PAVEMENT DESIGN - SGC 793: SPECIAL MODULE: March 4, 2010

Stress - In - Motion (SIM) Technology in South Africa

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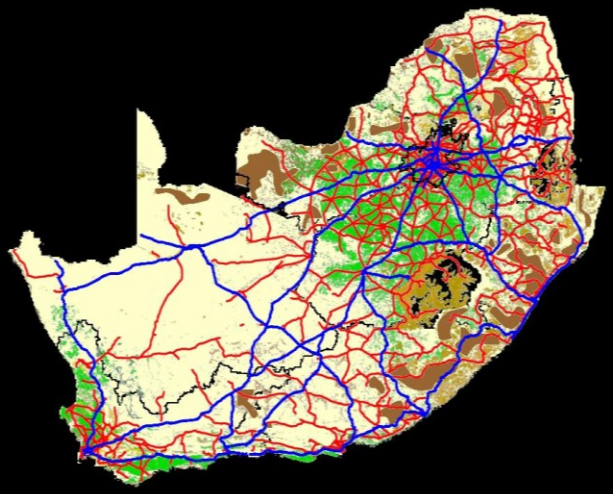

Stress – In – Motion (SIM) Technology = The measurement of 3D tyre/pavement contact stresses from moving vehicles

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Layout of this Presentation:

- Introduction
- Background: Pavements
- SIM & HVS Equipment
- 3D SIM Results
- Conclusions

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"GOOD ROADS LEAD TO PROSPERITY"..

..motto of the South African Road Federation

J F Kennedy: .."Its not wealth that creates roads, but roads that create wealth"…

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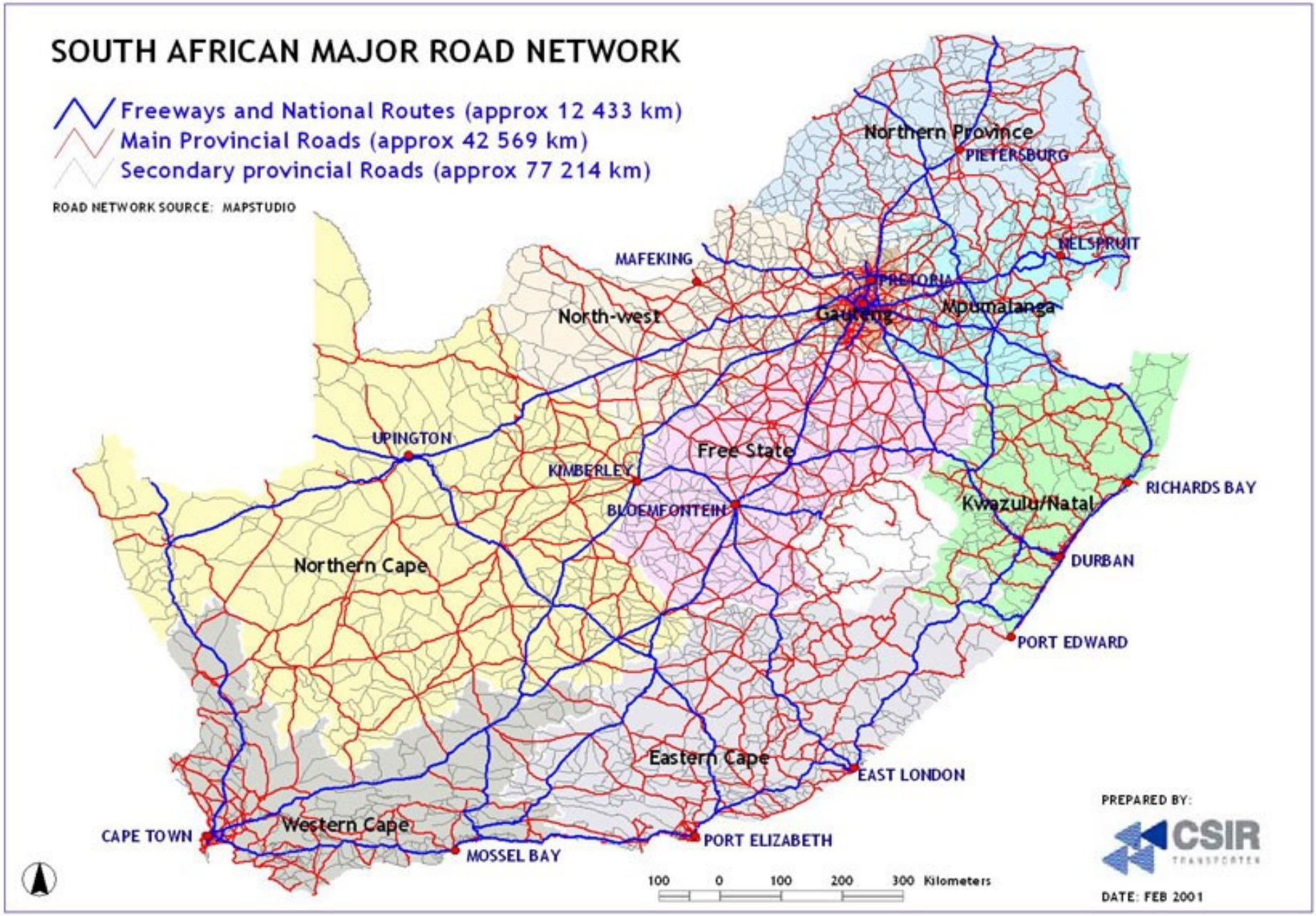
SOUTH AFRICAN MAJOR ROAD NETWORK
Freeways and National Routes (approx 12 433 km)
Main Provincial Roads (approx 42 569 km)
Secondary provincial Roads (approx 77 214 km)
ROAD NETWORK SOURCE: MAPSTUDIO
Northern Province
PIETERSBURG
NELSPRUIT
MAFEKING
PRETORIA
Gauteng
Mpumalanga
North-west
UPINGTON
Free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

ROAD/ PAVEMENT DAMAGE…

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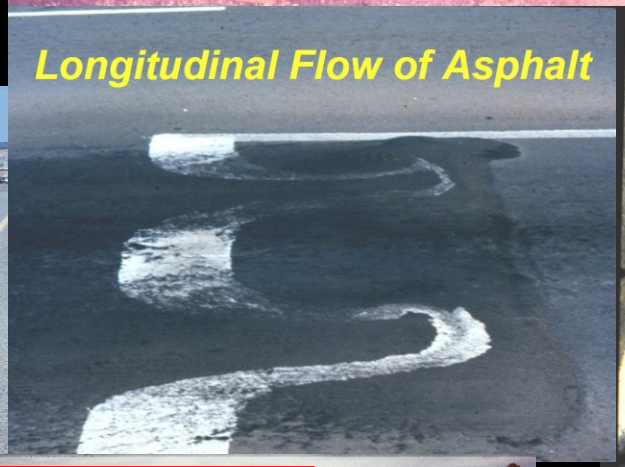
RUTTING


Surface Disintegration…


Fatigue Cracking and aging


Delamination..


Longitudinal Flow of Asphalt


SURFACE DISINTEGRATION

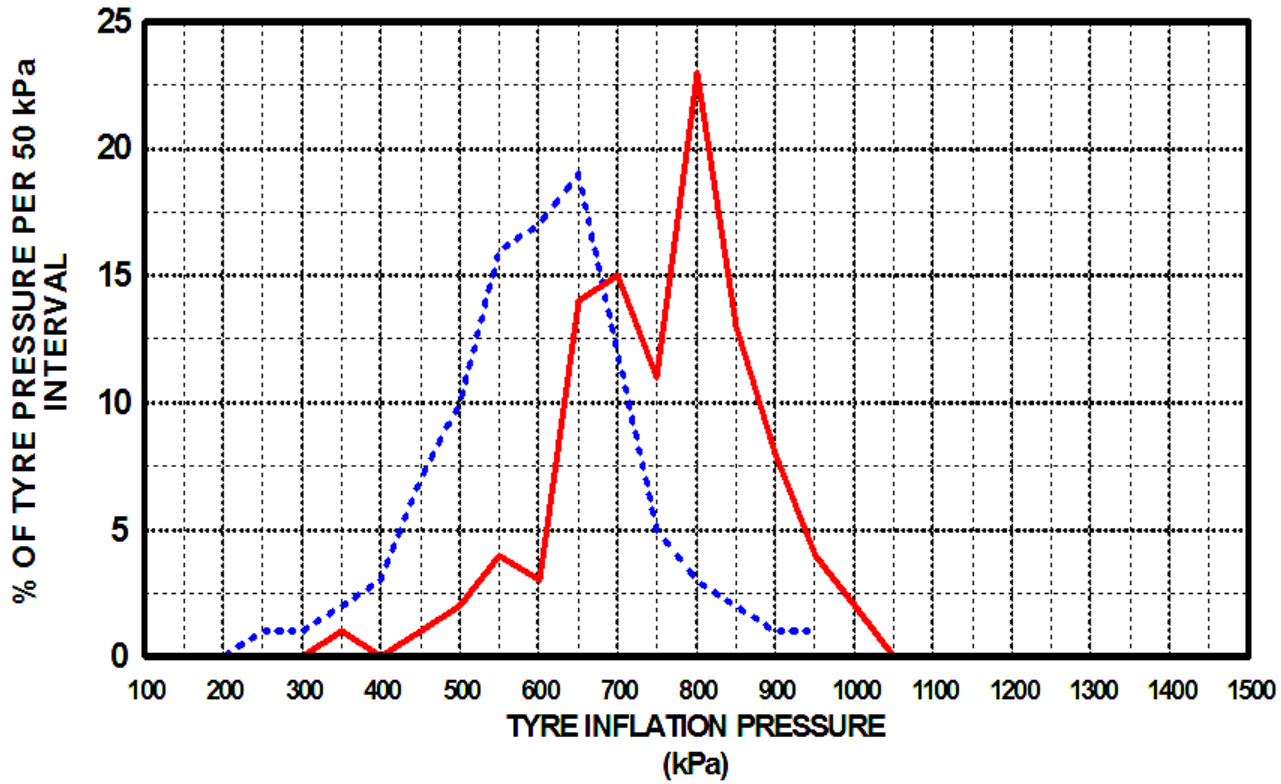

POTHOLES :
Water & Loads …


Potholes & Patching…


Sub-grade Failures….


Water & Safety…

Truck Tire Inflation Pressure in South Africa:



Van Vuuren (1974)	De Beer (1995)
Average: 620 kPa	Average: 733 kPa

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

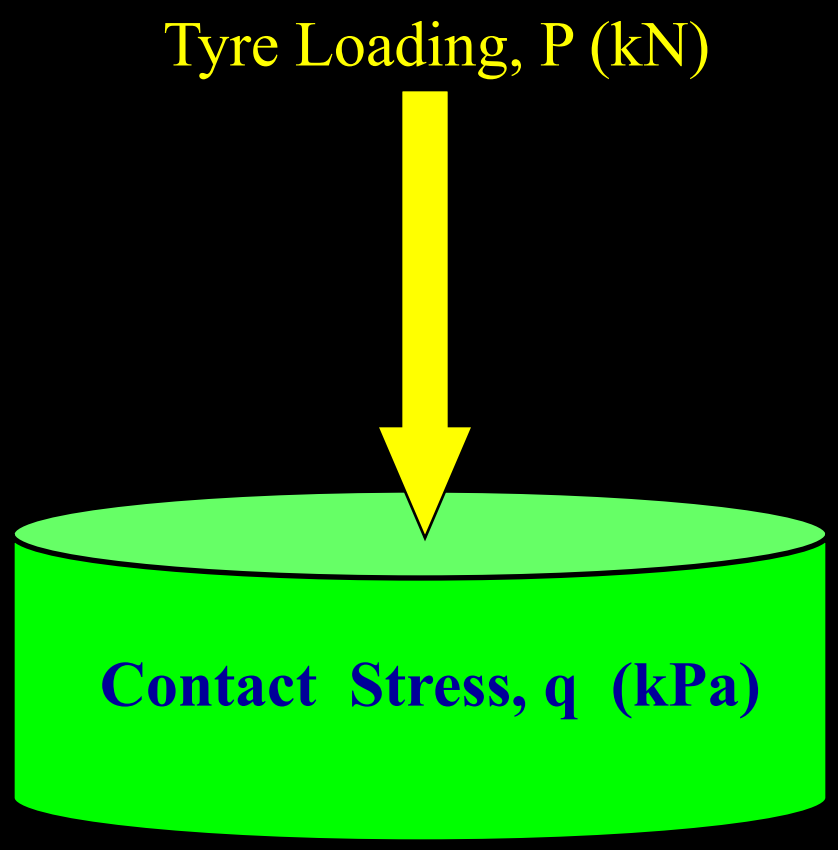
~ 20 % Increase in 20 Years

I believe that part of the problem is :

"In Pavement Engineering, worldwide today, the representation of pneumatic tyre/pavement contact stresses is *oversimplified* by using a circular disc of uniformly distributed pressure, *equal or less* than the tyre inflation pressure".

..Strong indications suggests that this may be far from real - world conditions….

Design Tyre Loading (1D): ELSYM, RUBICON



HVS-SIM Projects Objective:

..To obtain a more realistic tyre/pavement contact stress representation under the pneumatic tyres of the Heavy Vehicle Simulator (HVS)…

..This is to improve pavement tests and analysis, in general….

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[illegible] - [illegible]


TRANSVAALSE PAAIEDEPARTEMENT
TRANSVAALSE PAAIEDEPT.
TRANSVAAL ROADS DEPT.

HVS Mark IV+

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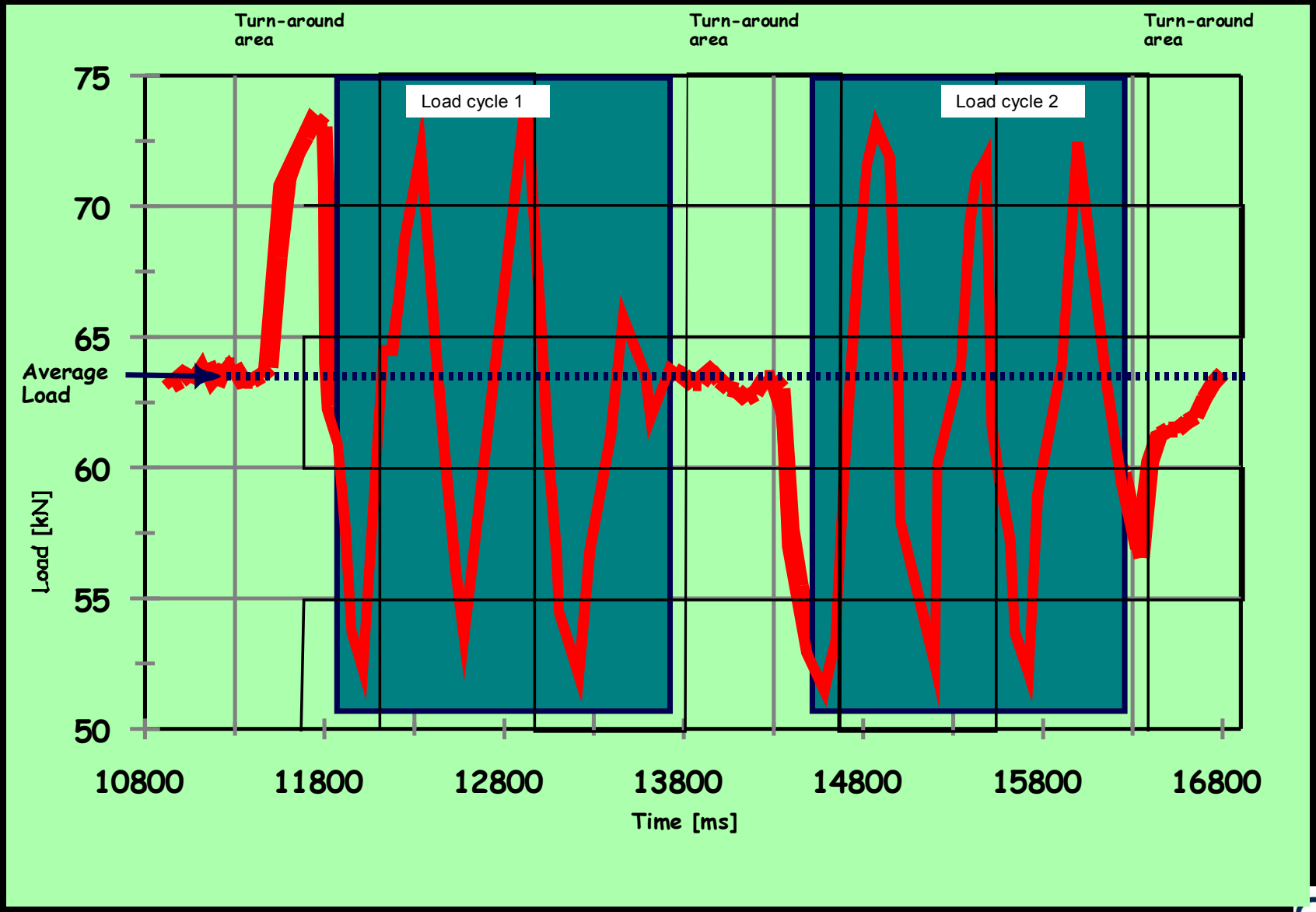
NEW HVS MkIV (PLUS): TYPICAL DYNAMIC LOAD HISTORY

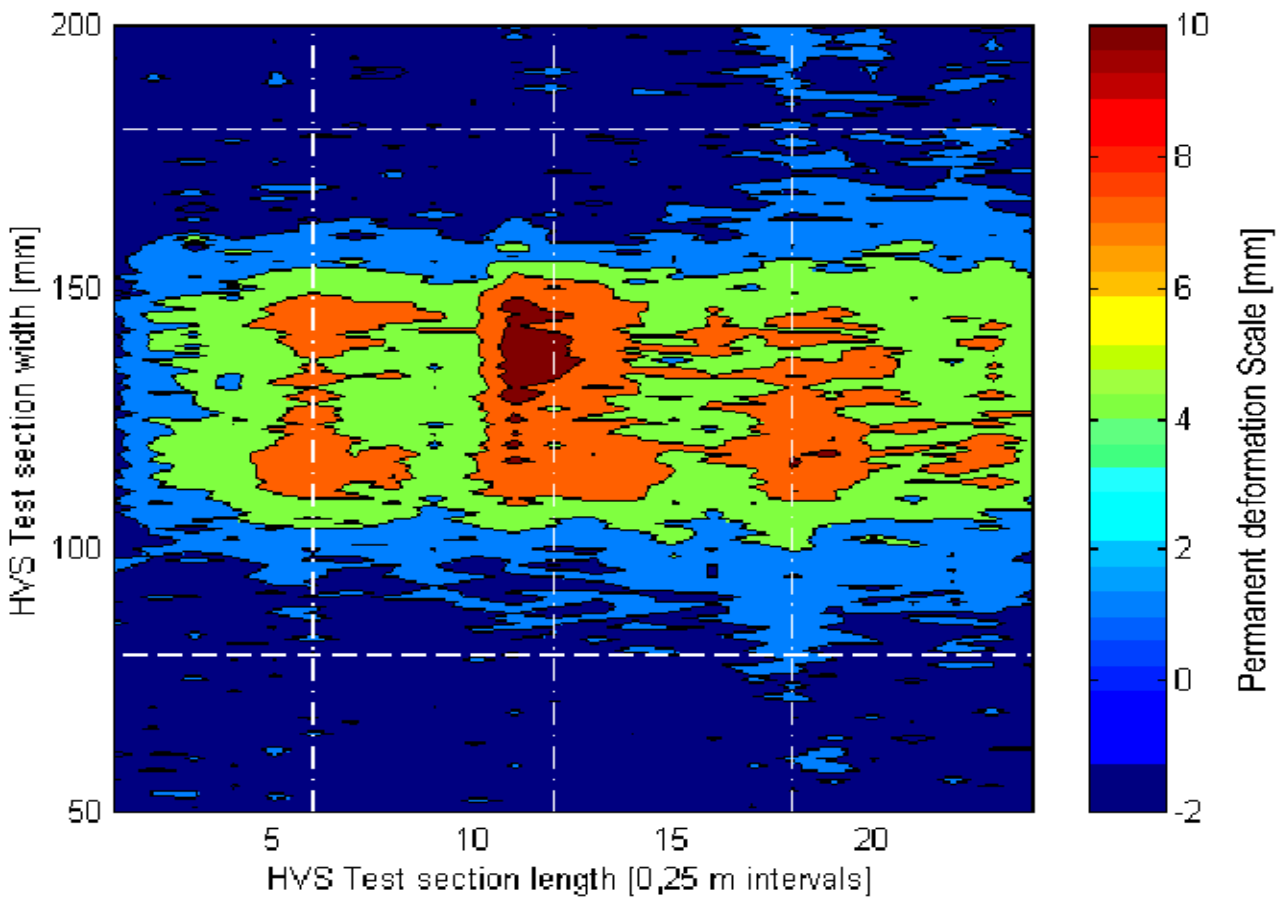


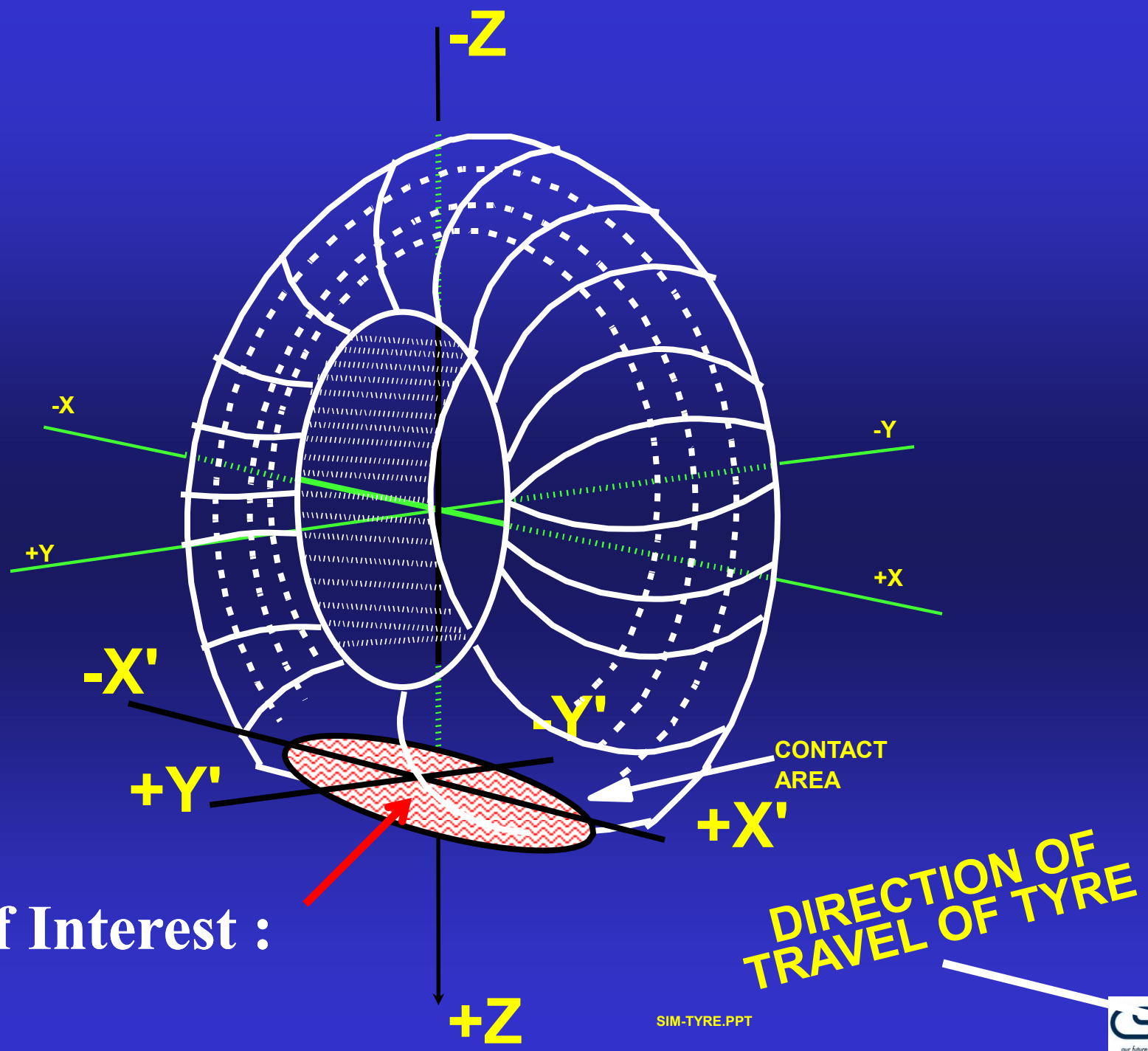
Dynamic Load (HVS Mk IV Plus)

Moving Dynamic Load (sinusoidal)

Uni-directional Load

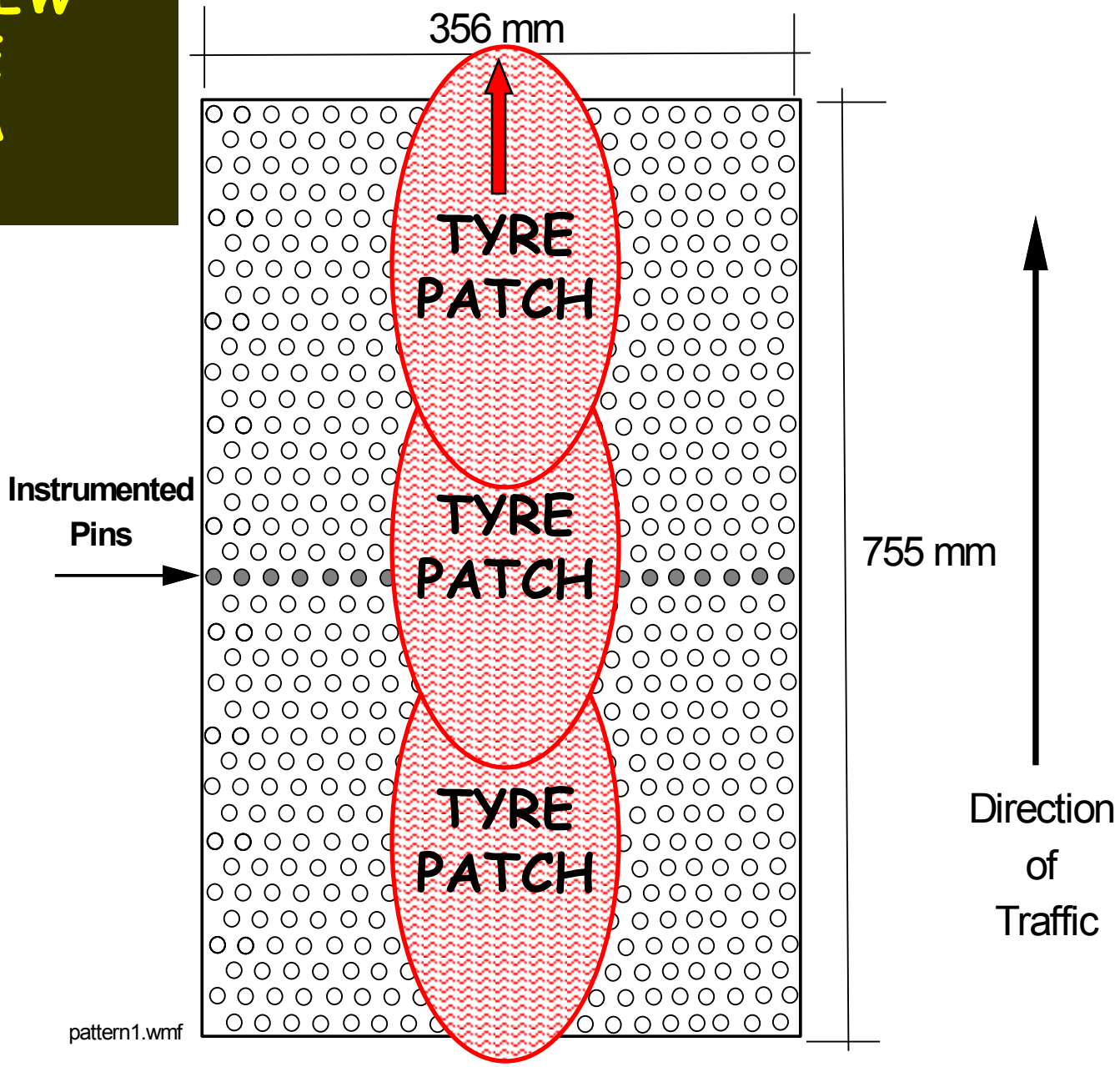
Permanent Surface Deformation



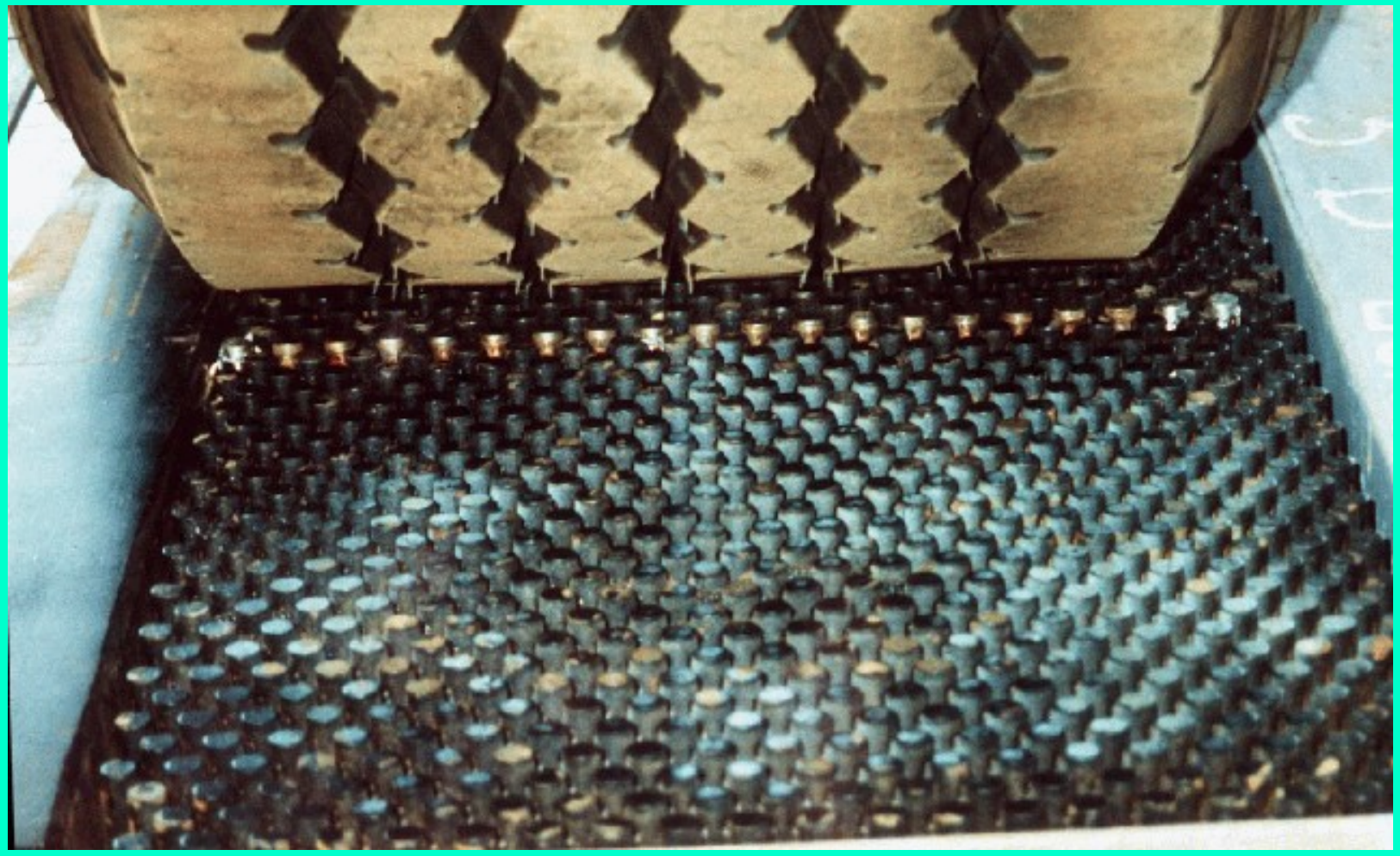


Area of Interest :

TOP VIEW OF THE VRSPTA MK II



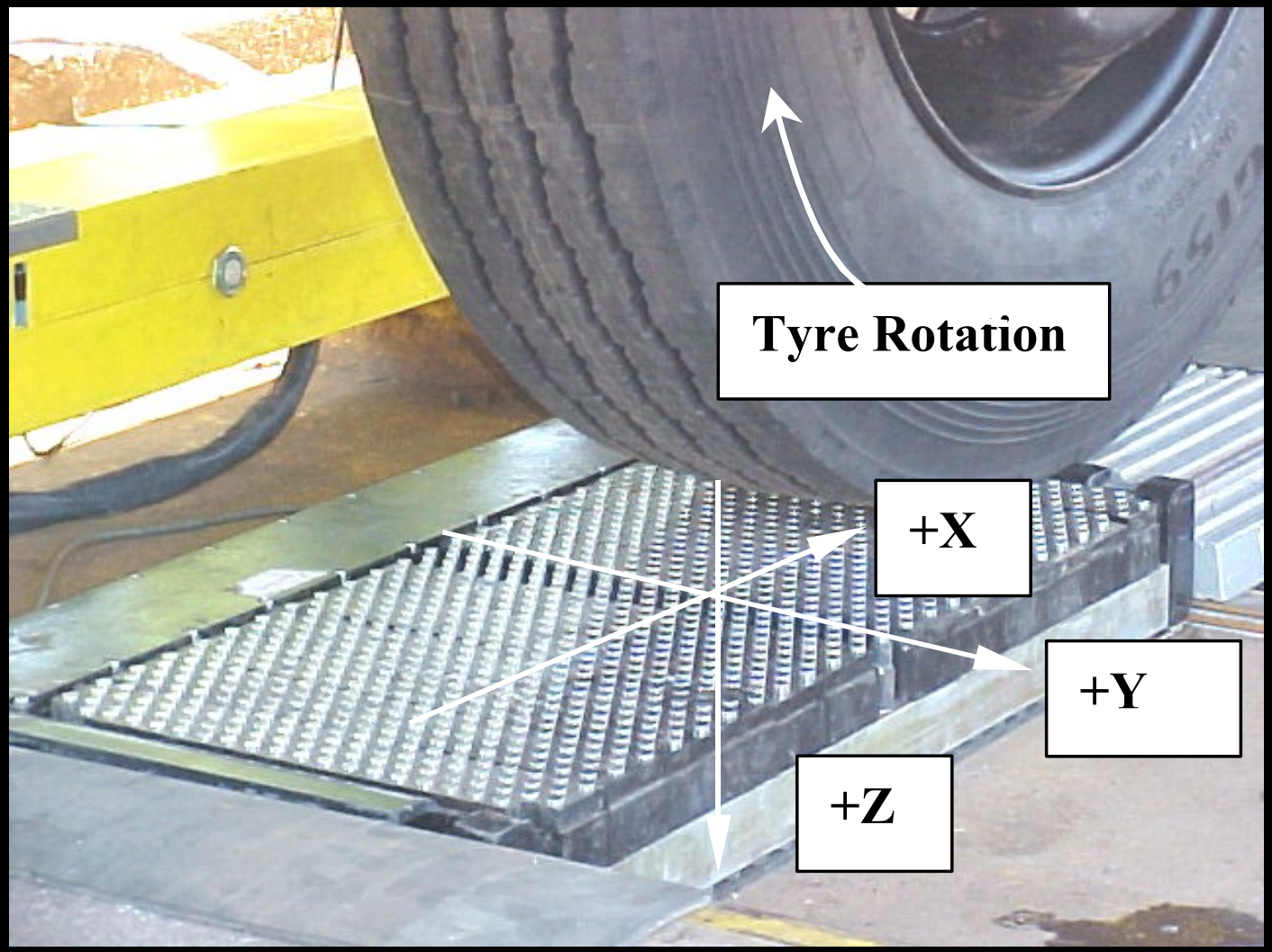
315/80 R22.5 HVS TIRE ON VRSPTA



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

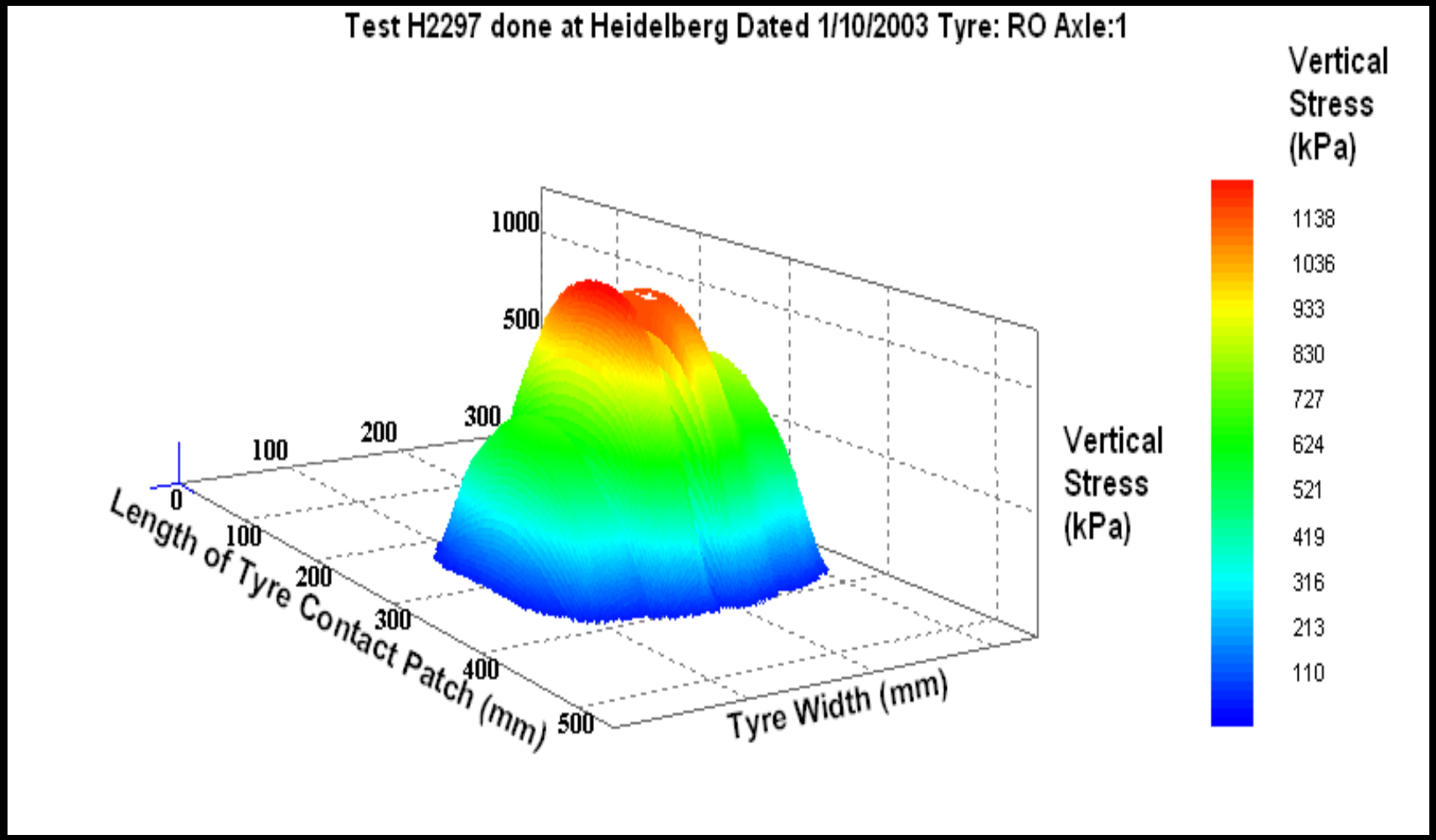
EXAMPLE OF FOOTPRINT TO FOLLOW…..

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

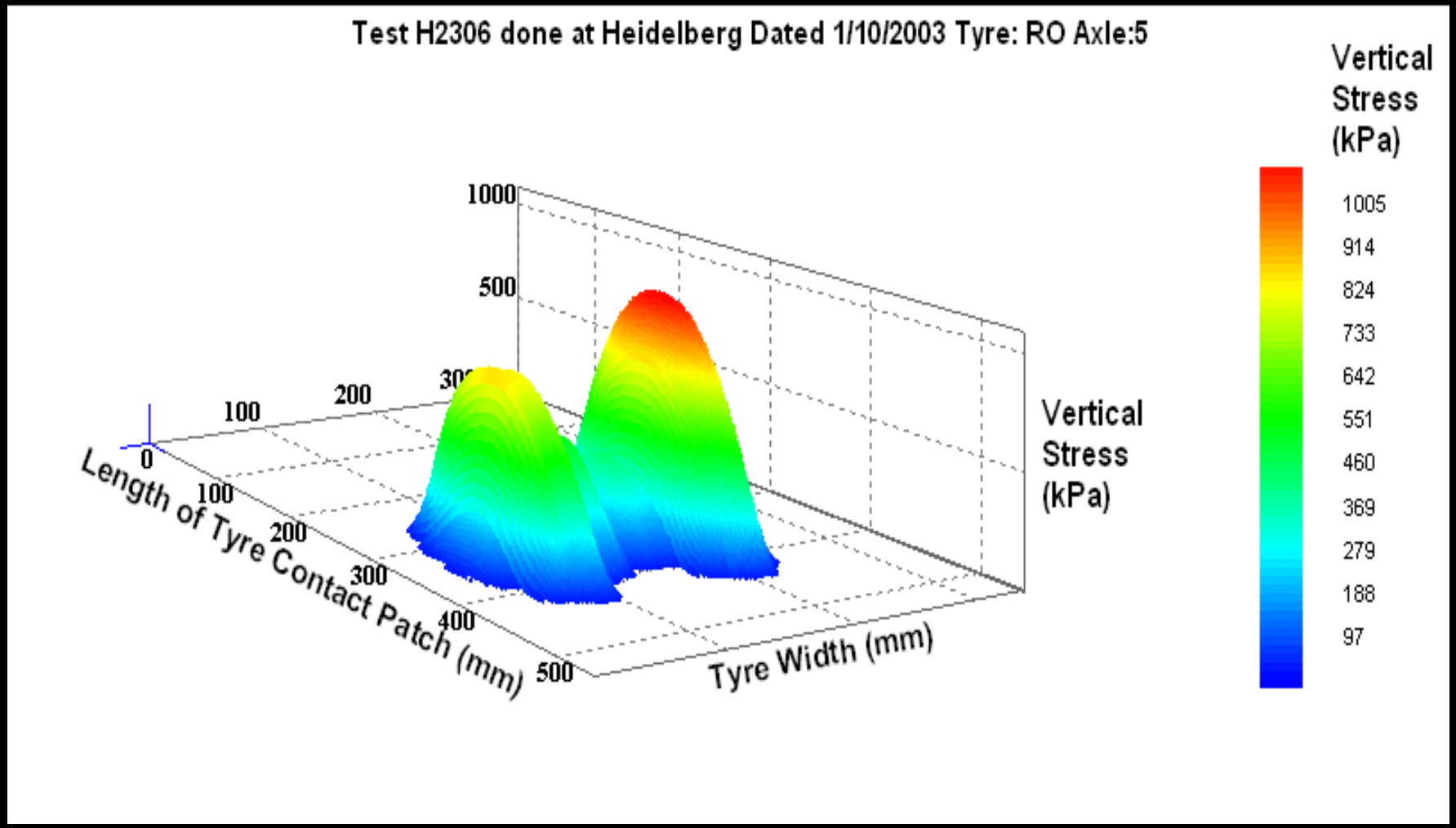


Complex Nature of tyre-surface interaction. (MMLS3 on SIM Device)

Vertical Contact Stress – "n" Shape



Vertical Contact Stress – “m” Shape



CONTACT STRESS DATA (BOLD TIRE)

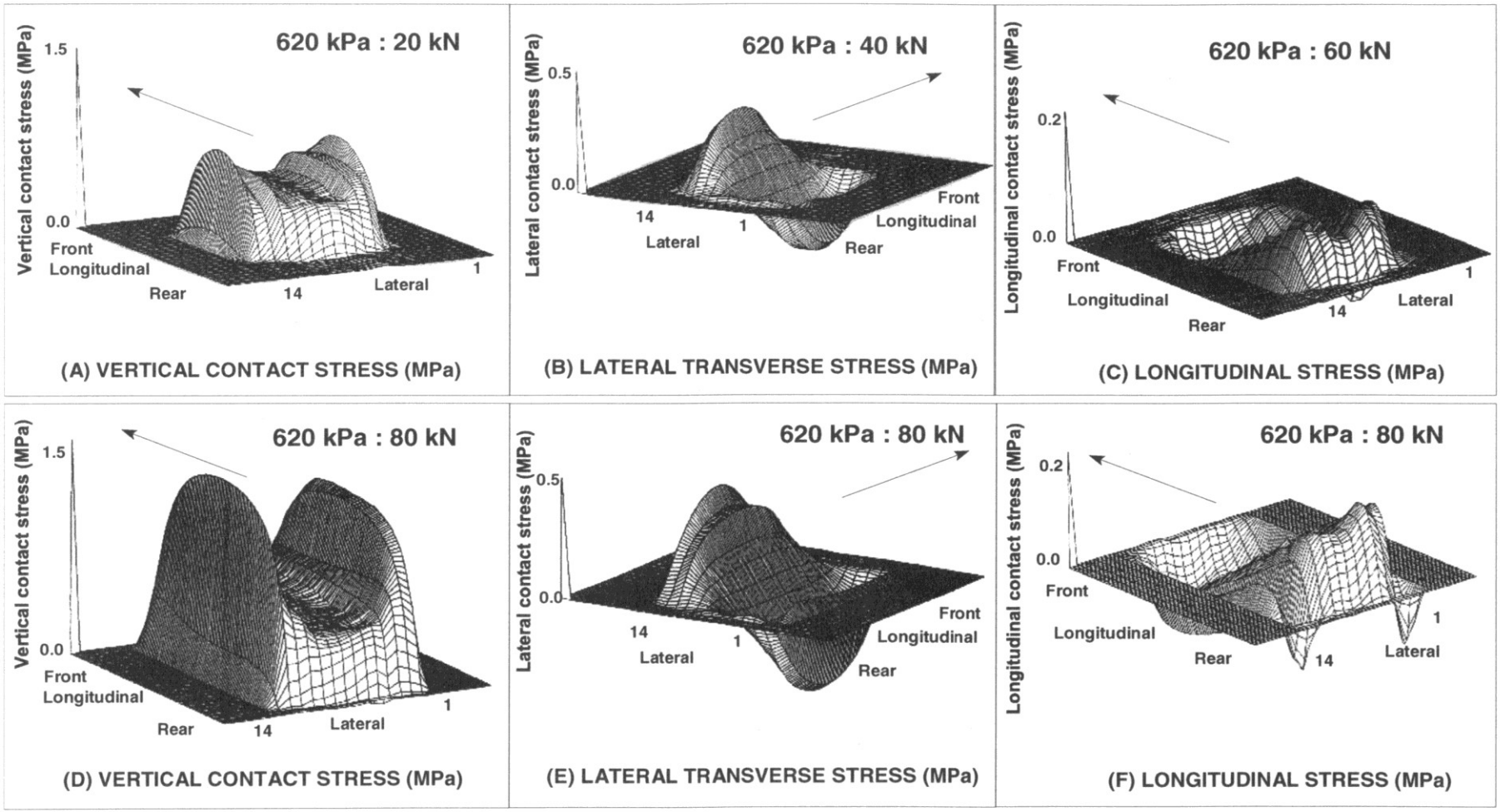


FIGURE 6 : Typical contact stress distributions measured with the VRSPTA system for a slow moving (1,2 km/h) free rolling smooth single truck tyre (Goodyear 11.00 X 20, 14 Ply rating)

11.00 - R22.5 RADIAL HVS TYRES
(AFTER CULLINAN ROAD 2388 TESTS)

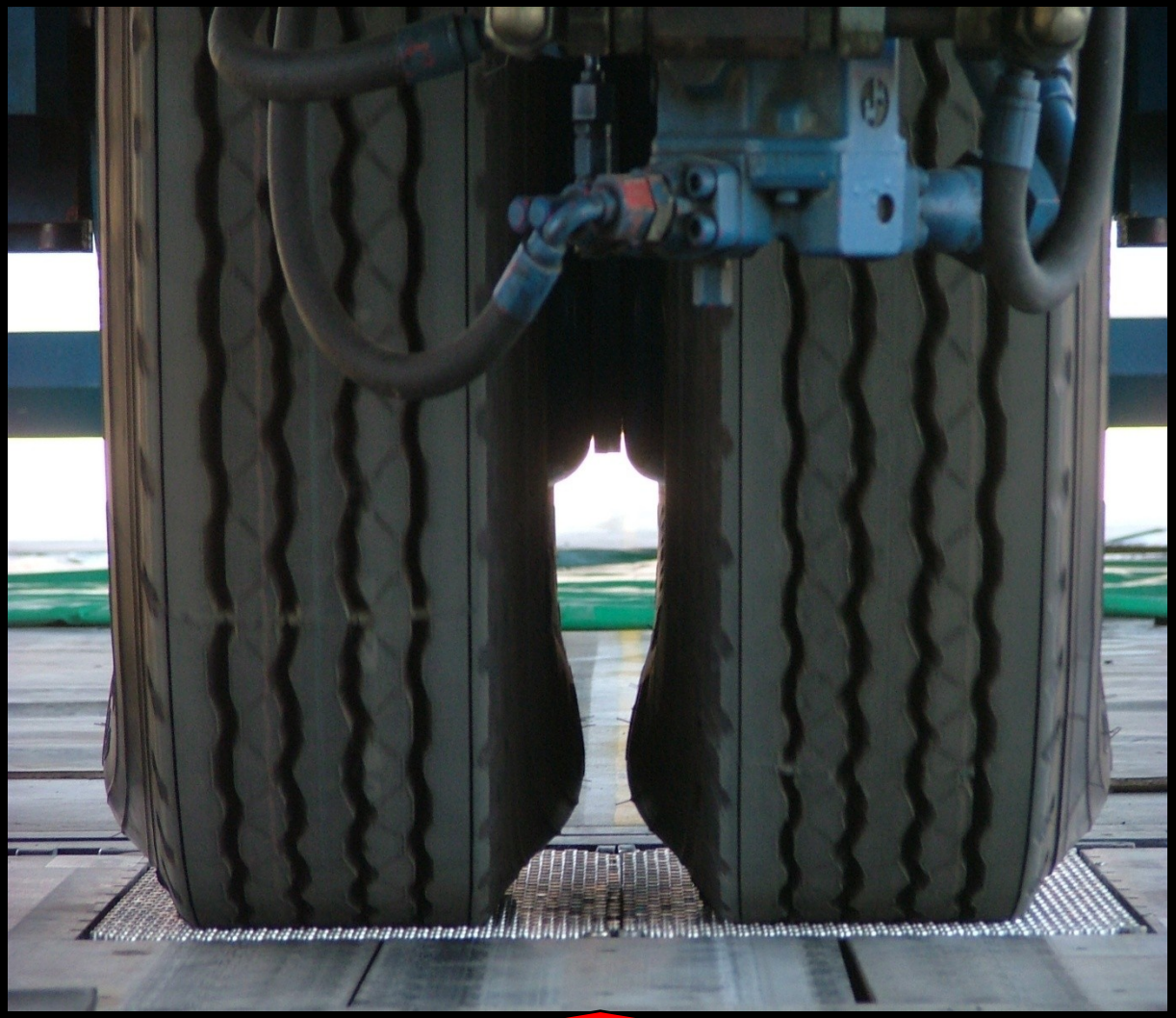
--STATIC TYRE PRINTS--

HVS DUAL TYRE FOOTPRINT @ 30 kN & 420 kPa, USING PAINT

HVS04+:

12.00-R22.5 TYRES -

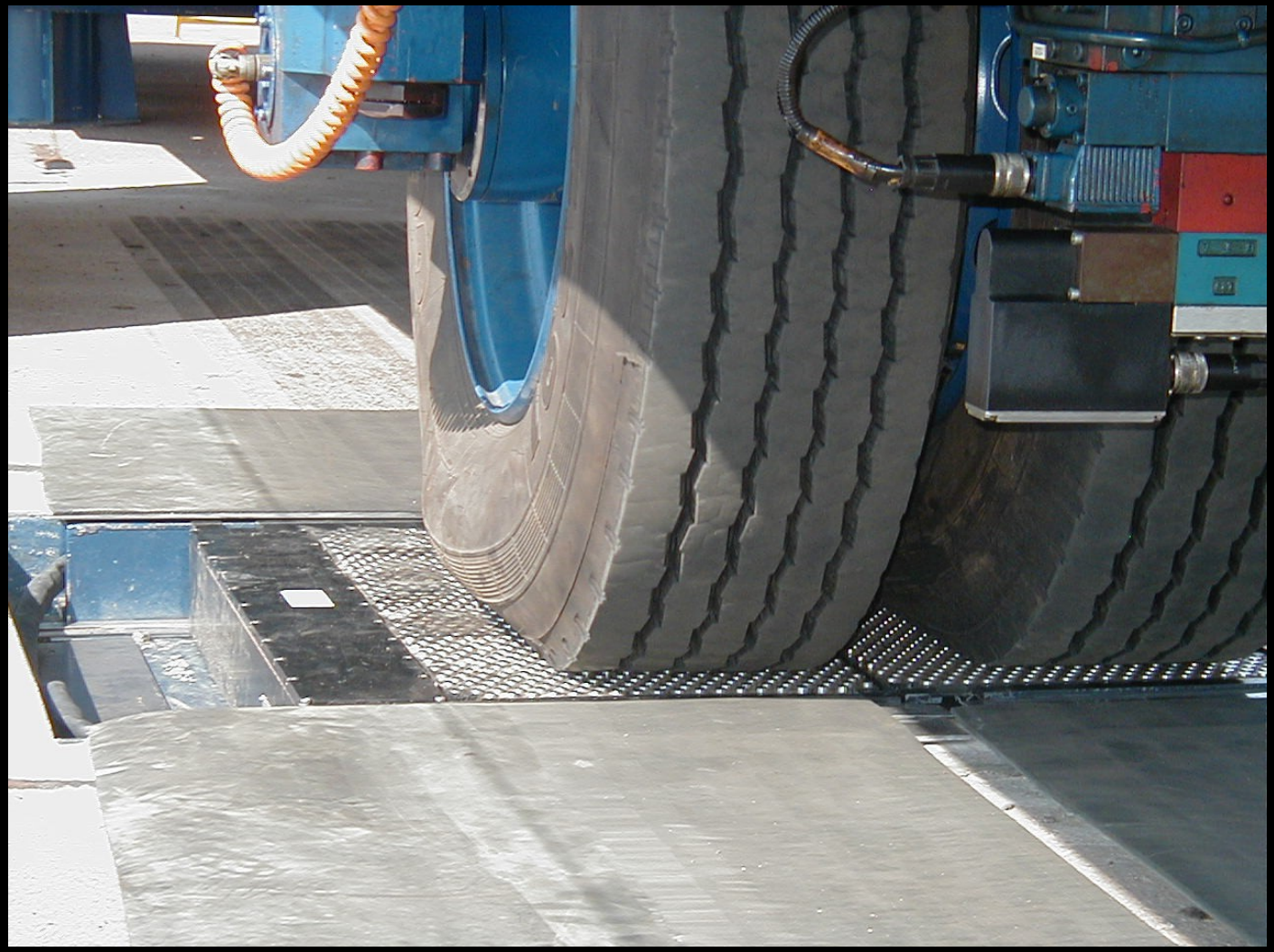
UNDER HIGH LOADING –



Note the “bulging” of both tyres

HVS DUAL TYRE FOOTPRINT @ 70 kN & 420 kPa, USING PAINT

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



THE HVS-SIM DATA……
Cross sections through tyre

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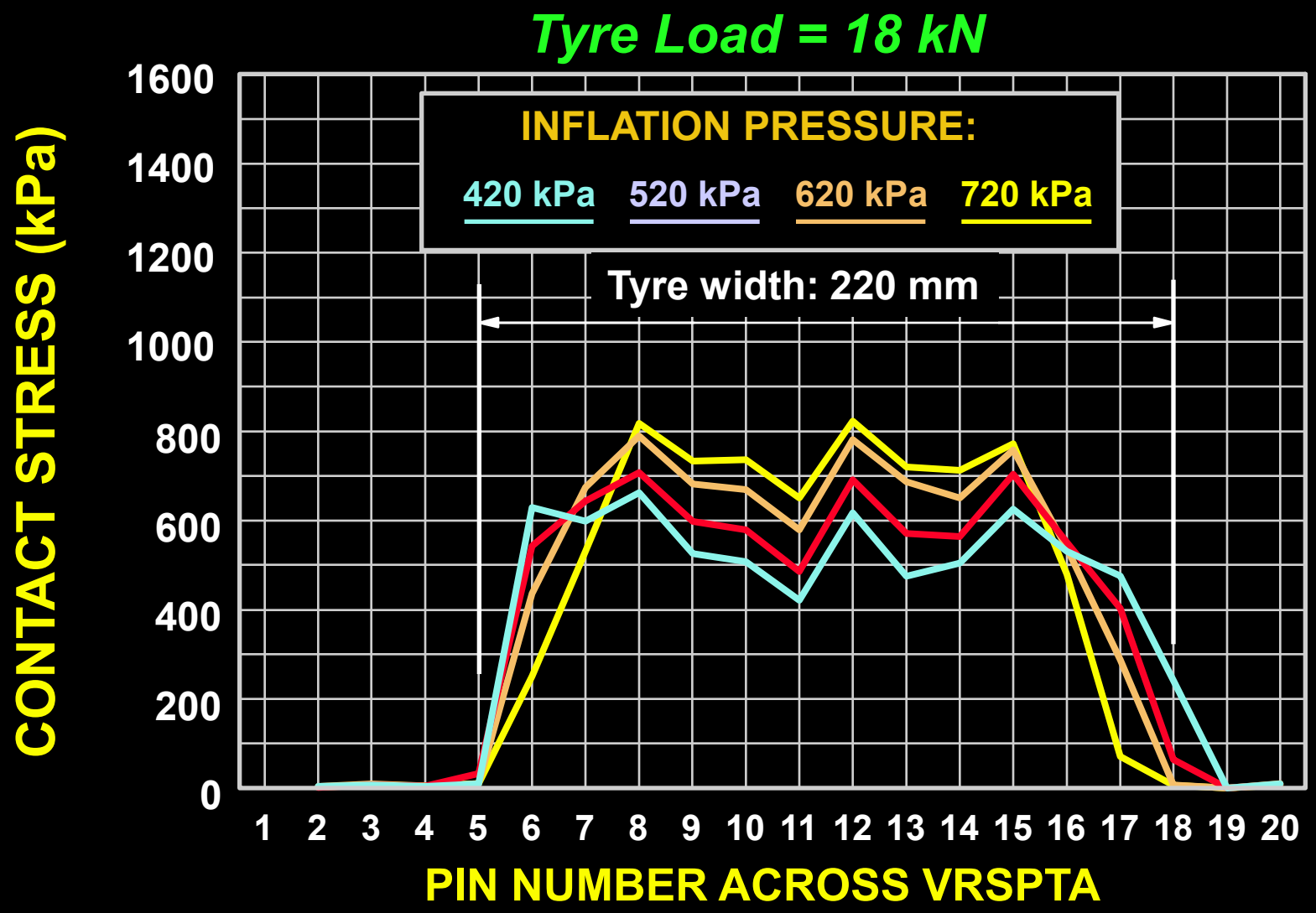


FIGURE 11

Maximum vertical stress at CONSTANT LOAD and various inflation pressures

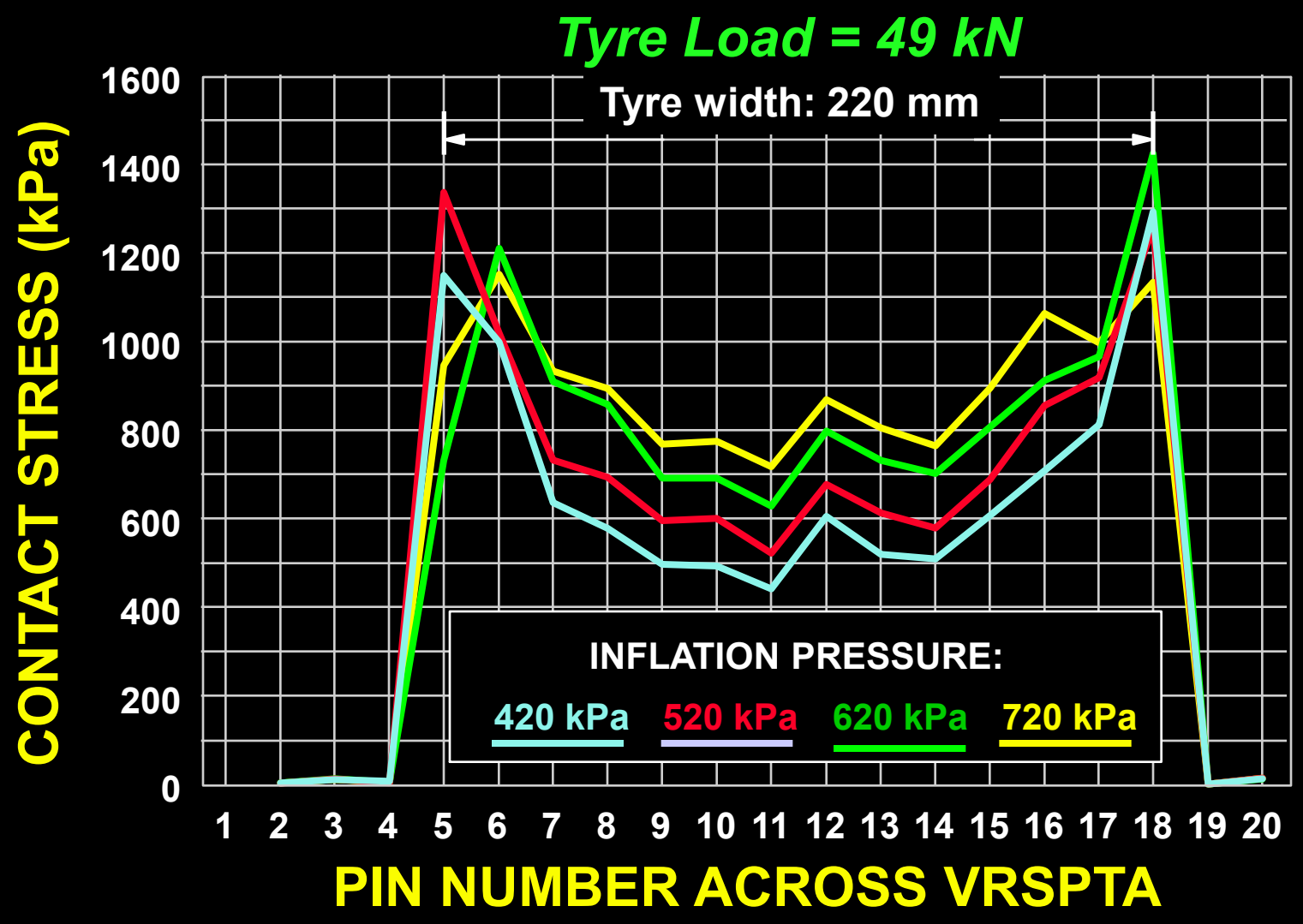


FIGURE 12

Maximum vertical stress at CONSTANT LOAD and various inflation pressures

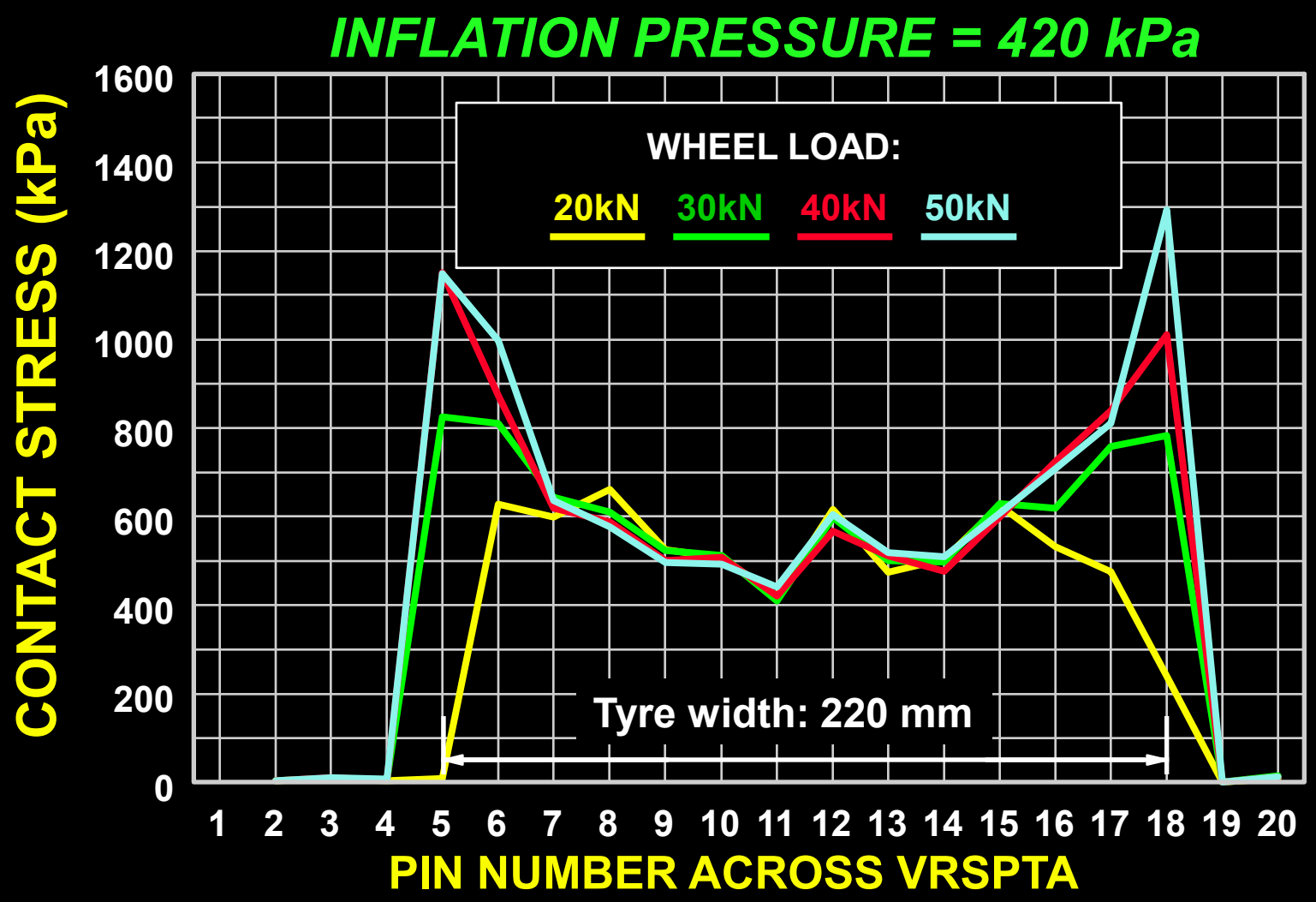


FIGURE 13

Maximum vertical stress at CONSTANT INFLATION PRESSURE at various loads

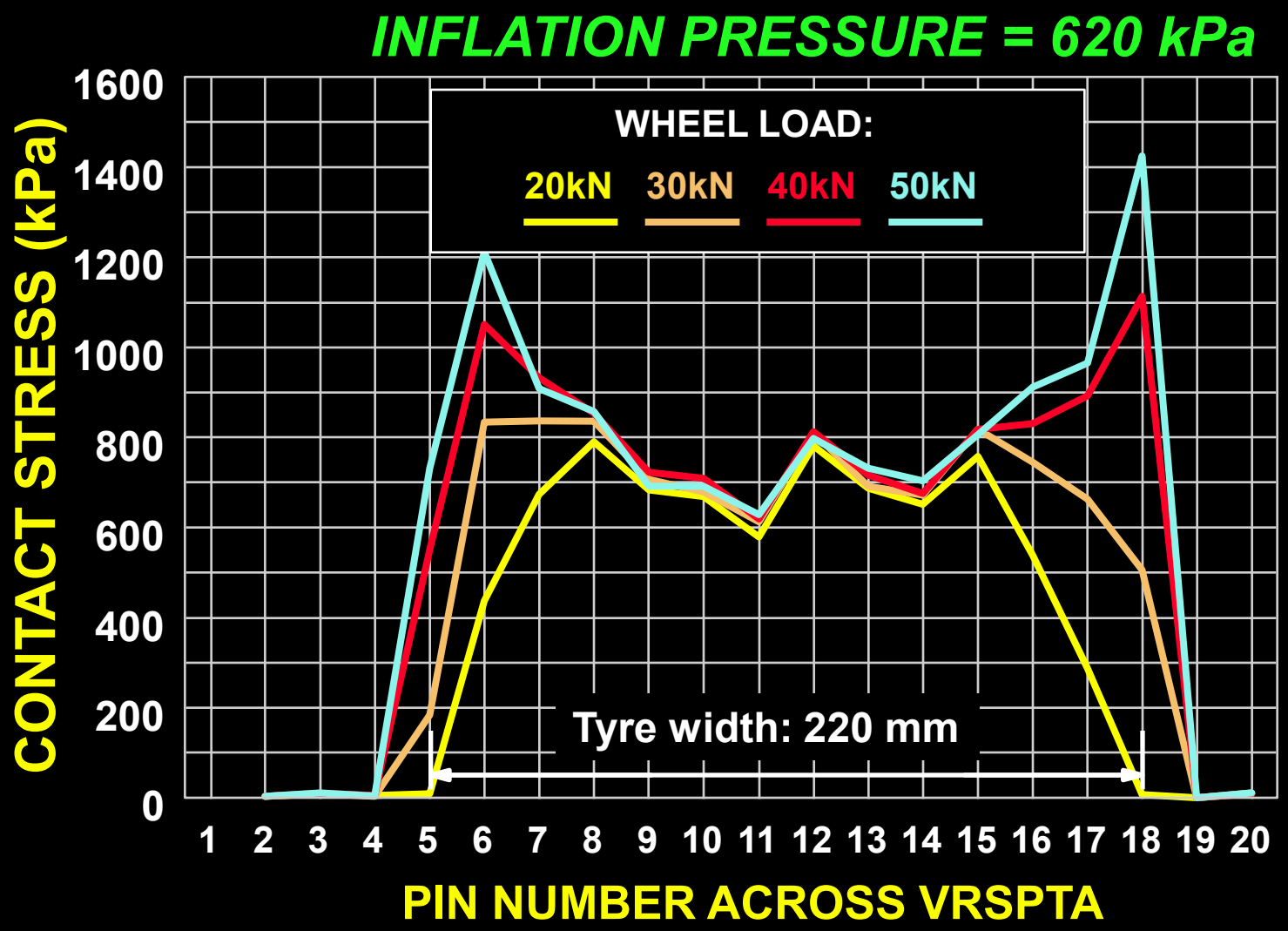
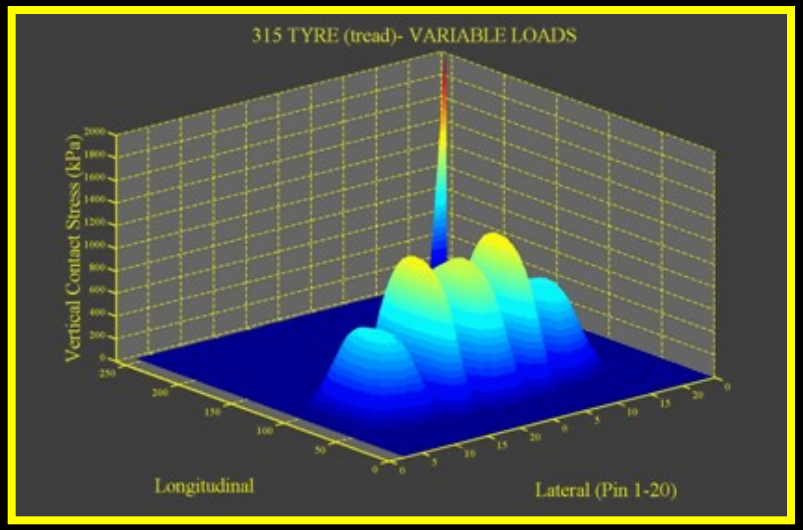
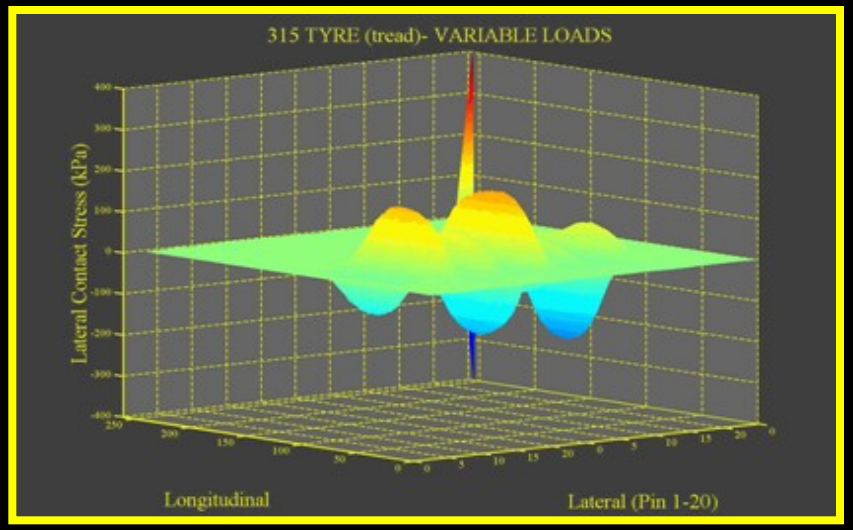


FIGURE 14

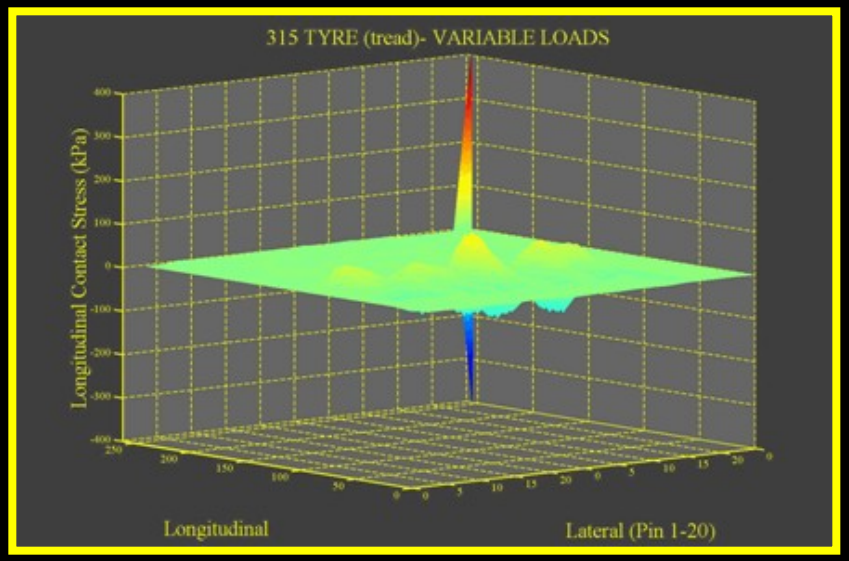
Maximum vertical stress at CONSTANT INFLATION PRESSURE and various loads

Typical SIM 3D Data Sets - Variable loading:

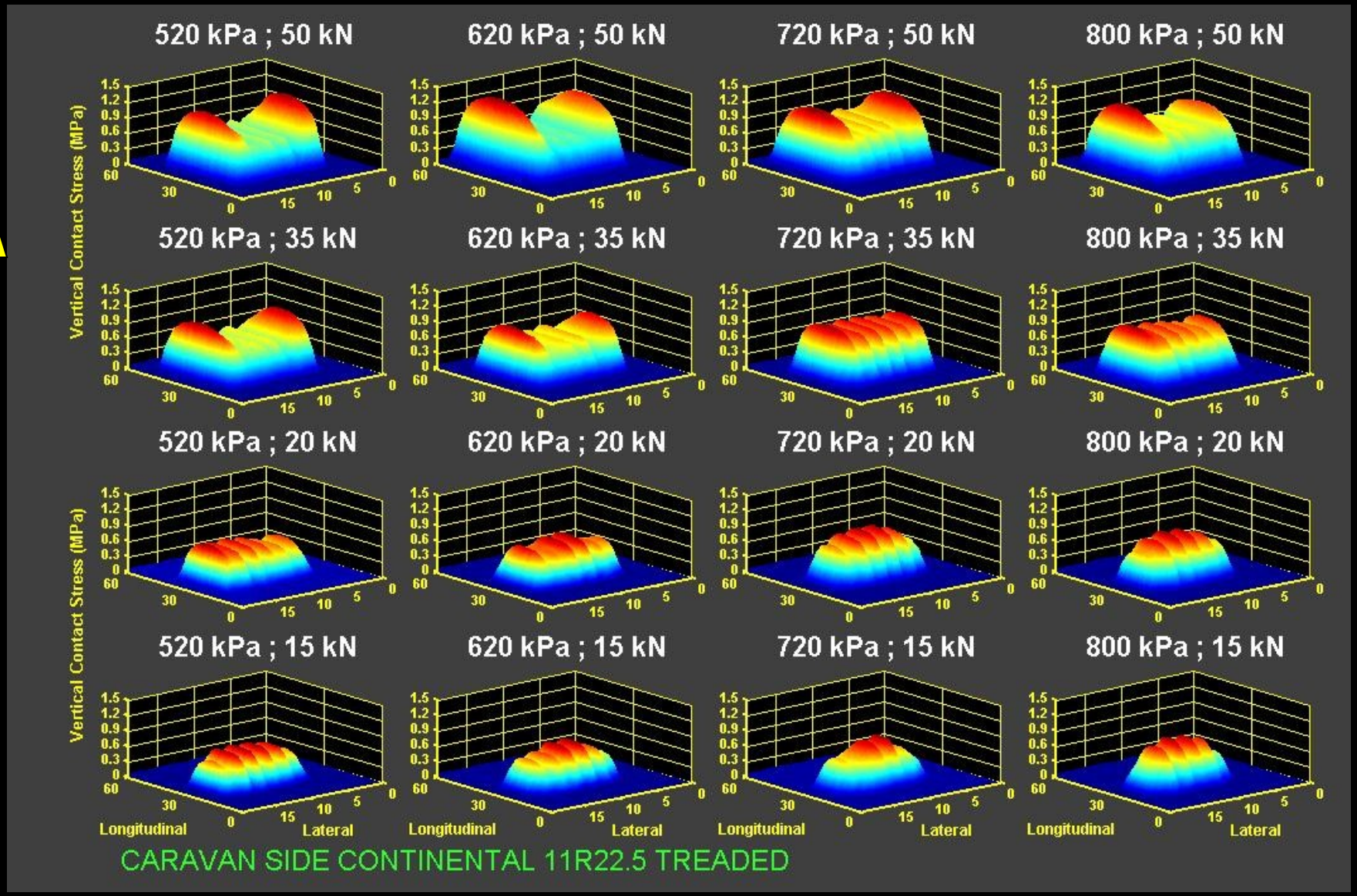




3D – Z,X,Y - Contact Stresses: Variable loads: 315/80 R22.5 Tire

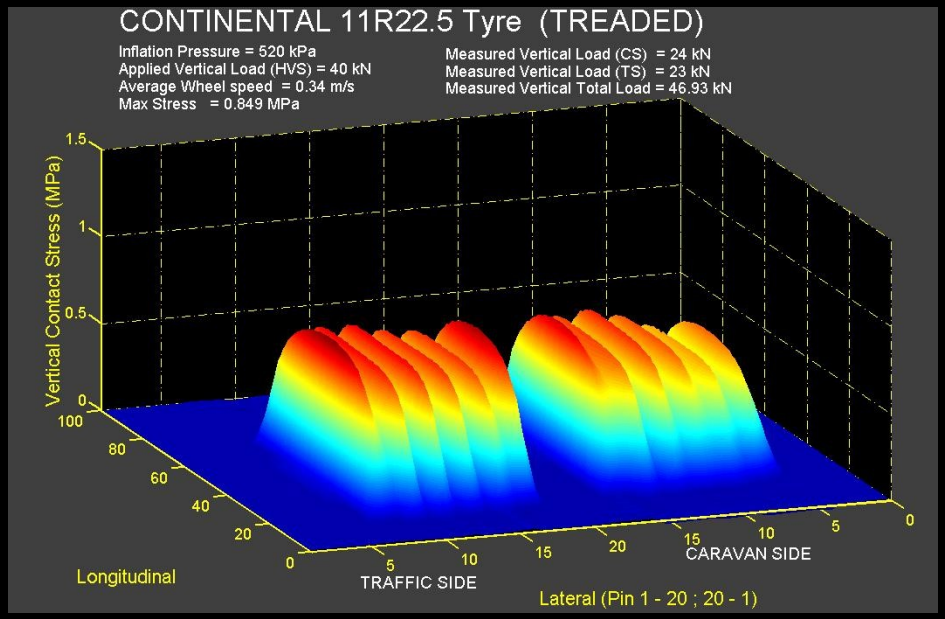


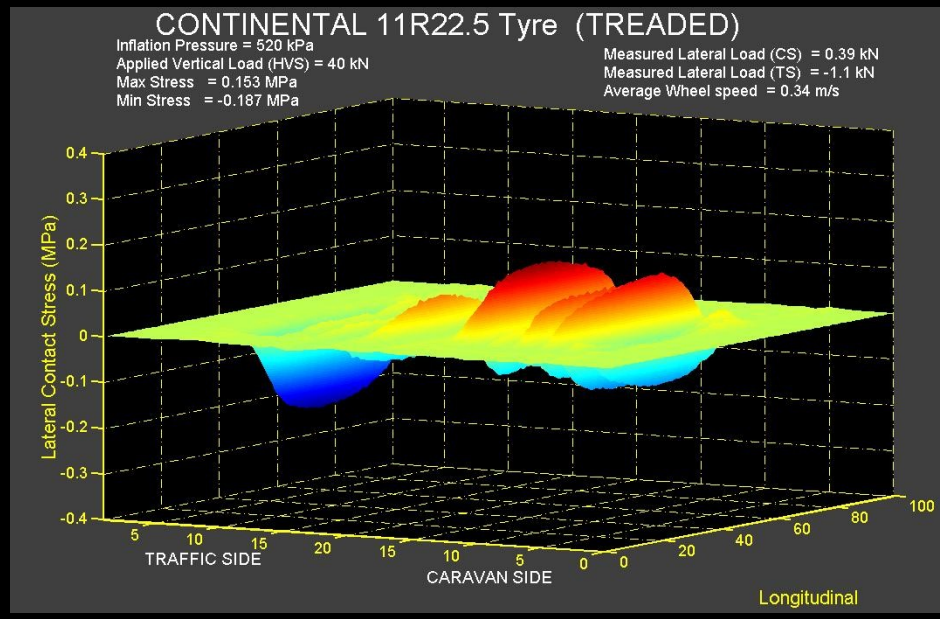
HVS 04 SIM MEASUREMENTS OF 11R22.5 TYRE

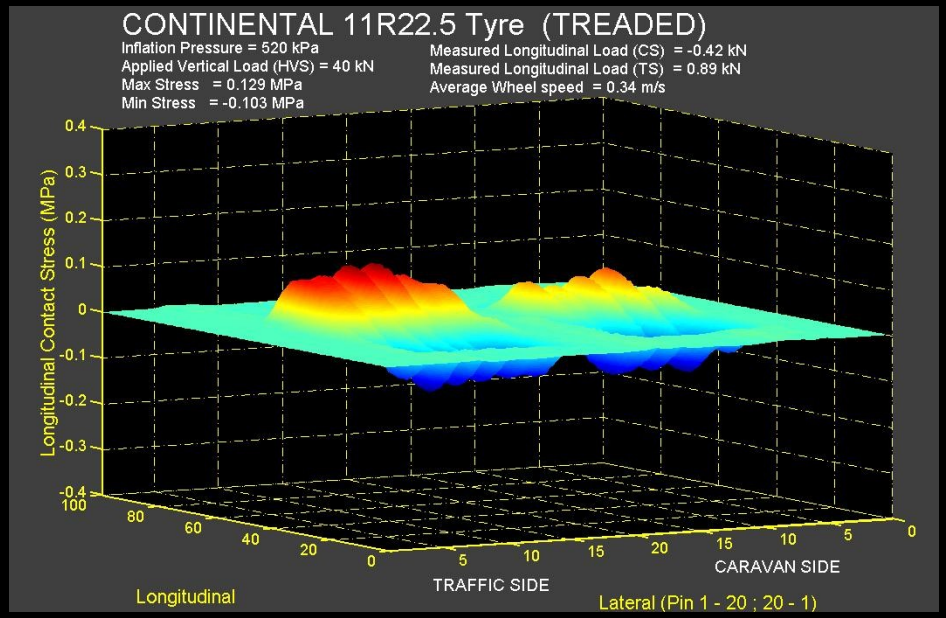


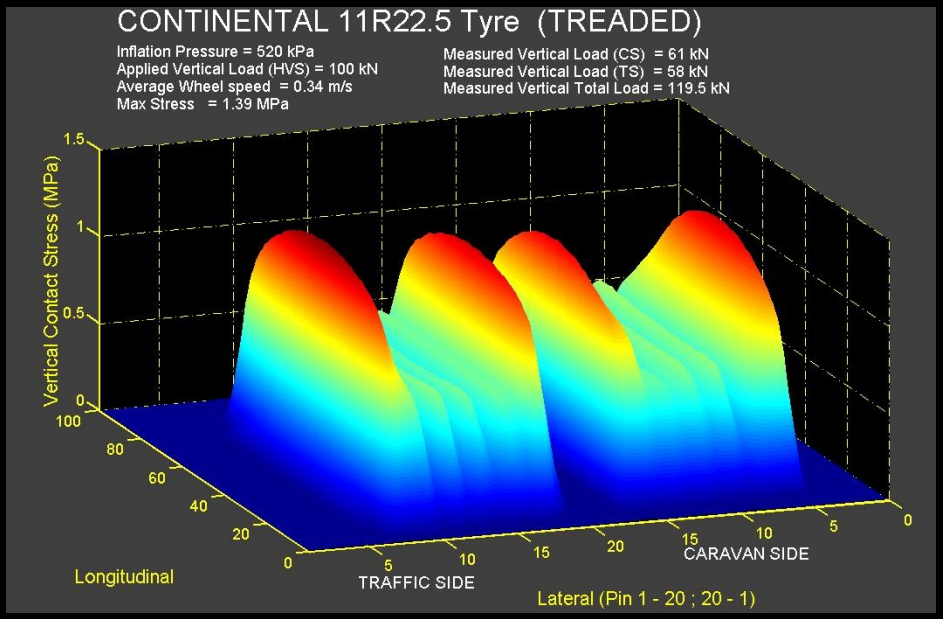
LOAD

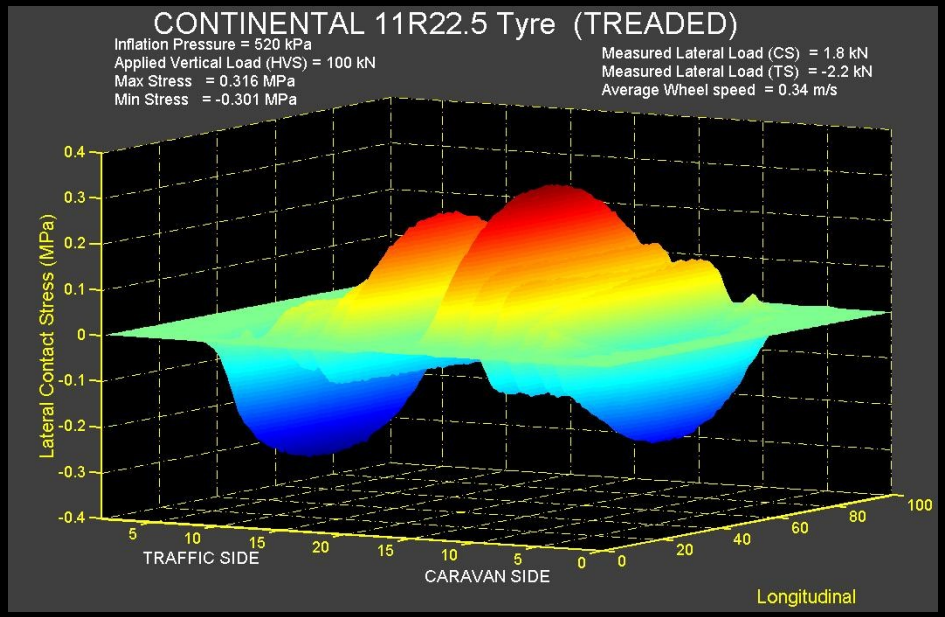
INFLATION PRESSURE

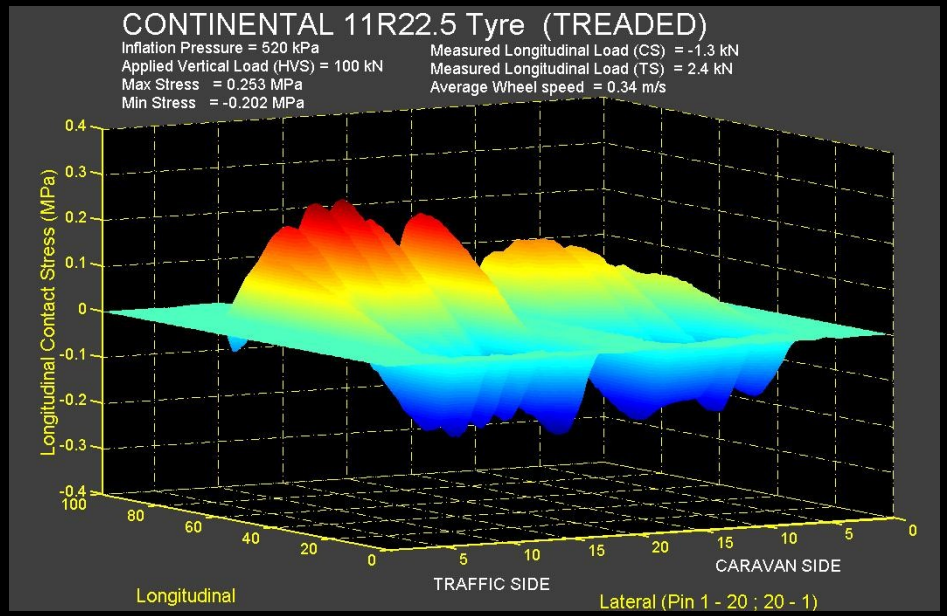

CONTINENTAL 11R22.5 Tyre (TREADED)
Inflation Pressure = 520 kPa
Applied Vertical Load (HVS) = 40 kN
Average Wheel speed = 0.34 m/s
Max Stress = 0.849 MPa
Measured Vertical Load (CS) = 24 kN
Measured Vertical Load (TS) = 23 kN
Measured Vertical Total Load = 46.93 kN
Vertical Contact Stress (MPa)
1.5
1
0.5
0
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)


CONTINENTAL 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
Lateral Contact Stress (MPa)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
5
10
15
20
TRAFFIC SIDE
15
10
5
0
CARAVAN SIDE
0
20
40
60
80
100
Longitudinal

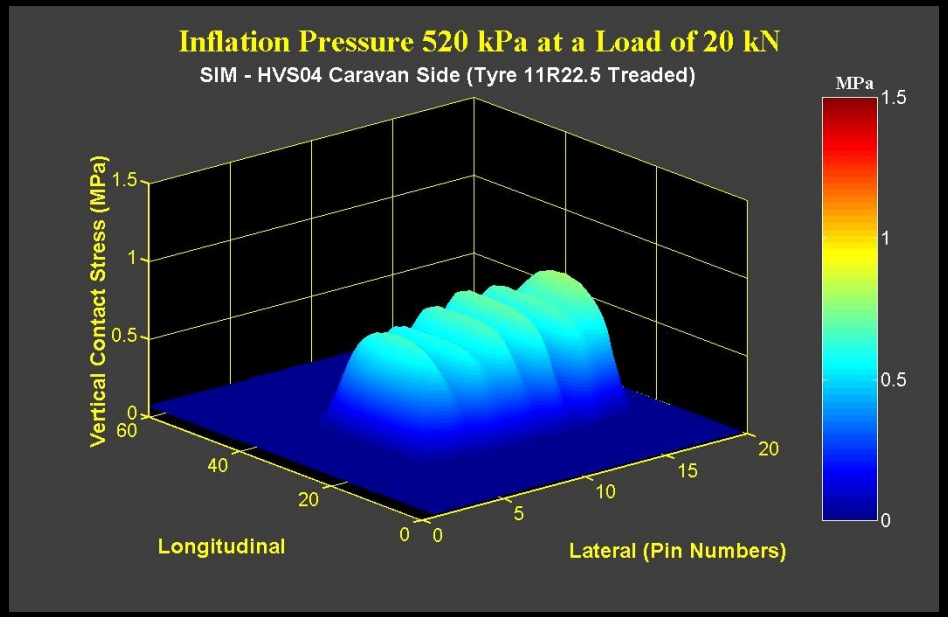

CONTINENTAL 11R22.5 Tyre (TREADED)
Inflation Pressure = 520 kPa
Applied Vertical Load (HVS) = 40 kN
Max Stress = 0.129 MPa
Min Stress = -0.103 MPa
Measured Longitudinal Load (CS) = -0.42 kN
Measured Longitudinal Load (TS) = 0.89 kN
Average Wheel speed = 0.34 m/s
Longitudinal Contact Stress (MPa)
0.4
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)

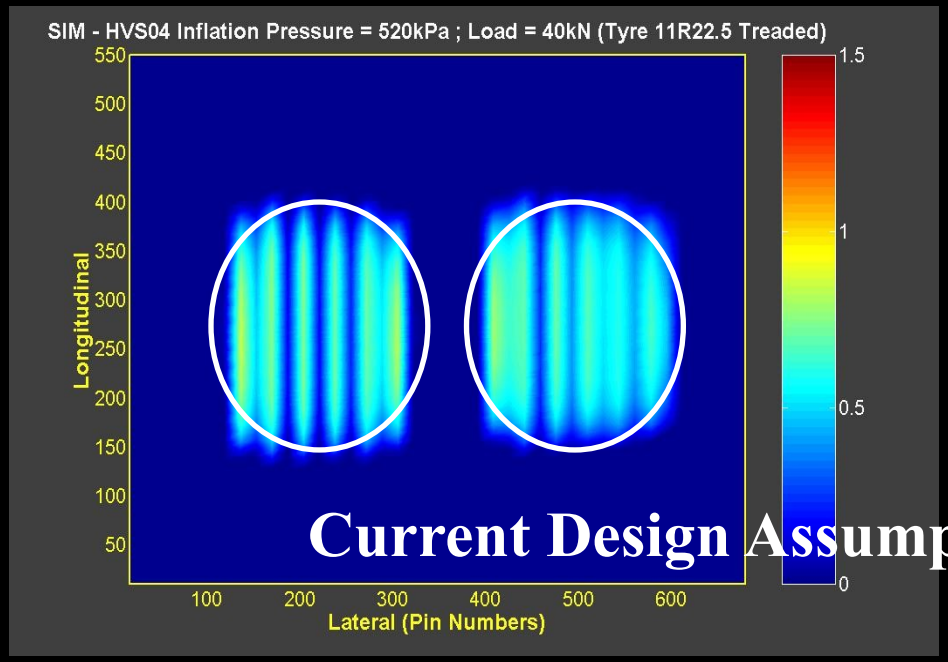

CONTINENTAL 11R22.5 Tyre (TREADED)
Inflation Pressure = 520 kPa
Applied Vertical Load (HVS) = 100 kN
Average Wheel speed = 0.34 m/s
Max Stress = 1.39 MPa
Measured Vertical Load (CS) = 61 kN
Measured Vertical Load (TS) = 58 kN
Measured Vertical Total Load = 119.5 kN
Vertical Contact Stress (MPa)
Longitudinal
TRAFFIC SIDE
CARAVAN SIDE
Lateral (Pin 1 - 20 ; 20 - 1)


CONTINENTAL 11R22.5 Tyre (TREADED)
Inflation Pressure = 520 kPa
Applied Vertical Load (HVS) = 100 kN
Max Stress = 0.316 MPa
Min Stress = -0.301 MPa
Measured Lateral Load (CS) = 1.8 kN
Measured Lateral Load (TS) = -2.2 kN
Average Wheel speed = 0.34 m/s
Lateral Contact Stress (MPa)
TRAFFIC SIDE
CARAVAN SIDE
Longitudinal

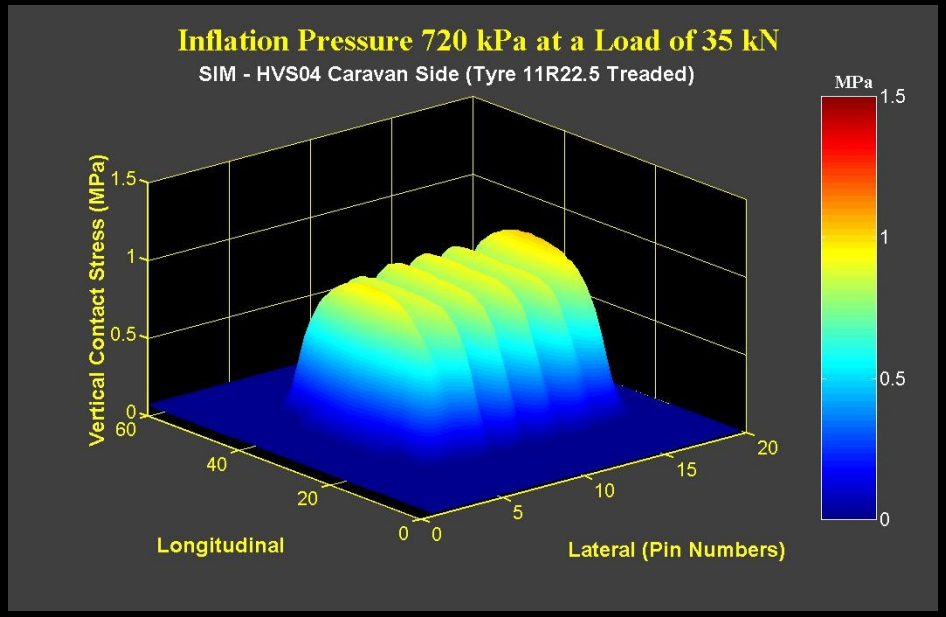

CONTINENTAL 11R22.5 Tyre (TREADED)
Inflation Pressure = 520 kPa
Applied Vertical Load (HVS) = 100 kN
Max Stress = 0.253 MPa
Min Stress = -0.202 MPa
Measured Longitudinal Load (CS) = -1.3 kN
Measured Longitudinal Load (TS) = 2.4 kN
Average Wheel speed = 0.34 m/s
Longitudinal Contact Stress (MPa)
Longitudinal
TRAFFIC SIDE
CARAVAN SIDE
Lateral (Pin 1 - 20 ; 20 - 1)

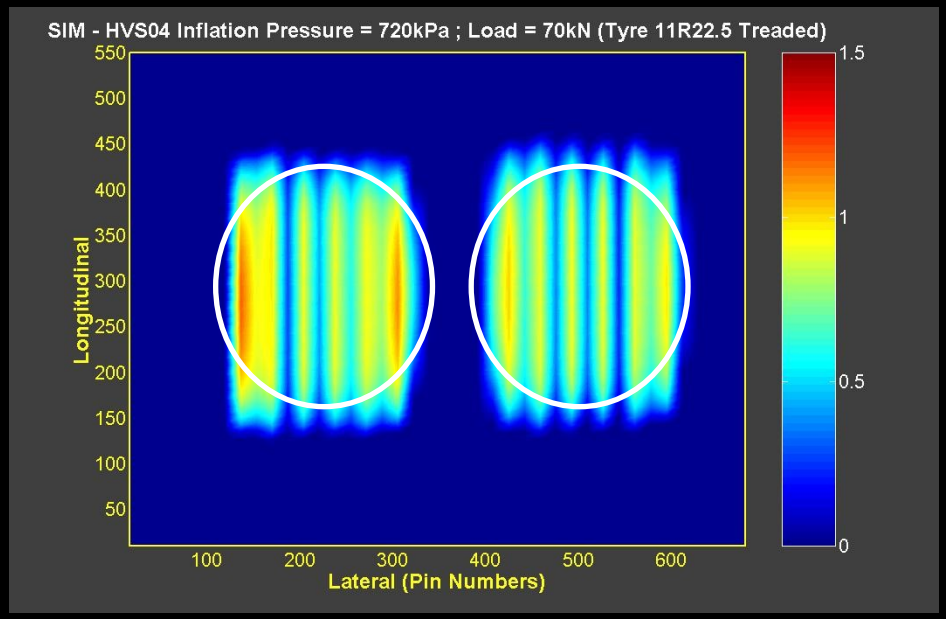
Footprint of 20 kN, 520 kPa tyre i.e. (80 kN Axle)



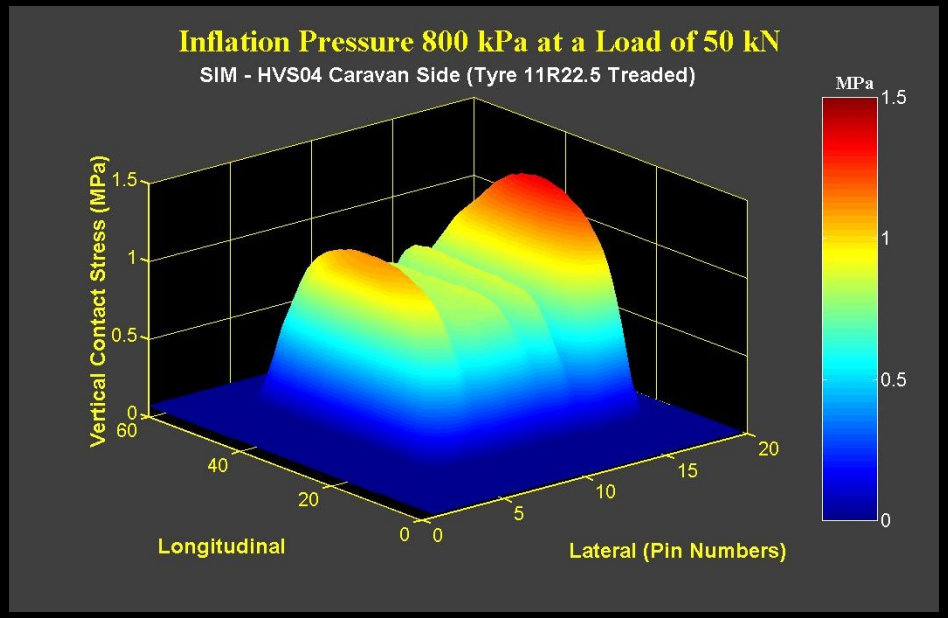


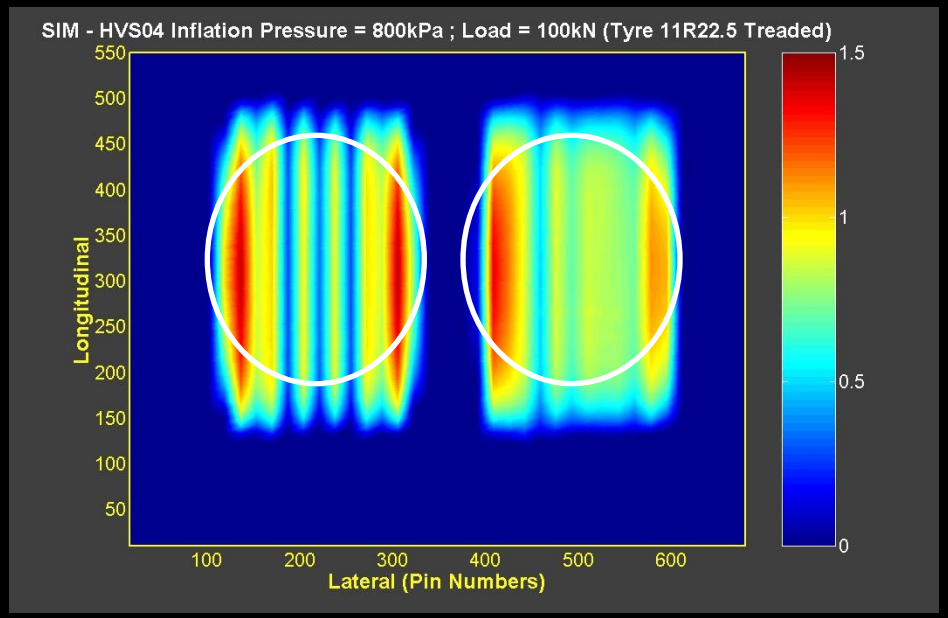
Footprint of 35 kN, 720 kPa tyre i.e. (140 kN Axle)



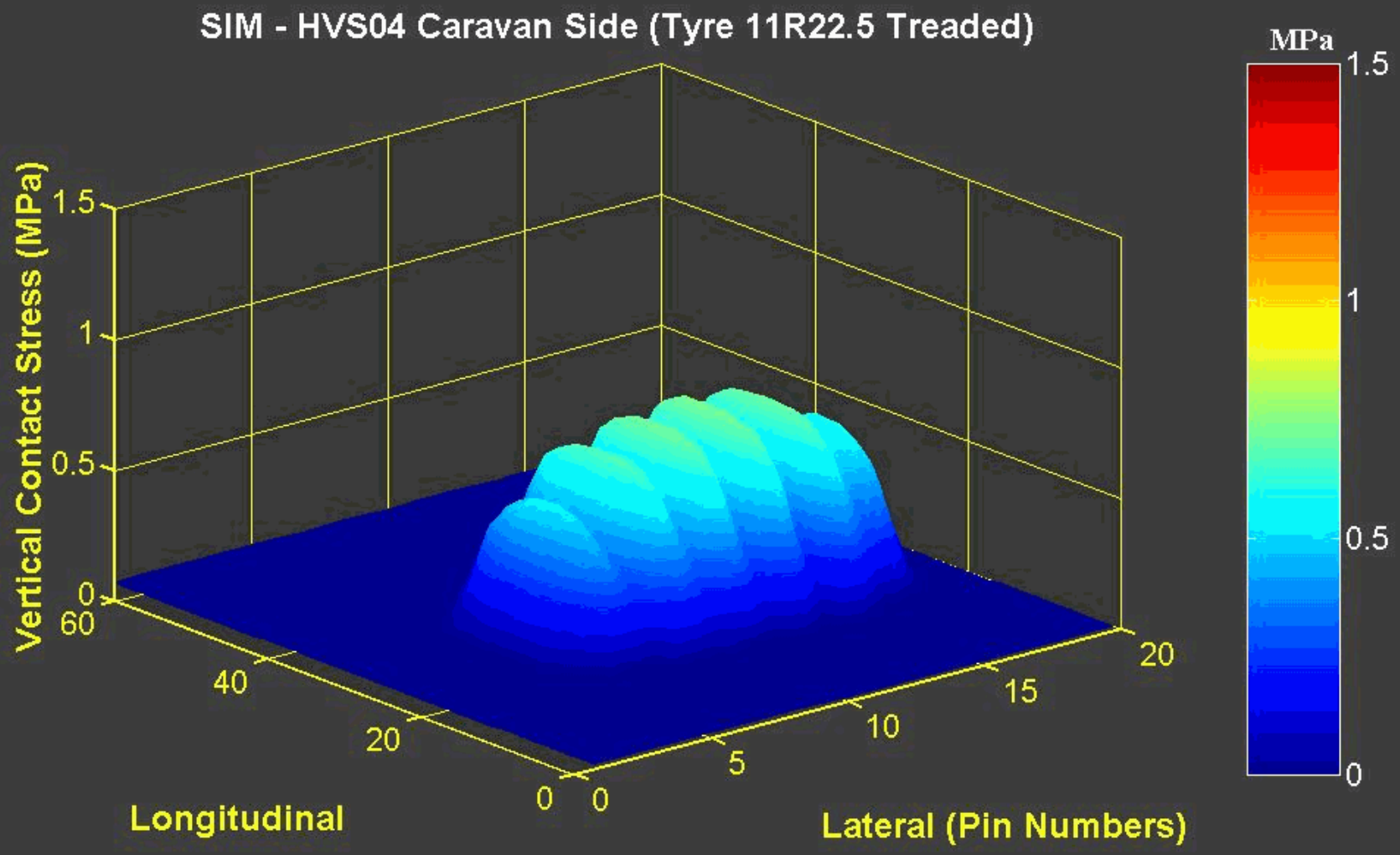


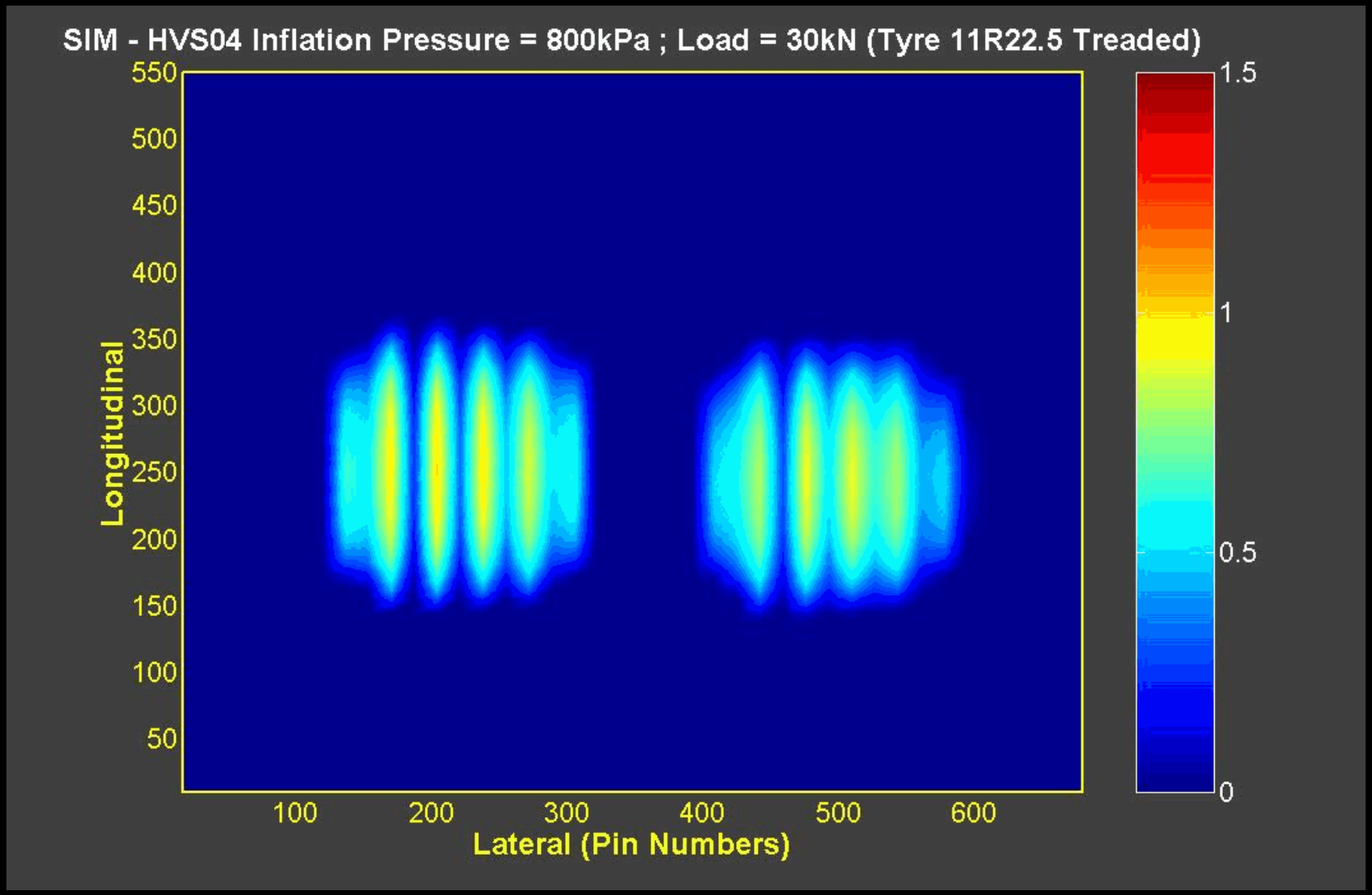
Footprint of 50 kN, 800 kPa tyre i.e. (200 kN Axle)





Inflation Pressure 520 kPa at Variable Loads of 15 kN - 50 kN




SIM - HVS04 Inflation Pressure = 800kPa ; Load = 30kN (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

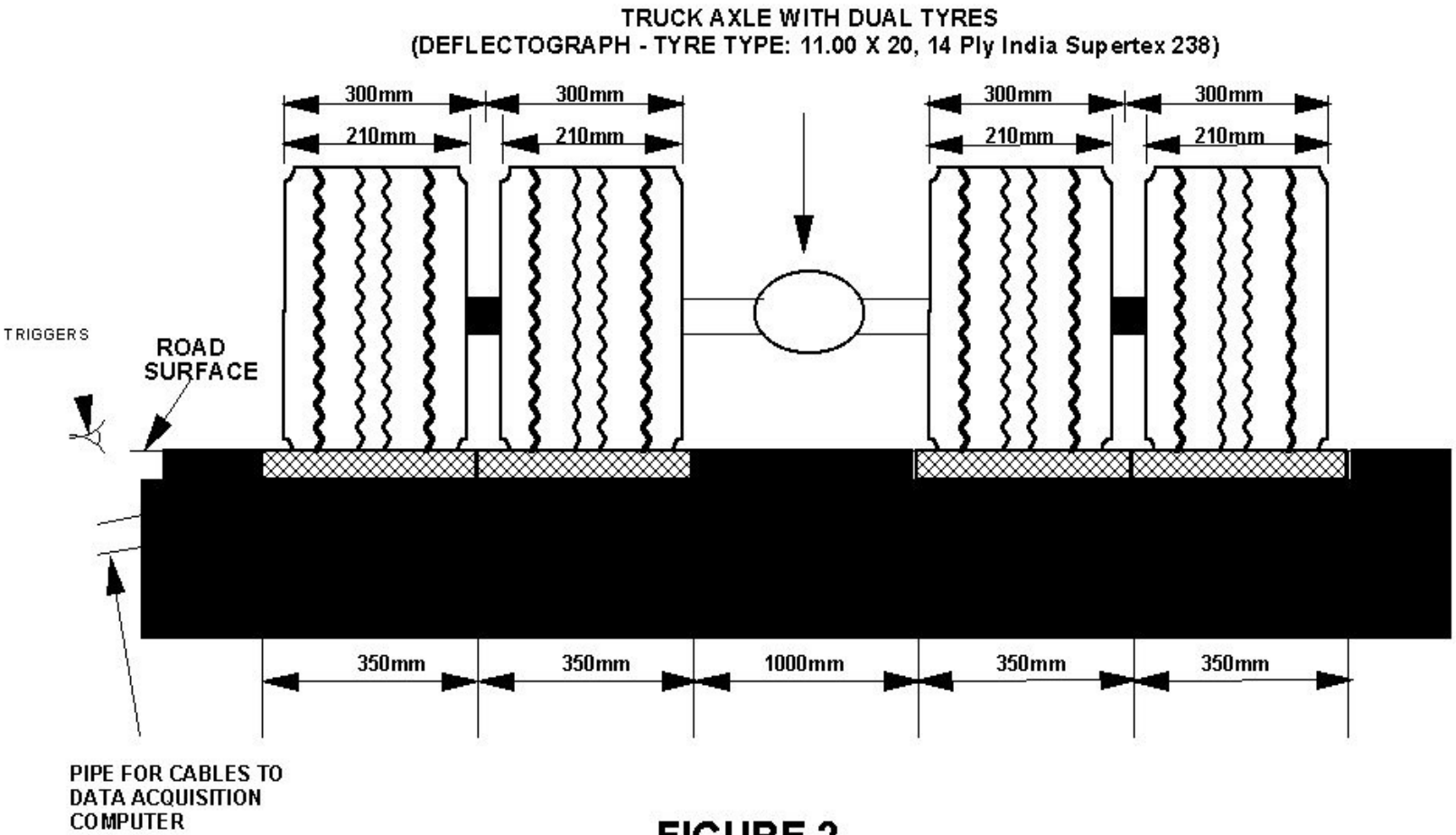


FIGURE 2

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

SIM3.DRW

MANTSOLE TRAFFIC CONTROLL CENTRE (TCC) ON NATIONAL ROAD NR 1 (N1)

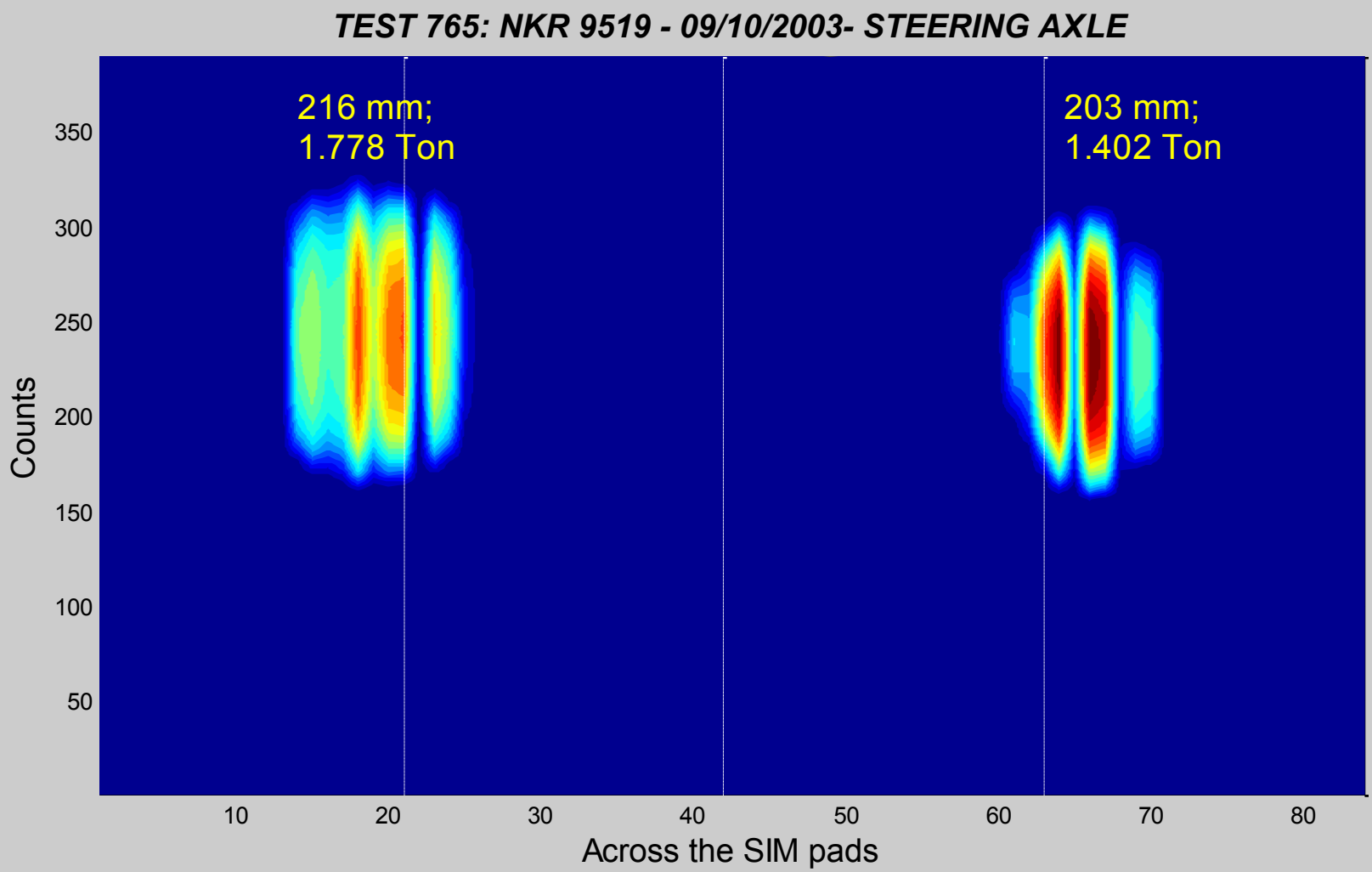
STOP
50 m
12 11'97

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

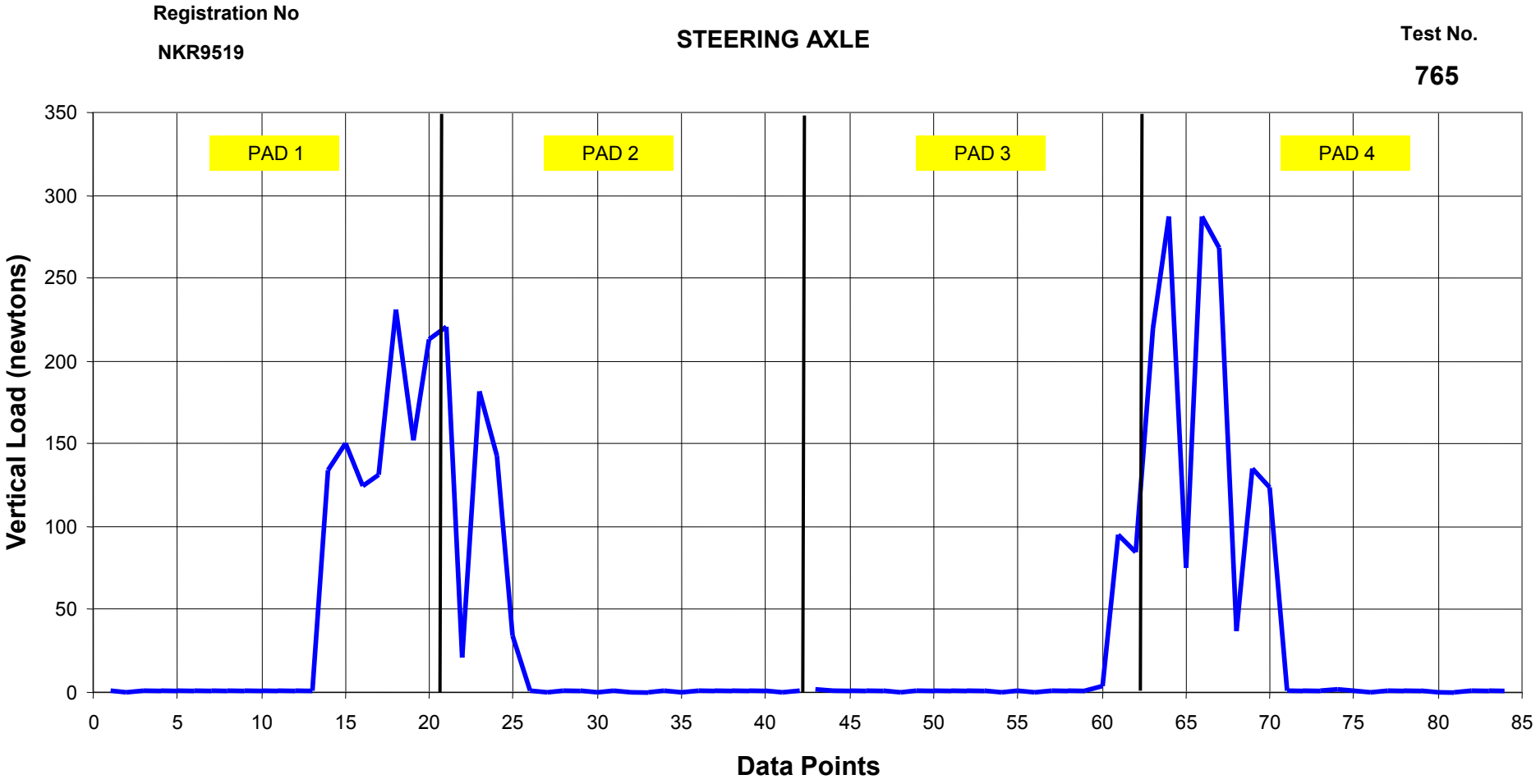
In operation: Quad (full) SIM pad configuration at a typical weighbridge site on National Road 3 (N3), near Heidelberg in Gauteng.

In operation: SIM N3-TCC

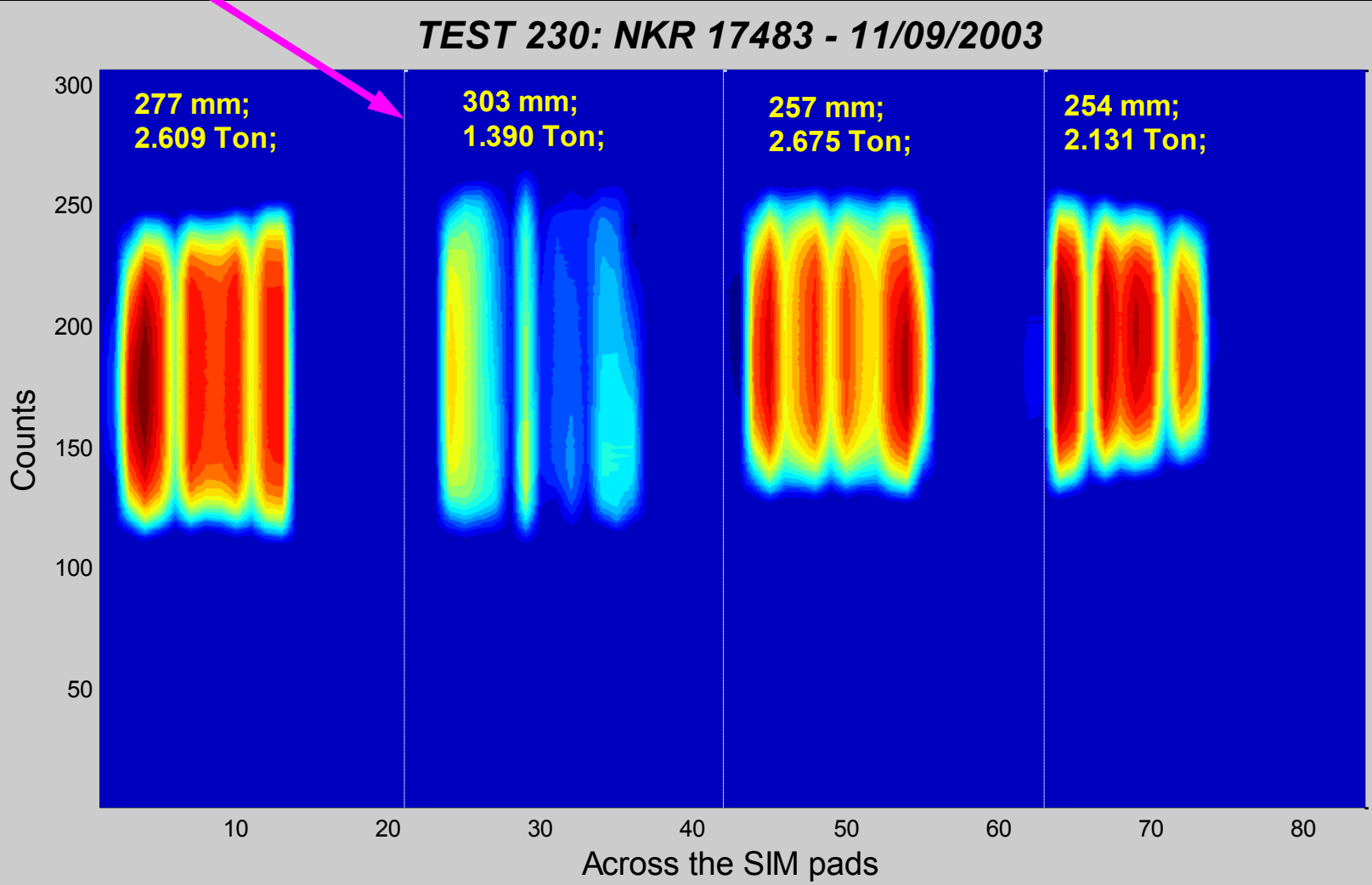
STEERING AXLE



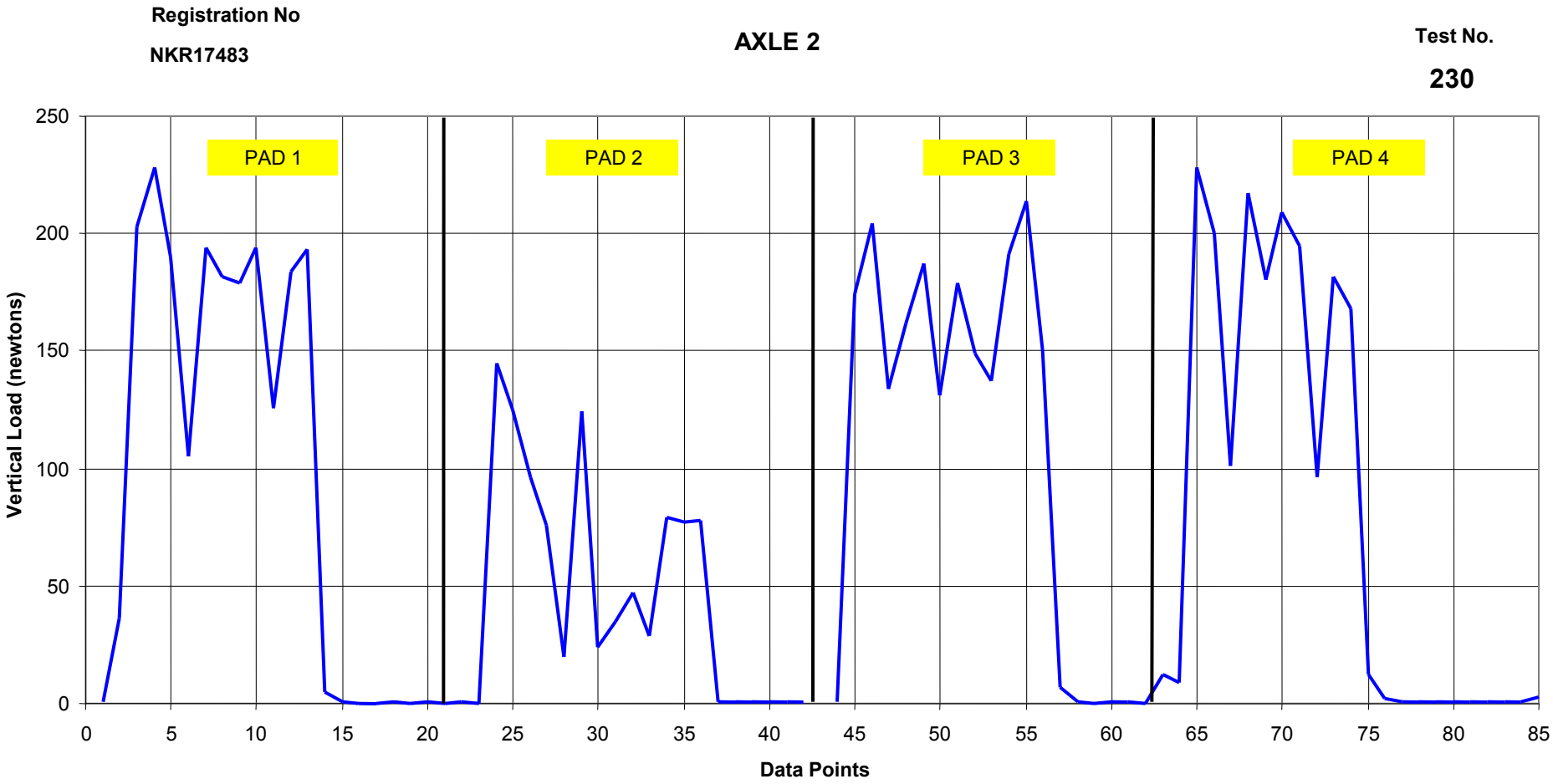
STEERING AXLE



REAR AXLE – UNEQUAL LOADING



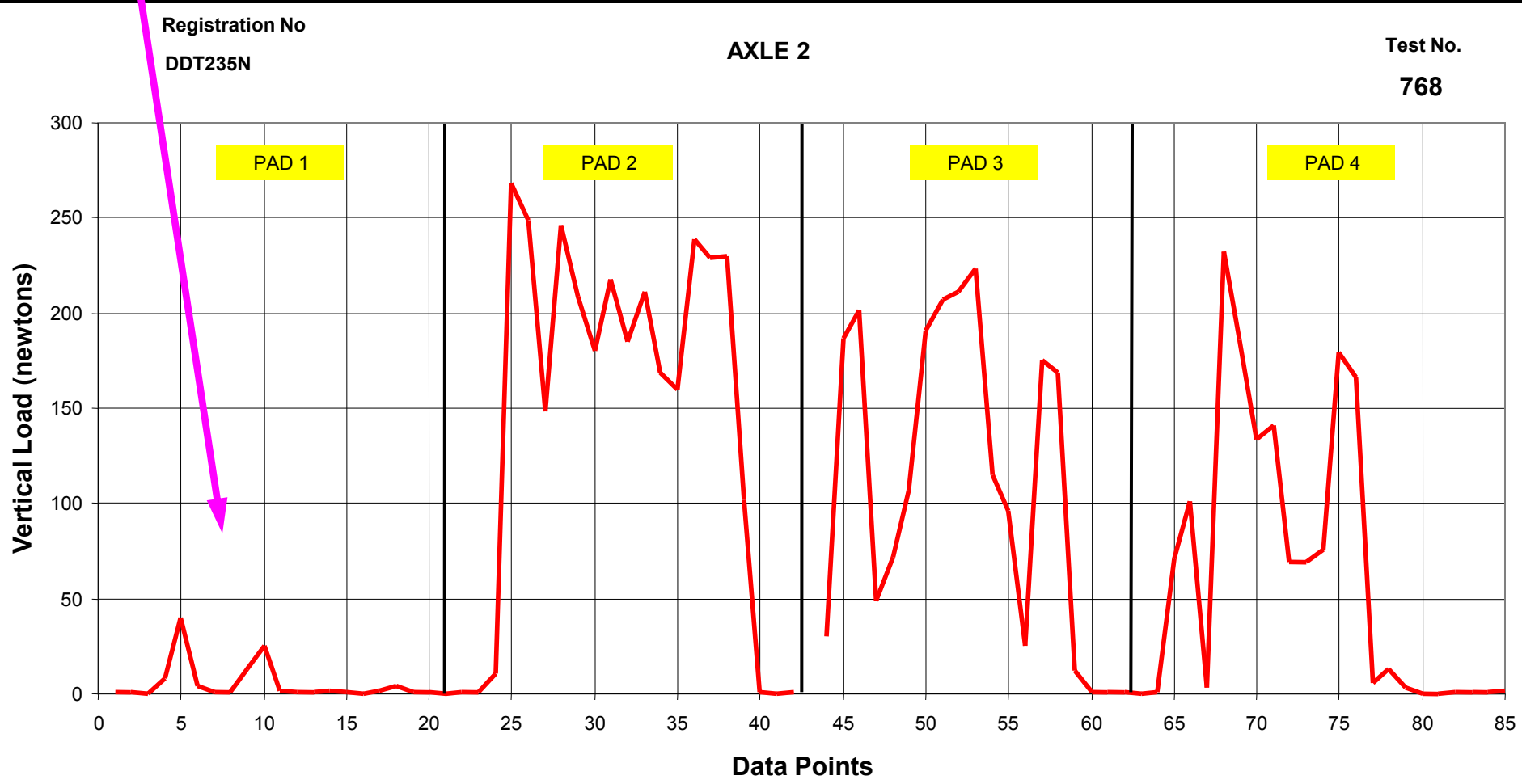
REAR AXLE – UNEQUAL LOADING



Tyre barely in contact with surface

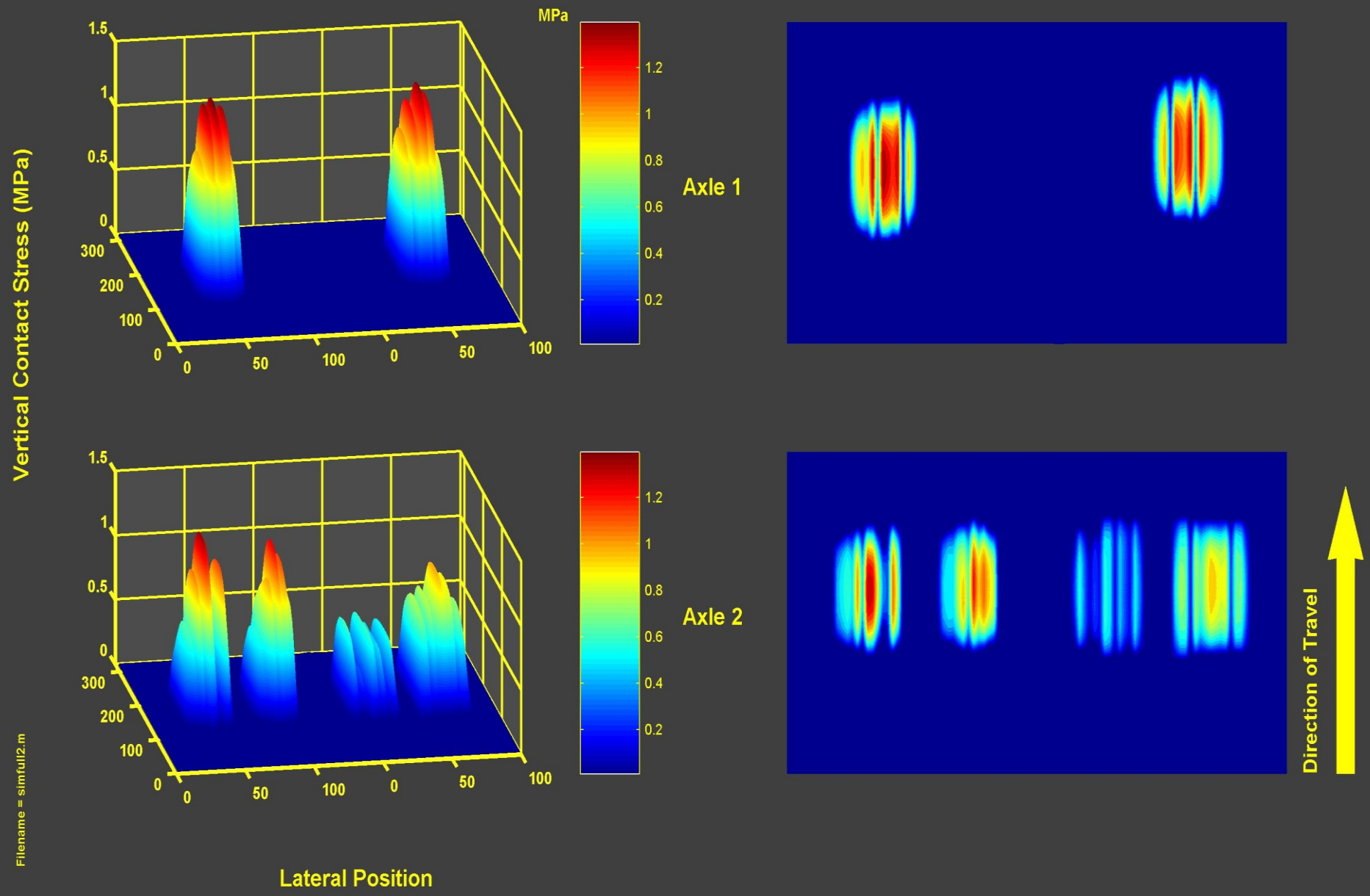
MAXIMUM VERTICAL STRESS

TYRE barely in contact with surface



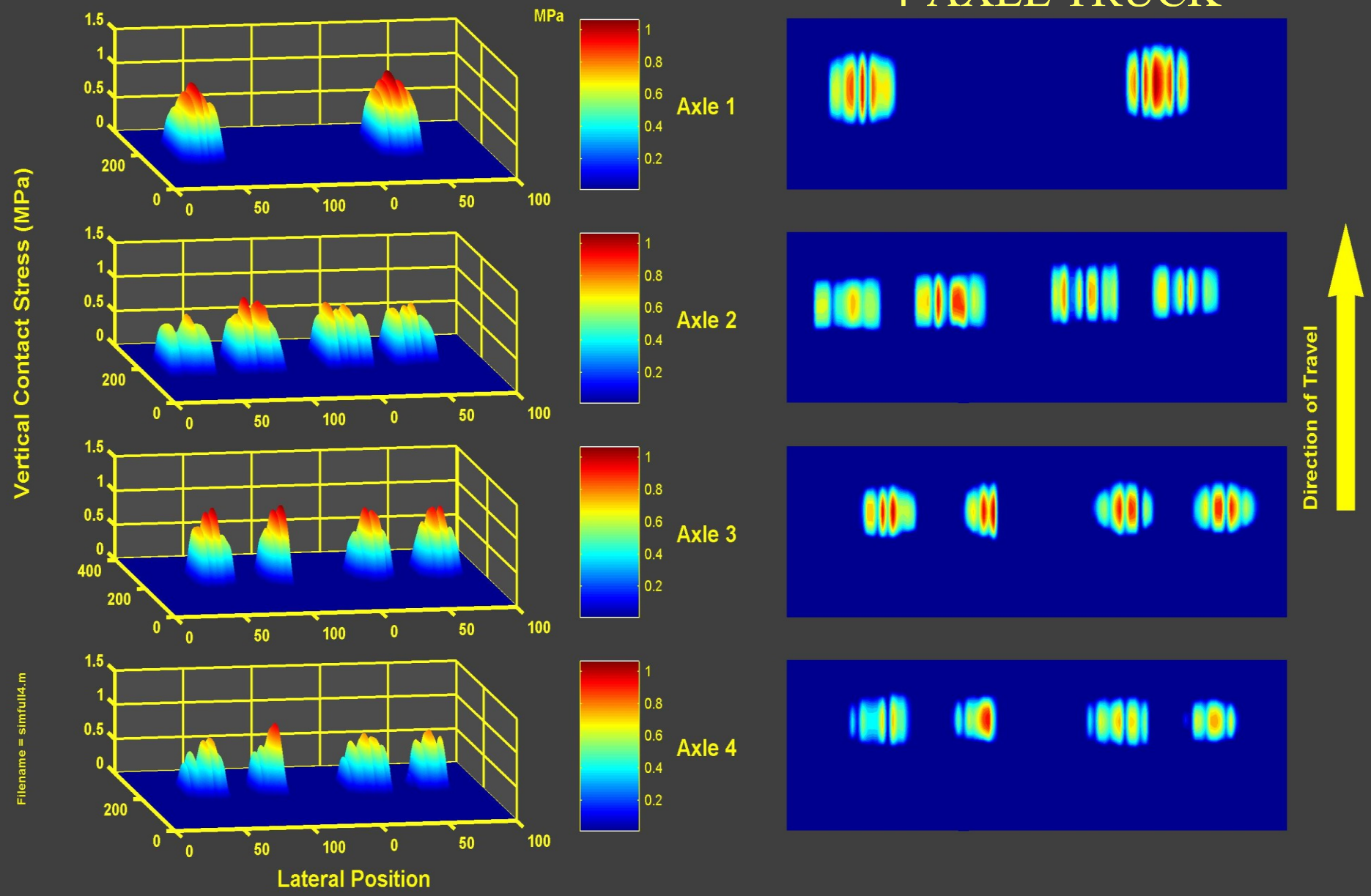
Test H451 done at Heidelberg : Date 04/09/2003

2-AXLE TRUCK

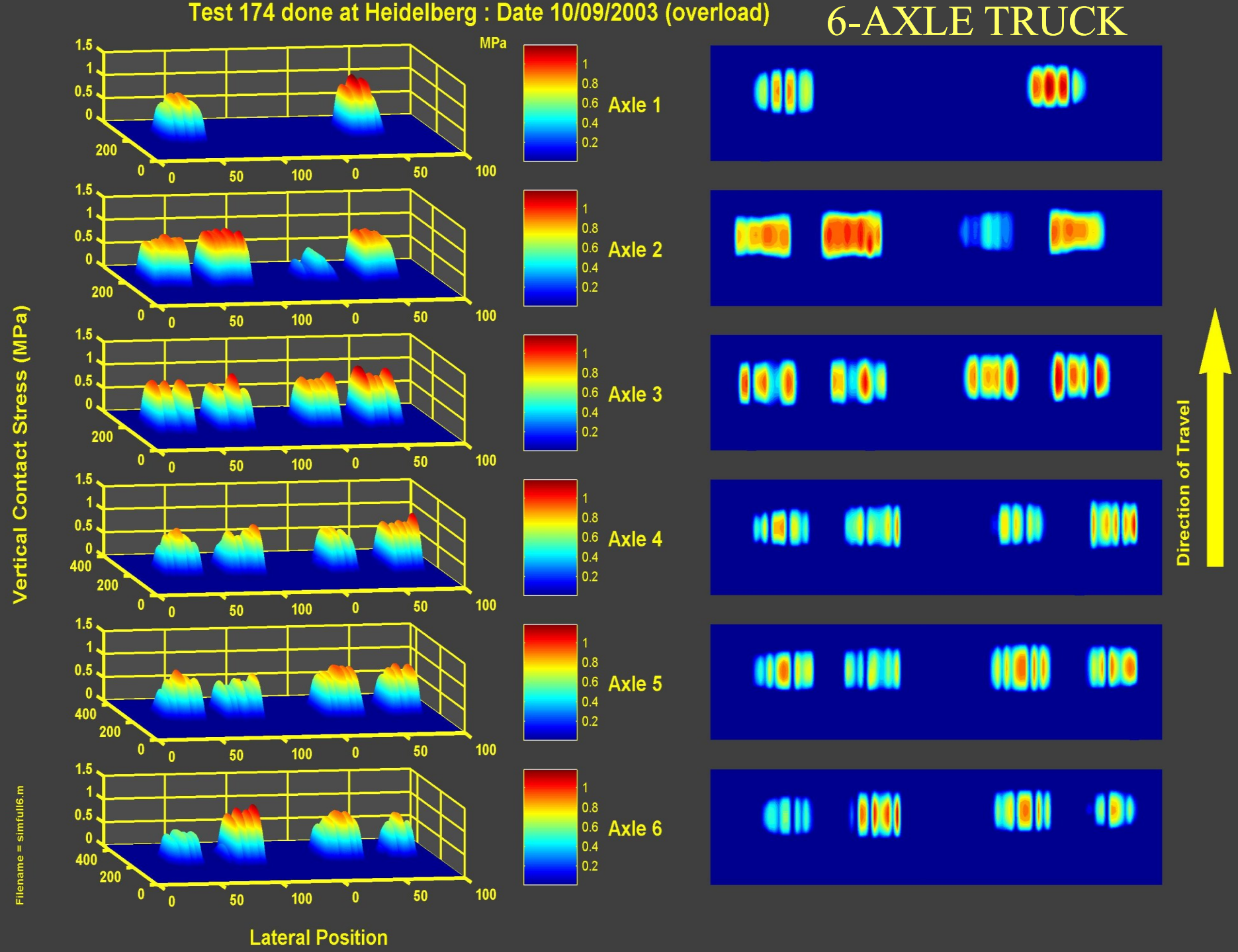


Test H1070 done at Heidelberg : Date 10/09/2003

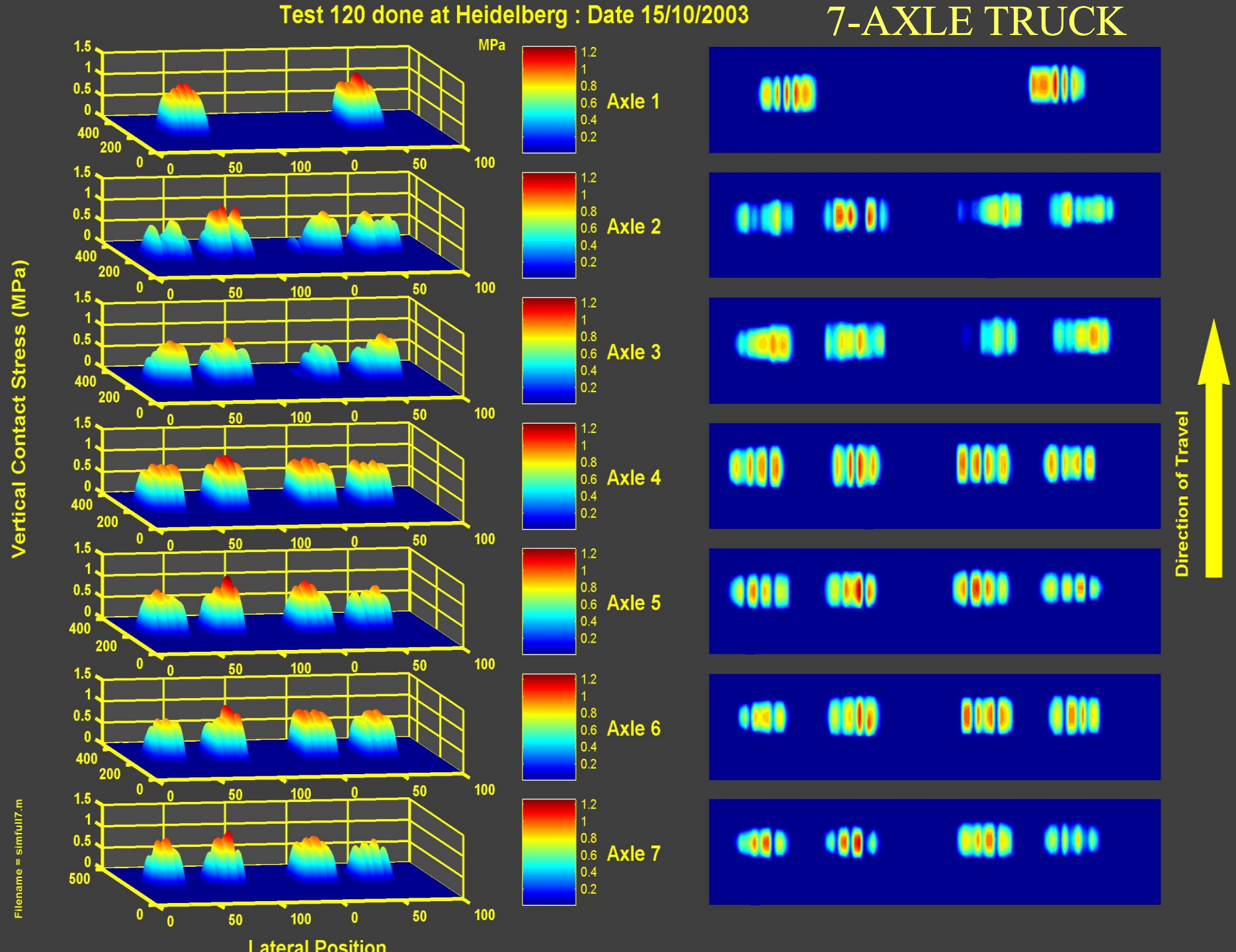
4-AXLE TRUCK



6-AXLE TRUCK


Test 174 done at Heidelberg : Date 10/09/2003 (overload)
MPa
Axle 1
Axle 2
Axle 3
Axle 4
Axle 5
Axle 6
Vertical Contact Stress (MPa)
Lateral Position
Direction of Travel
Filename = simfull6.m

7-AXLE TRUCK


Test 120 done at Heidelberg : Date 15/10/2003
Vertical Contact Stress (MPa)
MPa
Axle 1
Axle 2
Axle 3
Axle 4
Axle 5
Axle 6
Axle 7
Lateral Position
Direction of Travel
Filename = simfull7.m

COMPUTER ANALYSES OF ROAD PAVEMENT STRUCTURES

- ✓ ***SYMPLISTIC ANALYSIS: MULTI-LAYER - LINEAR - ELASTIC THEORY;***

- ✓ ***COMPLEX: FINITE ELEMENT METHOD + NON – LINEAR - ELASTIC THEORIES;***

ELSYM5M PAVEMENT ANALYSIS (1D)
&
Further FEM Analysis (1D,2D,or 3D)

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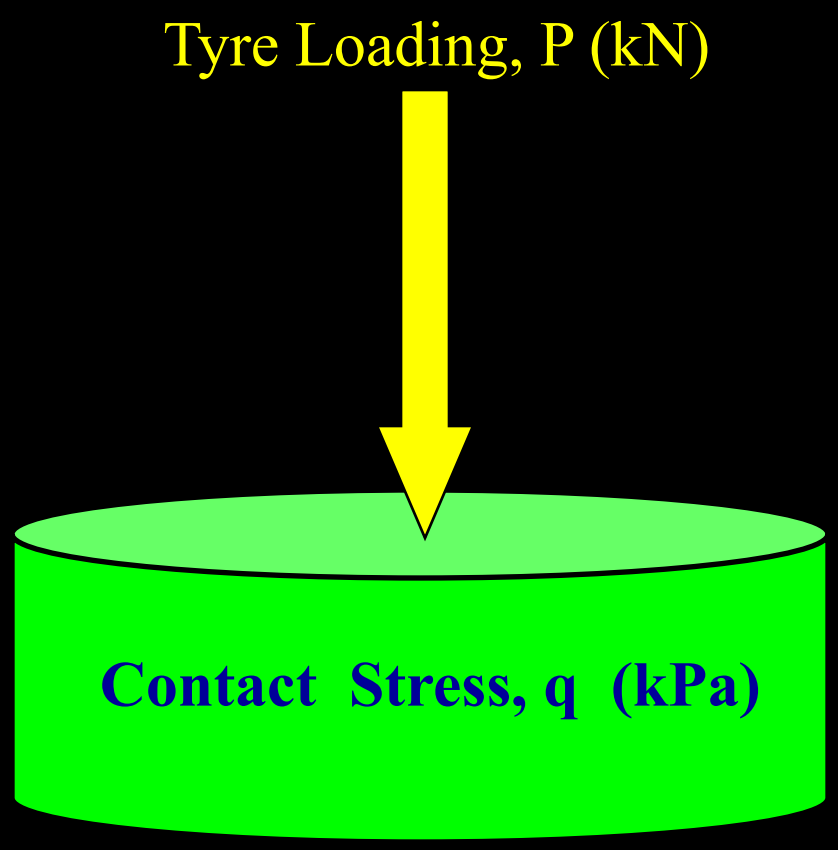
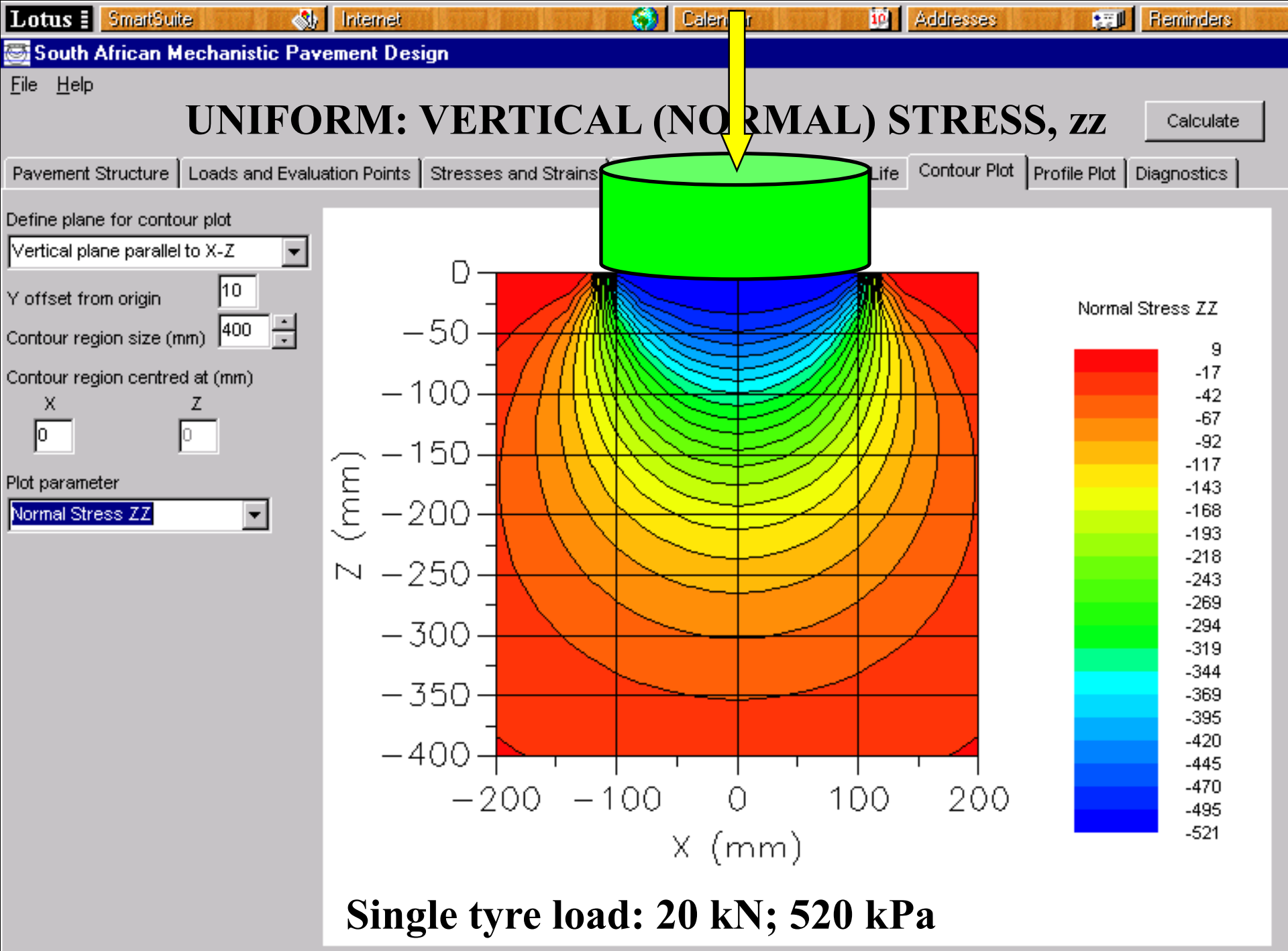
Design Tyre Loading (1D): ELSYM, RUBICON

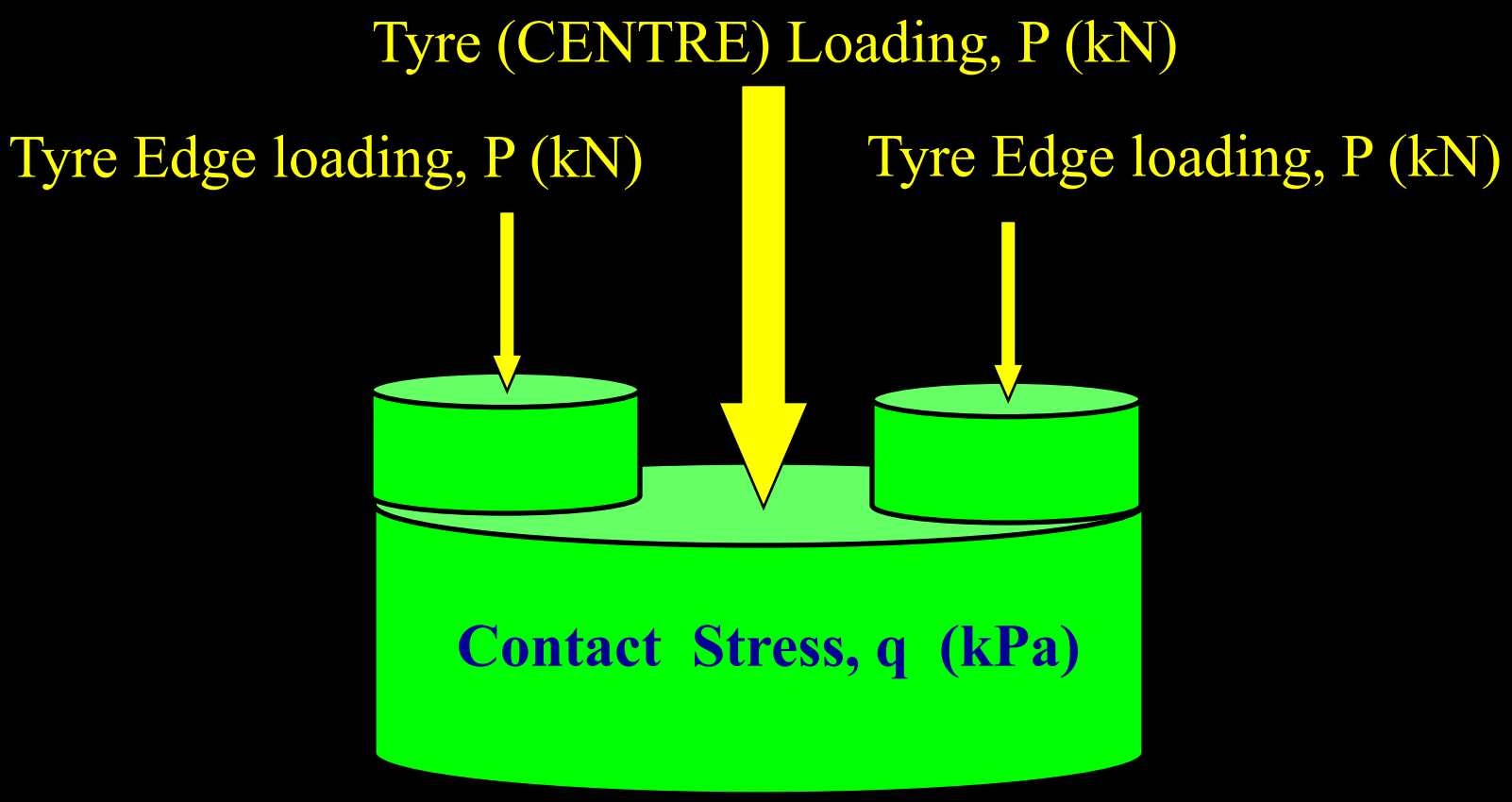


UNIFORM: VERTICAL (NORMAL) STRESS, zz

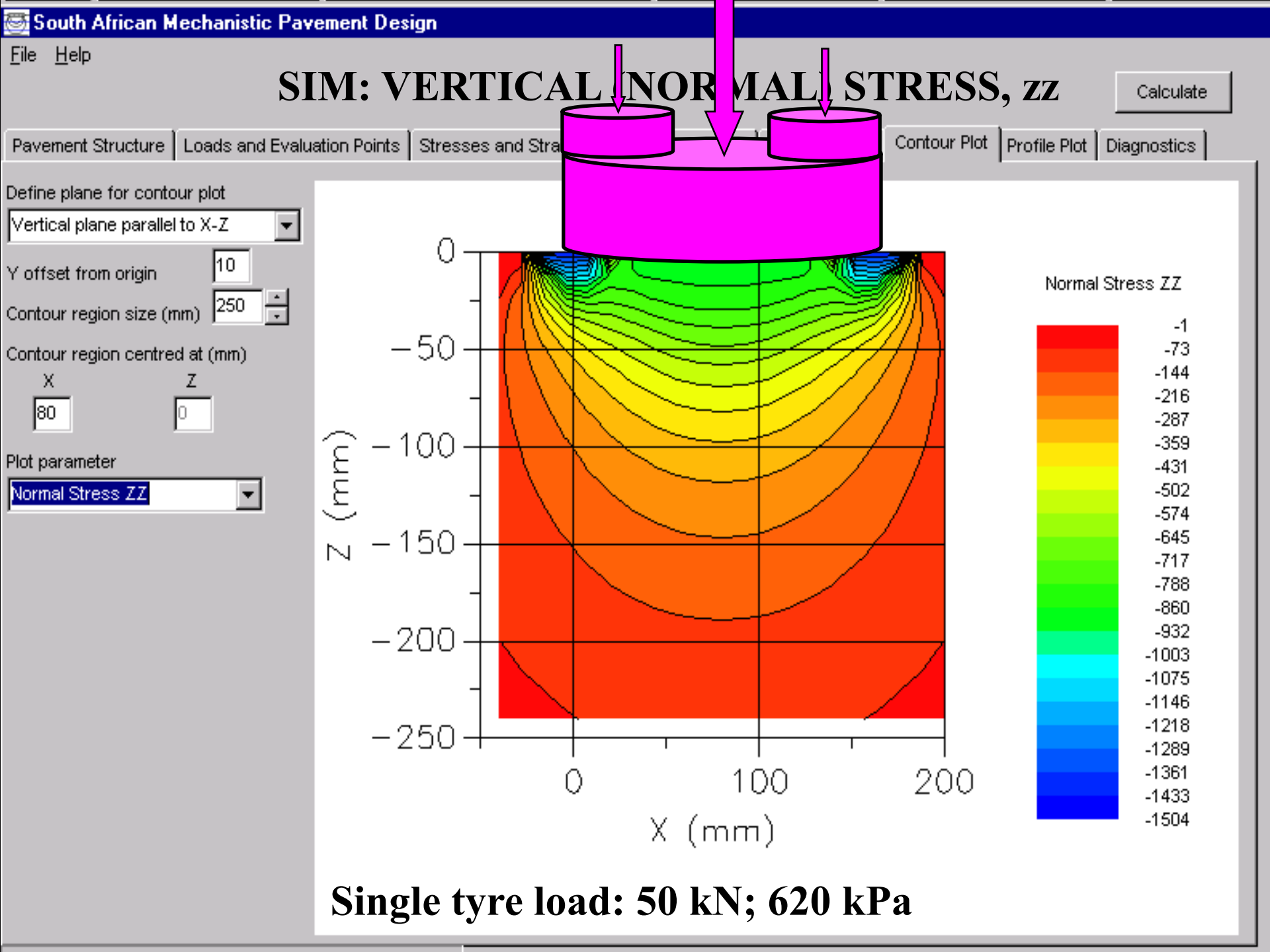


Single tyre load: 20 kN; 520 kPa

Modified (1D): ELSYM, RUBICON



SIM: VERTICAL (NORMAL) STRESS, zz



Single tyre load: 50 kN; 620 kPa

2D or 3D FEM Analysis:

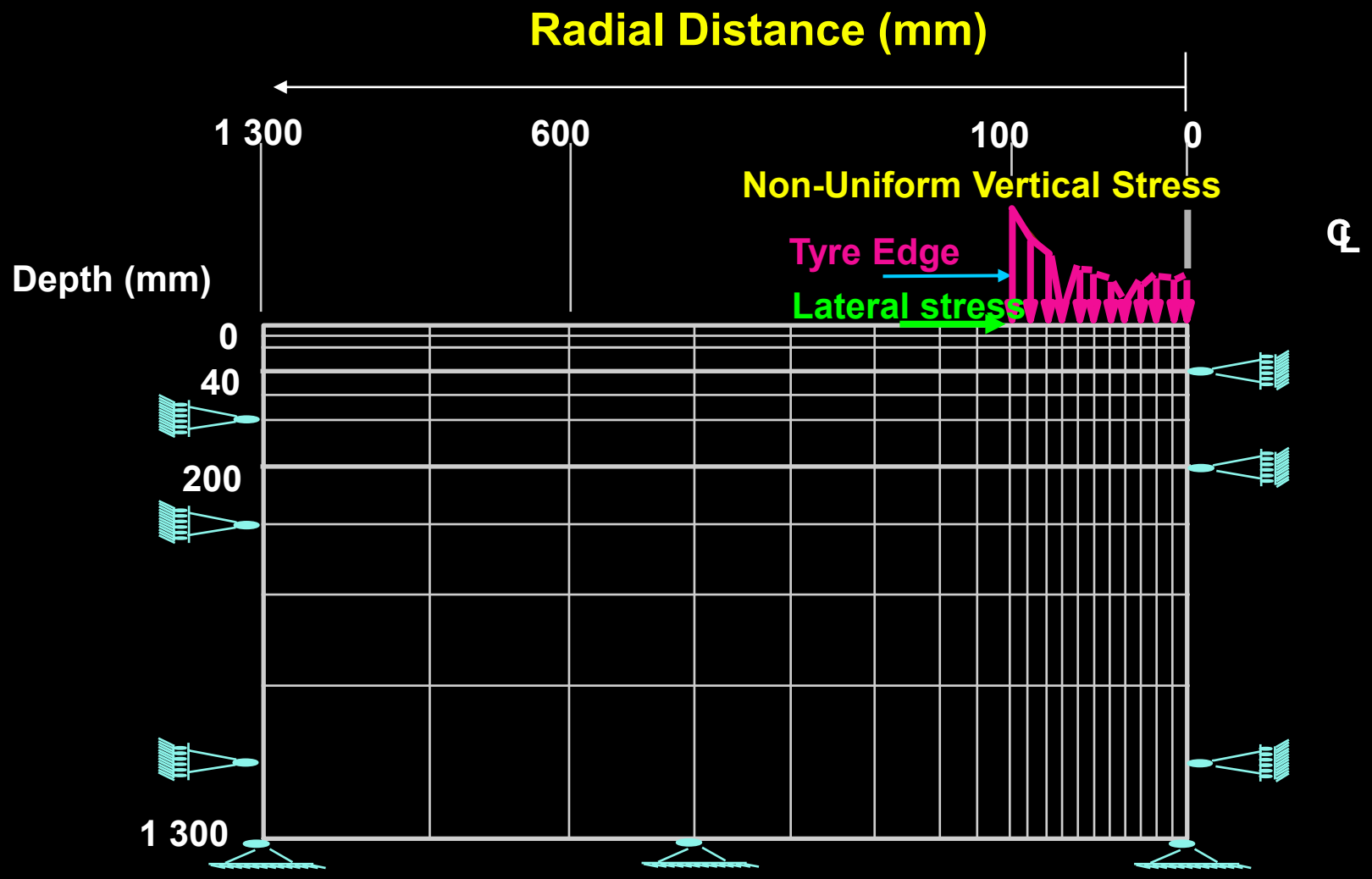
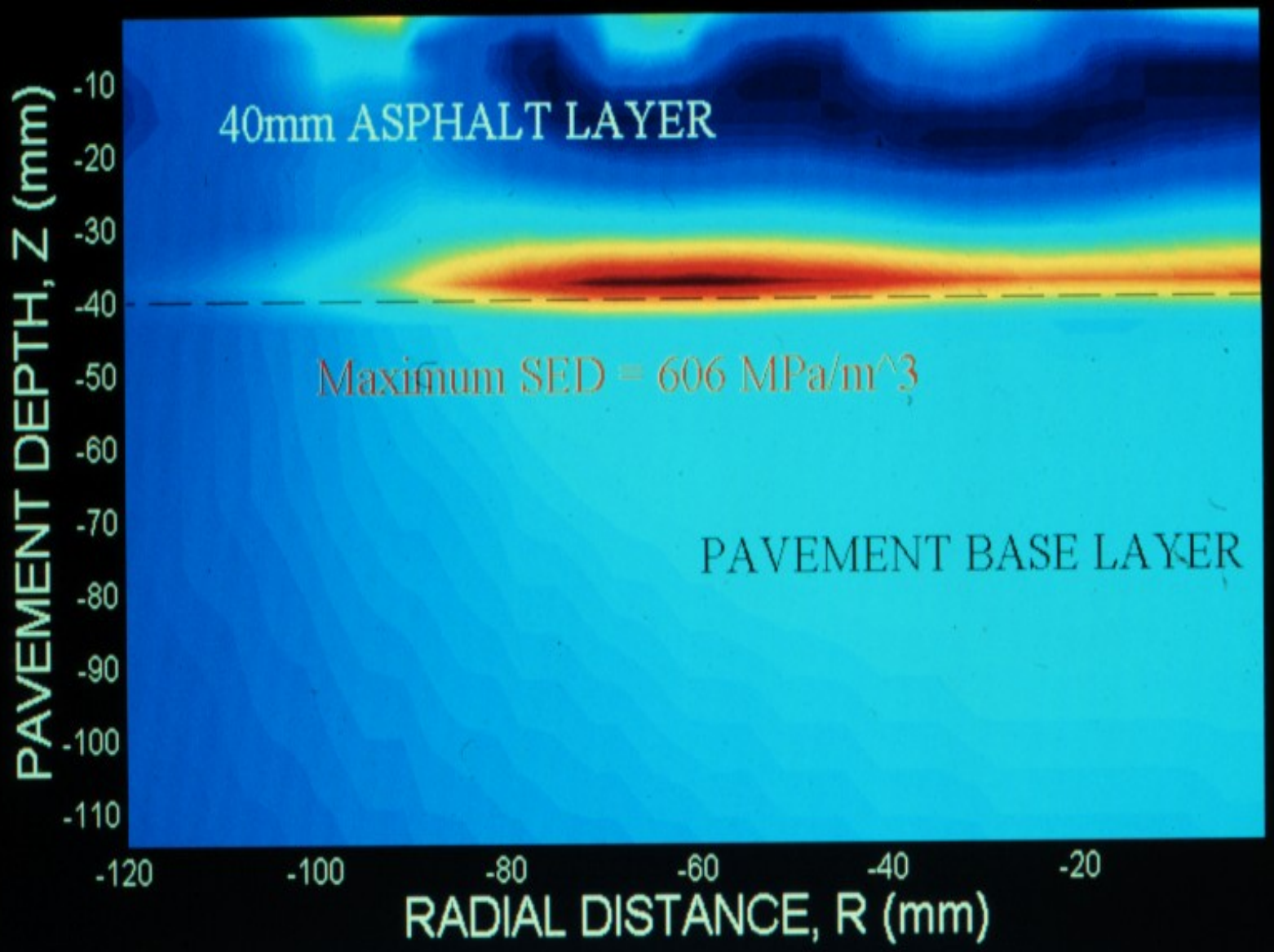


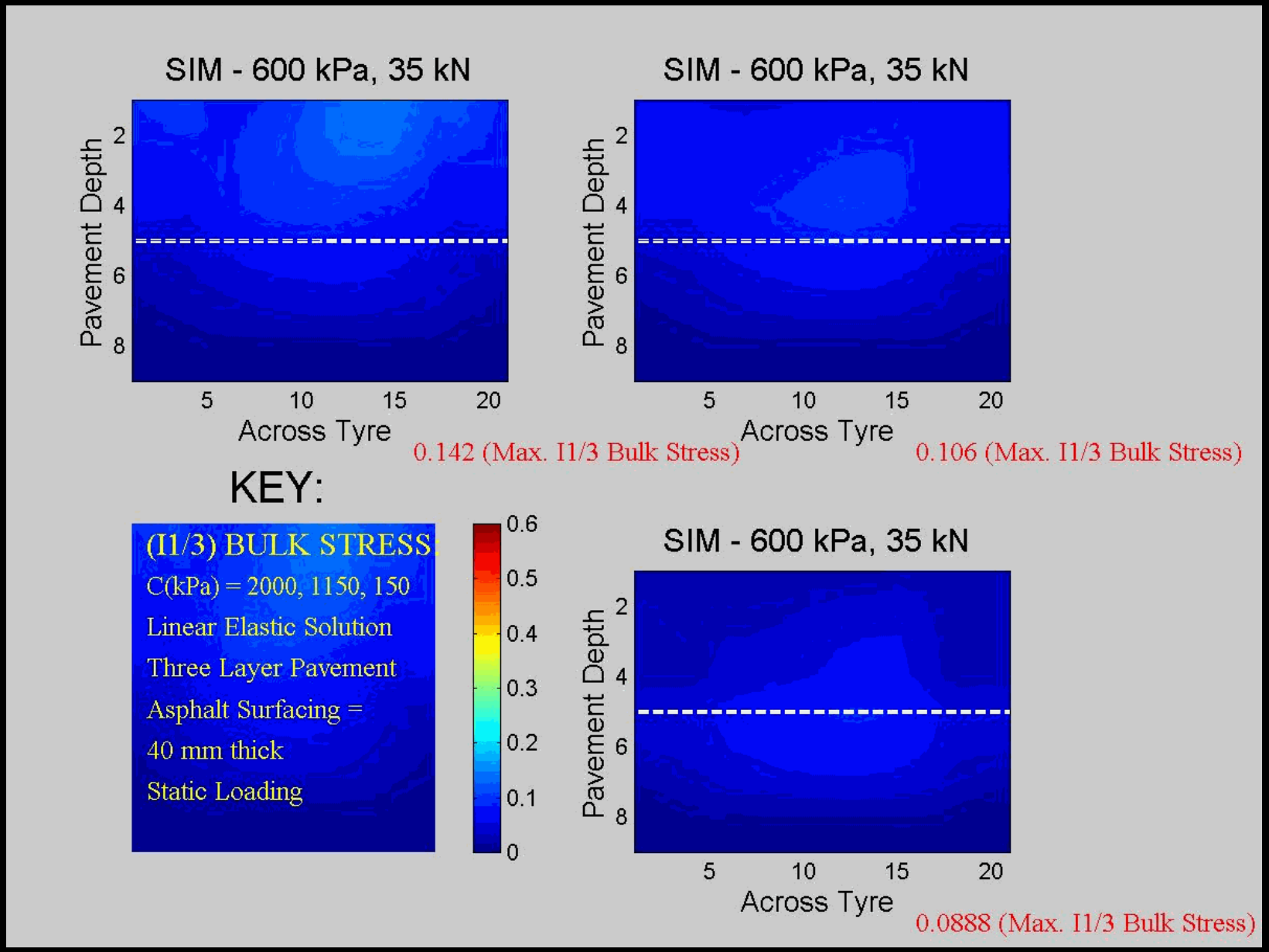
FIGURE: 29

Axi-symmetrical Finite Element Model used in this study

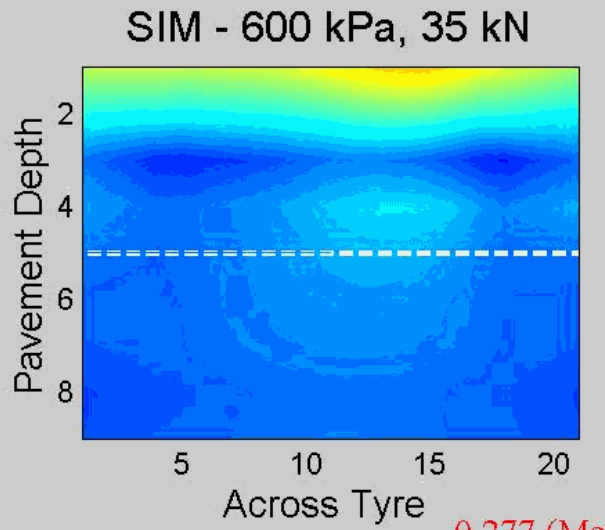
NON-UNIFORM STRESS (EDGE) (420 kPa)
STRAIN ENERGY OF DISTORTION (SED)



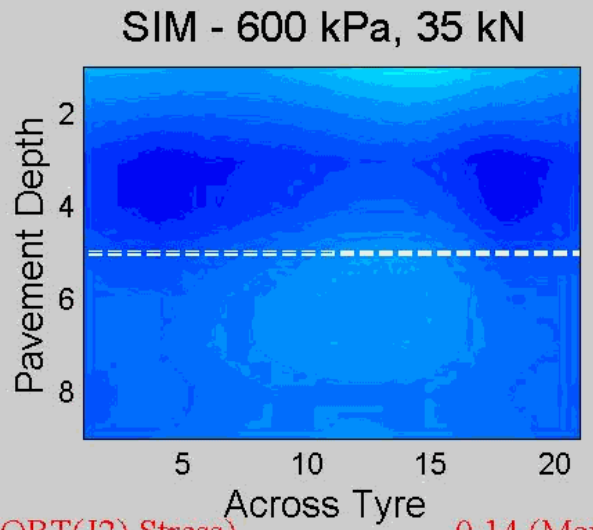
I/3 – BULK STRESS IN ASPHALT



SQRT (J2) - SHEAR POTENTIAL IN ASPHALT

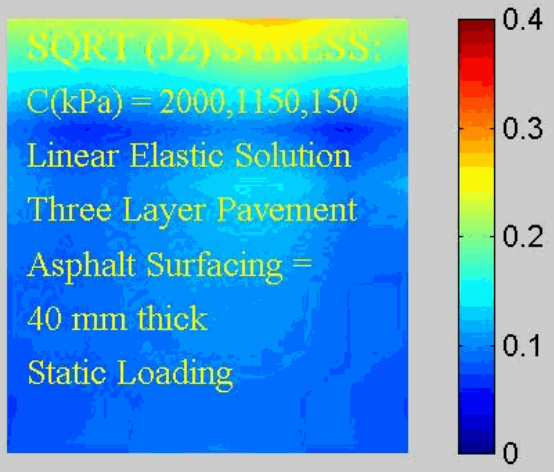


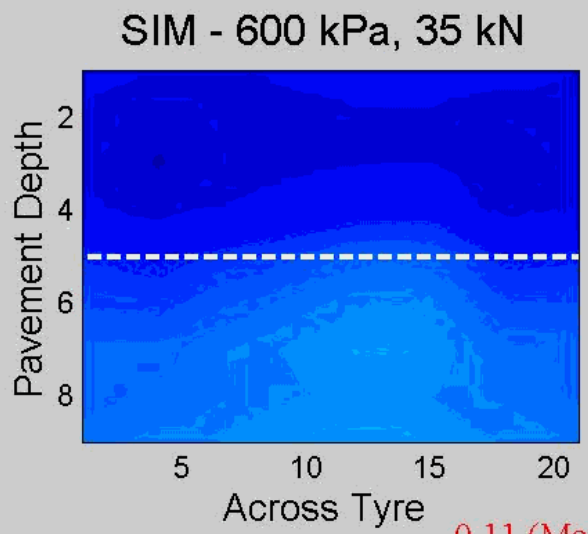
0.277 (Max. SQRT(J2) Stress)



0.14 (Max. SQRT(J2) Stress)

KEY:





0.11 (Max. SQRT(J2) Stress)

CONCLUSIONS…..

- **SIM Technology resulted in improved pneumatic tyre/pavement contact stress definitions and quantifications;**
- **Improved selection of HVS *tyre and inflation pressure* levels;**
- **Improved potential for *more rational* pavement design,performance and analysis methods;**
- **Potential savings of *ZARmillions*, if effectively employed…**

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I Thank You all