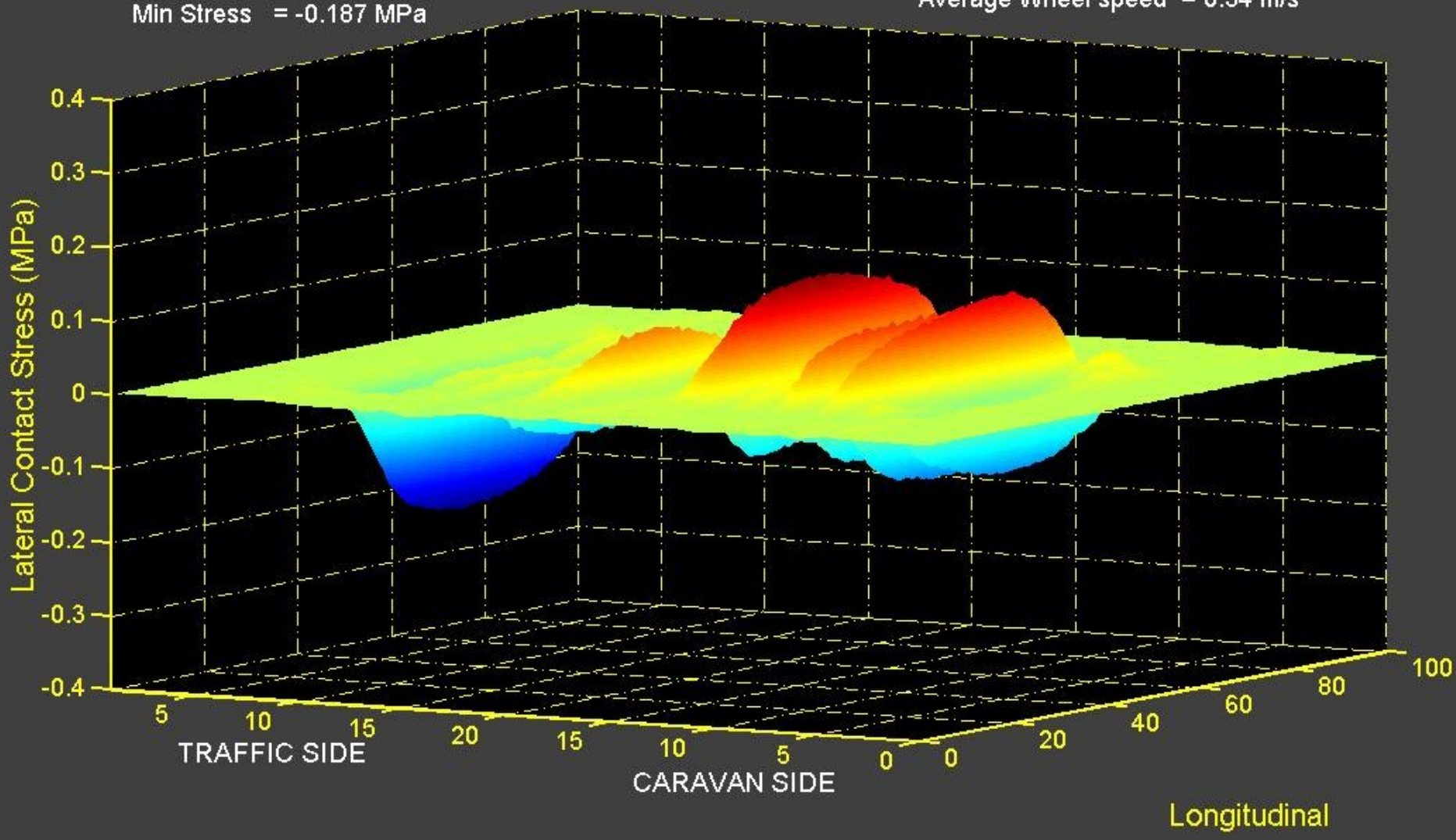
Measured Vertical Load (CS) = 24 kN
Measured Vertical Load (TS) = 23 kN
Measured Vertical Total Load = 46.93 kN

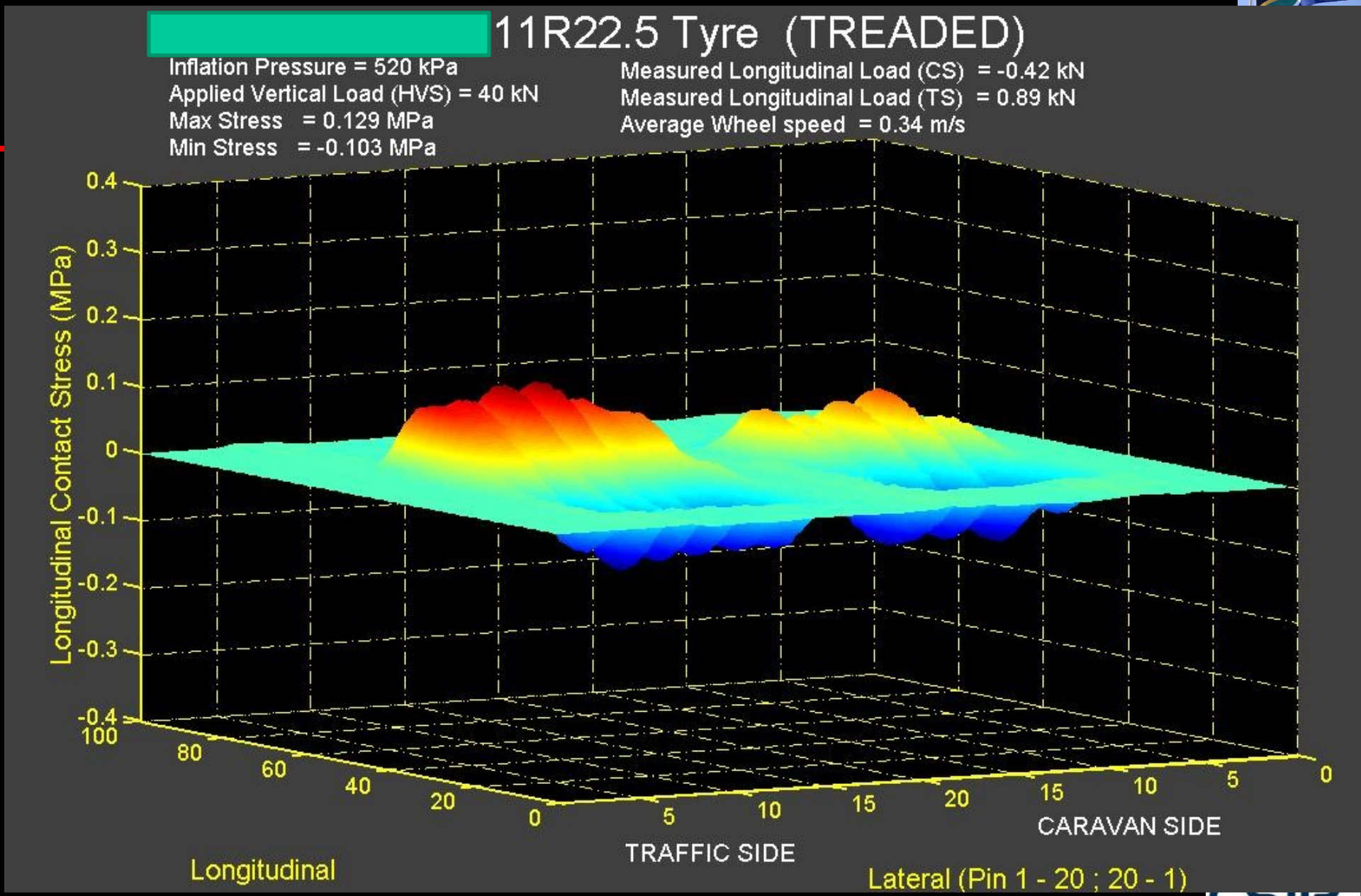


11R22.5 Tyre (TREADED)

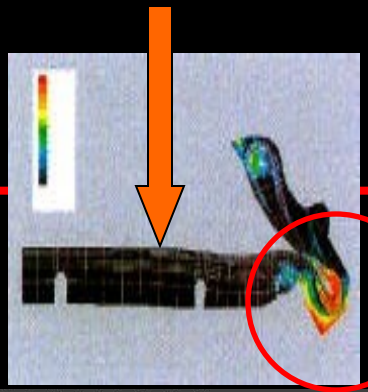
Inflation Pressure = 520 kPa
Applied Vertical Load (HVS) = 40 kN
Max Stress = 0.153 MPa
Min Stress = -0.187 MPa

Measured Lateral Load (CS) = 0.39 kN
Measured Lateral Load (TS) = -1.1 kN
Average Wheel speed = 0.34 m/s

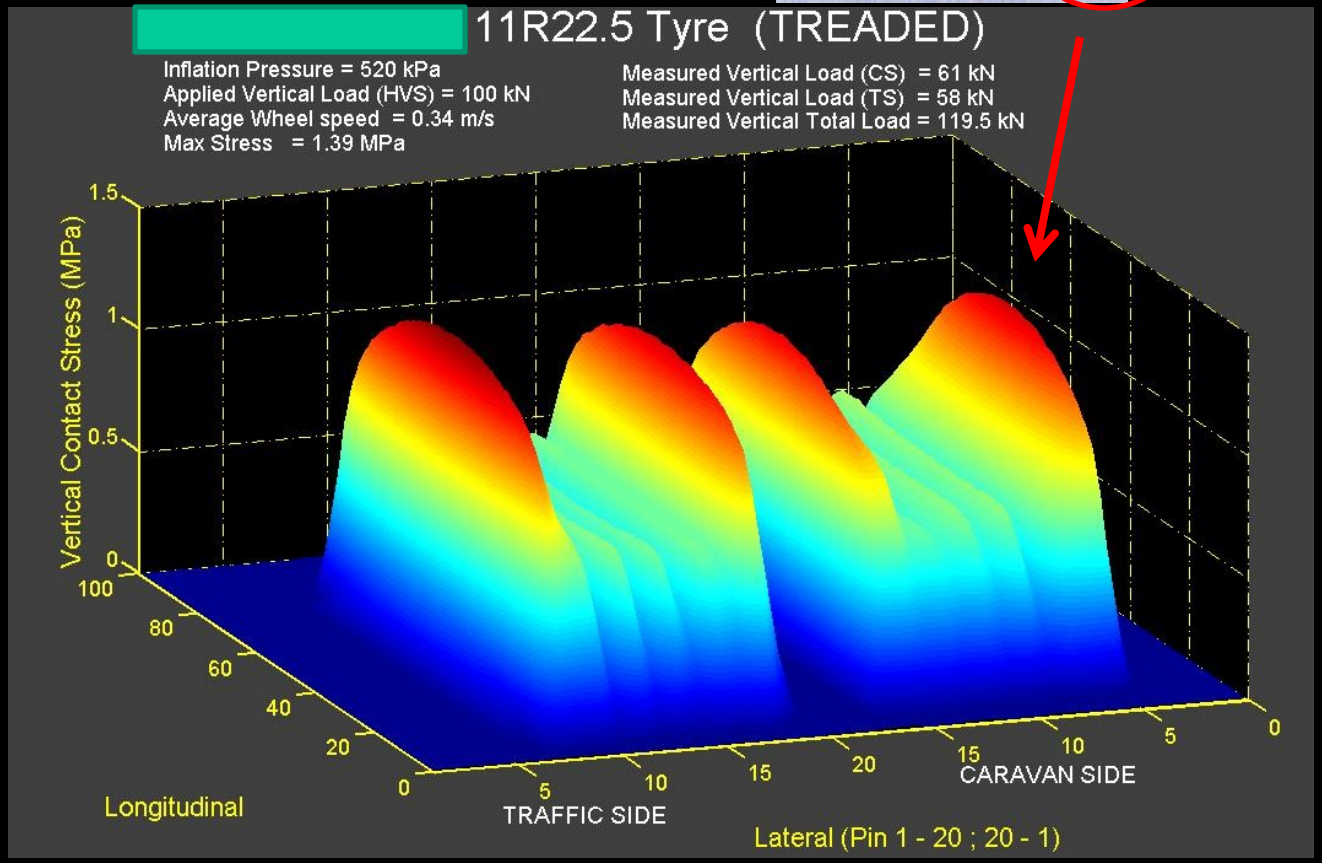


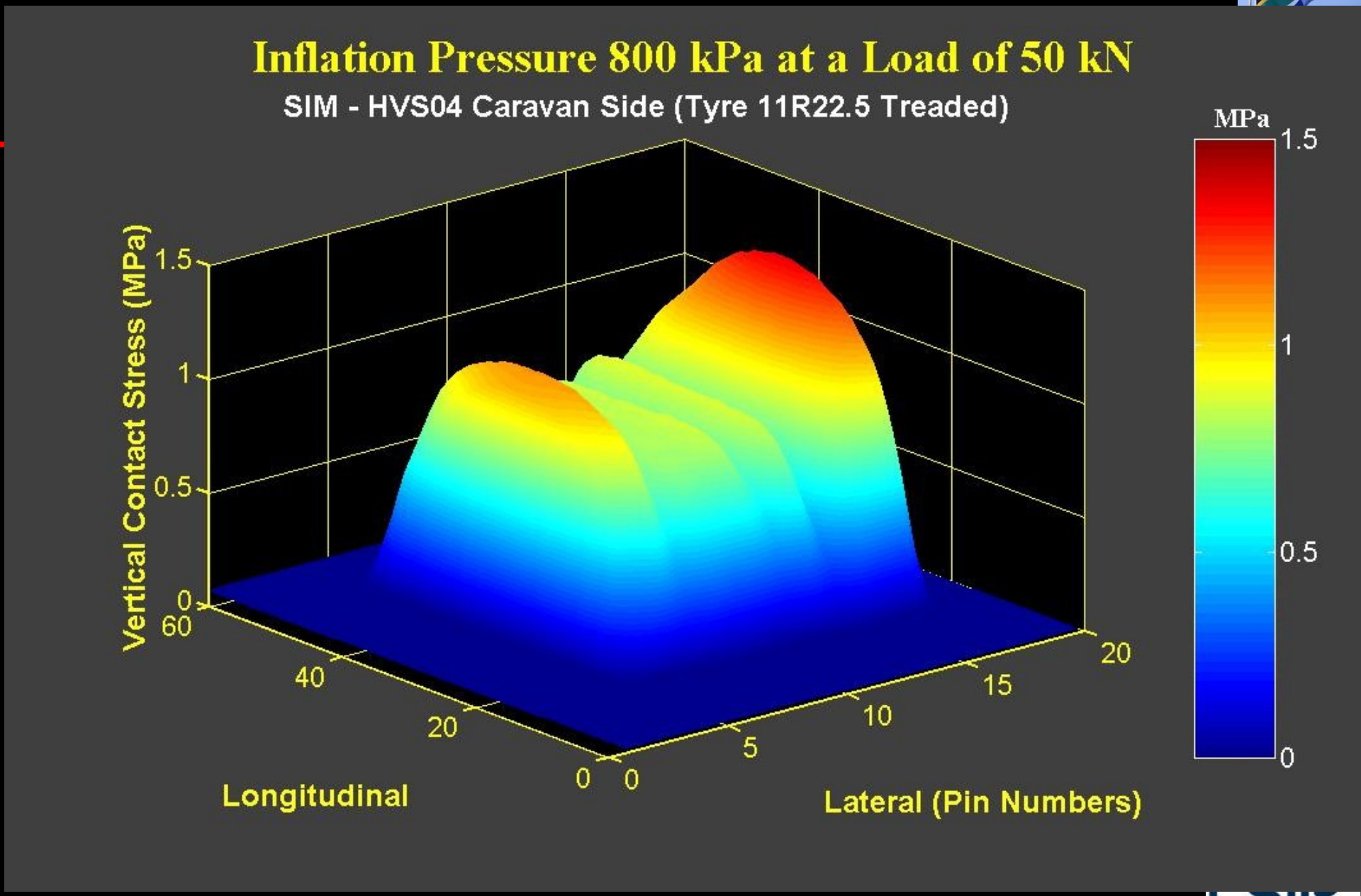

11R22.5 Tyre (TREADED)
Inflation Pressure = 520 kPa
Applied Vertical Load (HVS) = 40 kN
Max Stress = 0.129 MPa
Min Stress = -0.103 MPa
Measured Longitudinal Load (CS) = -0.42 kN
Measured Longitudinal Load (TS) = 0.89 kN
Average Wheel speed = 0.34 m/s
Longitudinal Contact Stress (MPa)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
100
80
60
40
20
0
Longitudinal
5
10
15
20
TRAFFIC SIDE
15
10
5
0
CARAVAN SIDE
Lateral (Pin 1 - 20 ; 20 - 1)

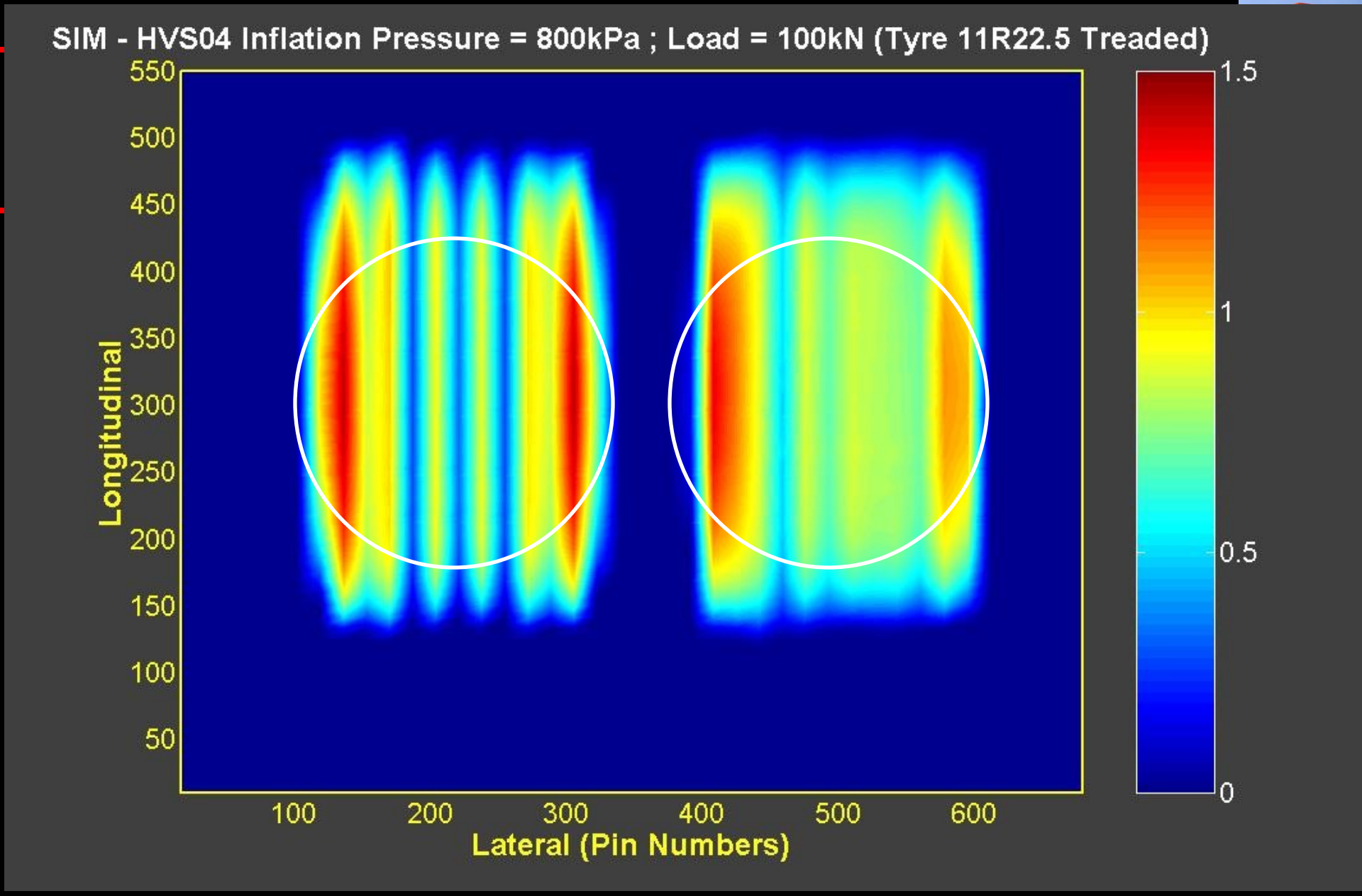
OVER-LOADING/UNDER INFLATION

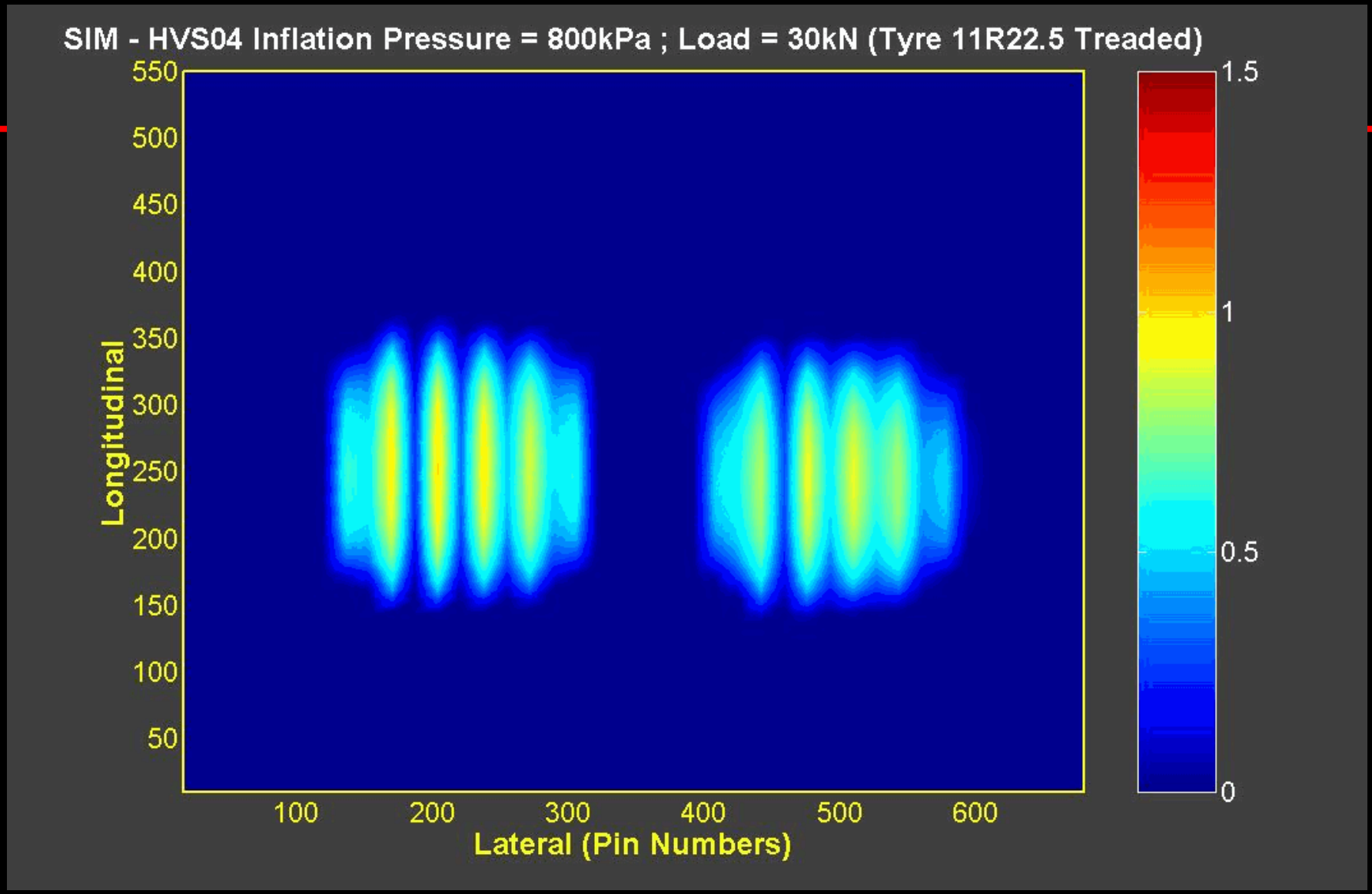


Tyre Edge

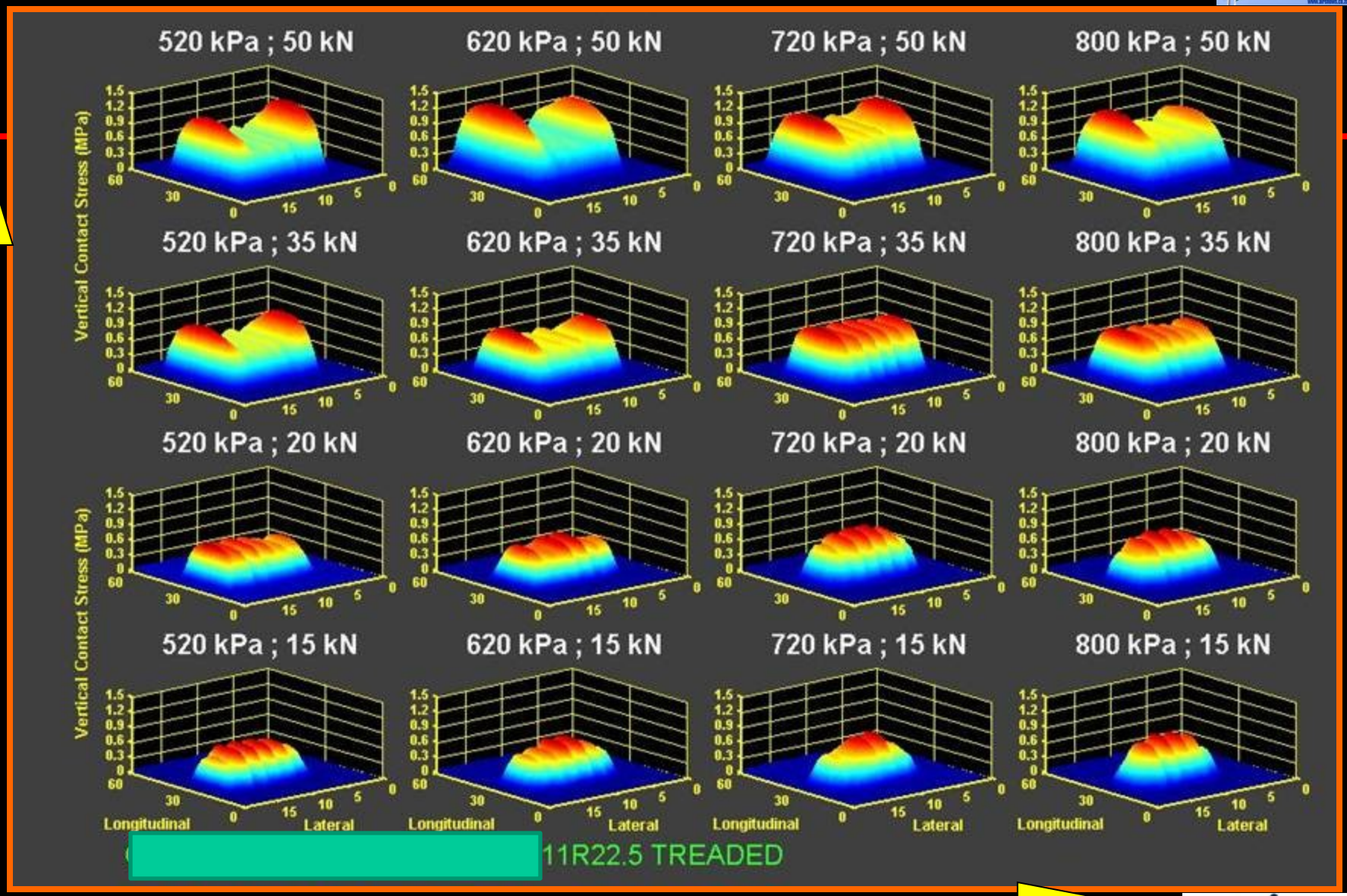



Inflation Pressure 800 kPa at a Load of 50 kN
SIM - HVS04 Caravan Side (Tyre 11R22.5 Treaded)
Vertical Contact Stress (MPa)
1.5
1
0.5
0
60
40
20
0
Longitudinal
0
5
10
15
20
Lateral (Pin Numbers)
MPa
1.5
1
0.5
0


SIM - HVS04 Inflation Pressure = 800kPa ; Load = 100kN (Tyre 11R22.5 Treaded)
Longitudinal
550
500
450
400
350
300
250
200
150
100
50
100
200
300
400
500
600
Lateral (Pin Numbers)
1.5
1
0.5
0



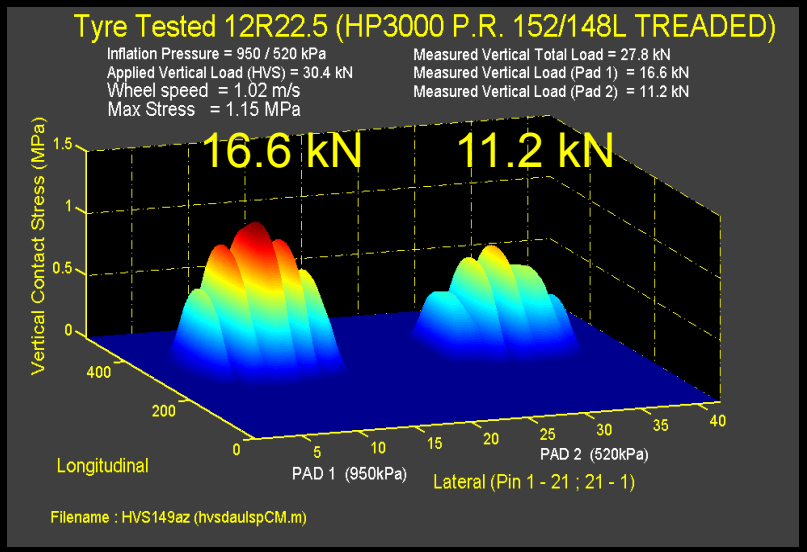
TYRE "FINGER PRINTING": VERTICAL STRESS PROFILES

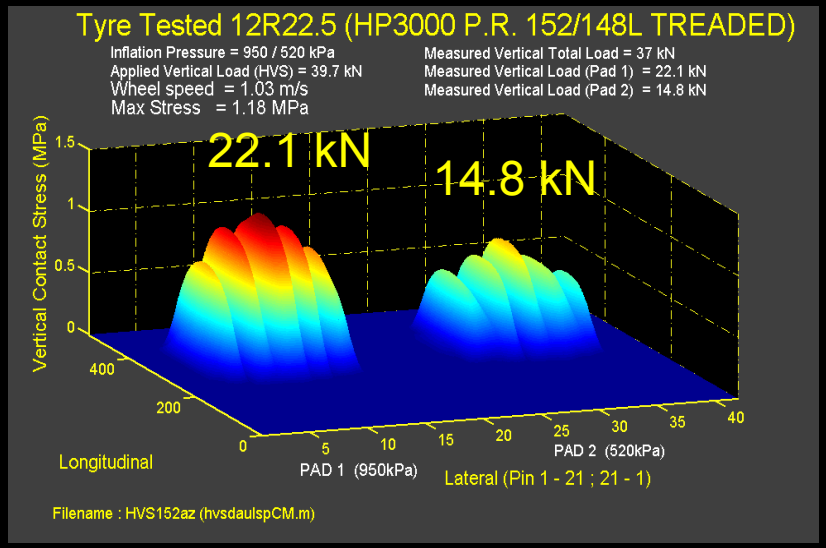


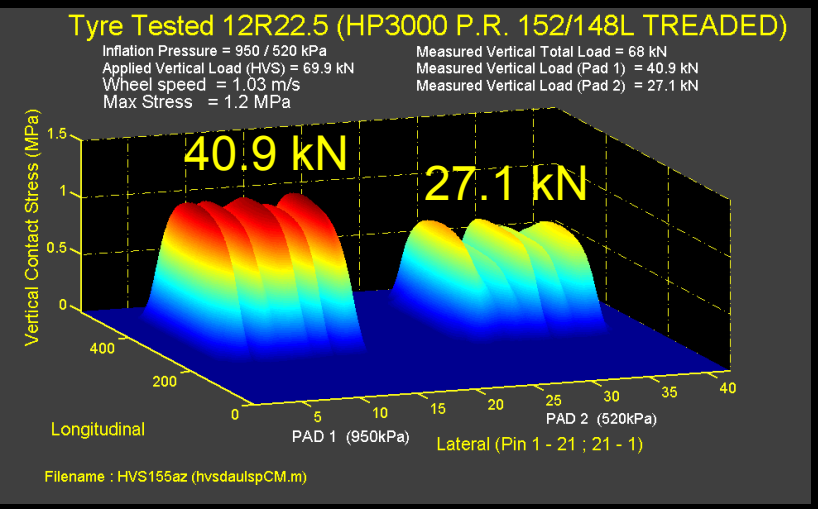
LOAD

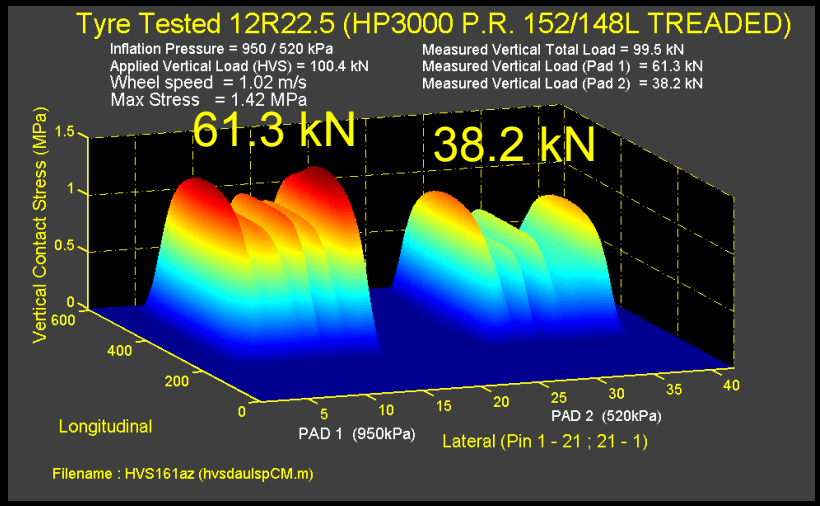
INFLATION PRESSURE

DIFFERENTIAL TYRE PRESSURES(12R22.5): 950/520 kPa @ 30 kN; 40 kN;70 kN and 100 kN









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TYRE DEFLECTION & TYRE PRINTS – NB !

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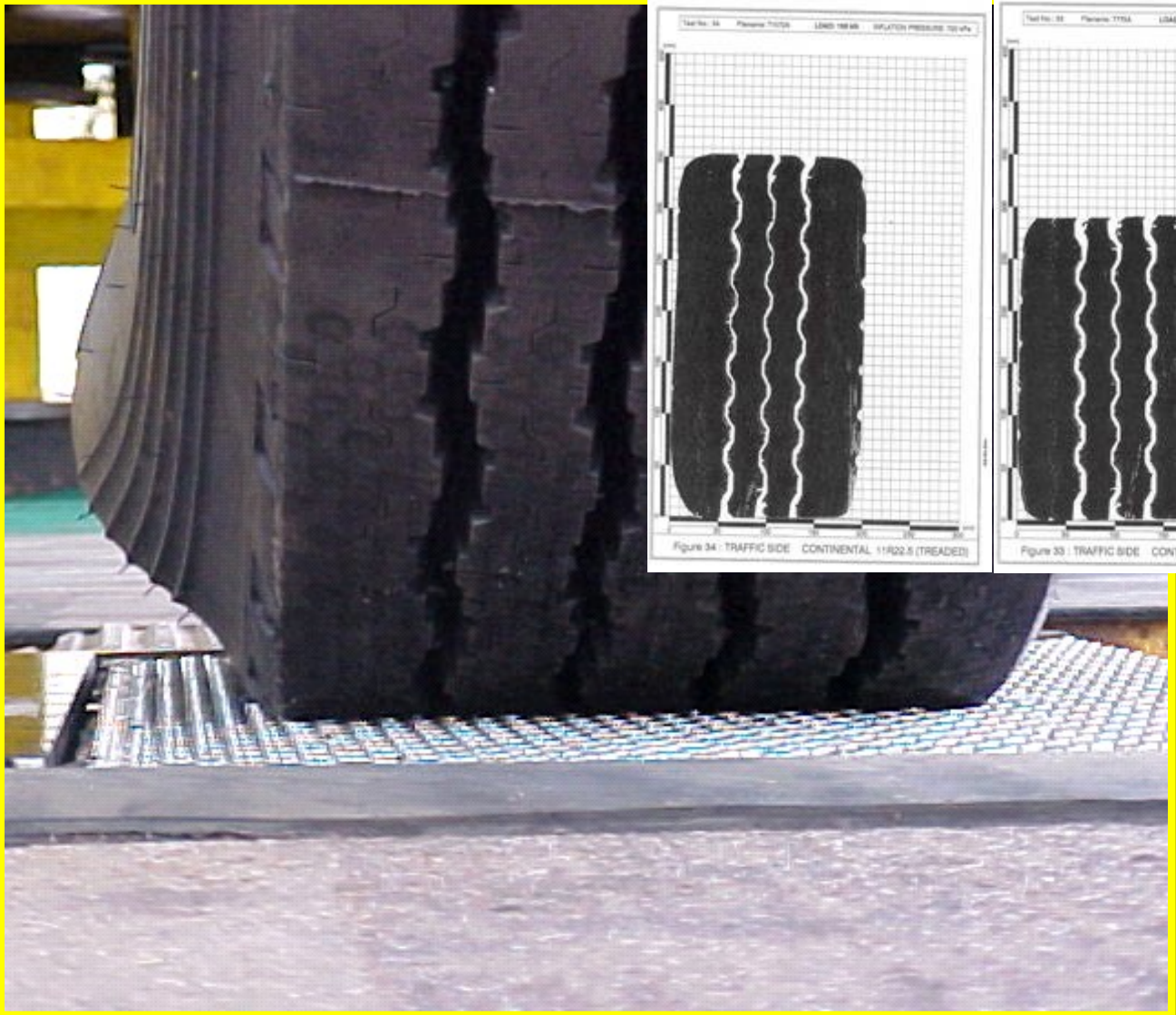
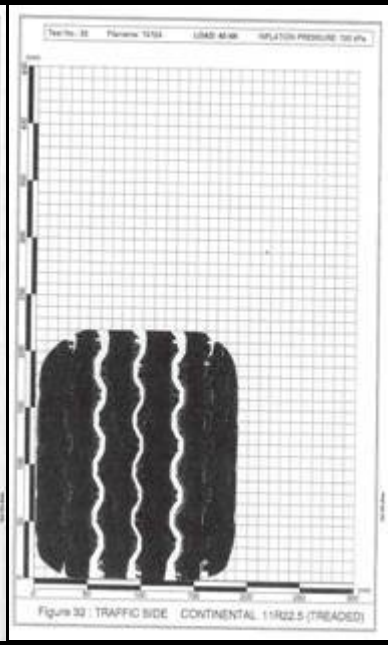
TRANSPORTEK

STATIC TYRE PRINTS (12R22.5)

315/80 R22.5 HVS Tyre: Overloaded…..





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SIM systems..

Quad Stress-In-Motion (SIM) system:

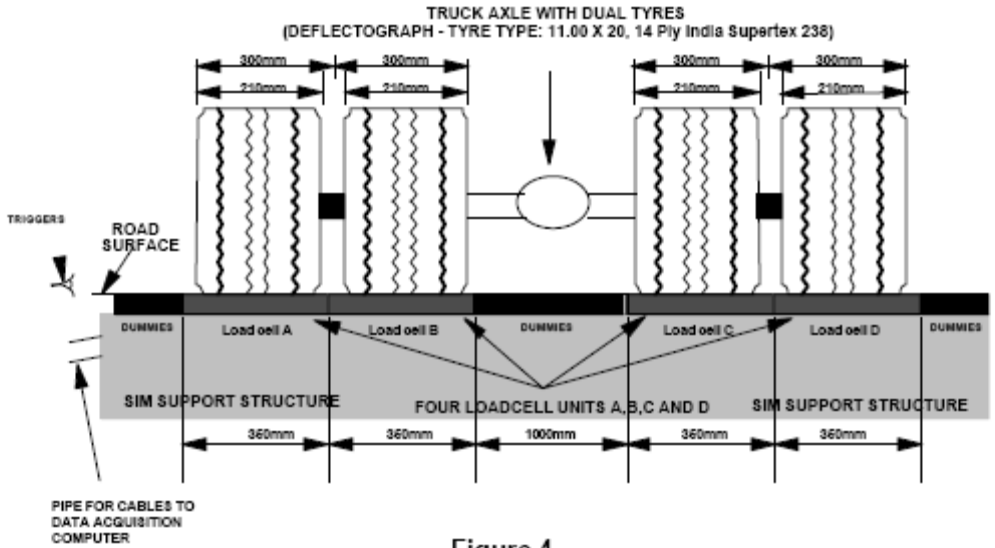

Figure 4

TYPICAL LAYOUT OF THE VRSPTA MARK III SIM SYSTEM
WITH A TYPICAL TRUCK AXLE (DUAL TYRES)

SIM3.DRW

QUAD SIM PAD TESTING AT WEIGH-BRIDGE SITE: N3 NORTH – HEIDELBERG TRAFFIC CONTROL CENTRE

STRESS-IN-MOTION TESTING ON N3 NORTH (HEIDELBERG): QUAD SIM SYSTEM IN OPERATION

STRESS-IN-MOTION TESTING ON N3 NORTH (HEIDELBERG)

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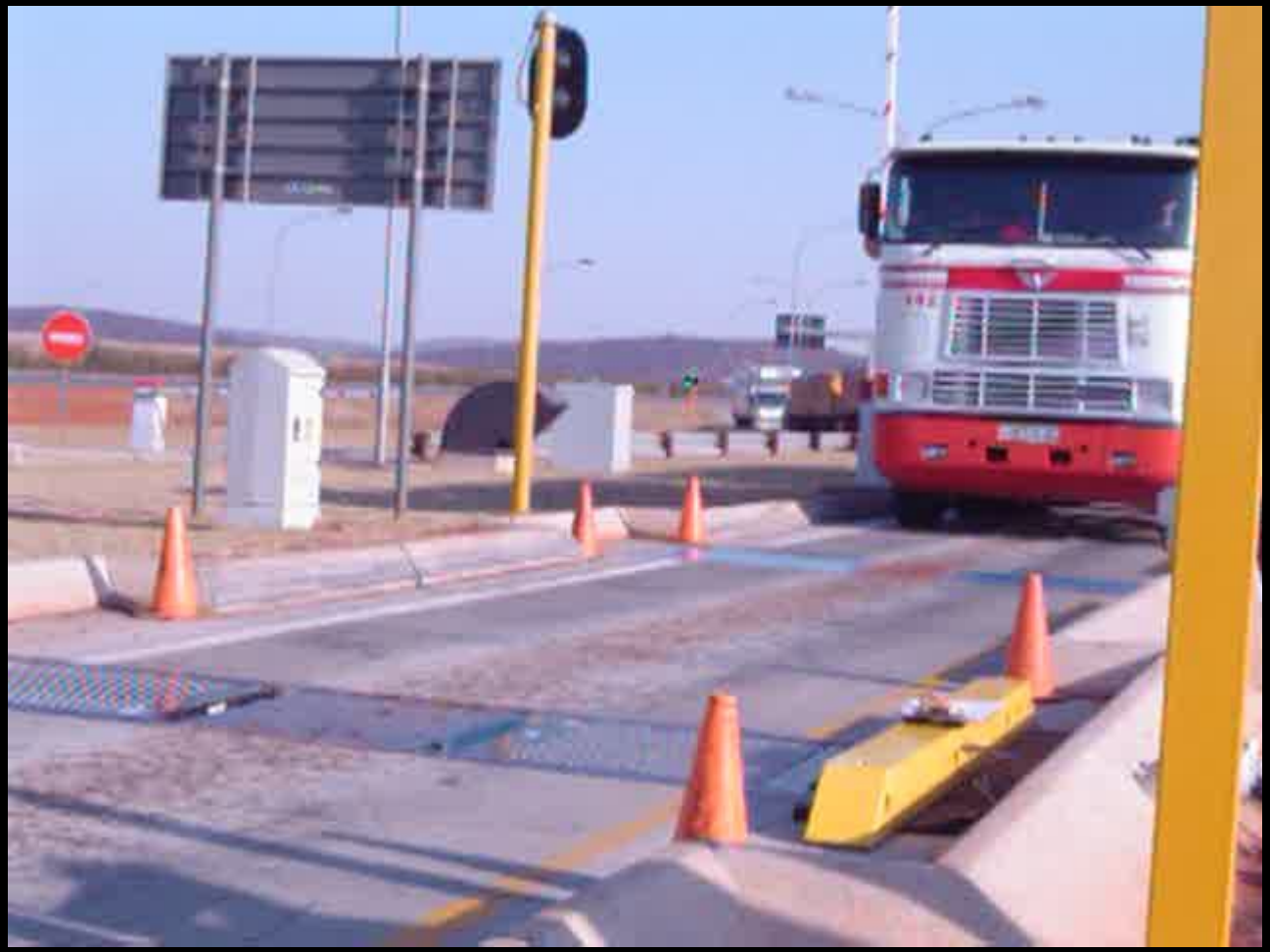
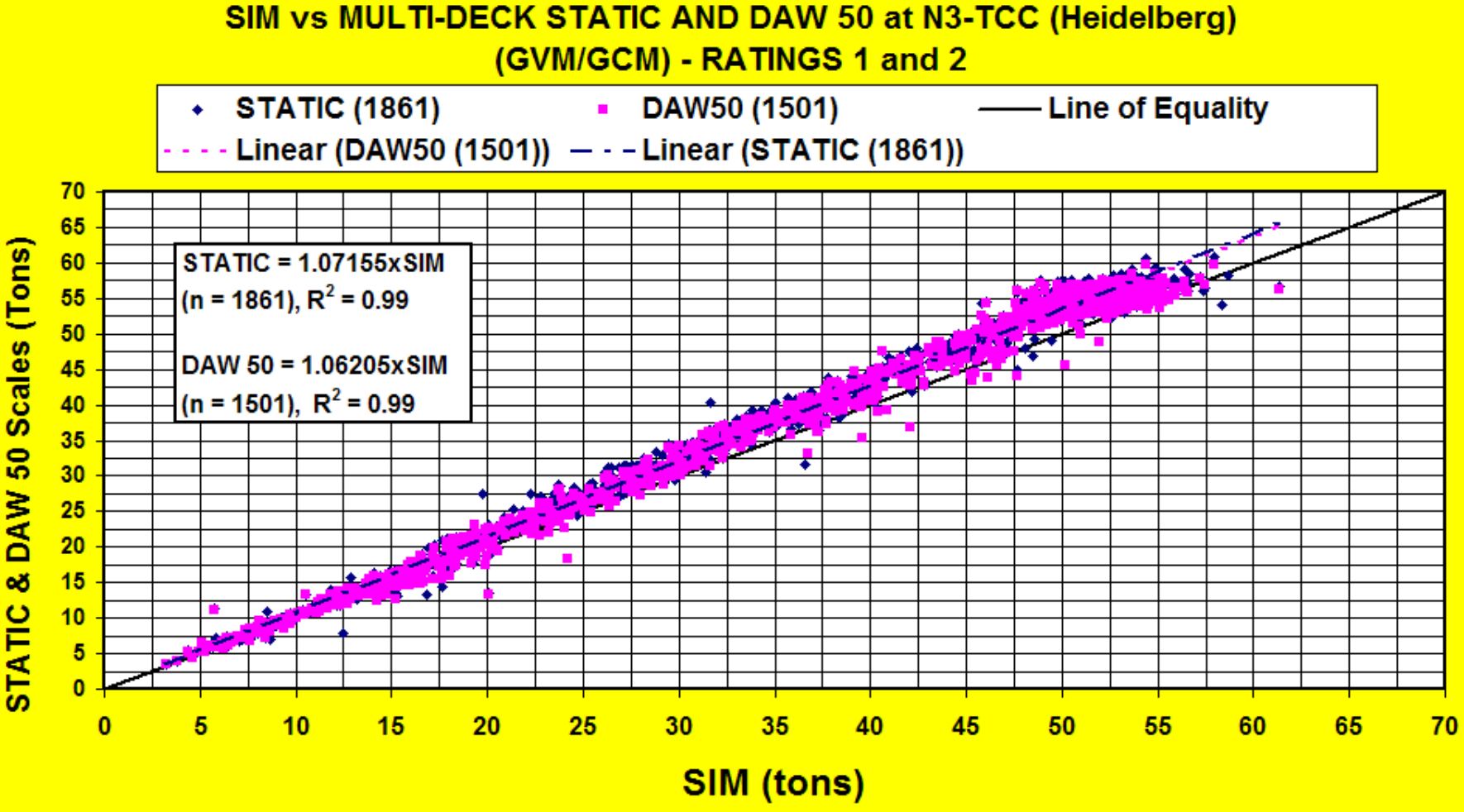
Example SIM testing during 2003



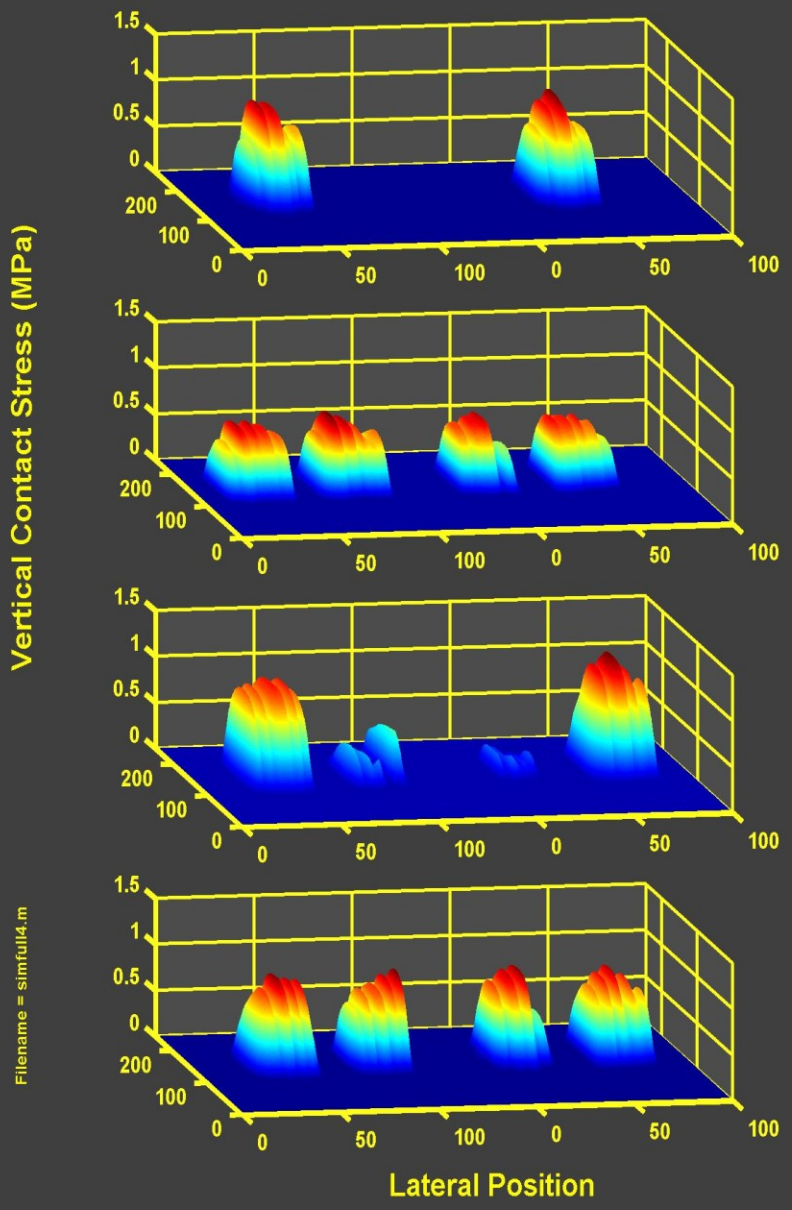
Example SIM testing during 2003

Example SIM testing during 2003

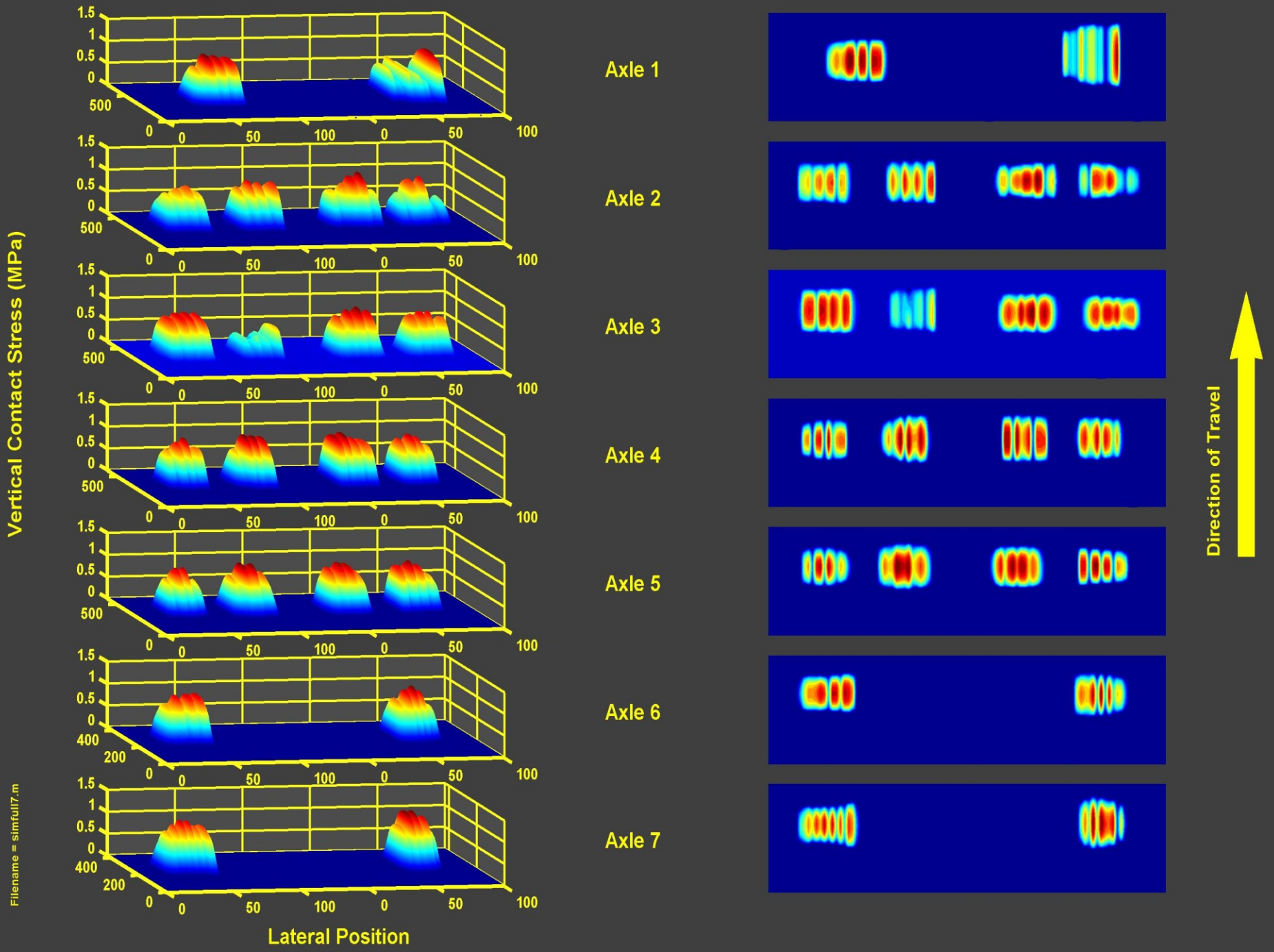
LOAD COMPARISON – FIELD WITH REAL TRUCKS
N3 TCC - HEIDELBERG



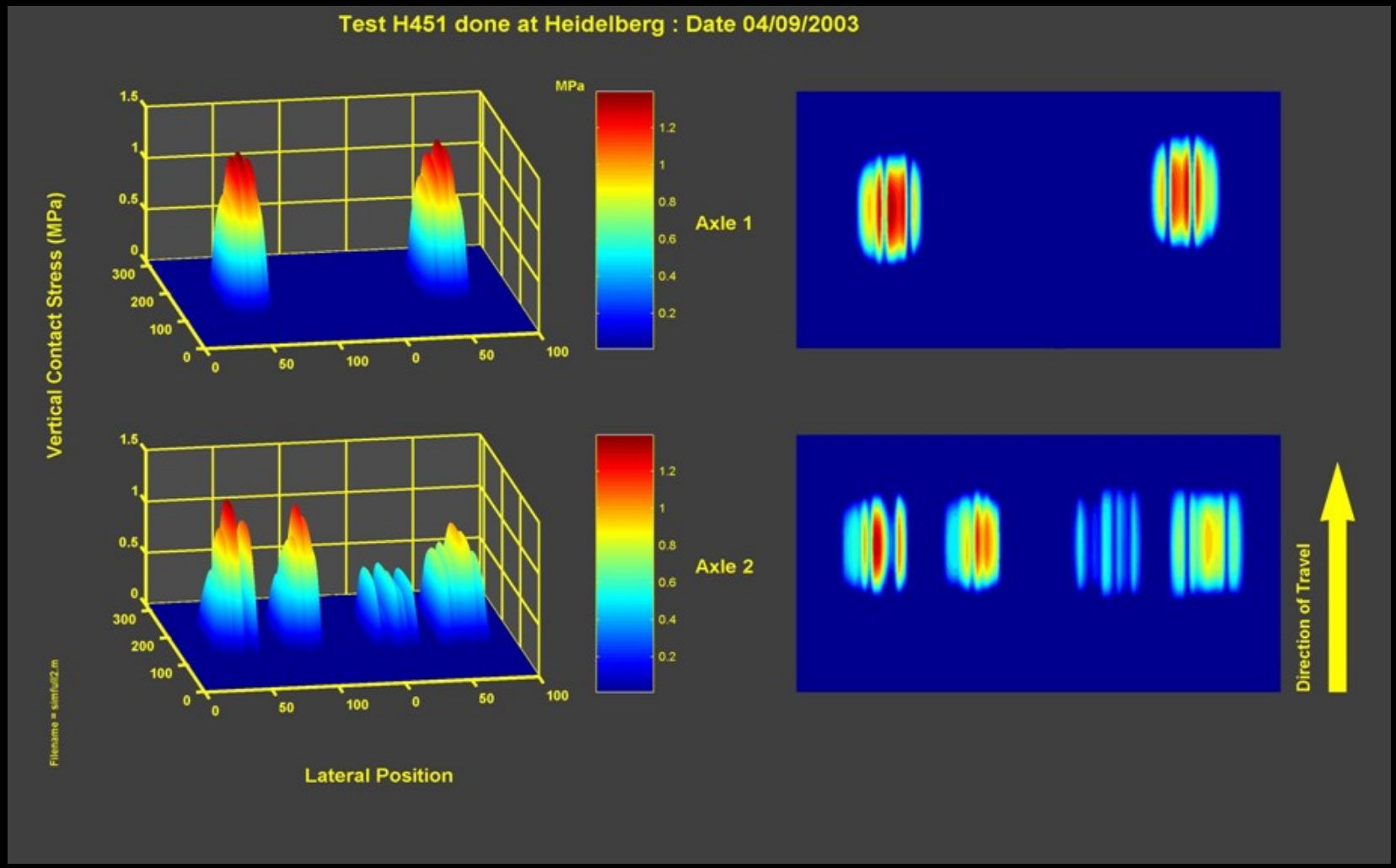
Test H833 done at Heidelberg : Date 09/09/2003



Test H595 done at Heidelberg : Date 15/09/2003

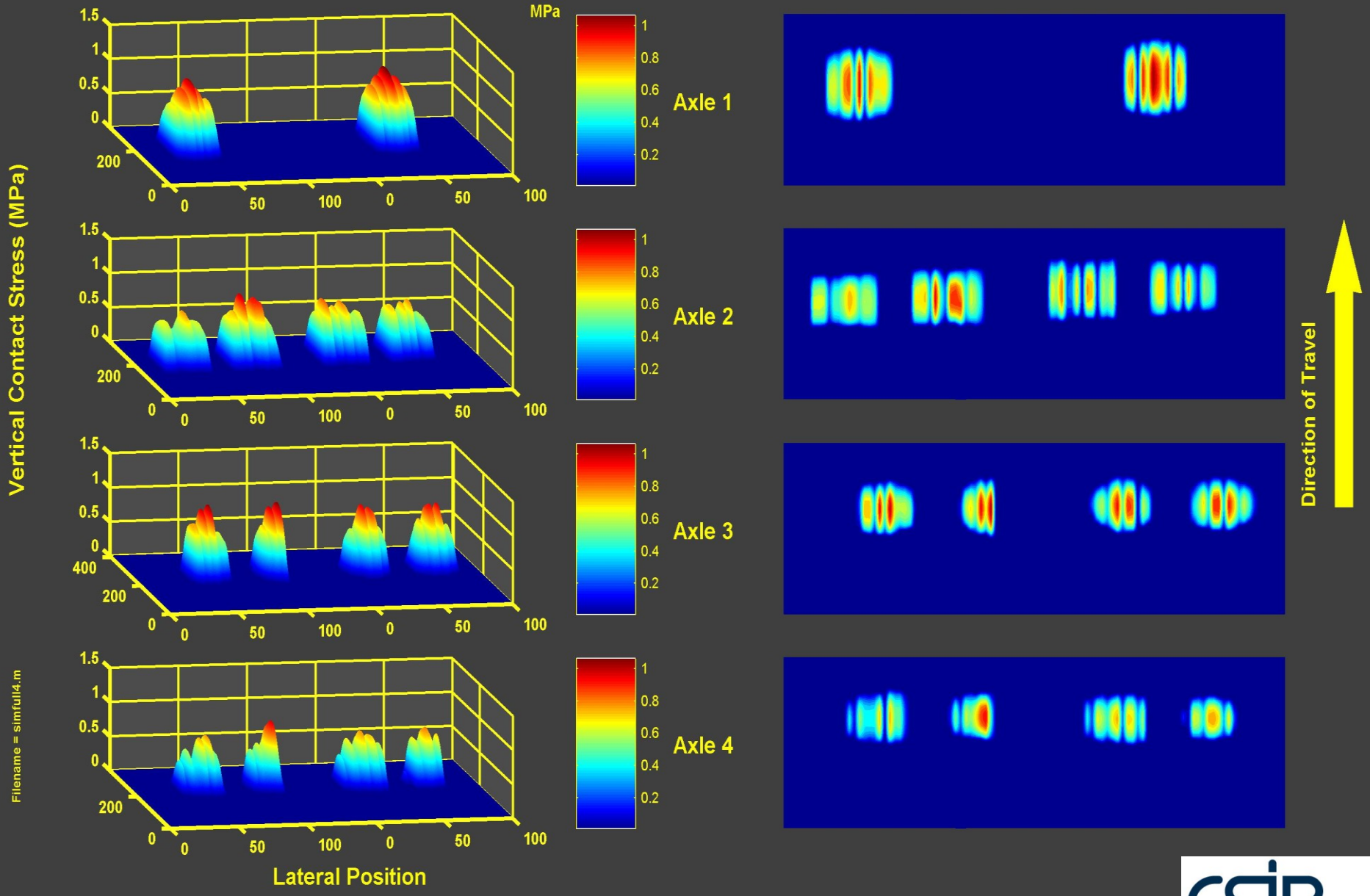


Measured Tyre Foot Prints :Two Axle Truck – Vertical Contact Stress –…..



Test H1070 done at Heidelberg : Date 10/09/2003

4 Axle Truck….



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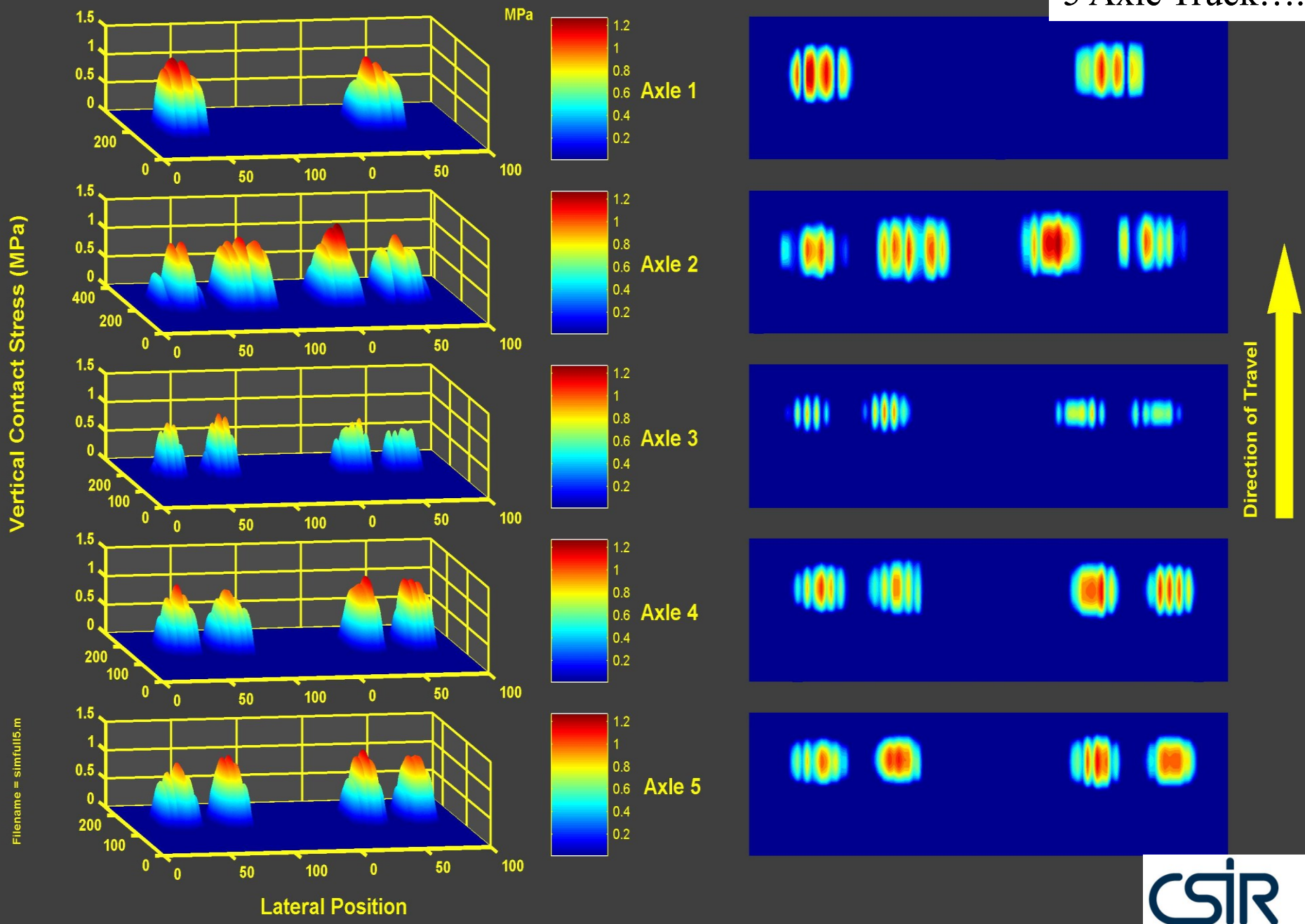
Test H1077 done at Heidelberg : Date 10/09/2003

5 Axle Truck….



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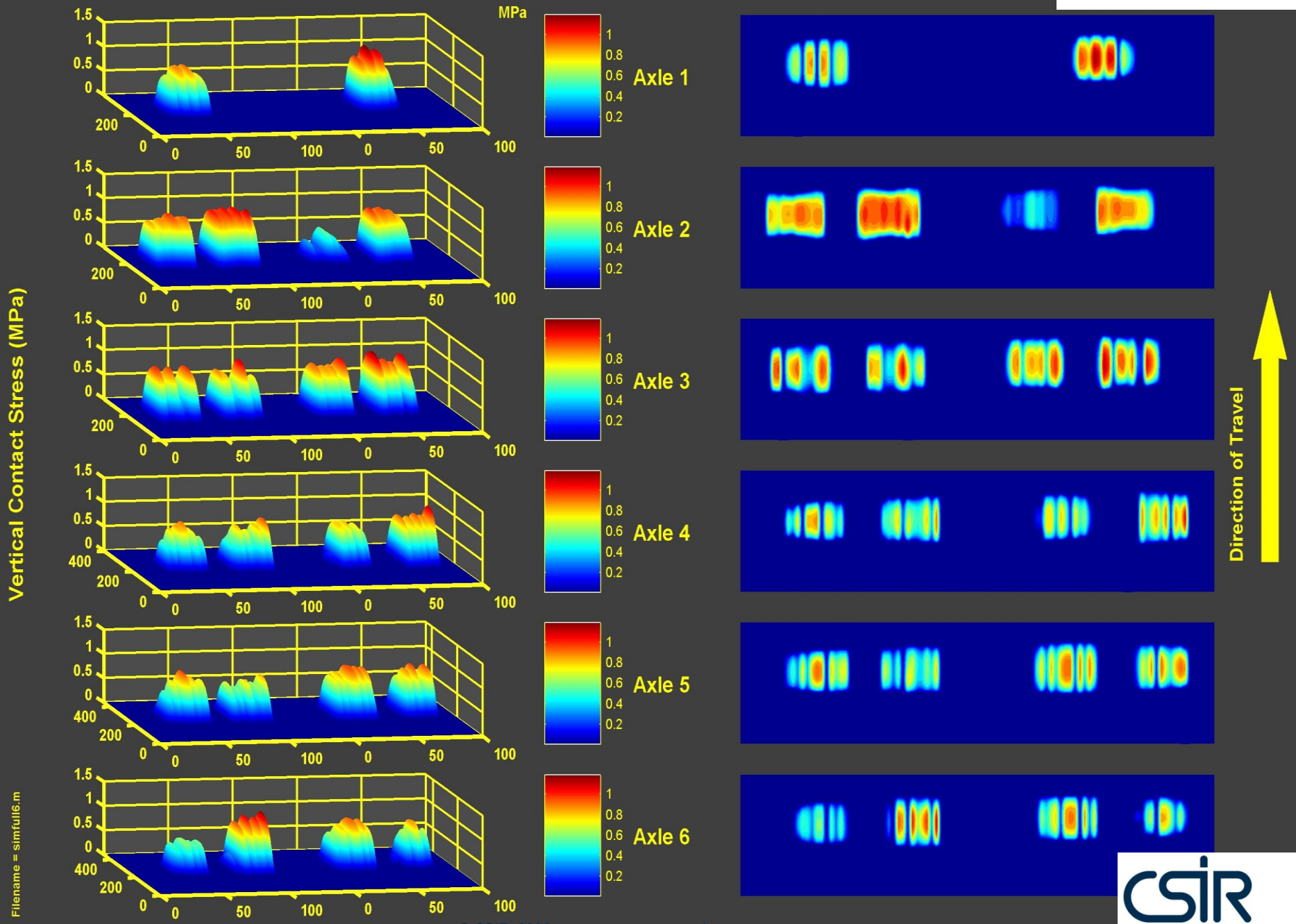
Test 174 done at Heidelberg : Date 10/09/2003 (overload)

6 Axle Truck….



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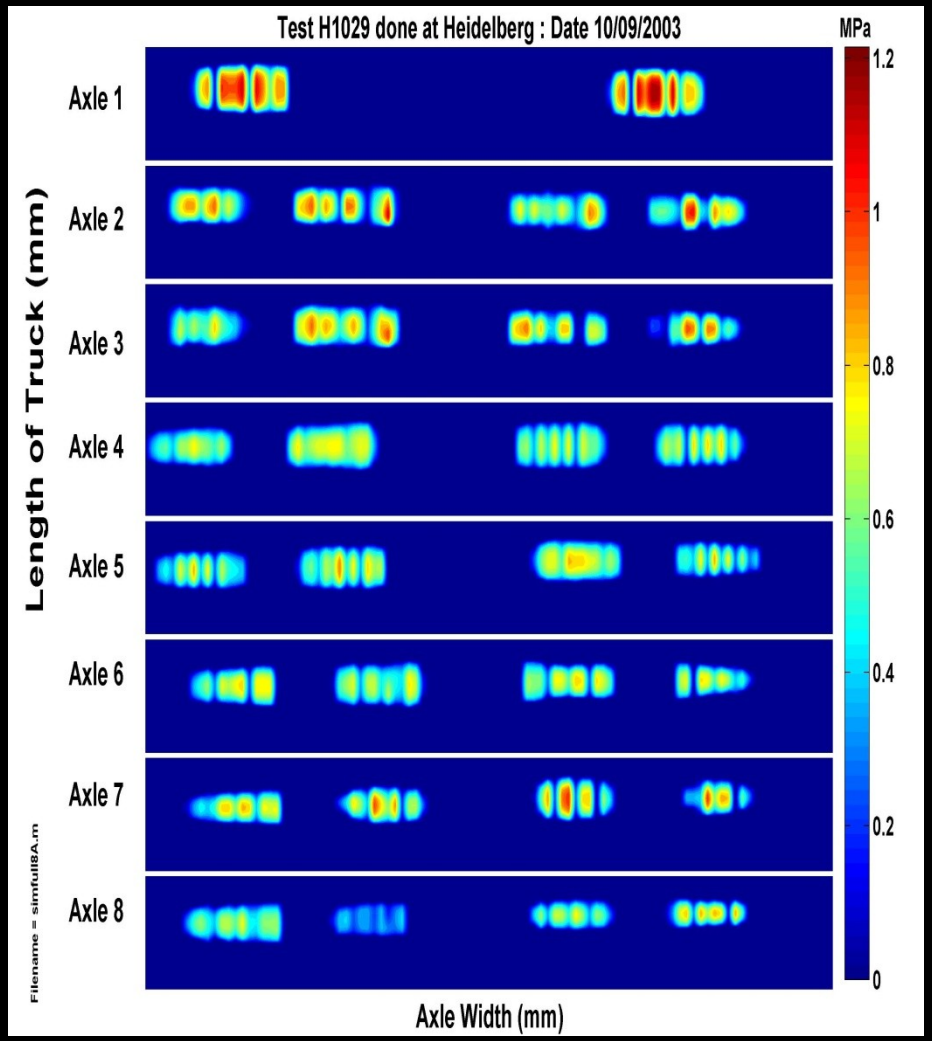
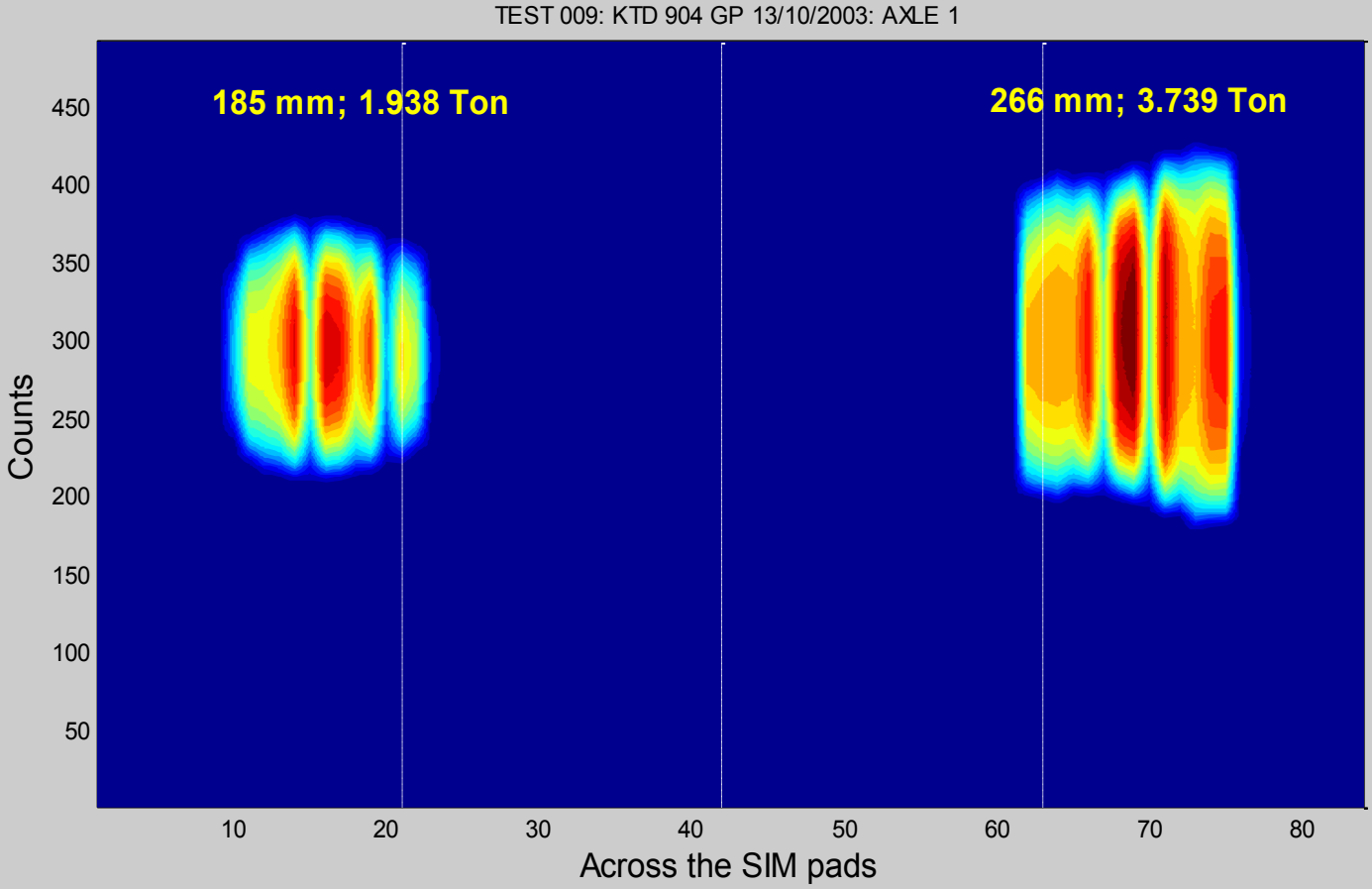
Eight (8) Axle Truck – Vertical Contact Stress - Foot Prints….

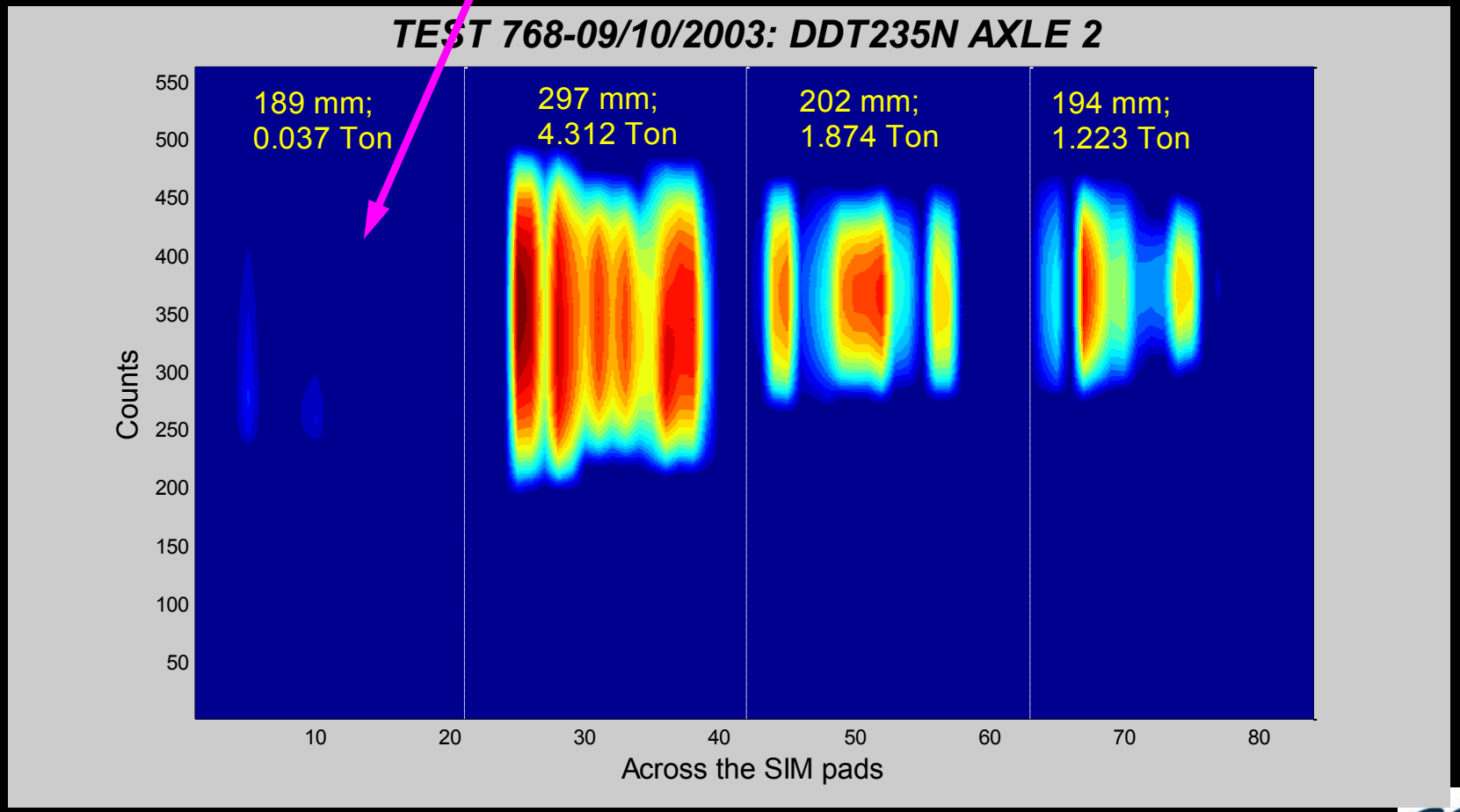


STEERING AXLE – UNEQUAL LOADING……

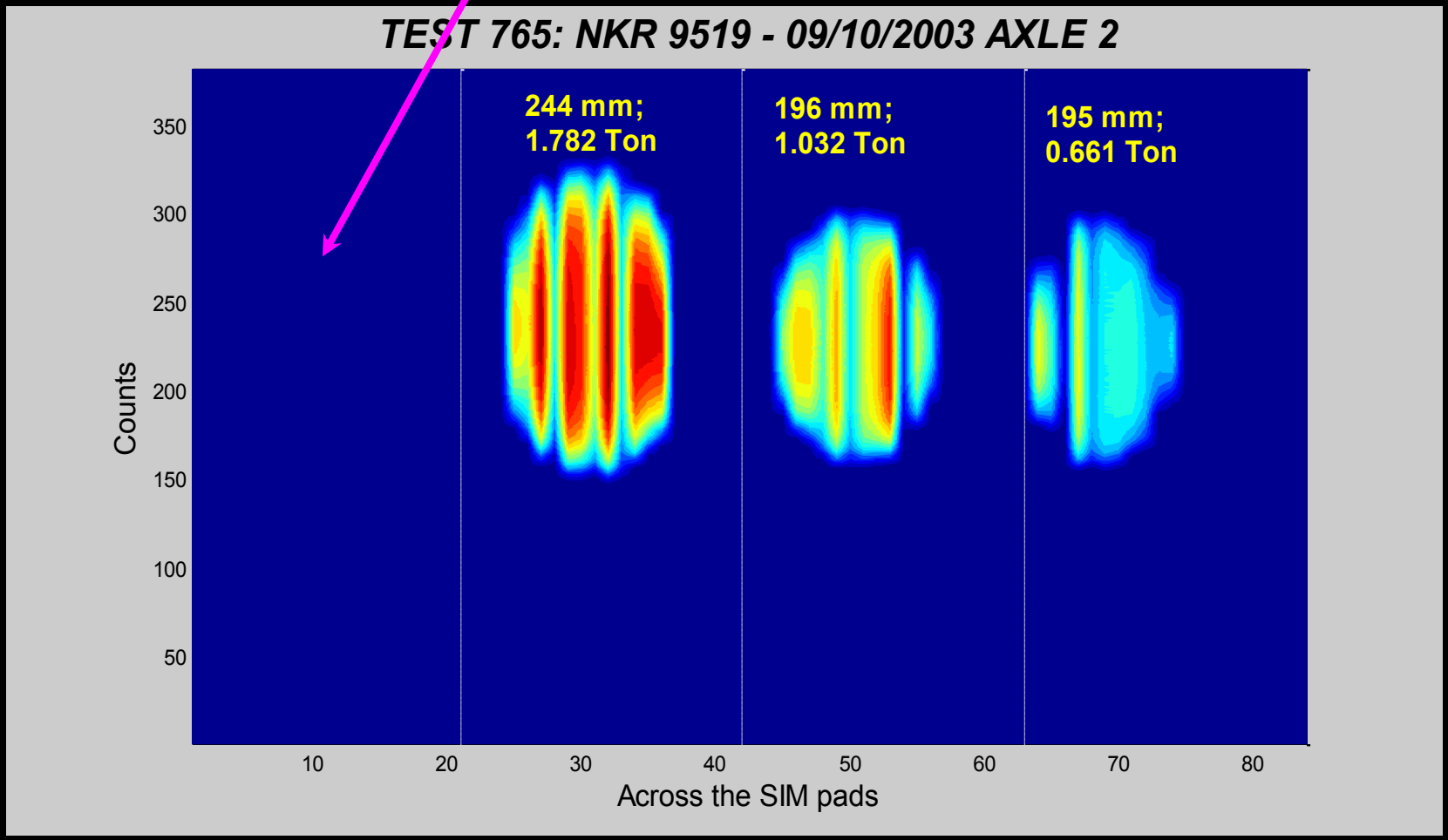


UNEQUAL LOADING ON TRUCK TYRES….

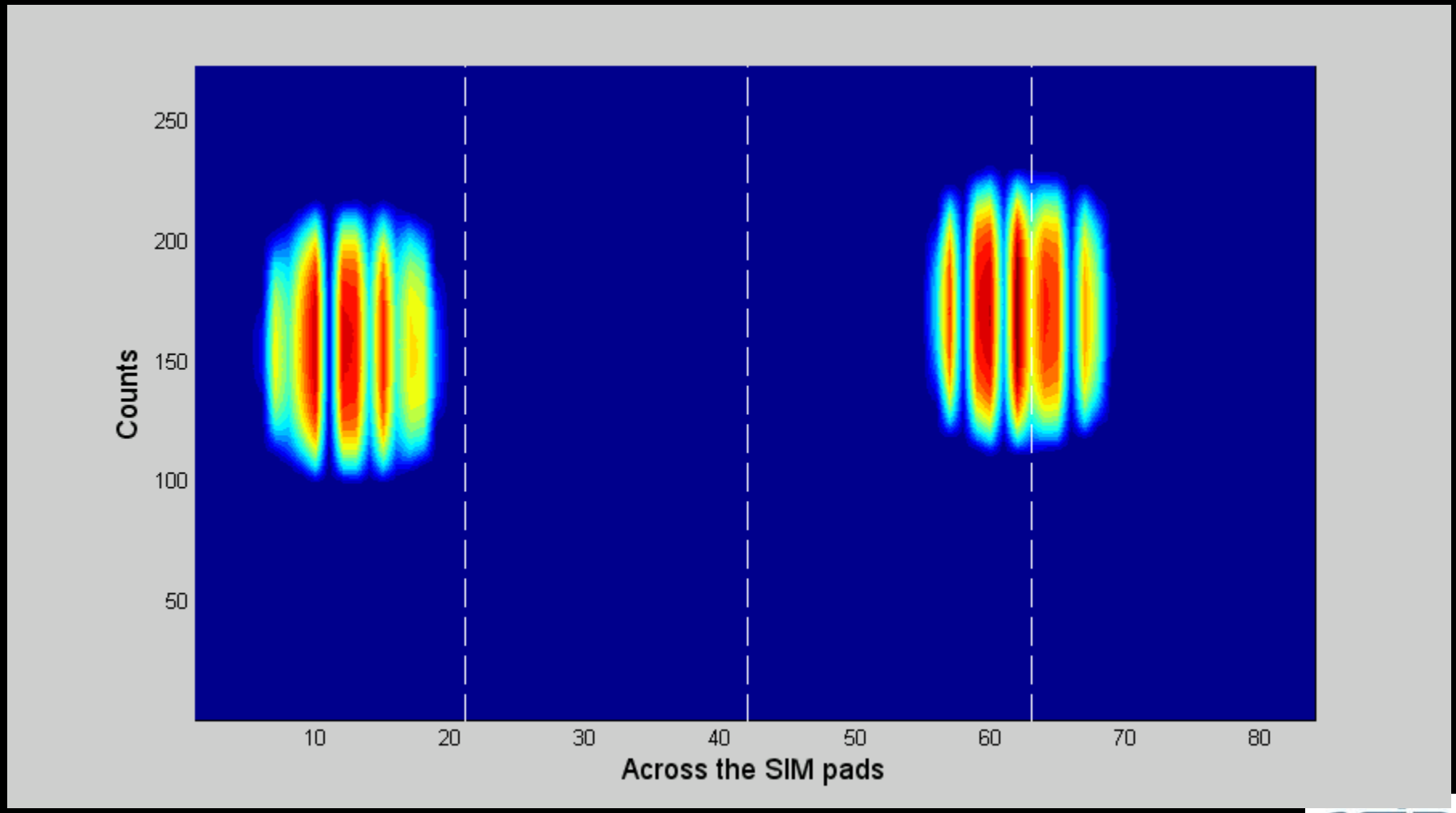
TYRE BARELY IN CONTACT WITH SURFACE



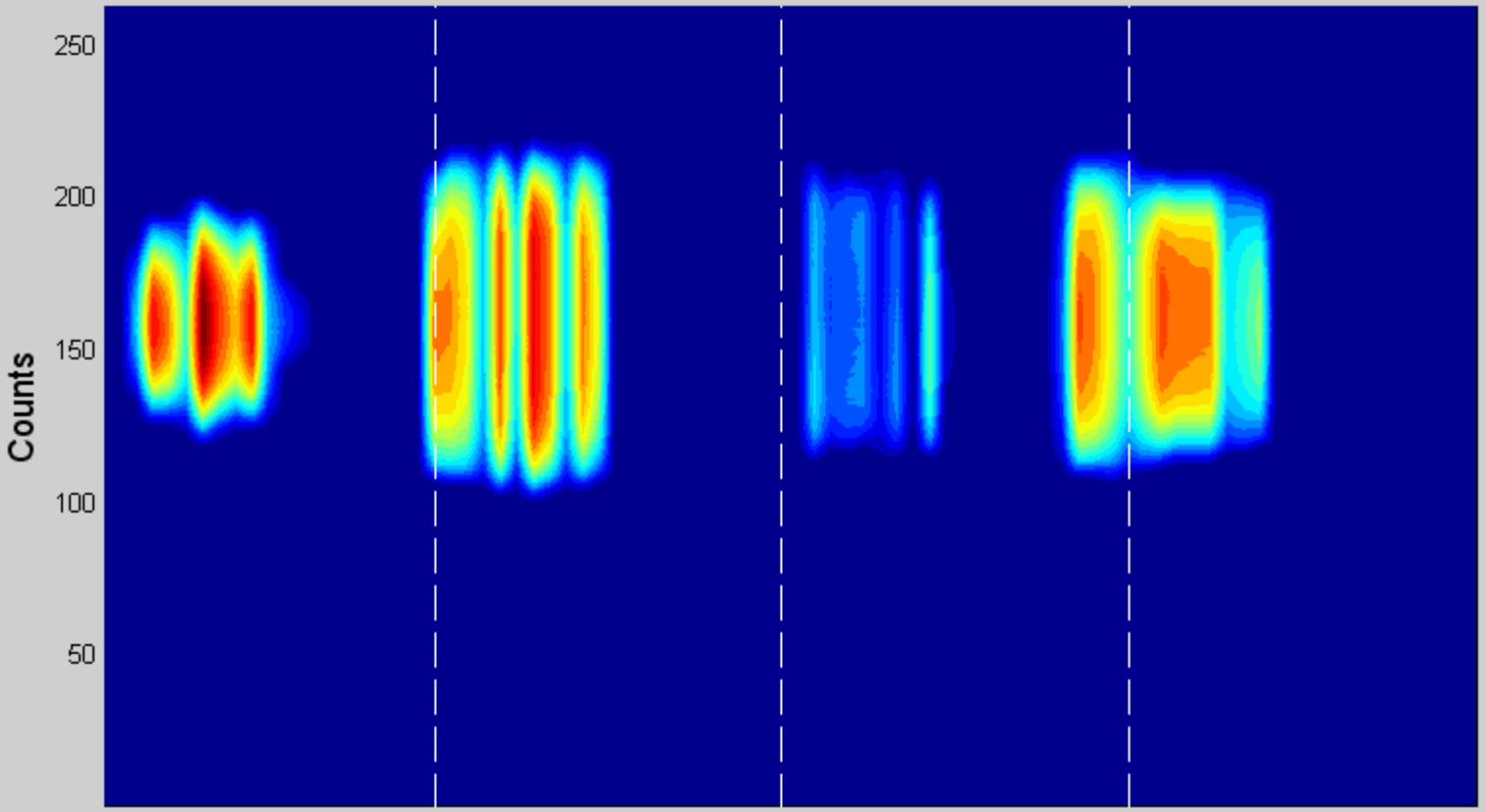
AXLE 2: MISSING TYRE……. !!



TYPICAL STEERING AXLE: VERTICAL STRESS

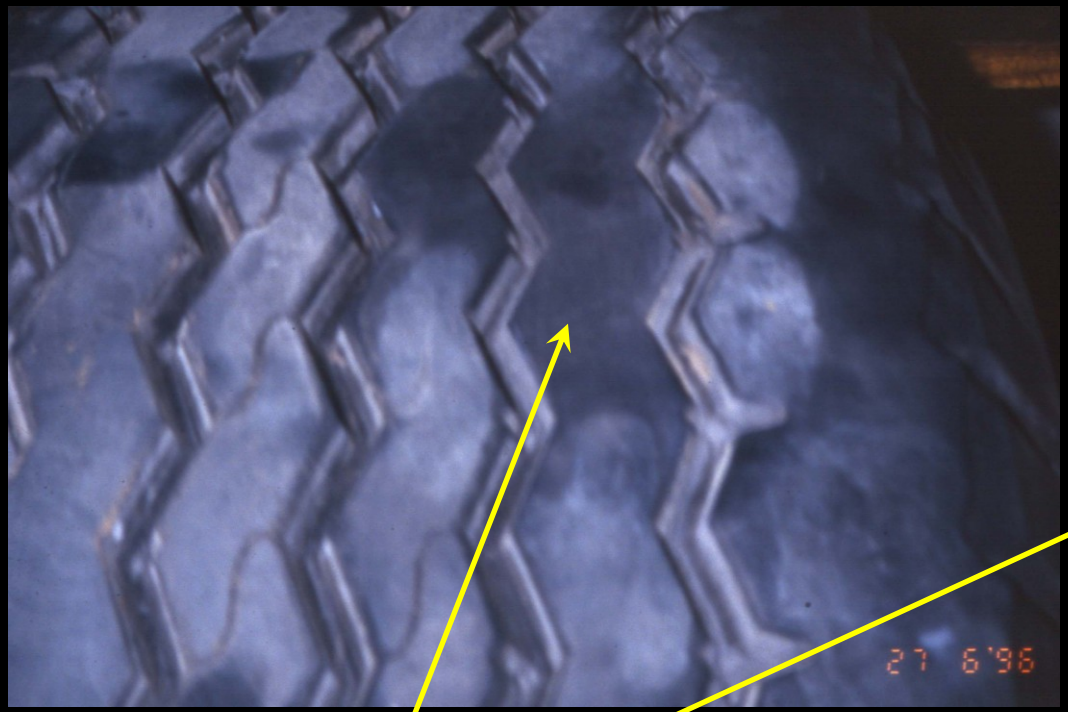


AXLE 2- DRIVING AXLE

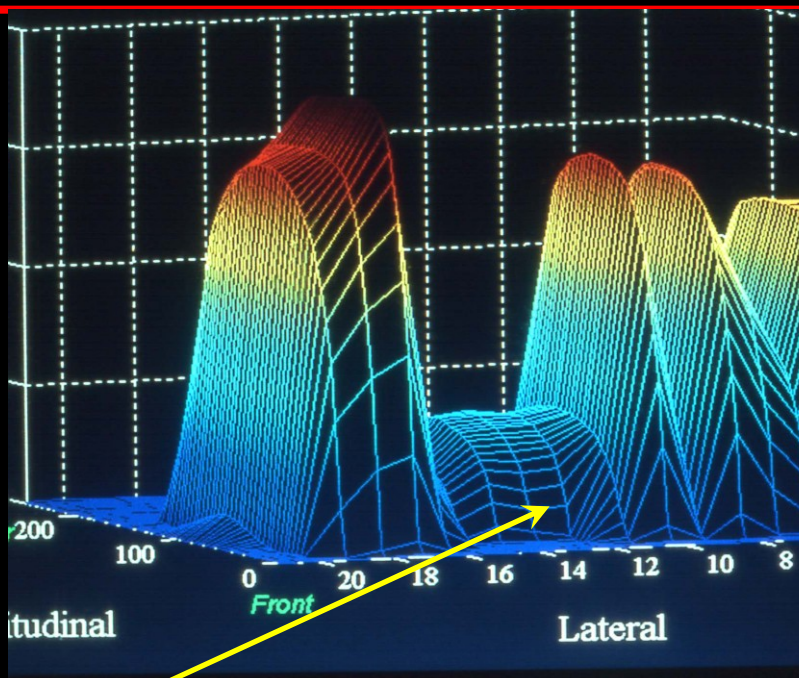


..damaged tyres…

Damaged Tyre Surfaces: Effect on Contact Stresses

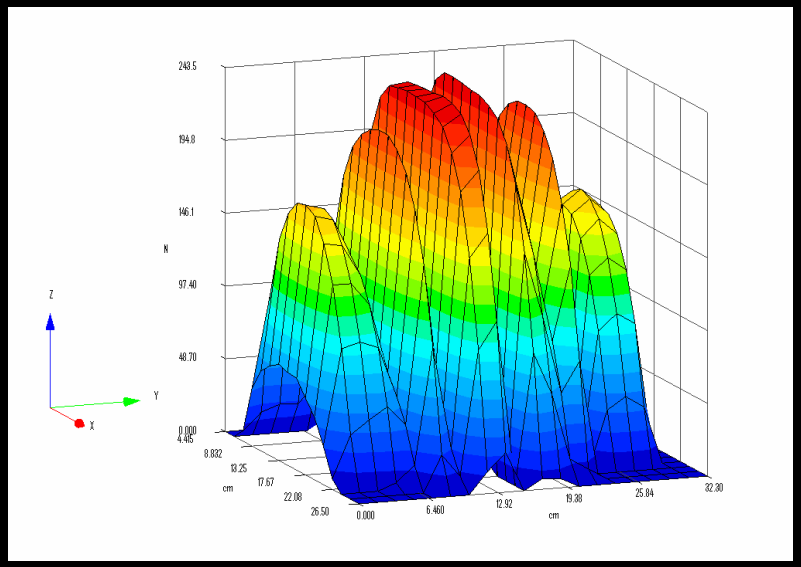


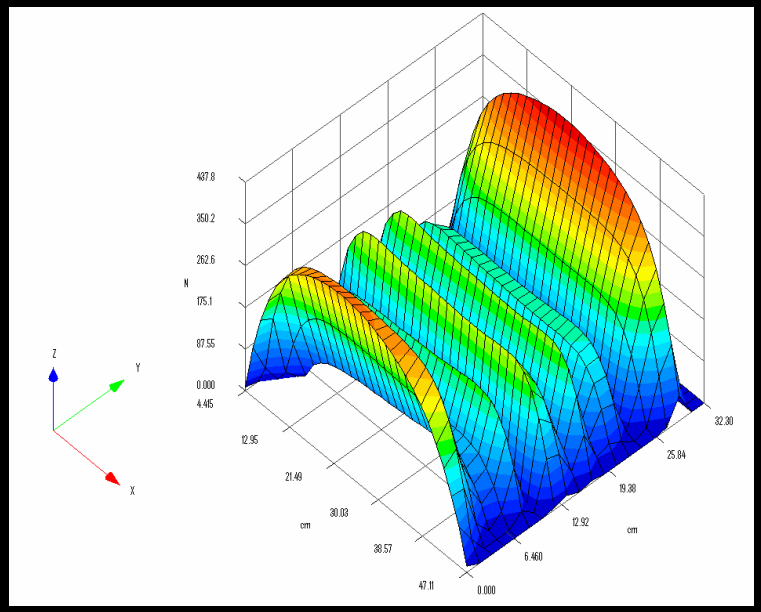
Flat Spot



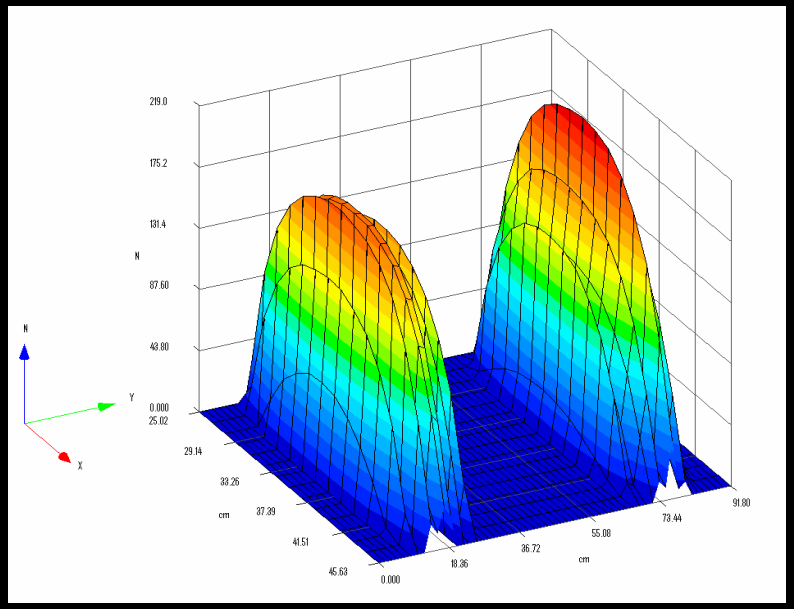
Vertical Stresses

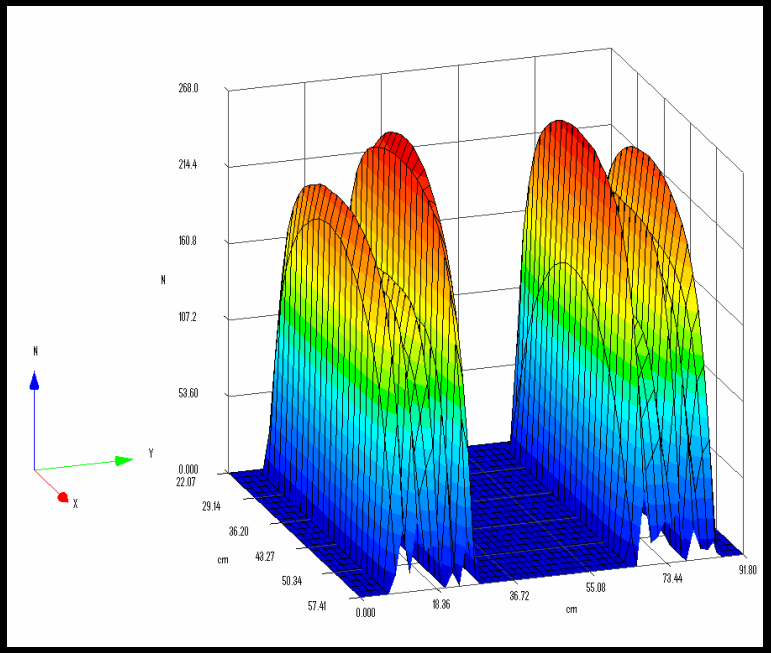
Wide Base Single Tyre- Input Data: Vertical Stress Patterns: “n” and “m” – Shapes…





Wide Base Single Tyre- Input Data: Vertical Stress Patterns: “n” and “m” – Shapes…





Rutting- Controlled testing with Heavy Vehicle Simulator (HVS)…

Vertical Tyre Stress: “n-Shape” tyre stress results in “n-Shape” rutting in asphalt overlay..

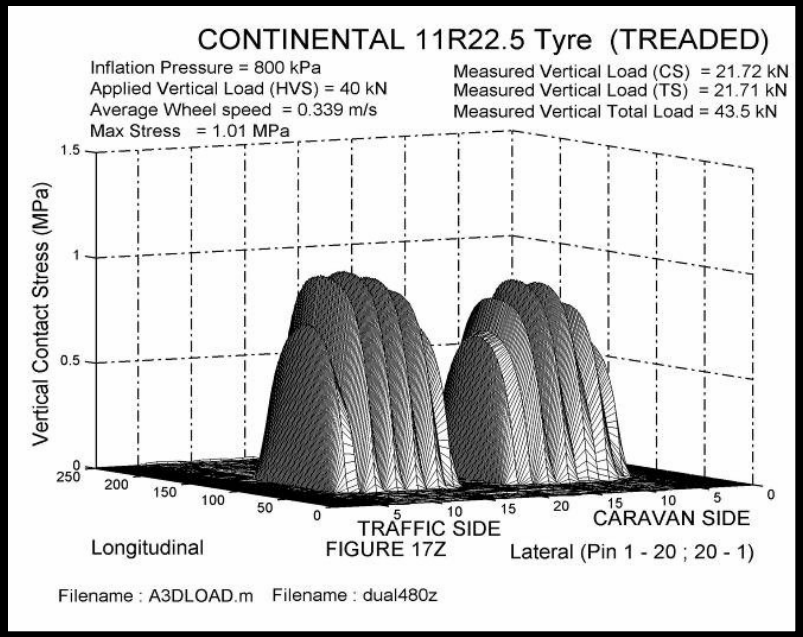
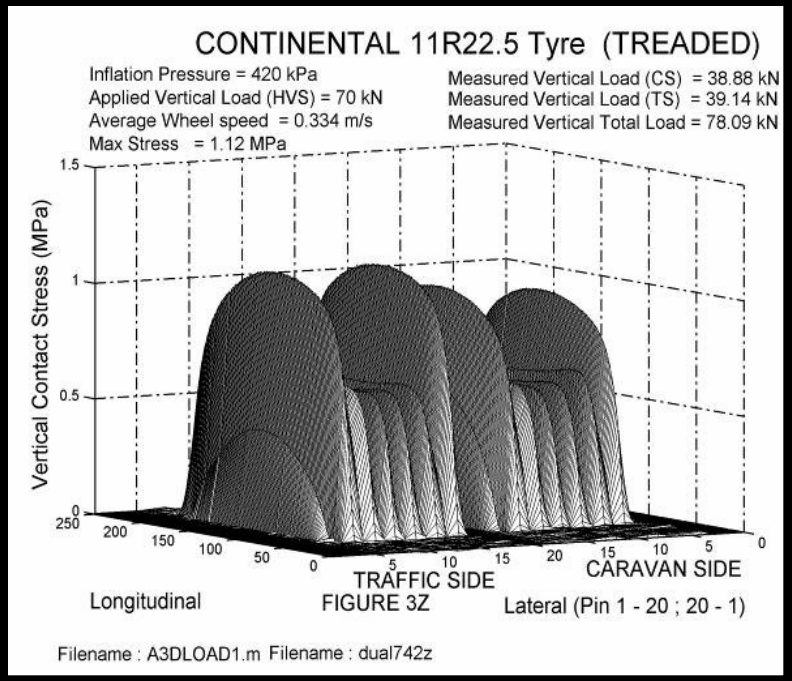


FIGURE 17Z

Vertical Tyre Stress: “m-Shape” stress result in “m-Shape” rutting in asphalt overlay..



TyreStress Software for Tyre Data Handling and Pavement Design

TyreStress Software:

C:\Program Files\TyreStress Beta\TyreStress Combined MultipleEqRadii.exe

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TyreStress

File Options Screen capture Circular Loads Help Exit Calc Loads and press

Tyre type

Goodyear 10 x 20 Cross-Bias 14-ply (Smooth) (S
Goodyear 11 x 20 Cross-Bias 14-ply (SA - HVS)
Goodyear 425-65 R22.5 (SA)
Michelin E-22.5 315-80 R22.5 (SA)
Continental 11 x R22.5 (SA - HVS)
Firestone 12 x R22.5 G391 (SA - HVS)-2004
Goodyear 315-80 R22.5 G391 (Steering - SA)-20(
Firestone 12 x R22.5 G391 (SA - HVS)-2006
Goodrich Aircraft BF tyre (SA)
Goodyear 315-80 R22.5 G391 (Steering - SA)-20(

Load pressure values

Load per tyre (kN) Parameter range

20

20 - 50

Pressure (kPa)

420

420 - 720

Direction for interpolation

X Y Z

Submit values

Next test

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TiP = Tyre inflation Pressure (kPa), L = Load (kN)

TiP = 420 L = 20	TiP = 520 L = 20	TiP = 620 L = 20	TiP = 720 L = 20
TiP = 420 L = 30	TiP = 520 L = 30	TiP = 620 L = 30	TiP = 720 L = 30
TiP = 420 L = 40	TiP = 520 L = 40	TiP = 620 L = 40	TiP = 720 L = 40
TiP = 420 L = 50	TiP = 520 L = 50	TiP = 620 L = 50	TiP = 720 L = 50

Ready X = 0 Y = 0.000 0 0 0 NUM

start 2 Windows ... Microsoft Pow... TyreStress EN Desktop 01:56 PM

Goodyear 315-80 R22.5 G391 (Steering - SA)-2006

File Options Screen capture Circular Loads Help Exit Calc Loads and press

Tyre type

- Goodyear 10 x 20 Cross-Bias 14-ply (Smooth) (S
- Goodyear 11 x 20 Cross-Bias 14-ply (SA - HVS)
- Goodyear 425-65 R22.5 (SA)
- Michelin E-22.5 315-80 R22.5 (SA)
- Continental 11 x R22.5 (SA - HVS)
- Firestone 12 x R22.5 G391 (SA - HVS)-2004
- Goodyear 315-80 R22.5 G391 (Steering - SA)-20(
- Firestone 12 x R22.5 G391 (SA - HVS)-2006
- Goodrich Aircraft BF tyre (SA)
- Goodyear 315-80 R22.5 G391 (Steering - SA)-20(

Load pressure values

Load per tyre (kN) Parameter range

20 20 - 100

Pressure (kPa)

520 520 - 1000

Direction for interpolation

X Y Z

Submit values

Next test

Goodyear 315-80 R22.5 G391
(Steering - SA)-2006

Direction: (Z)

Inflation pressure: 520 (kPa)

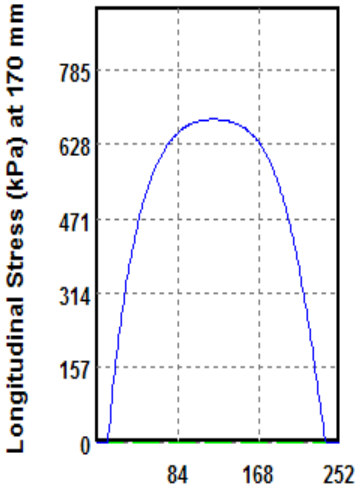
Applied Vertical Tyre Load: 20 (kN)

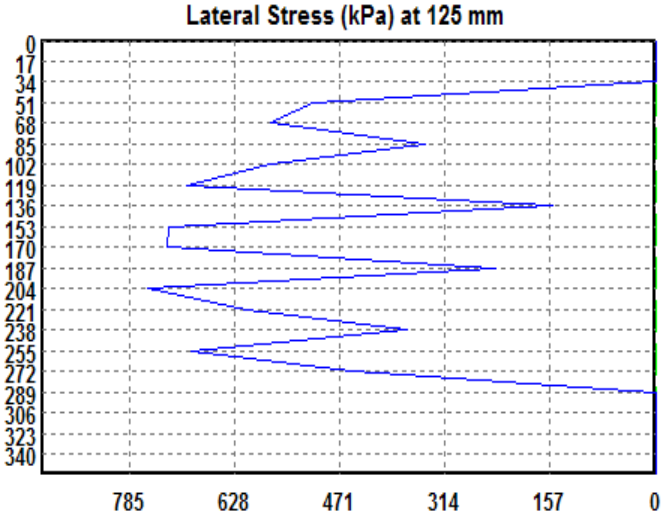
SIM Measured Tyre Load (Z): 20.4 (kN)

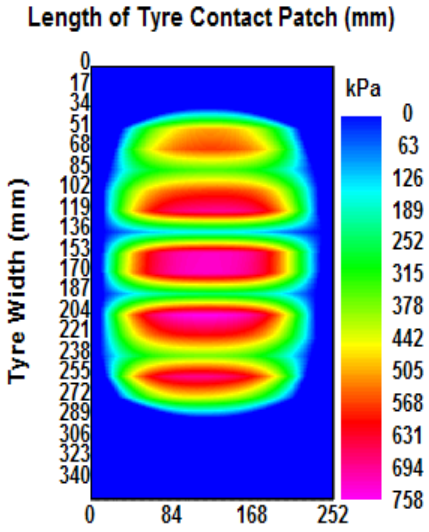
Estimated contact area: 510.5 (cm²)

Equivalent uniform contact stress: 399.8 (kPa)

Radius of equivalent circular area: 127.5 (mm)







Ready

X = 125 Y = 170.000 680.815 Min:0 Max:758 NUM

start 2 Windows ... Microsoft Pow... Goodyear 315... EN Desktop 01:57 PM

Goodyear 315-80 R22.5 G391 (Steering - SA)-2006

File Options Screen capture Circular Loads Help Exit Calc Loads and press

Tyre type

- Goodyear 10 x 20 Cross-Bias 14-ply (Smooth) (S
- Goodyear 11 x 20 Cross-Bias 14-ply (SA - HVS)
- Goodyear 425-65 R22.5 (SA)
- Michelin E-22.5 315-80 R22.5 (SA)
- Continental 11 x R22.5 (SA - HVS)
- Firestone 12 x R22.5 G391 (SA - HVS)-2004
- Goodyear 315-80 R22.5 G391 (Steering - SA)-20(
- Firestone 12 x R22.5 G391 (SA - HVS)-2006
- Goodrich Aircraft BF tyre (SA)
- Goodyear 315-80 R22.5 G391 (Steering - SA)-20(

Load pressure values

Load per tyre (kN) Parameter range

21 20 - 100

Pressure (kPa)

520 520 - 1000

Direction for interpolation

X Y Z

Submit values

Next test

Goodyear 315-80 R22.5 G391
(Steering - SA)-2006

Direction: (Y)

Inflation pressure: 520 (kPa)

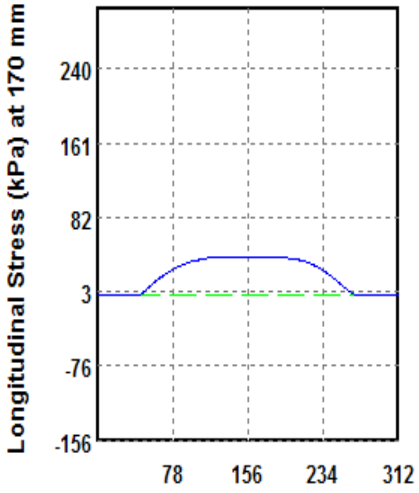
Applied Vertical Tyre Load: 21 (kN)

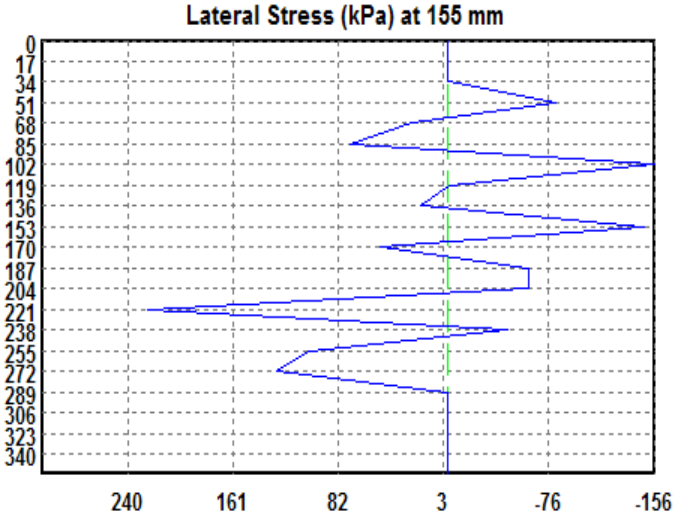
SIM Measured Tyre Load (Y): 0.2 (kN)

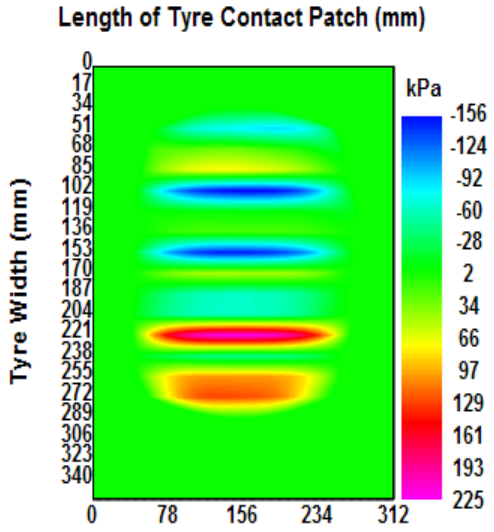
Estimated contact area: 651.0 (cm²)

Equivalent uniform contact stress: 2.6 (kPa)

Radius of equivalent circular area: 144.0 (mm)







Ready X = 155 Y = 170.000 39.638 Min:-156 Max:225 NUM

start 2 Windows ... Microsoft Pow... Goodyear 315... EN Desktop 01:58 PM

Goodyear 315-80 R22.5 G391 (Steering - SA)-2006

File Options Screen capture Circular Loads Help Exit Calc Loads and press

Tyre type

- Goodyear 10 x 20 Cross-Bias 14-ply (Smooth) (S
- Goodyear 11 x 20 Cross-Bias 14-ply (SA - HVS)
- Goodyear 425-65 R22.5 (SA)
- Michelin E-22.5 315-80 R22.5 (SA)
- Continental 11 x R22.5 (SA - HVS)
- Firestone 12 x R22.5 G391 (SA - HVS)-2004
- Goodyear 315-80 R22.5 G391 (Steering - SA)-20(
- Firestone 12 x R22.5 G391 (SA - HVS)-2006
- Goodrich Aircraft BF tyre (SA)
- Goodyear 315-80 R22.5 G391 (Steering - SA)-20(

Load pressure values

Load per tyre (kN) Parameter range

21 20 - 100

Pressure (kPa)

520 520 - 1000

Direction for interpolation

(•) X ( ) Y ( ) Z

Submit values

Next test

Goodyear 315-80 R22.5 G391
(Steering - SA)-2006

Direction: (X)

Inflation pressure: 520 (kPa)

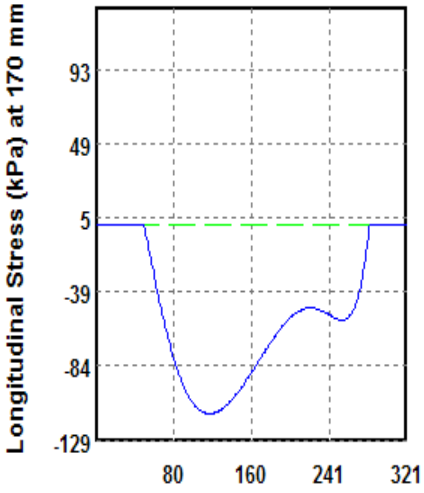
Applied Vertical Tyre Load: 21 (kN)

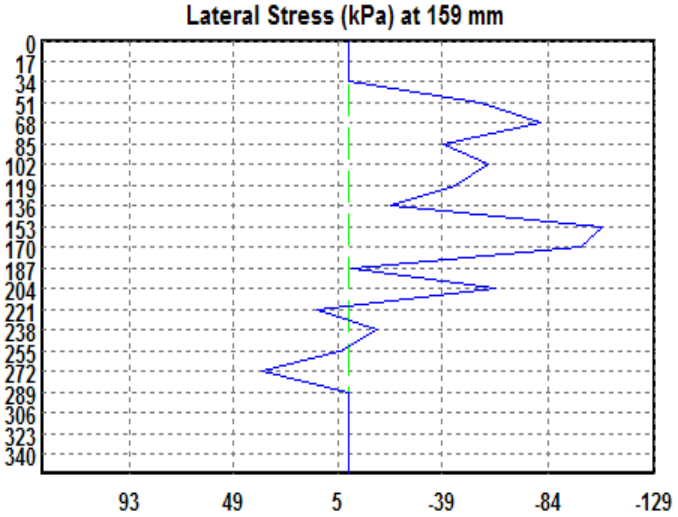
SIM Measured Tyre Load (X): -1.6 (kN)

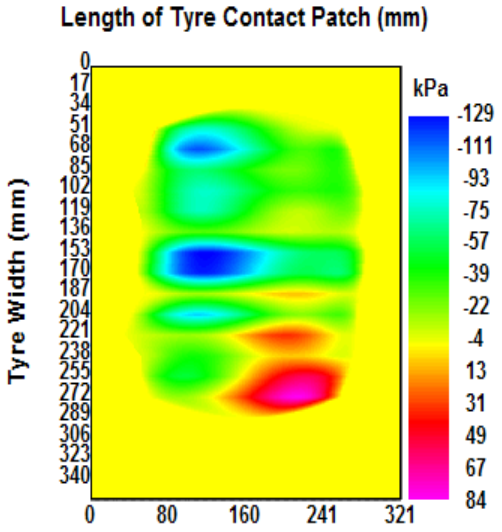
Estimated contact area: 668.5 (cm²)

Equivalent uniform contact stress: -24.3 (kPa)

Radius of equivalent circular area: 145.9 (mm)







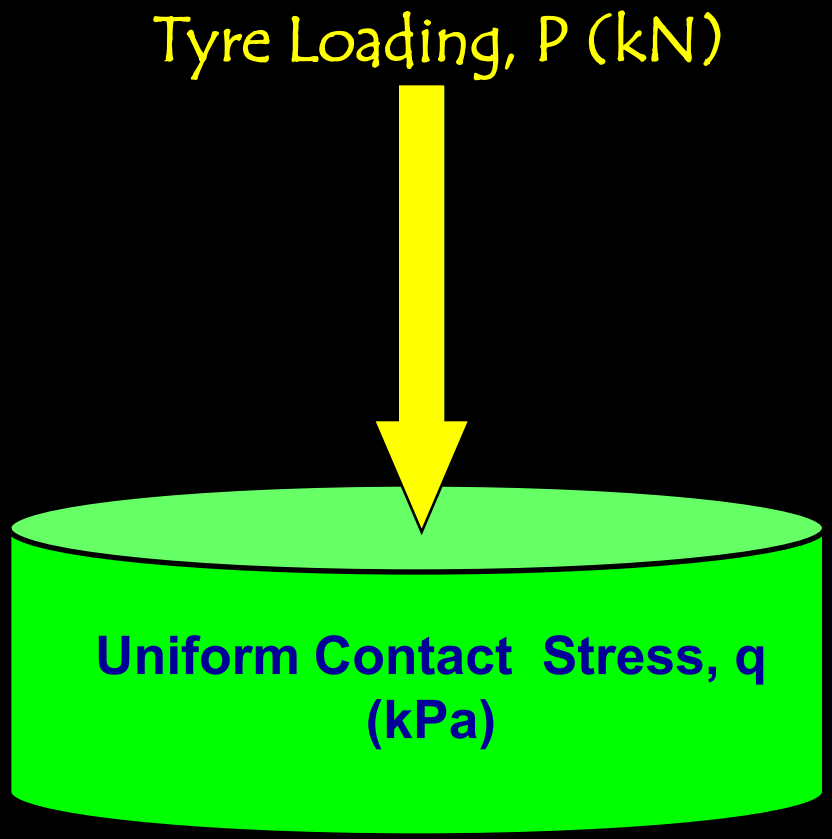
Ready X = 159 Y = 170.000 -88.2701 Min:-129 Max:85 NUM

start 2 Windows ... Microsoft Pow... Goodyear 315... EN Desktop 01:59 PM

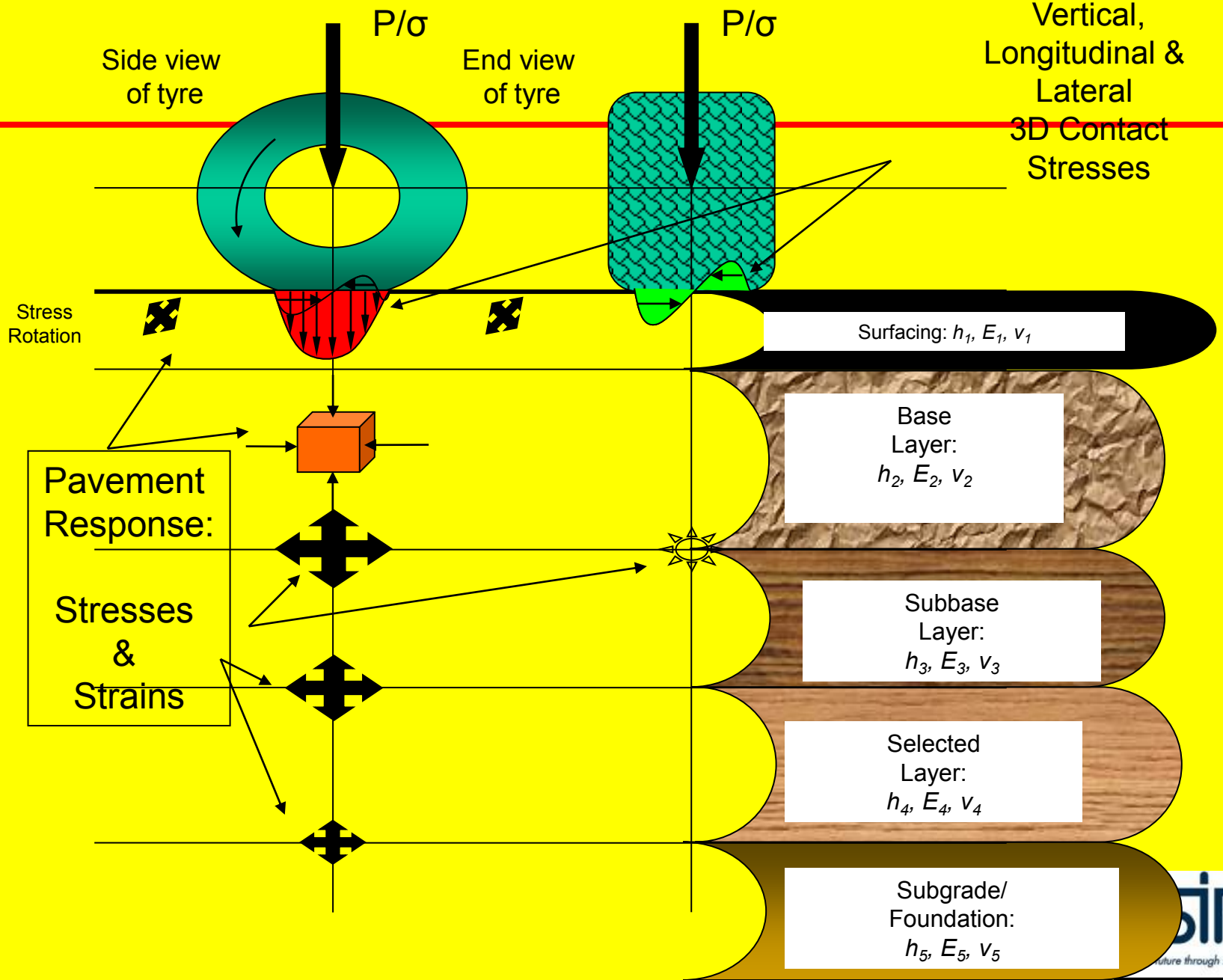
Assumption of Tyre Loading - Pavement Design Modeling:

- Circular;
- Variable load;
- Variable pressure,

but UNIFORM:



APPLIED LOAD/STRESSES



Lotus | SmartSuite | Internet | Calendar | Addresses | Reminders

South African Mechanistic Pavement Design

File Help

UNIFORM: VERTICAL (NORMAL) STRESS, zz

Calculate

Pavement Structure | Loads and Evaluation Points | Stresses and Strains | Design Pa... | Pavement Life | Contour Plot | Profile Plot | Diagnostics

Define plane for contour plot

Vertical plane parallel to X-Z

Y offset from origin: 10

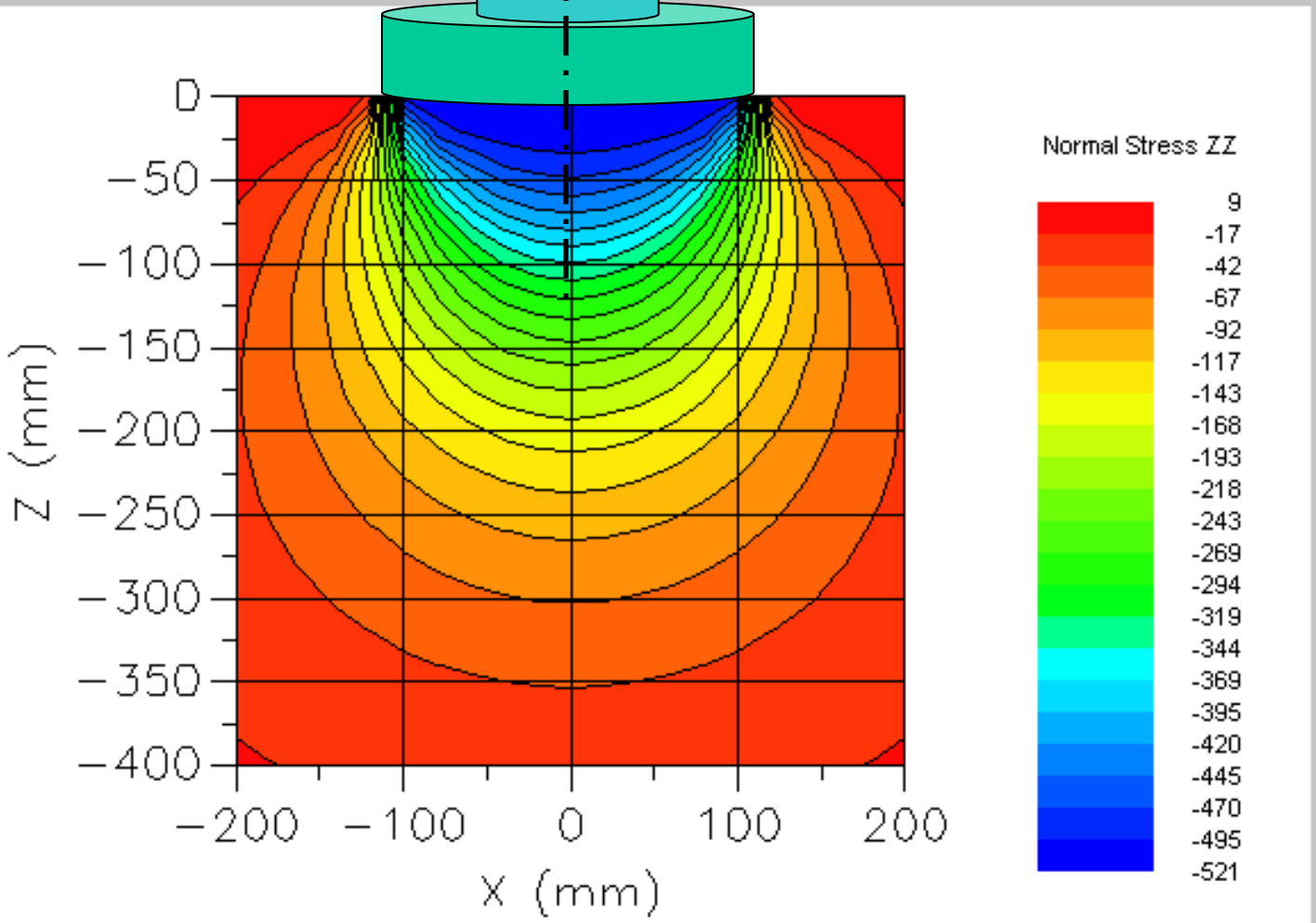
Contour region size (mm): 400

Contour region centred at (mm)

X: 0 Z: 0

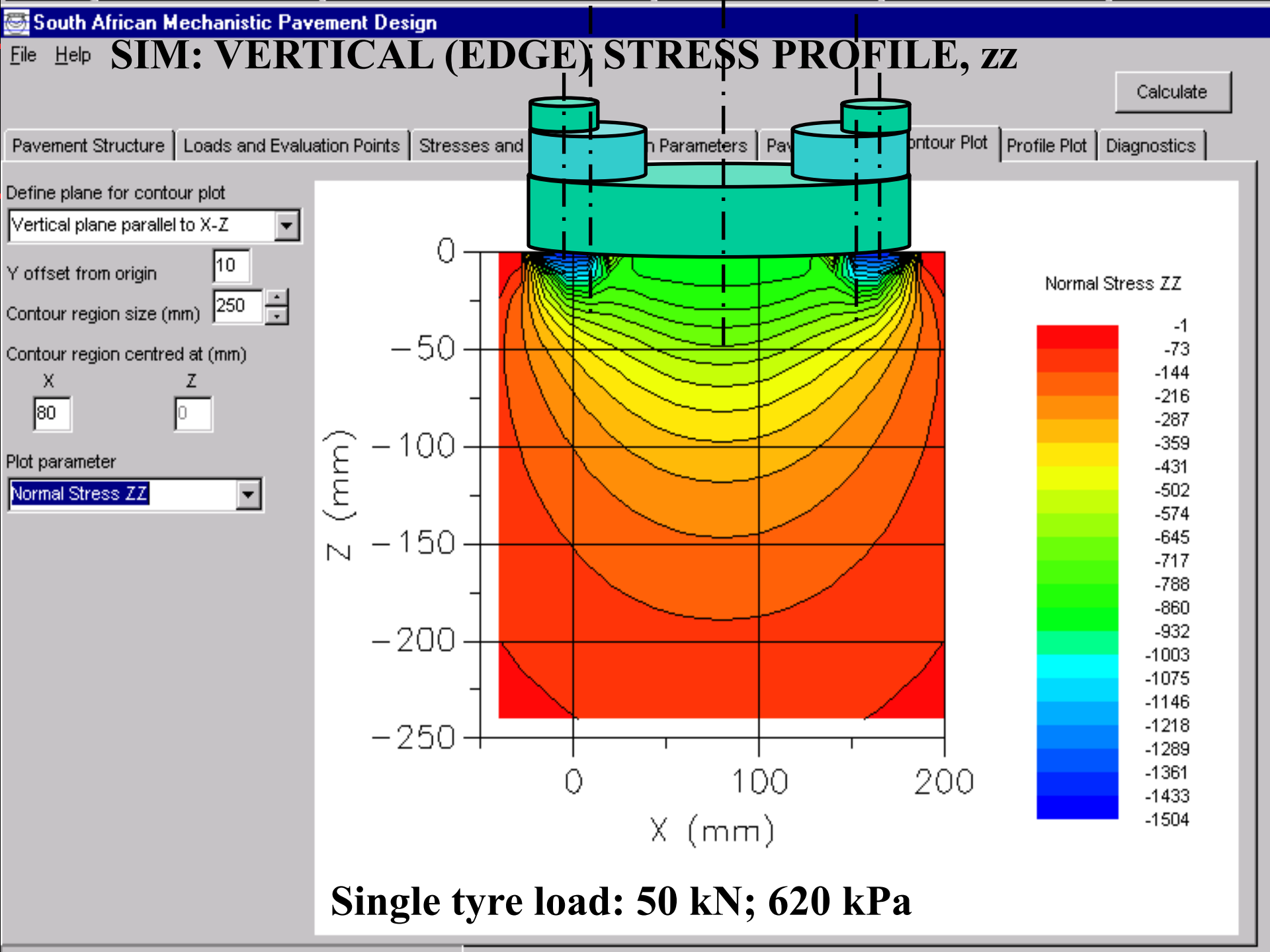
Plot parameter

Normal Stress ZZ



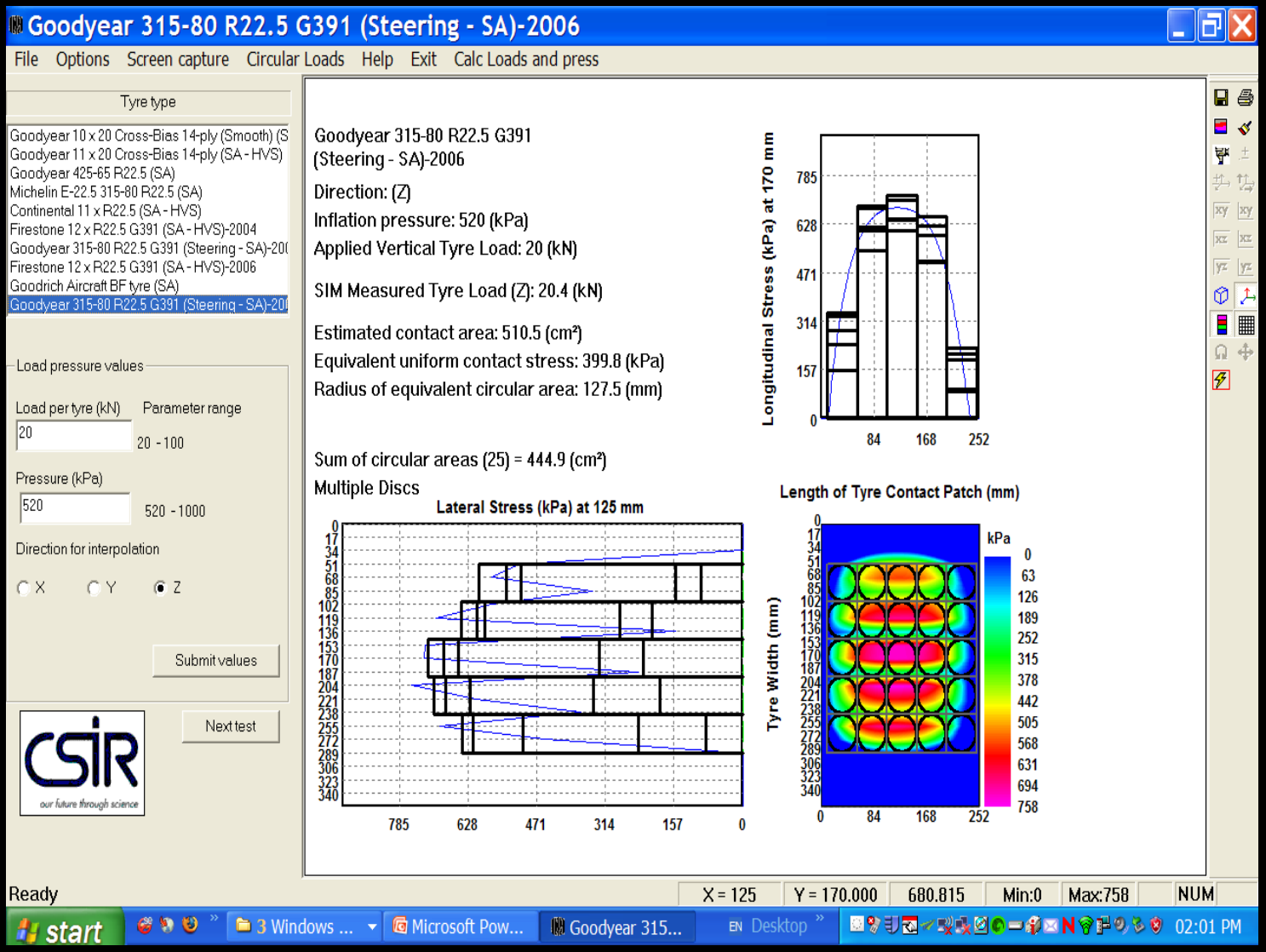
Single tyre load: 20 kN; 520 kPa

SIM: VERTICAL (EDGE) STRESS PROFILE, zz



Single tyre load: 50 kN; 620 kPa

From TyreStress to Pavement Design…..



Mechanistic - Road Pavement Analysis-Multi-Layer

TyreStress Software Result passed onto Pavement Design Software:

mePADS

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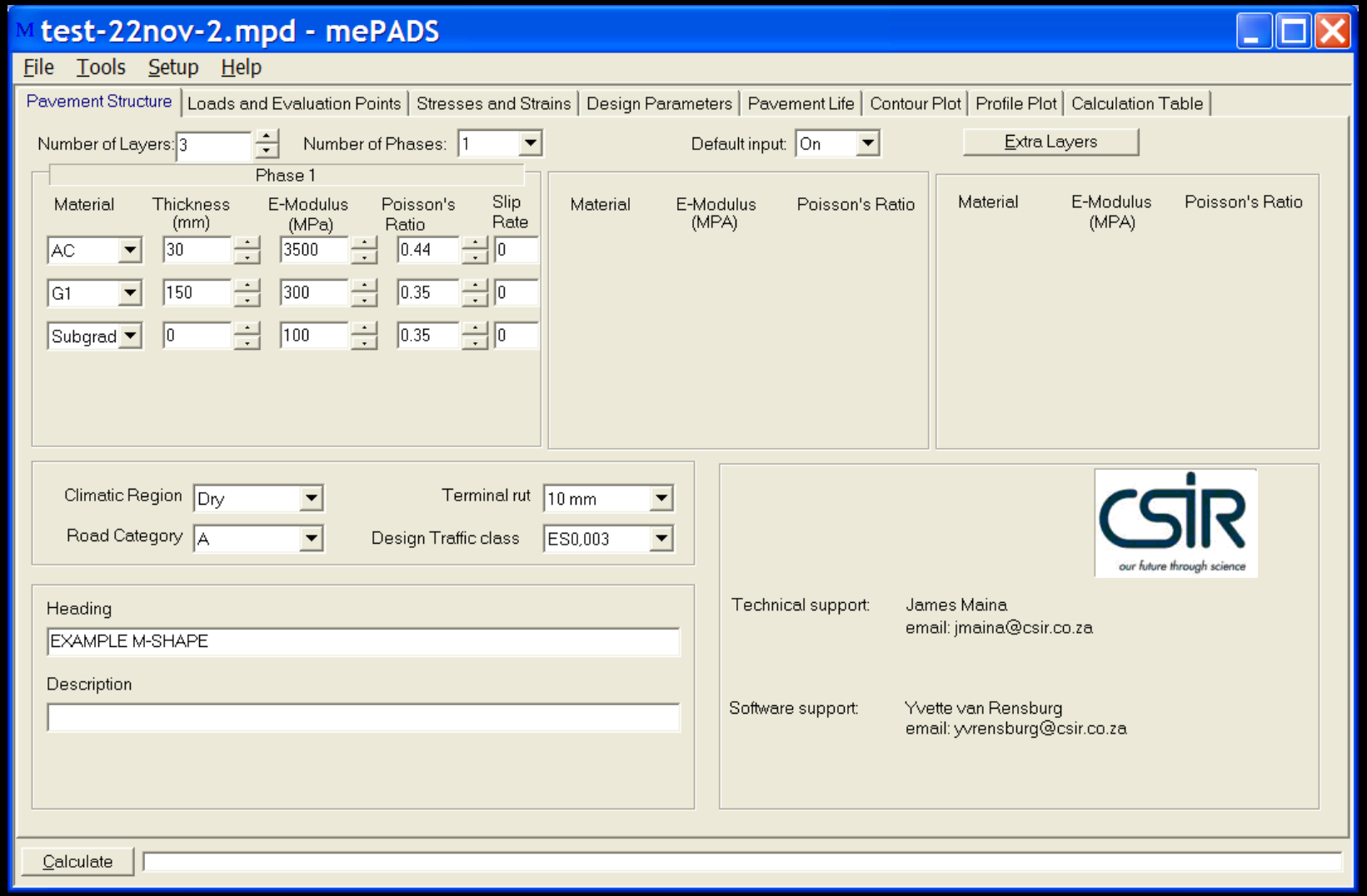
Mechanistic - Road Pavement Analysis-Multi-Layer



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315-80-20-520-Multiple.mpd - mePADS

File Tools Setup Help

Pavement Structure | Loads and Evaluation Points | Contour Plot | Profile Plot

Number of Layers: 3 Number of Phases: 1 Default input: On Extra Layers

Phase 1

Material	Thickness (mm)	E-Modulus (MPa)	Poisson's Ratio	Slip Rate
AC	30	3500	0.44	0
G1	150	300	0.35	0
Subgrad	0	100	0.35	0

Material	E-Modulus (MPA)	Poisson's Ratio

Material	E-Modulus (MPA)	Poisson's Ratio

Climatic Region: Dry Terminal rut: 10 mm

Road Category: A Design Traffic class: ES0,003

Heading

Description

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Technical support: James Maina
email: jmaina@csir.co.za

Software support: Yvette van Rensburg
email: yvrensburg@csir.co.za

Calculate Pavement system changed. Recalculate!

315-80-20-520-Multiple.mpd - mePADS

File Tools Setup Help

Pavement Structure | Loads and Evaluation Points | Contour Plot | Profile Plot

Design location

X: 0 Y: 0

Stresses and Strains

No of evaluation positions: 0

X Y Z

Extra points

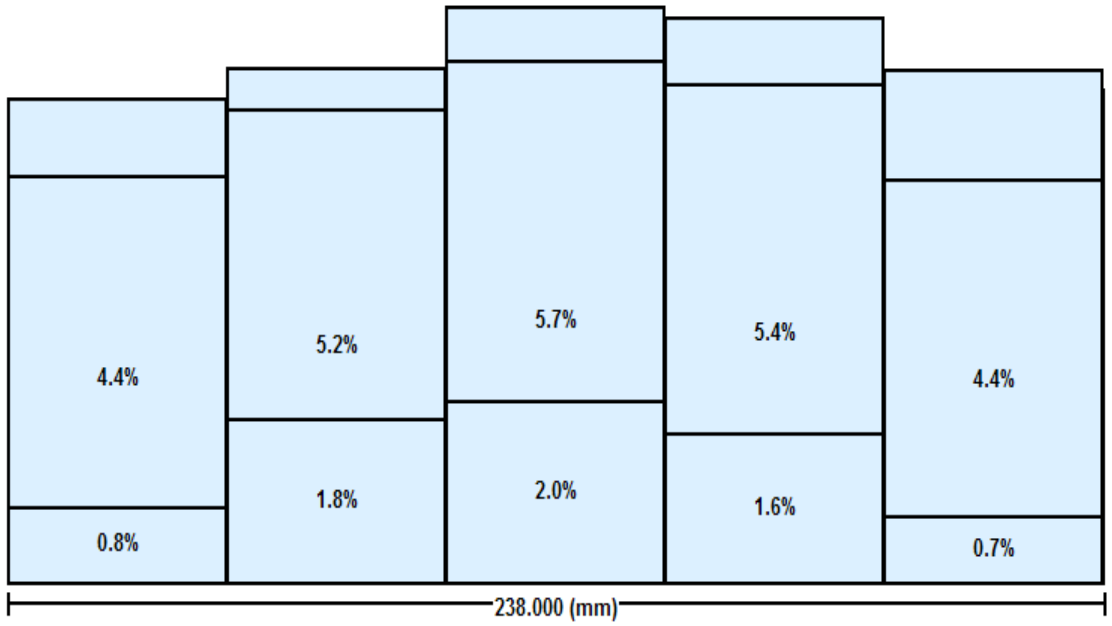
Load definition

No of loads: 25

TyreStress Loads | Std. Loads | Define Loads

Plot | Copy Chart

#	Vert Loa	Horz Loa	Angle X f	Torsion l	Shape	Centripet	She
1	0.271753	0	0	0	RECT	0	REC
2	0.96262	0	0	0	RECT	0	REC
3	1.07623	0	0	0	RECT	0	REC
4	0.903265	0	0	0	RECT	0	REC
5	0.168537	0	0	0	RECT	0	REC
6	0.501265	0	0	0	RECT	0	REC
7	1.08234	0	0	0	RECT	0	REC
8	1.14448	0	0	0	RECT	0	REC
9	1.05173	0	0	0	RECT	0	REC
10	0.367545	0	0	0	RECT	0	REC
11	0.58596	0	0	0	RECT	0	REC
12	1.2184	0	0	0	RECT	0	REC
13	1.28296	0	0	0	RECT	0	REC
14	1.16021	0	0	0	RECT	0	REC
15	0.405652	0	0	0	RECT	0	REC
16	0.607159	0	0	0	RECT	0	REC
17	1.20989	0	0	0	RECT	0	REC
18	1.25836	0	0	0	RECT	0	REC
19	1.10839	0	0	0	RECT	0	REC



Calculate | Pavement system changed. Recalculate!

Multiple Discs: 50kN 520kPa

Goodyear 315-80 R22.5 G391 (Steering - SA)-2006

Direction: [Z]

Inflation pressure: 520 (kPa)

Applied Vertical Tyre Load: 50 (kN)

SIM Measured Tyre Load [Z]: 47.7 (kN)

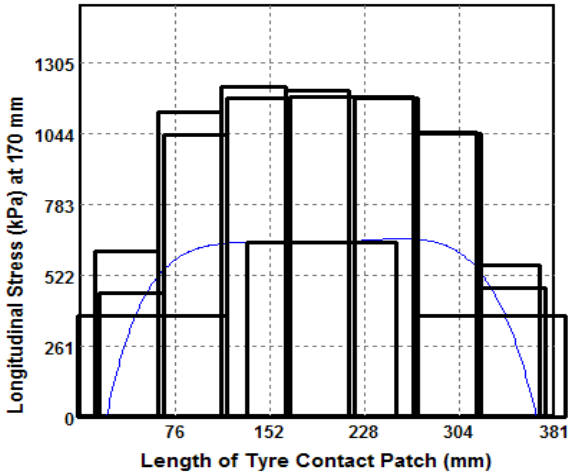
Estimated contact area: 818.6 (cm²)

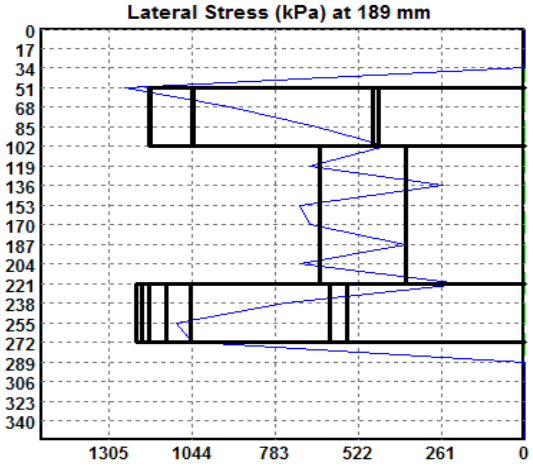
Equivalent uniform contact stress: 582.4 (kPa)

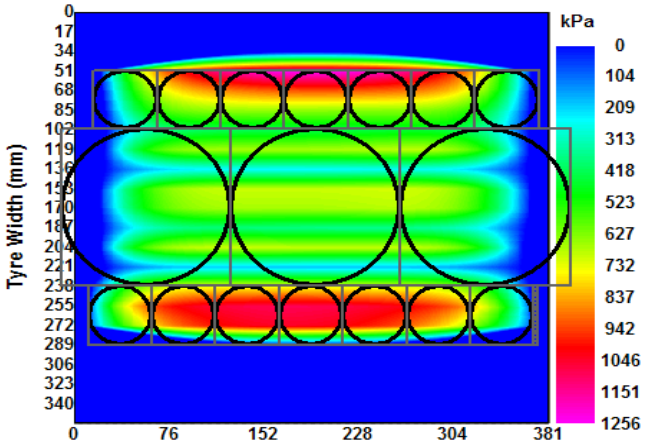
Radius of equivalent circular area: 161.4 (mm)

Load (kN)=12.7187,21.5405,13.4146

Stress (kPa)=777.69,443.945,789.903







315-80-20-520-Multiple.mpd - mePADS

File Tools Setup Help

Pavement Structure | Loads and Evaluation Points | Contour Plot | Profile Plot

Design location

X: 0 Y: 0

Stresses and Strains

No of evaluation positions: 0

X Y Z

Extra points

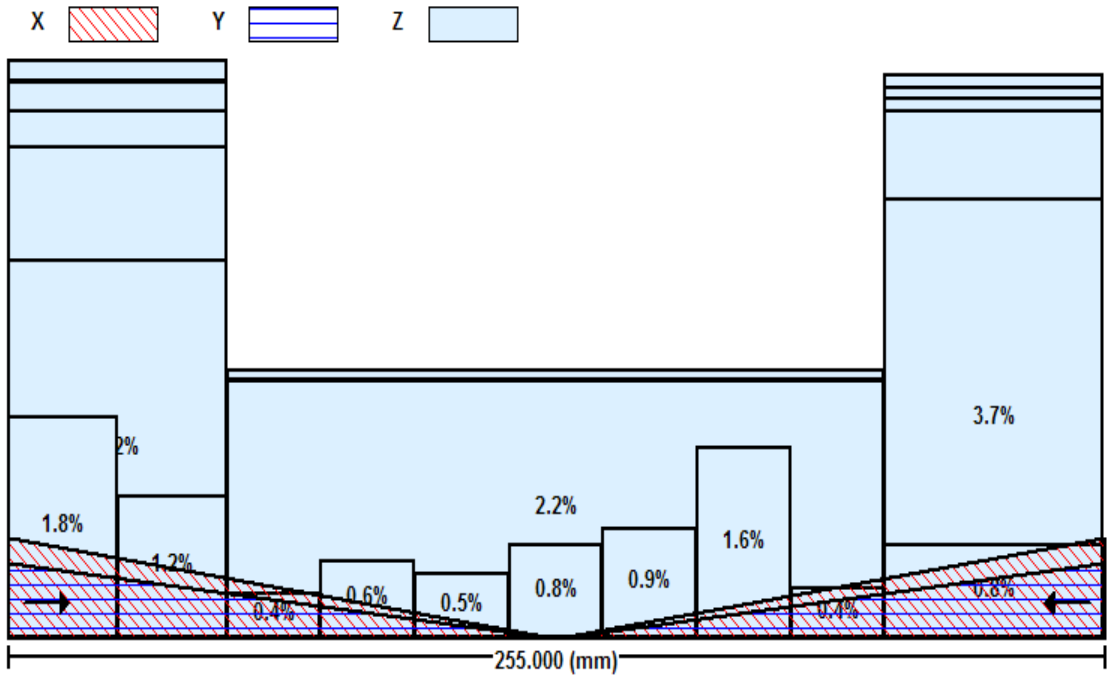
Load definition

No of loads: 42

TyreStress Loads | Std. Loads | Define Loads

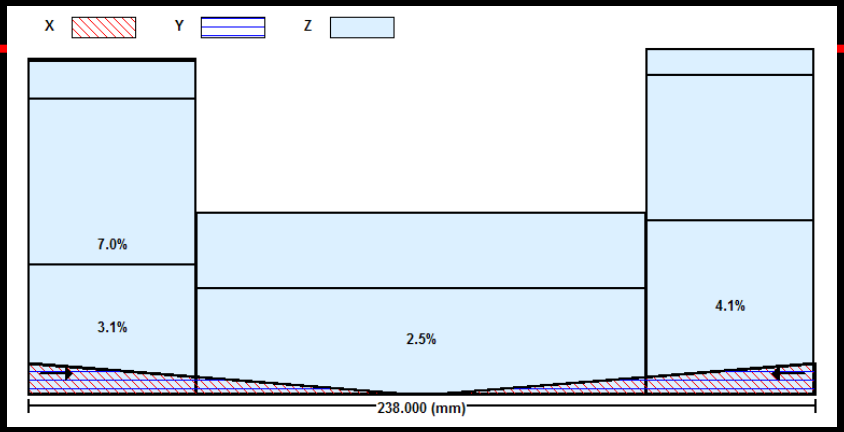
Plot | Copy Chart

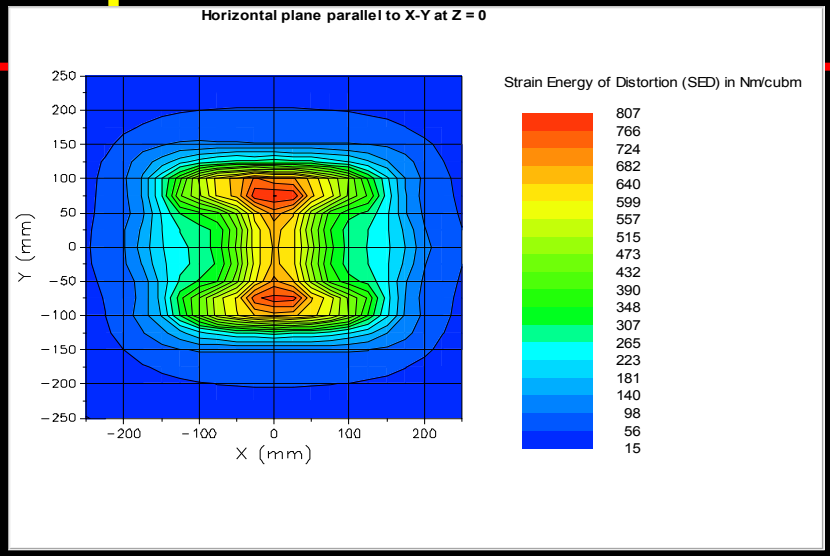
#	Vert Loa	Horz Loa	Angle X f	Torsion l	Shape	Centripet	She
1	11.4596	0	0	0	RECT	0	REC
2	11.1215	0	0	0	RECT	0	REC
3	0.128822	0	0	0	RECT	0	REC
4	0.111936	0	0	0	RECT	0	REC
5	0.171372	0	0	0	RECT	0	REC
6	0.087707	0	0	0	RECT	0	REC
7	0.130952	0	0	0	RECT	0	REC
8	0.037256	0	0	0	RECT	0	REC
9	11.0498	0	0	0	RECT	0	REC
10	0.037914	0	0	0	RECT	0	REC
11	0.067600	0	0	0	RECT	0	REC
12	0.056086	0	0	0	RECT	0	REC
13	0.081587	0	0	0	RECT	0	REC
14	0.095444	0	0	0	RECT	0	REC
15	0.167238	0	0	0	RECT	0	REC
16	0.042905	0	0	0	RECT	0	REC
17	2.75881	0	0	0	RECT	0	REC
18	2.66011	0	0	0	RECT	0	REC
19	2.56462	0	0	0	RECT	0	REC

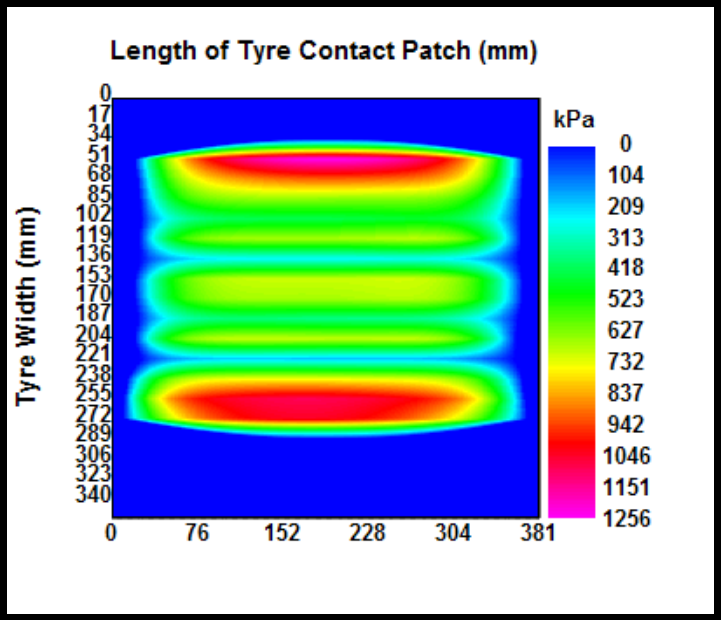


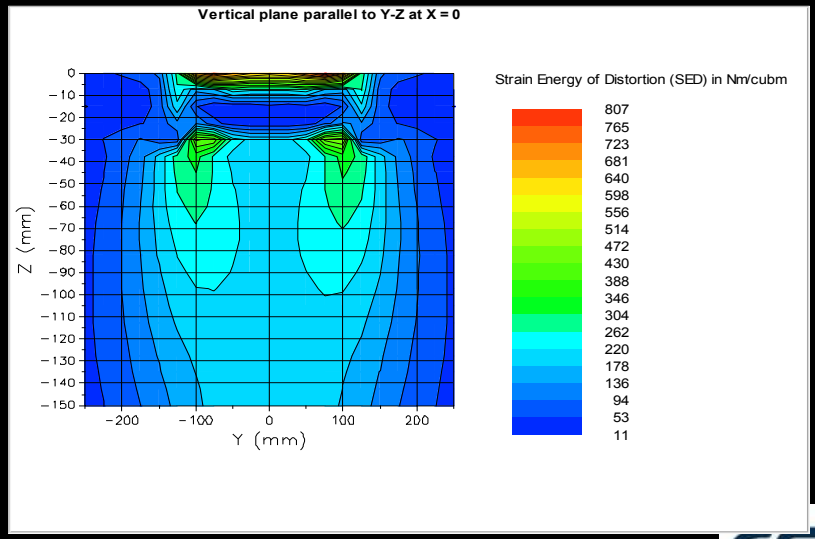
Calculate | Pavement system changed. Recalculate!

MePADS Outputs……

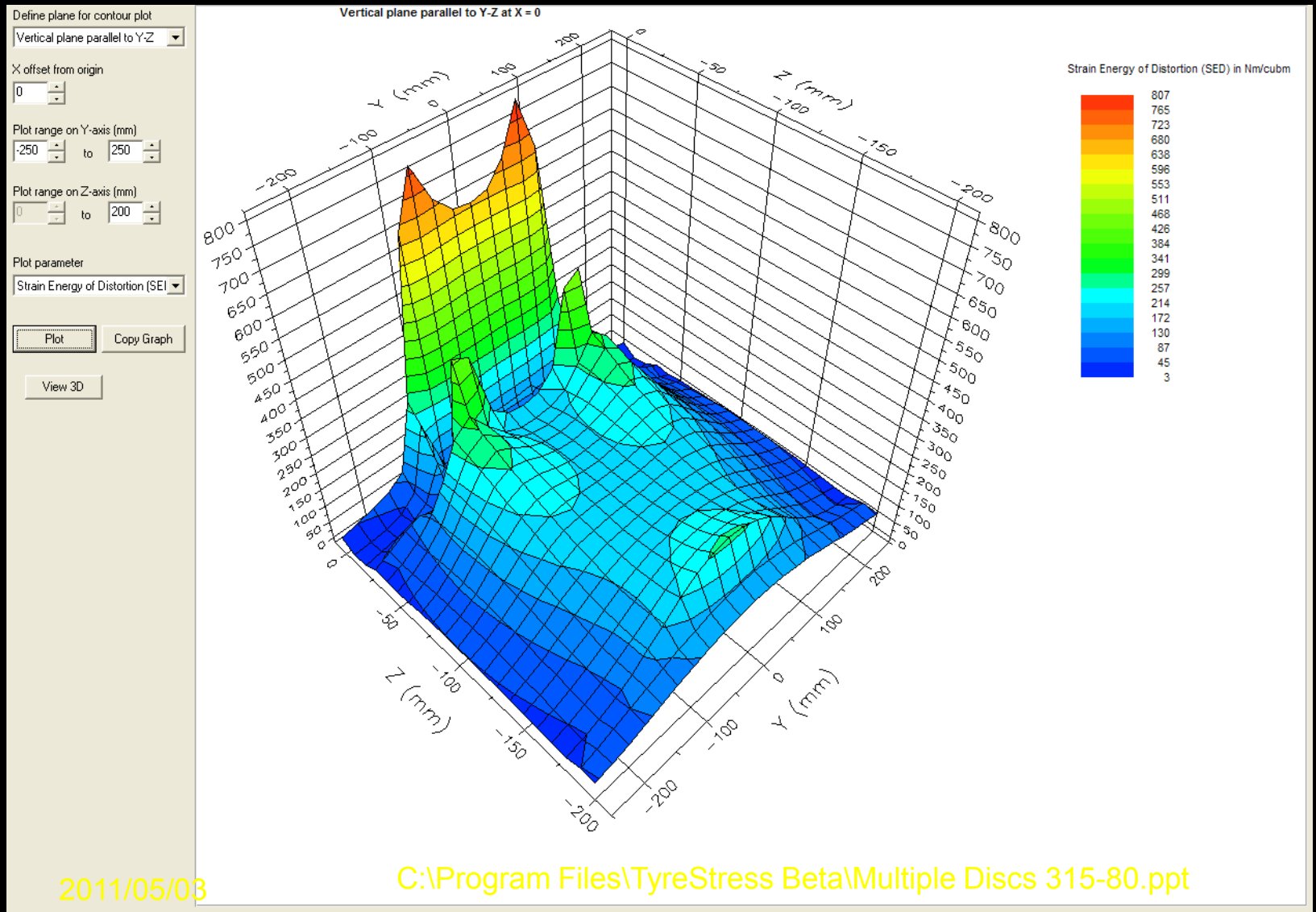




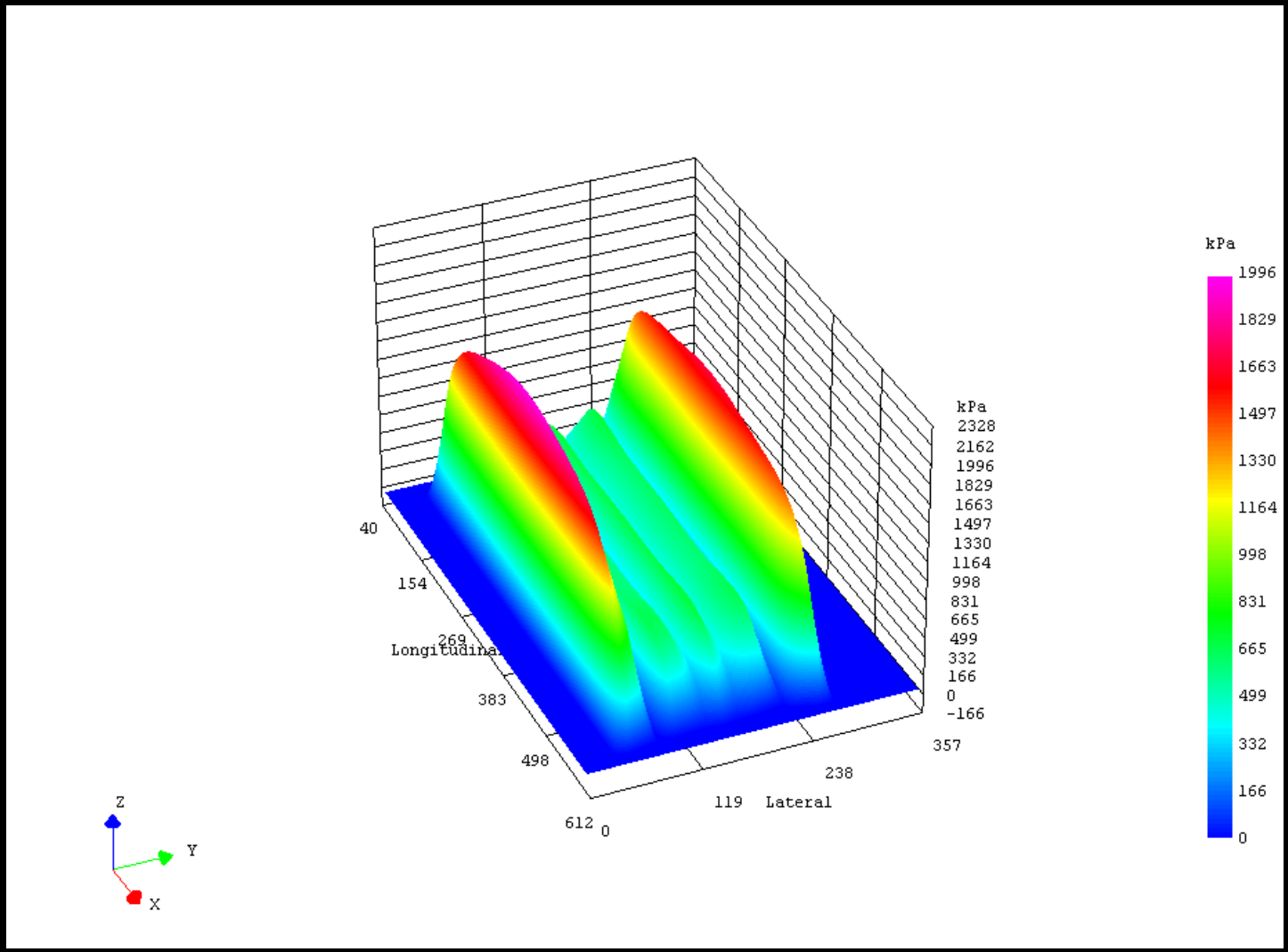




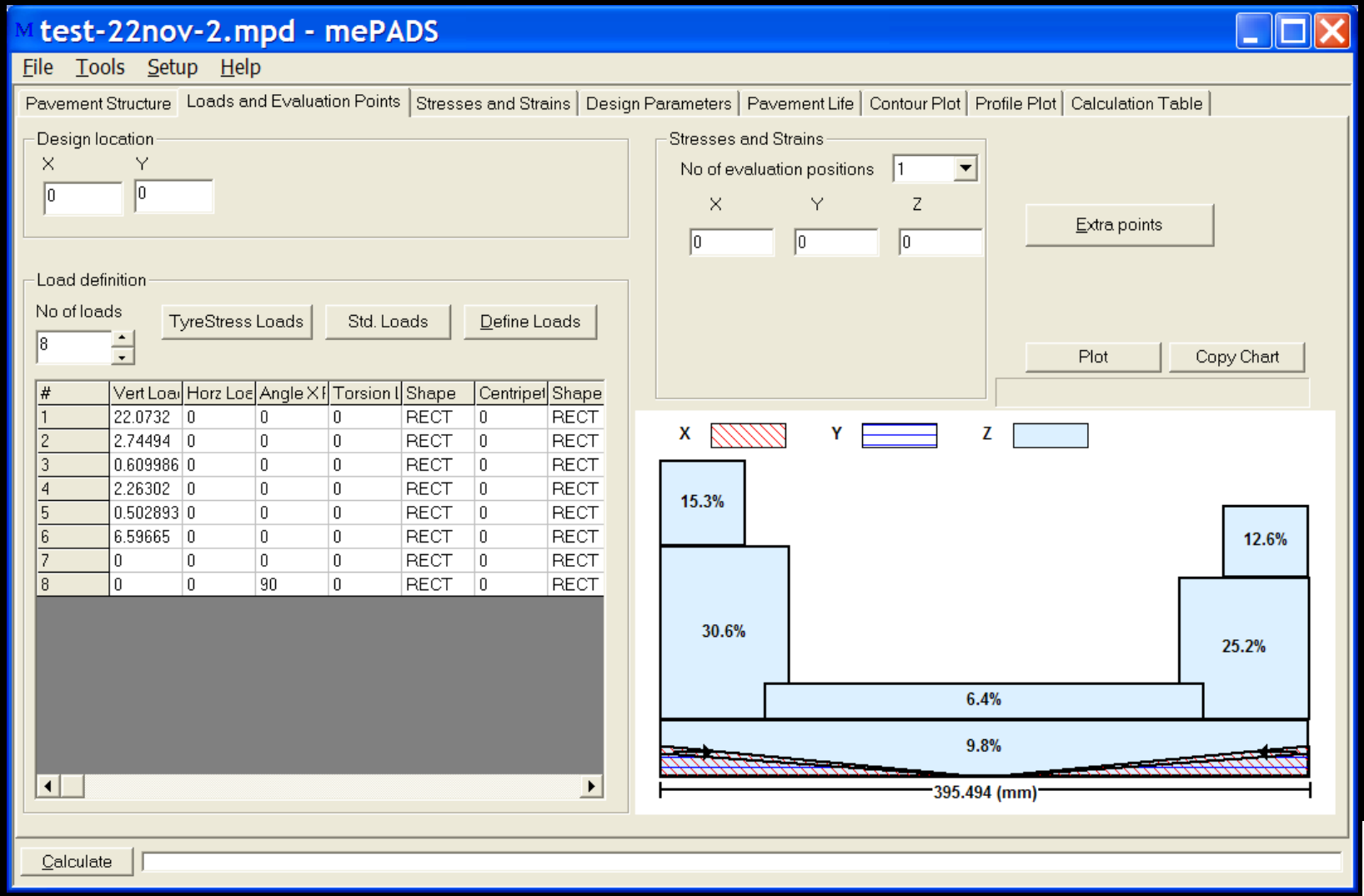
Strain-Energy of Distortion (SED)



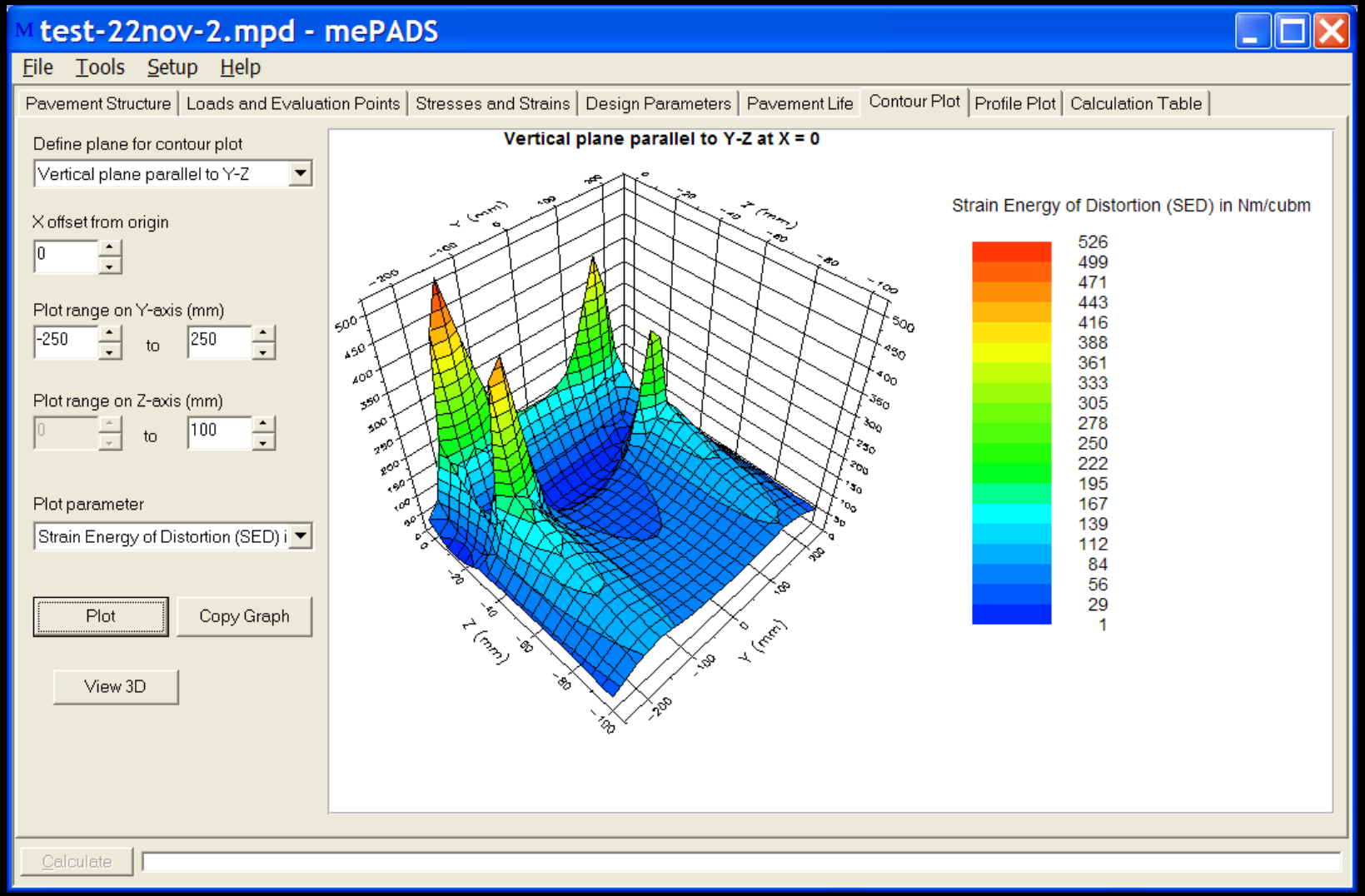
SIM Measured vertical tyre contact stress (z) – typical “m-shape”



Tyre Model: “m-shape” tyre contact stress (*idealized* from SIM measurements)

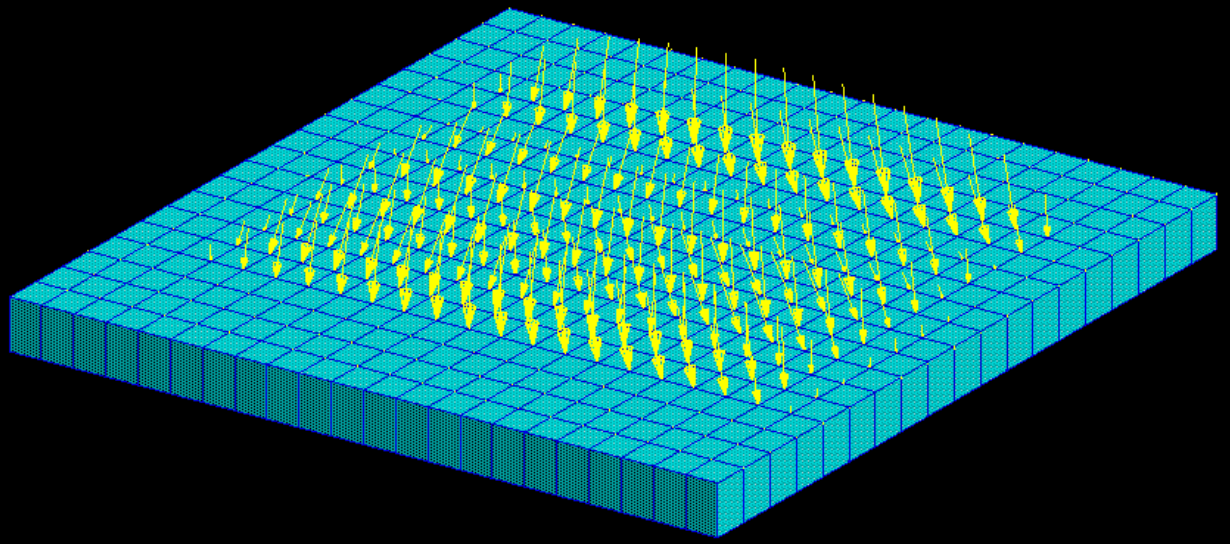


Output: Strain Energy of Distortion (SED) [m-shape tyre contact stress]

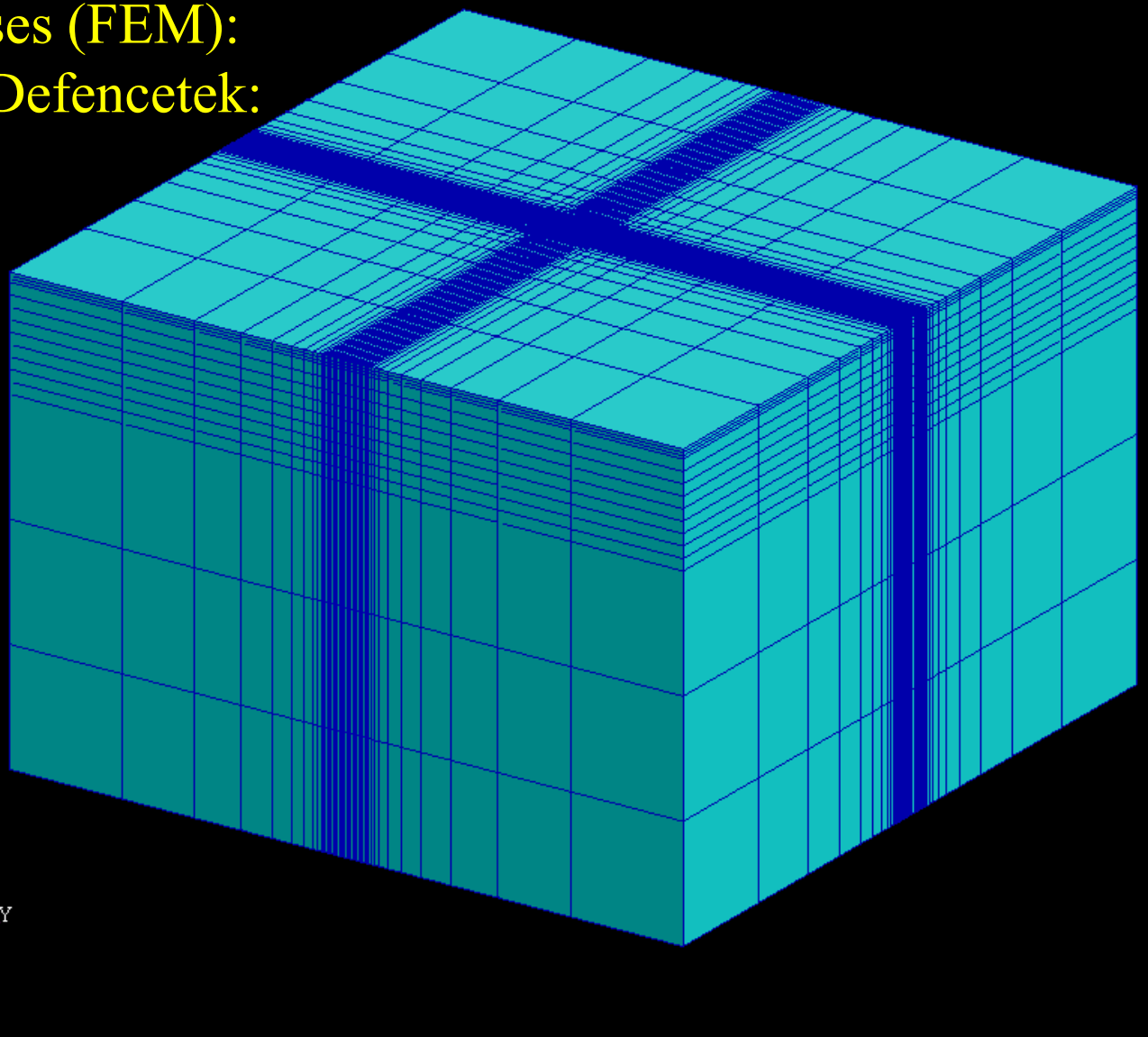


Application of non-uniform tyre loading:

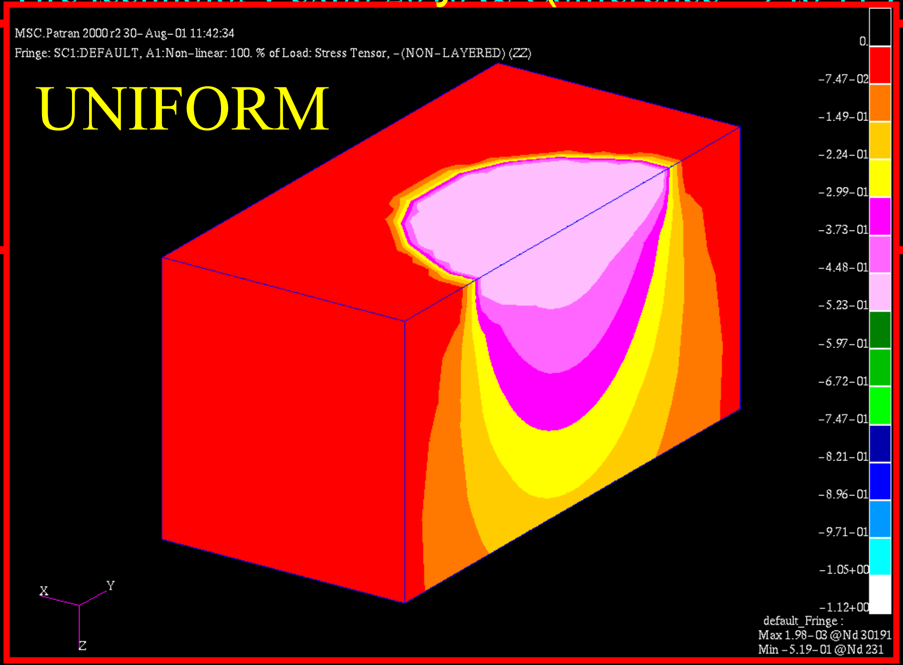
Finite Element Analyses (FEA),(NASTRAN;
FEAP- California, Abaqus

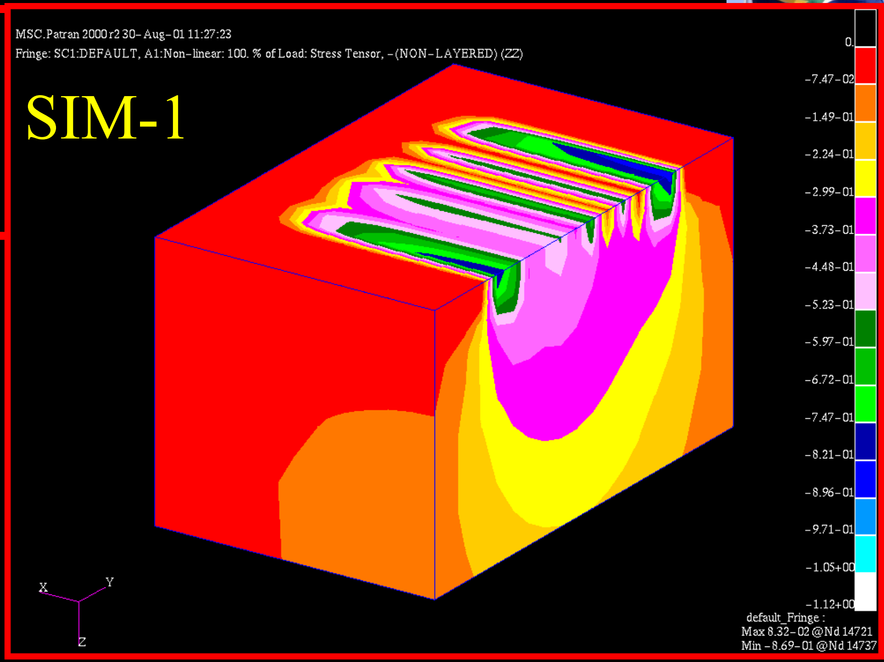


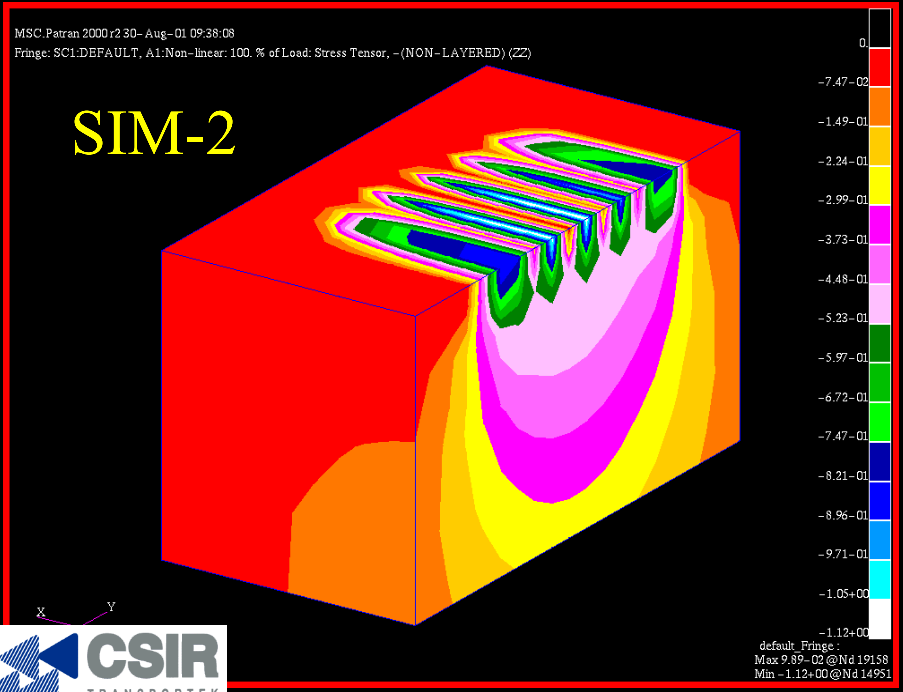
3D - Finite Element Analyses (FEM): CSIR Defencetek:

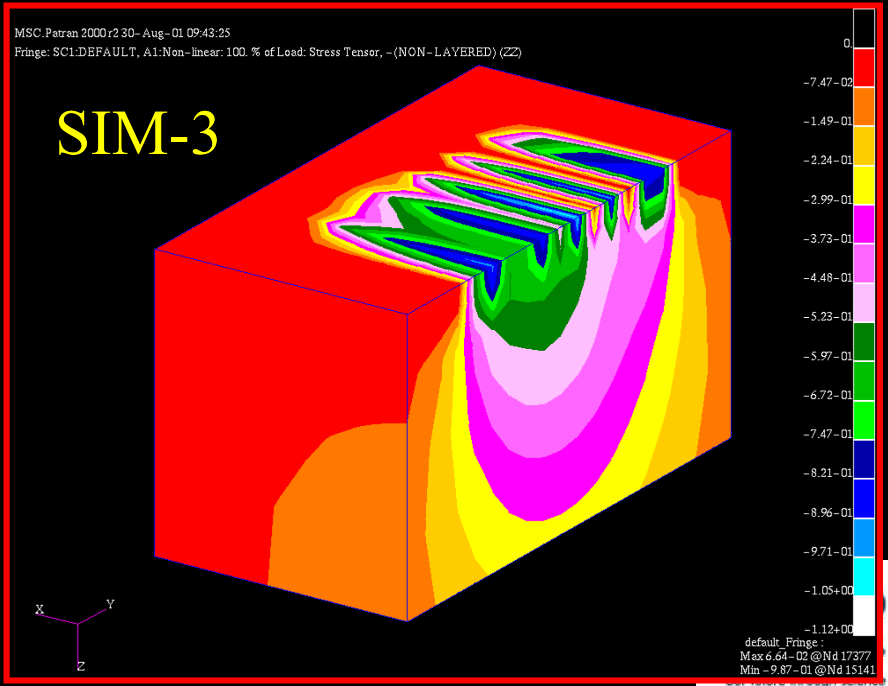


Finite Element Analysis (CSIR Defencetek)







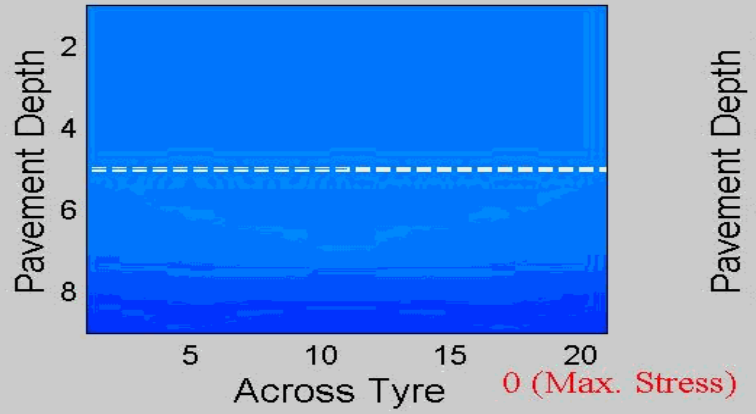


CSIR TRANSPORTEK

MODELED TYRE

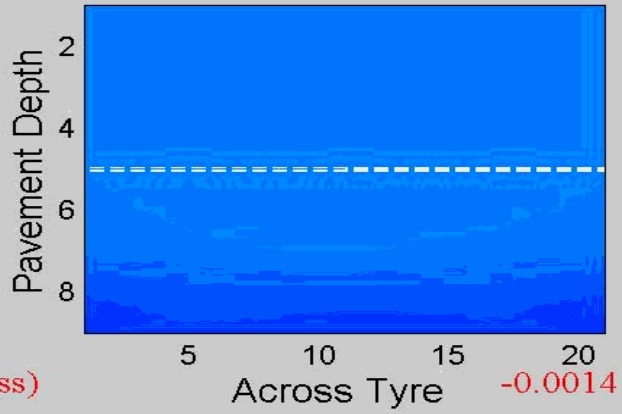
"REAL"-TYRE

UNIFORM LOAD - 520 kPa, 21 kN



0 (Max. Stress)

SIM - 600 kPa, 20 kN

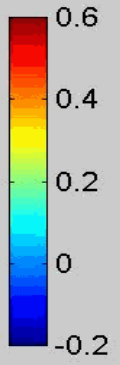


-0.0014 (Max. Stress)

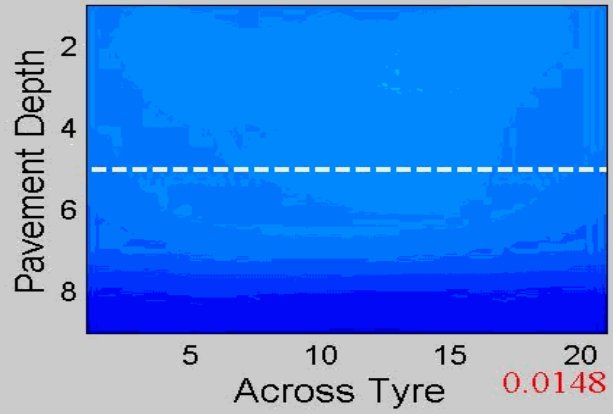
KEY:

VERTICAL STRESS:

Linear Elastic Solution
Three Layer Pavement
Asphalt Surfacing = 40 mm thick
Static Loading

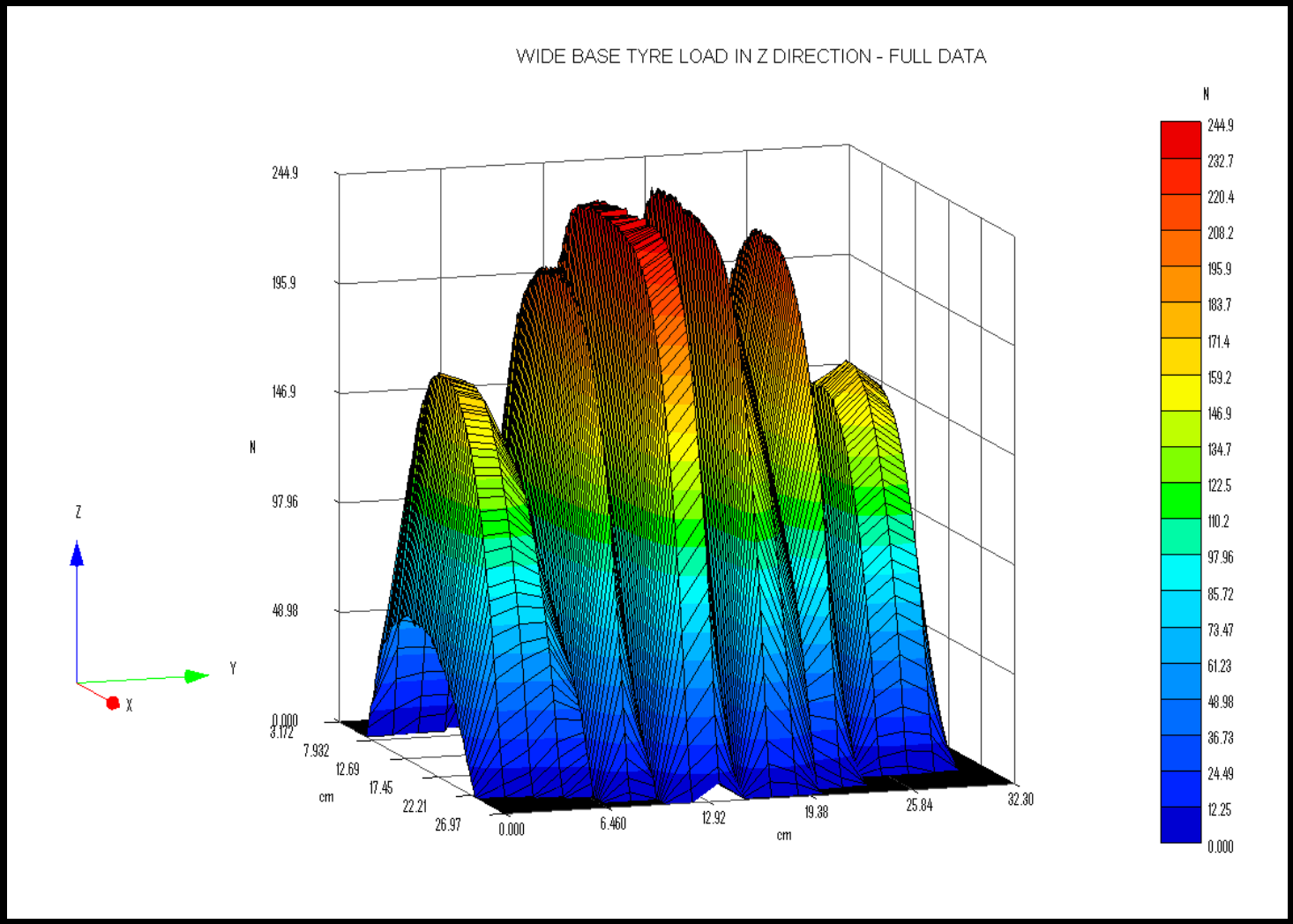


SIM - 600 kPa, 35 kN

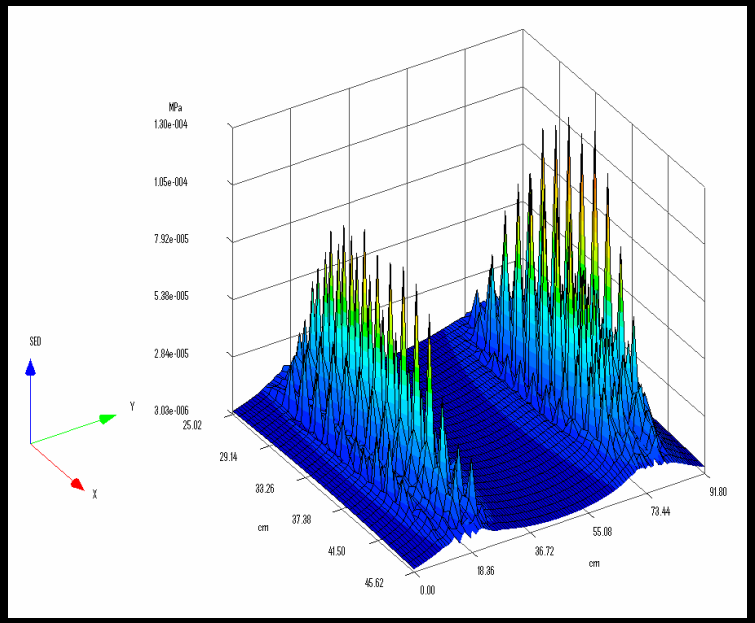


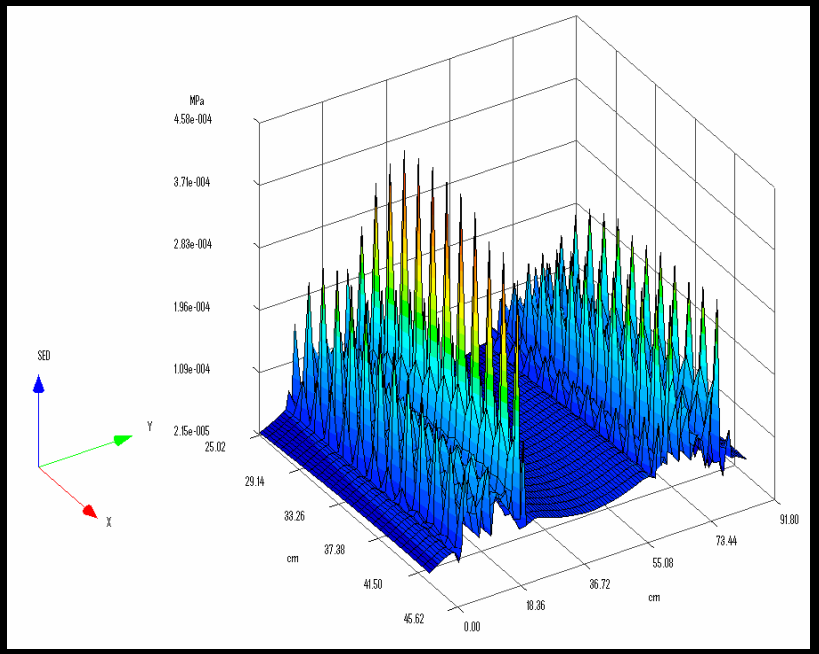
0.0148 (Max. Stress)

Vertical Tyre Stress: “n-Shape” tyre stress distribution.

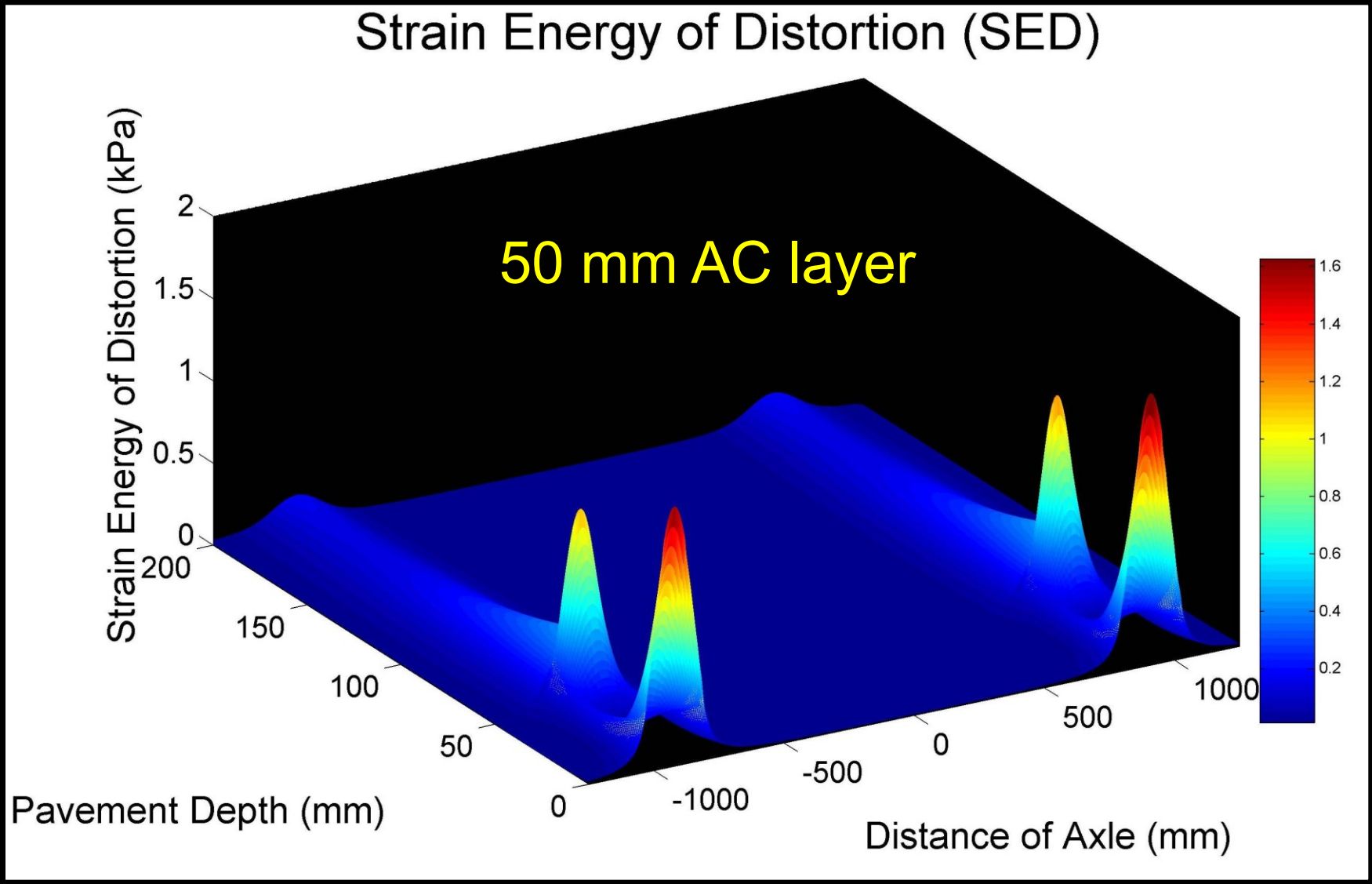


Strain Energy of Distortion (SED)- “n” and ”m – Shape” - dual tyres……





1 x Truck - 30 Tyres: 1 mm x 1 mm resolution – 500k points – SED under Steering Axle -



SUMMARY, CONCLUSIONS AND RECOMMENDATIONS (1)

- Tyre-pavement contact stresses can be quantified in 3D – using Stress-In-Motion (SIM) technology ;
- Results considered acceptable for advanced mechanistic pavement analysis ;
- Current data suggest that 3D Contact Stresses are complex, and may assist with advanced structural road pavement analysis ;

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS (2)

- Functional performance, such as rolling resistance not investigated yet, but may be done in near future ;
- Not treated in this presentation, but: *"X, Y Stress Excursion"* plots may also largely assist with above ;

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS (3)

- Effects on pavement infrastructure to be researched, also in economical terms for each Country/State ;
- Use of Cost/Benefit studies recommended ;
- Road Authorities to plan maintenance and rehabilitation accordingly;
- More Collaboration needed – Tyre/Tire Industry…..??;

CSIR
our future through science

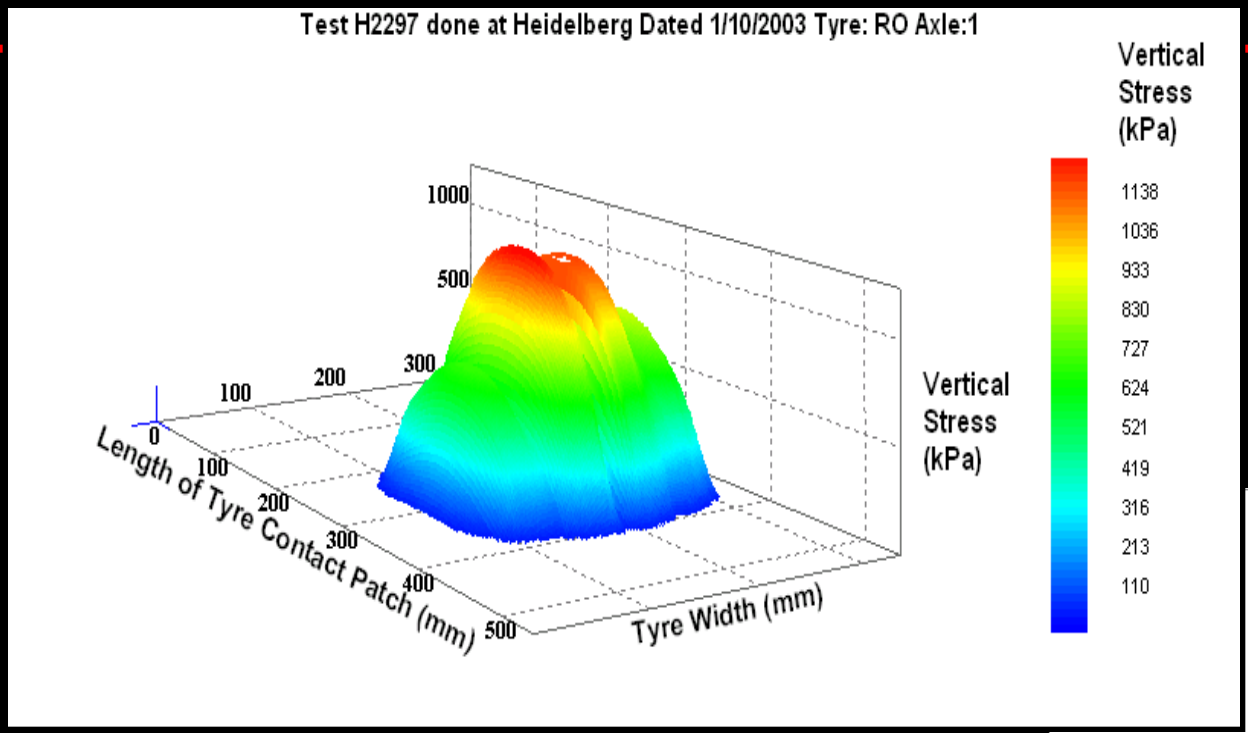
I thank you for your attention…

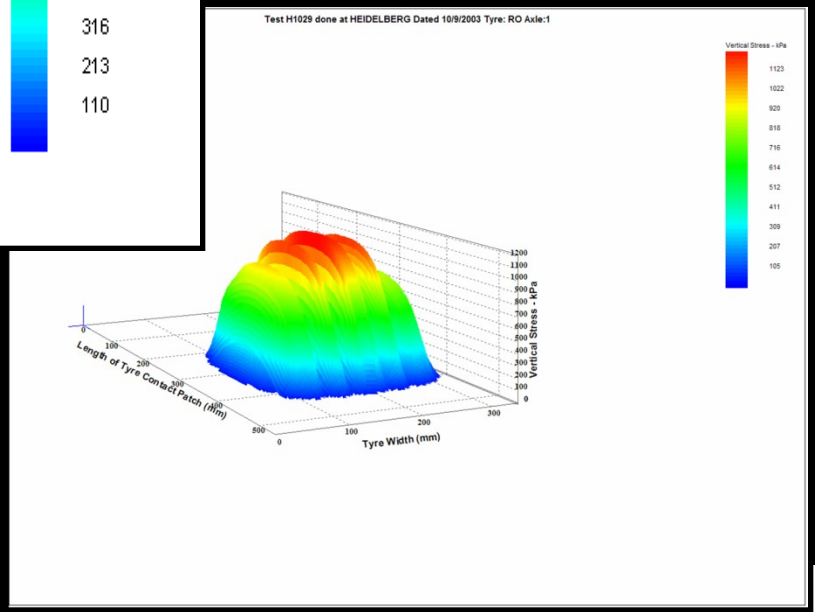
CSIR
our future through science

Aug 2004 – Preparing of dedicated Test Platform at Gautrans, Koedoespoort

September 2004 – 250 mm Concrete slab……

Vertical Contact Stress – “n” Shape





Vertical Contact Stress – “m” Shape