

78th TRB '99 Session 440

Latest Developments on Tyre Road Surface Interface Stress Measurements Using the 3-D Cell

(PP99-3486)

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Louw Kannemeyer (SANRA Ltd)

(1st Reference: 8th ICAP '97- *Seattle, USA*

ICAP '97

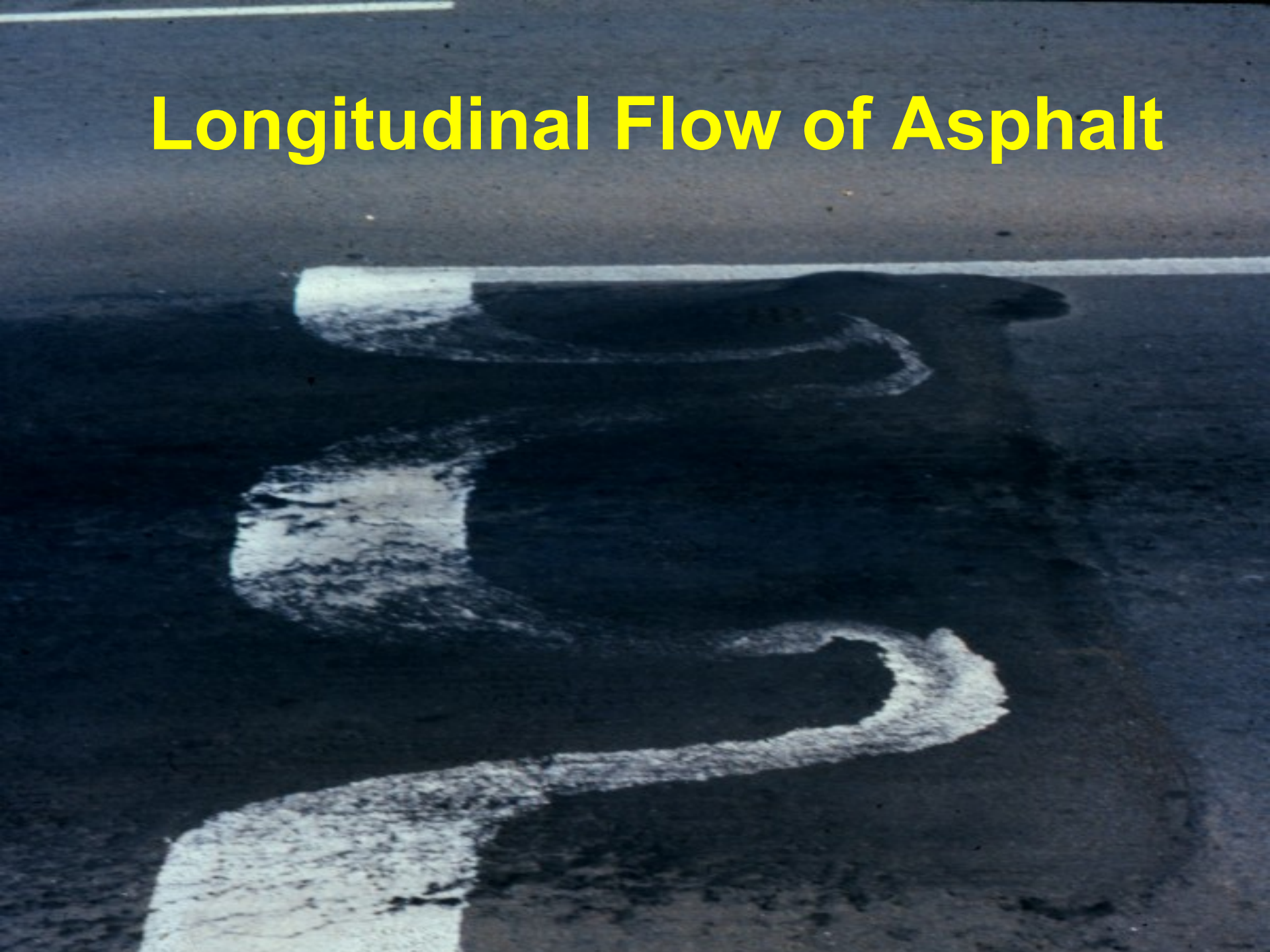
Stress - In - Motion (SIM)

CSIR, Transportek, South Africa



1977

Longitudinal Flow of Asphalt



Fatigue Cracking and aging





SURFACE DISINTEGRATION

TIRES





17 7'96





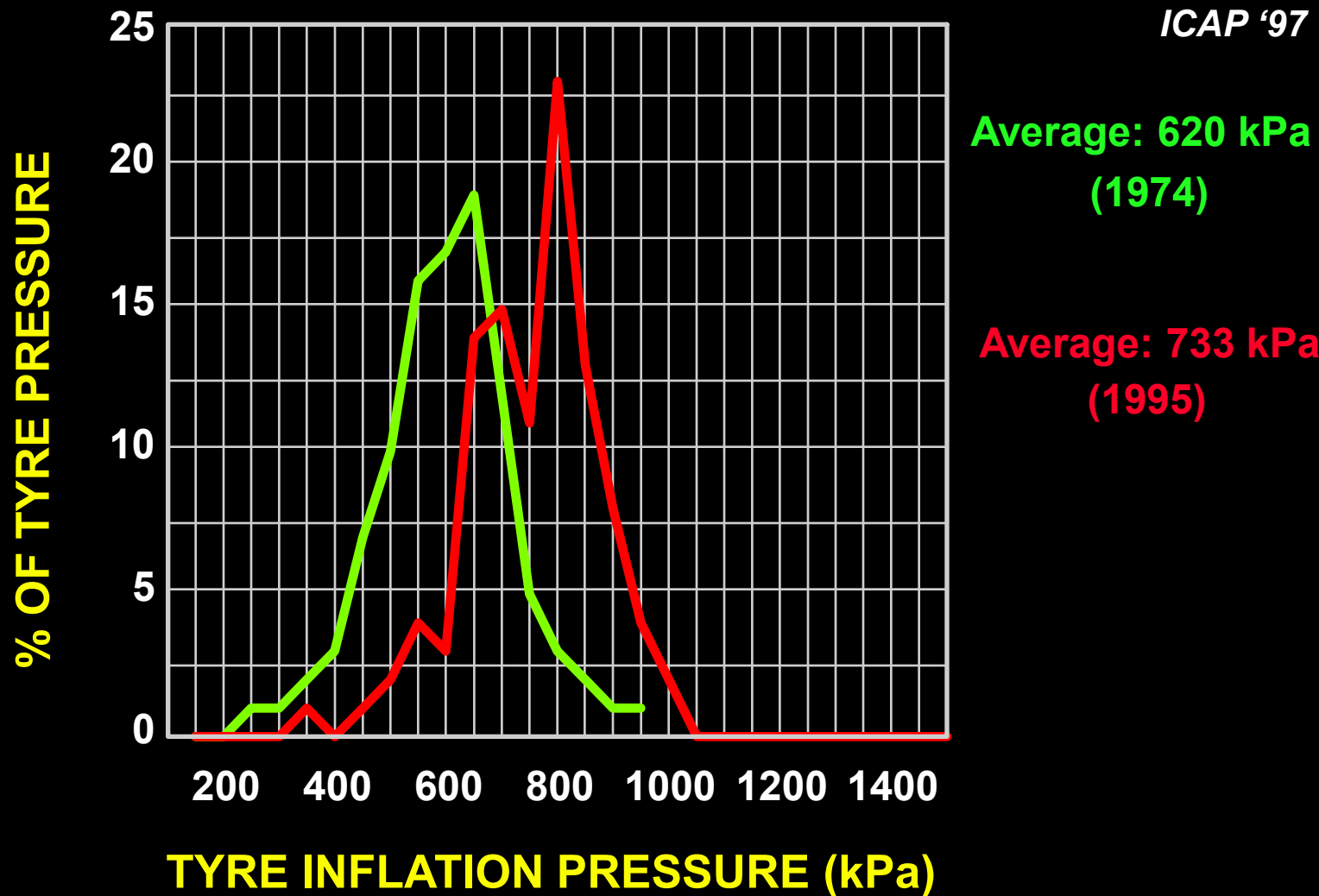


FIGURE 1a

Tyre inflation pressure distributions in South Africa (1974 - 1995)

Heavy vehicles: Axle Loads > 7 000 kg Survey: 1995

ICAP '97

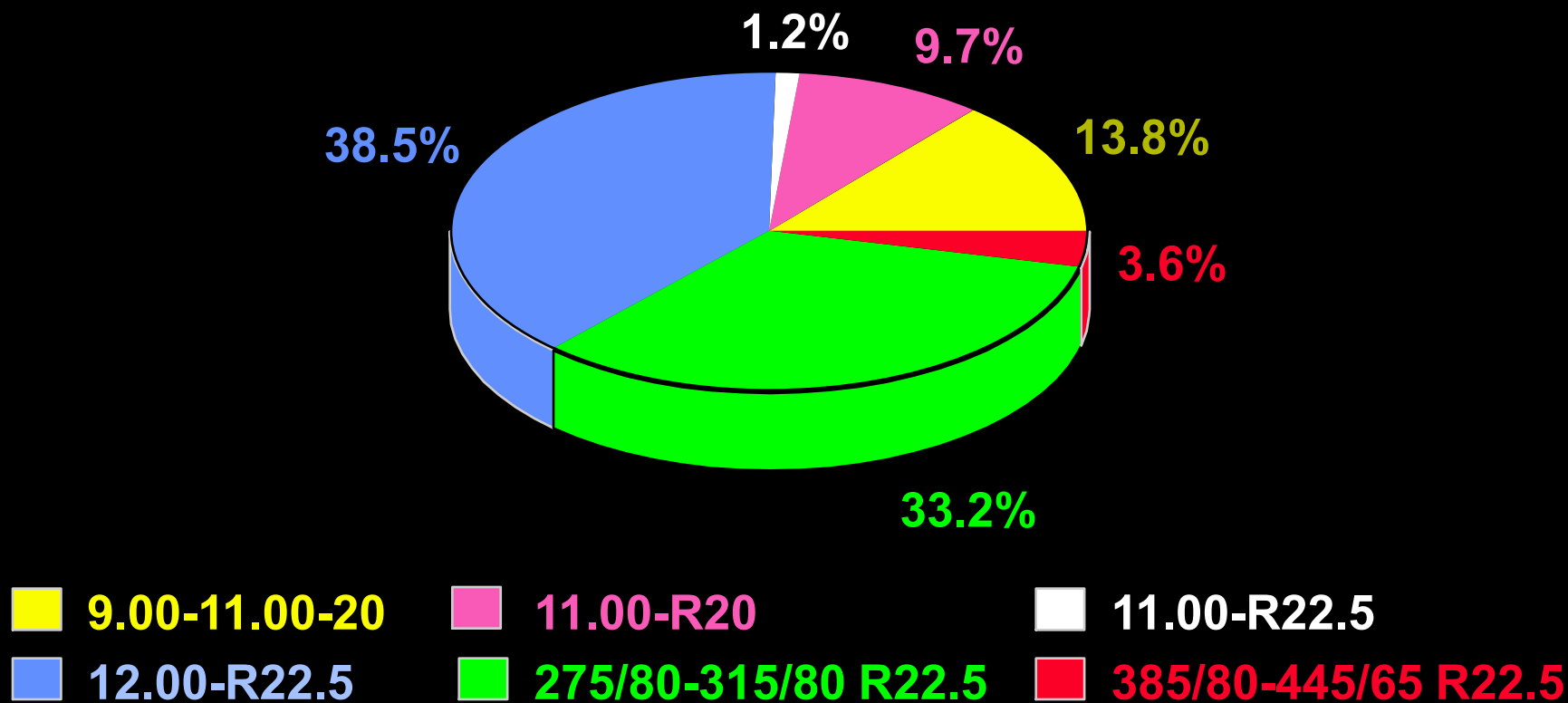


FIGURE 1b

Distribution of heavy truck tyre types in
South Africa

VRSPTA

Direction of travel

TYRE ON HVS (or Vehicle)

Pavement Surface

Computer set-up

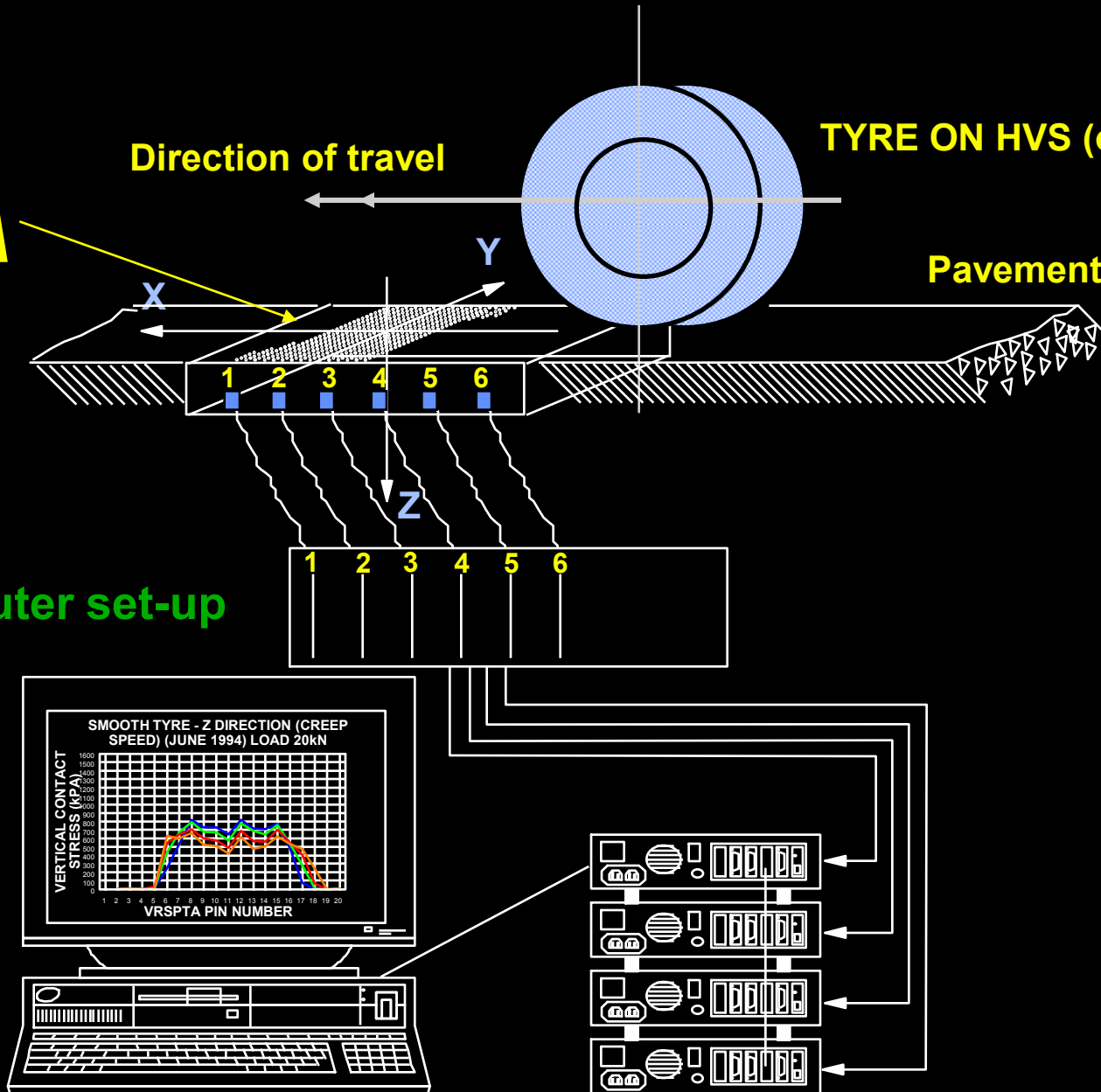


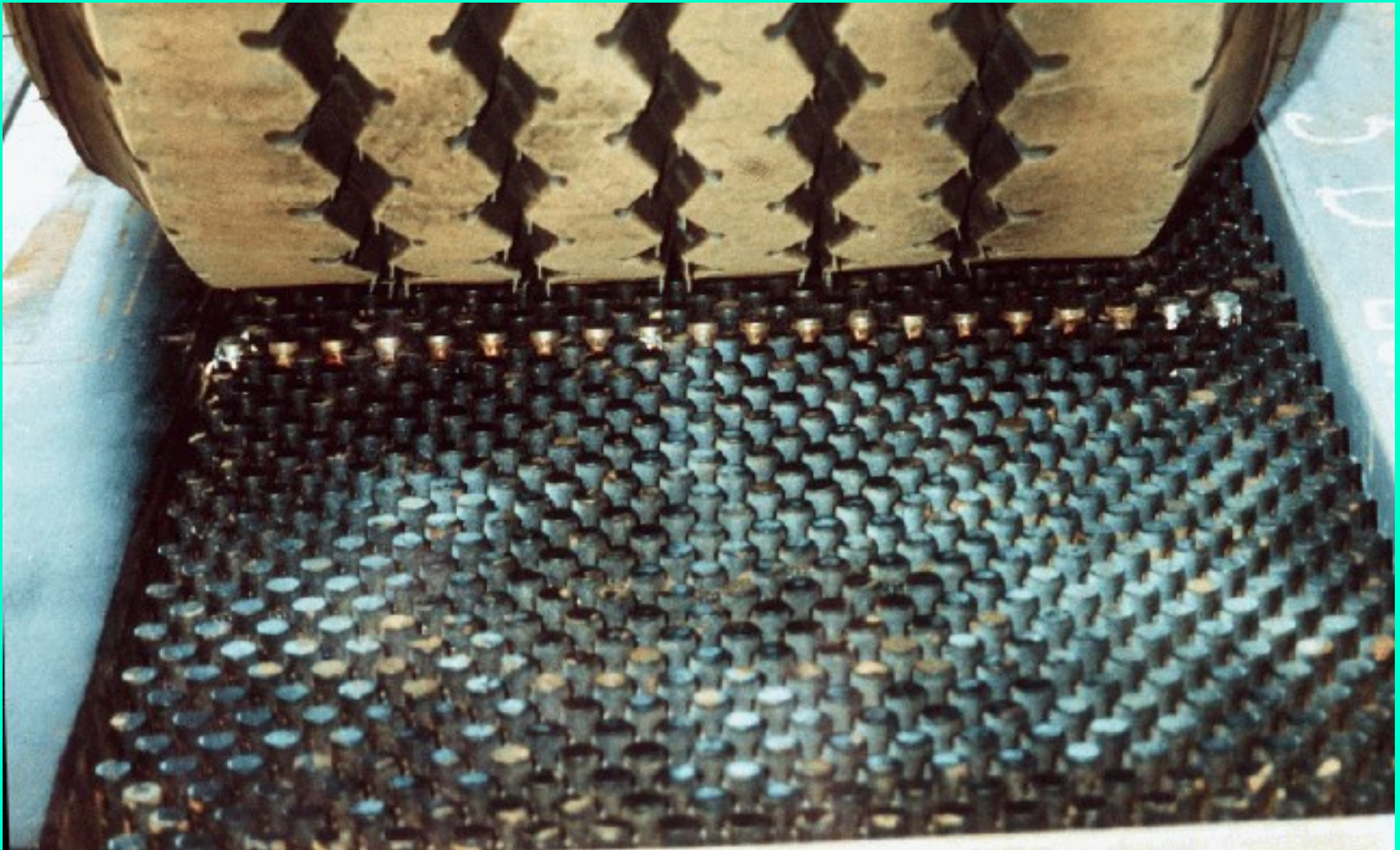
FIGURE 2
Schematic layout of VRSPTA system



VEHICLE-ROAD SURFACE PRESSURE TRANSDUCER ARRAY (VRSPA)



315/80 R22.5 HVS TYRE ON VRSPTA



425 /65 R22.5 HVS TYRE ON VRSPTA

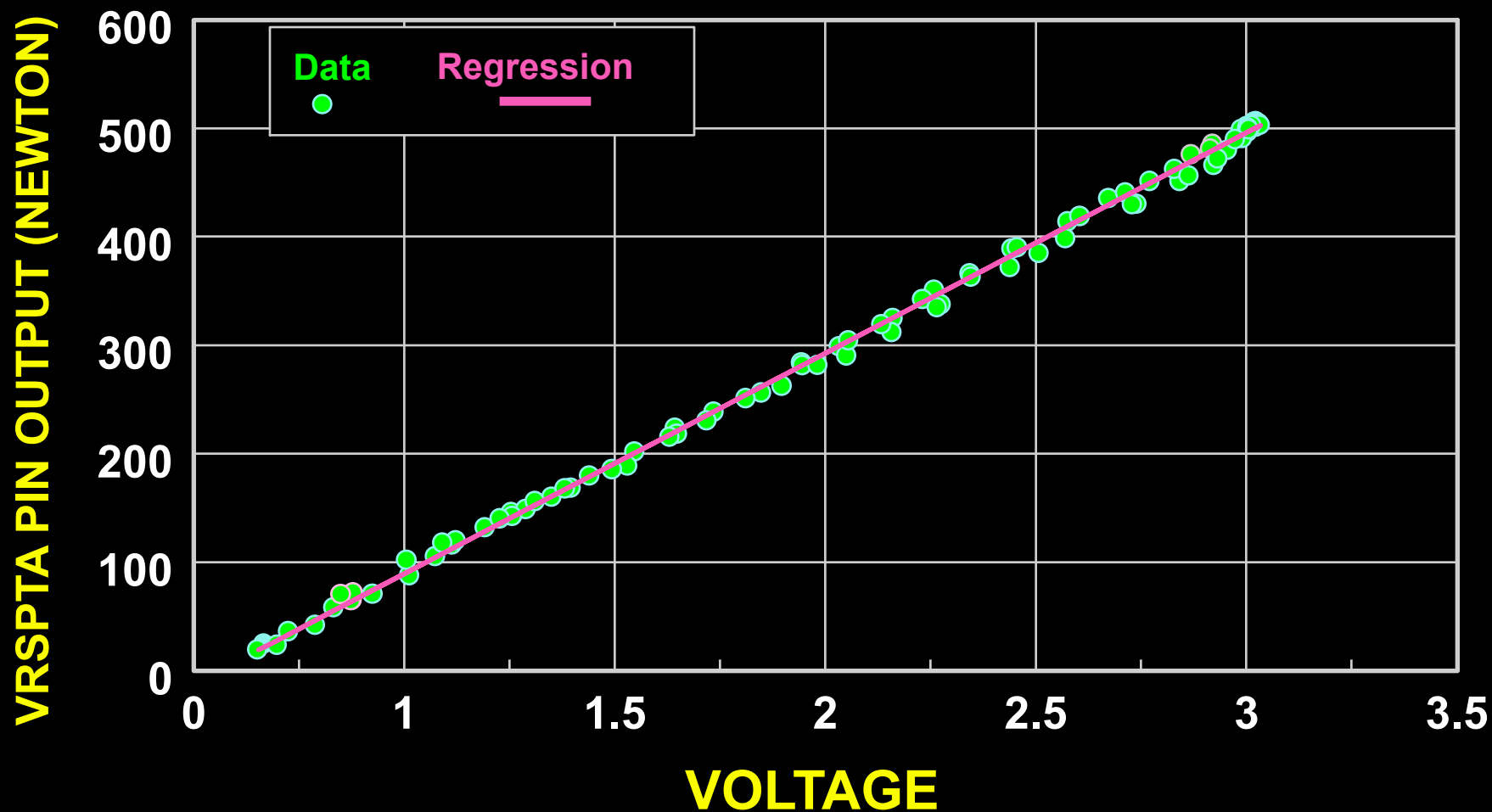


FIGURE 3

Laboratory calibration data of VRSPTA pins

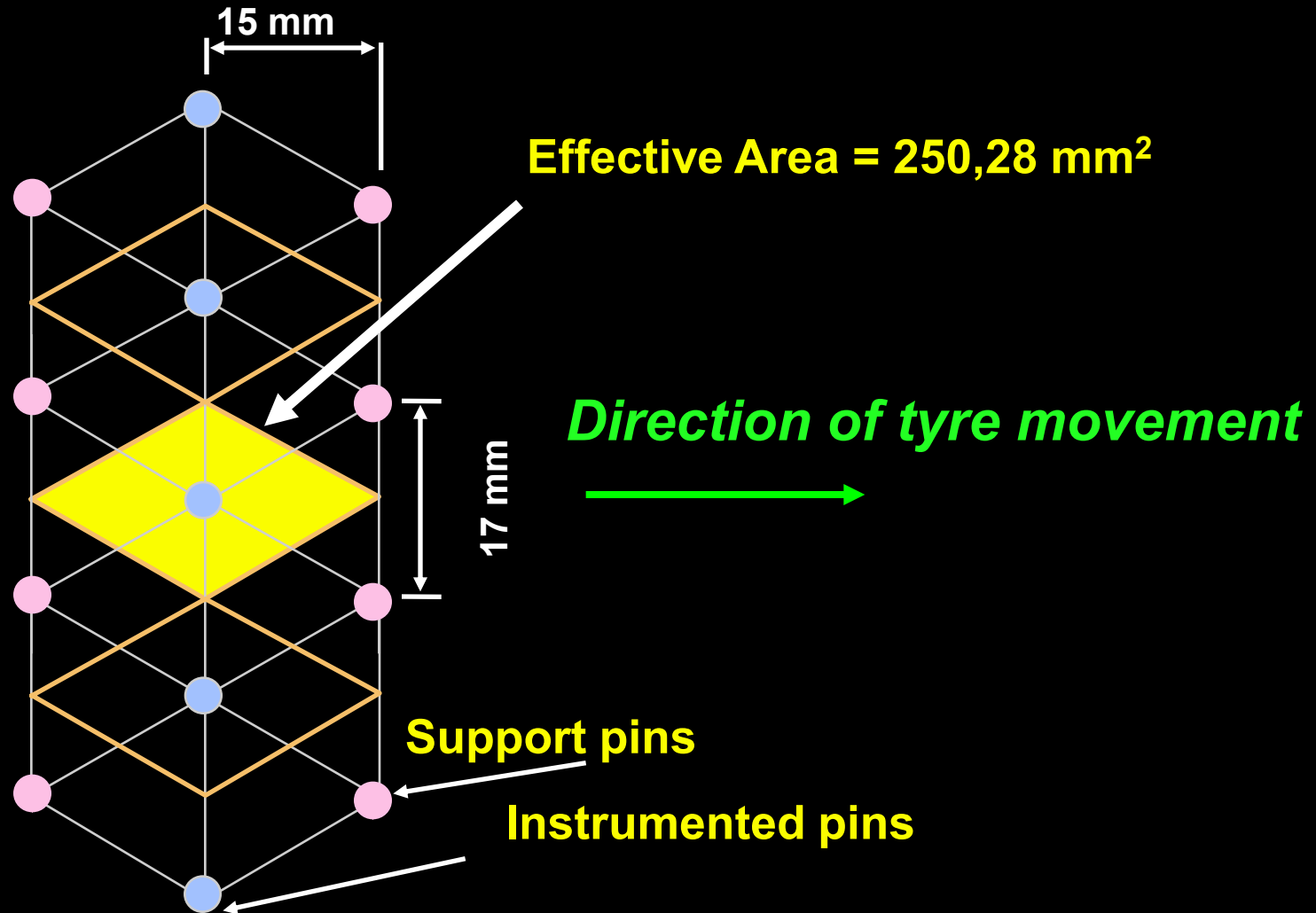


FIGURE 4

Effective Diamond Shaped Area used for the contact stress calculation in VRSPTA

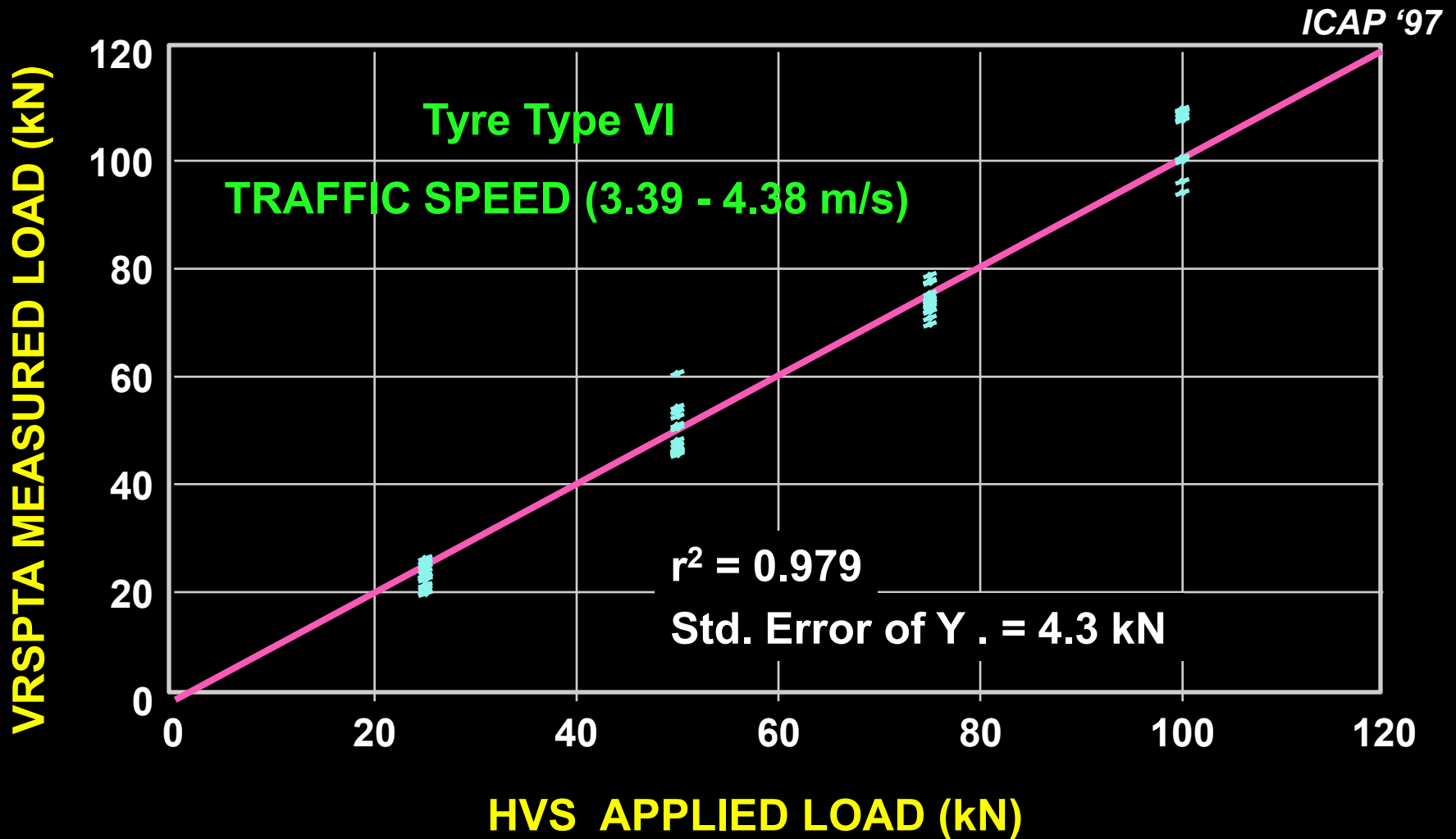
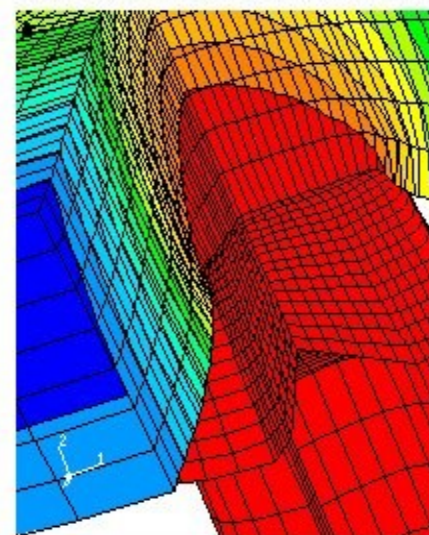
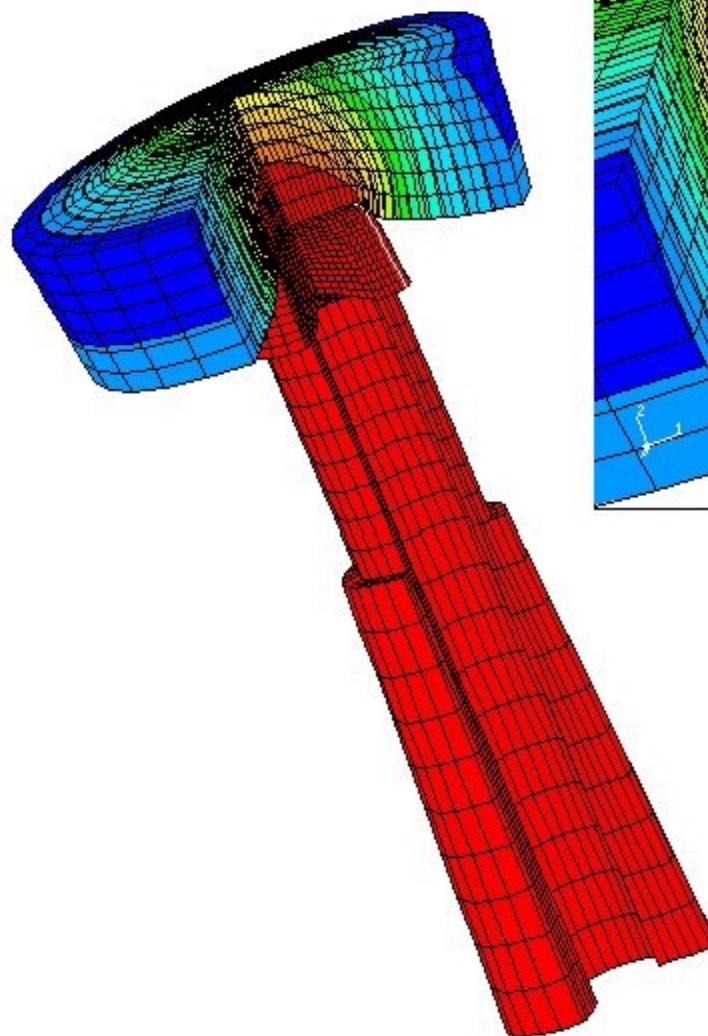
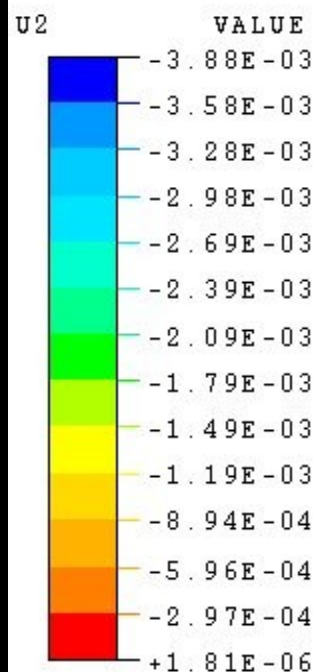


FIGURE 5

**Accuracy of the VRSP TA relative to HVS
applied load (random error)**



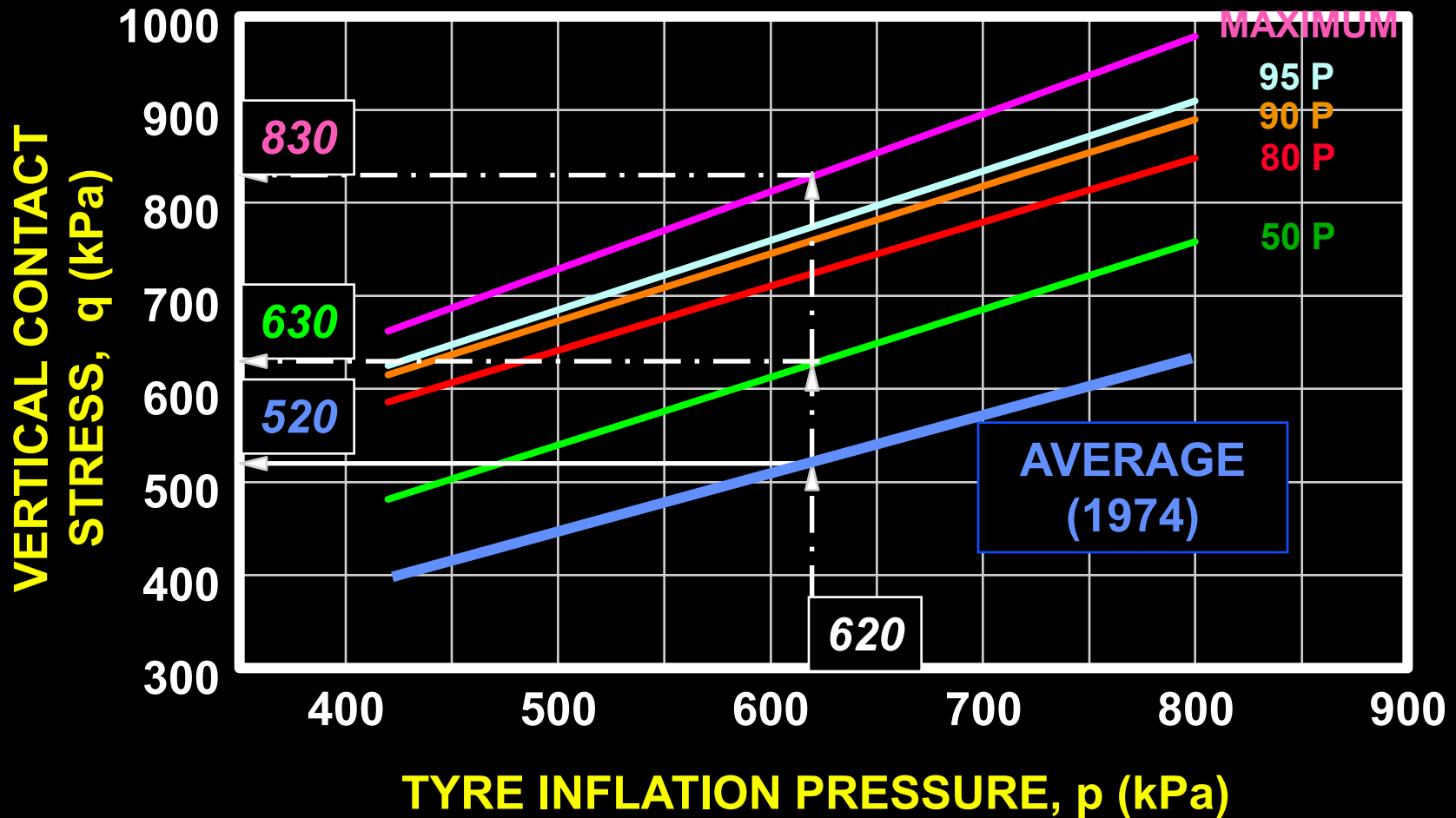


FIGURE 10
“Average” vertical contact stress
vs inflation pressure

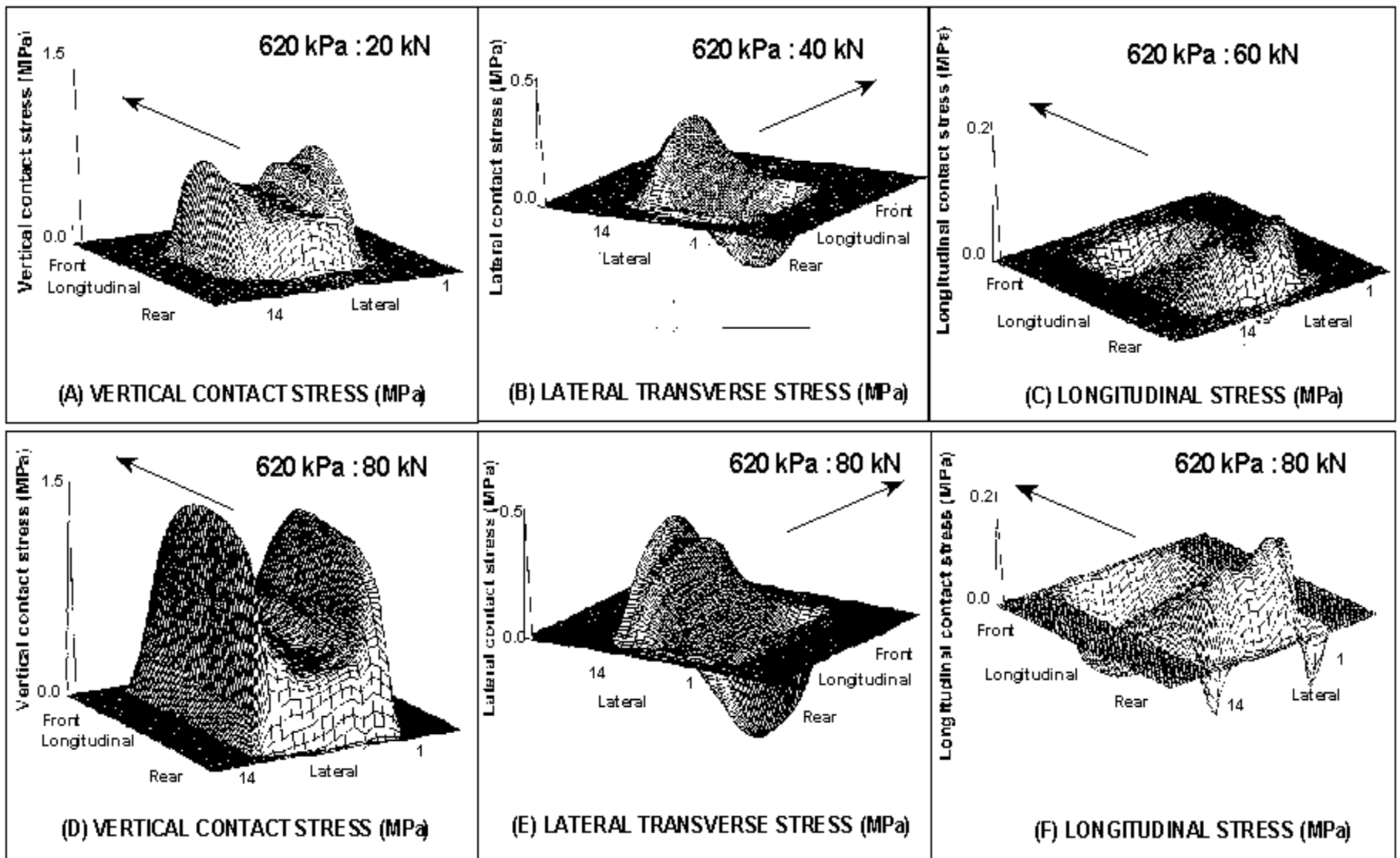
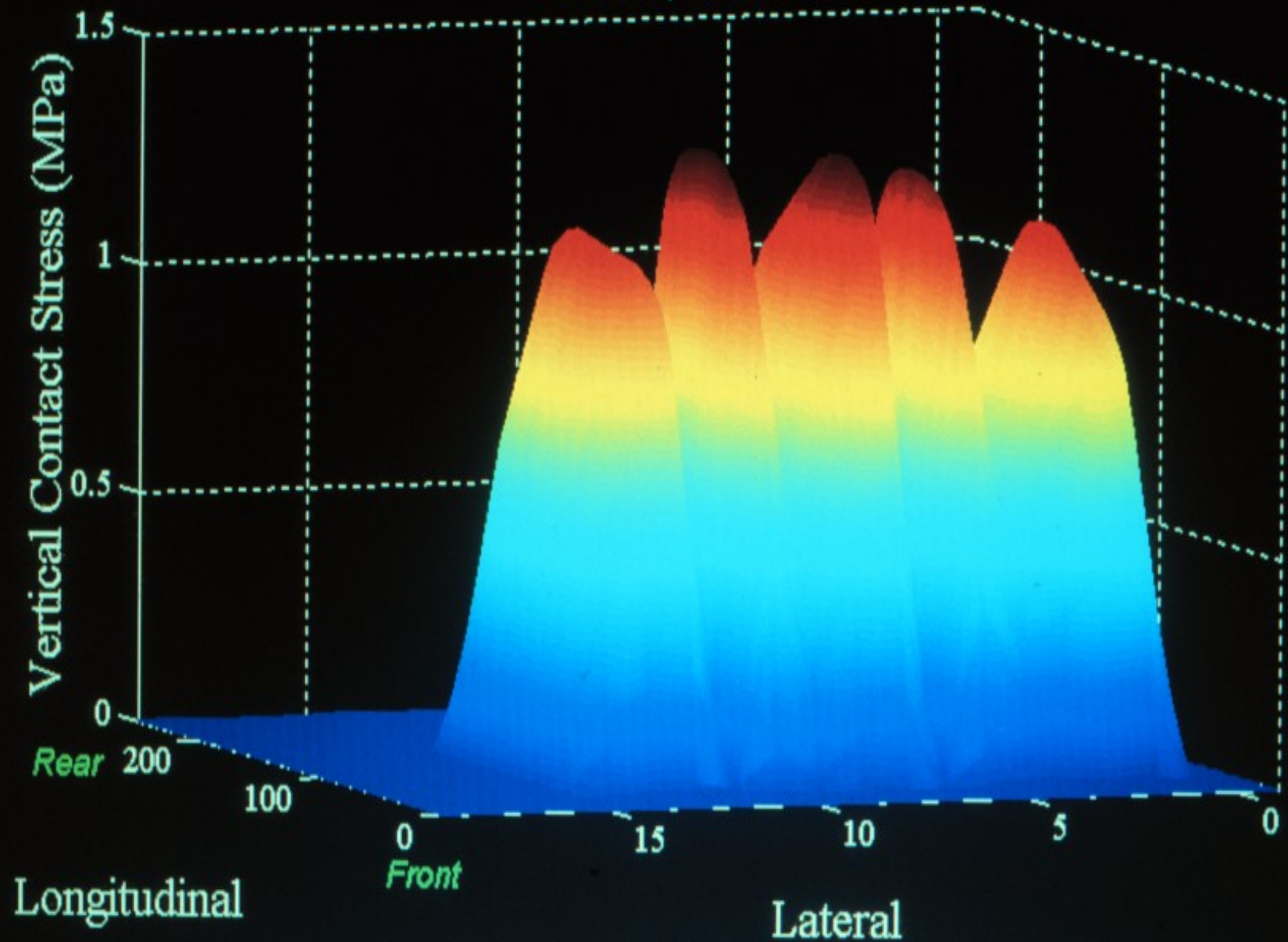


FIGURE 1a : Typical contact stress distributions measured with the VRSPTA system for a slow moving (1,2 km/h) free rolling smooth single truck tyre (Goodyear 11.00 X 20, 14 Ply rating) . The arrows indicate the direction of the rolling tyre during measurement. (After De Beer et al, 1997)

Vertical Contact Stress

315/80 R22.5 (tread)

800 kPa ; 40 kN



Tyre Load = 18 kN

CONTACT STRESS (kPa)

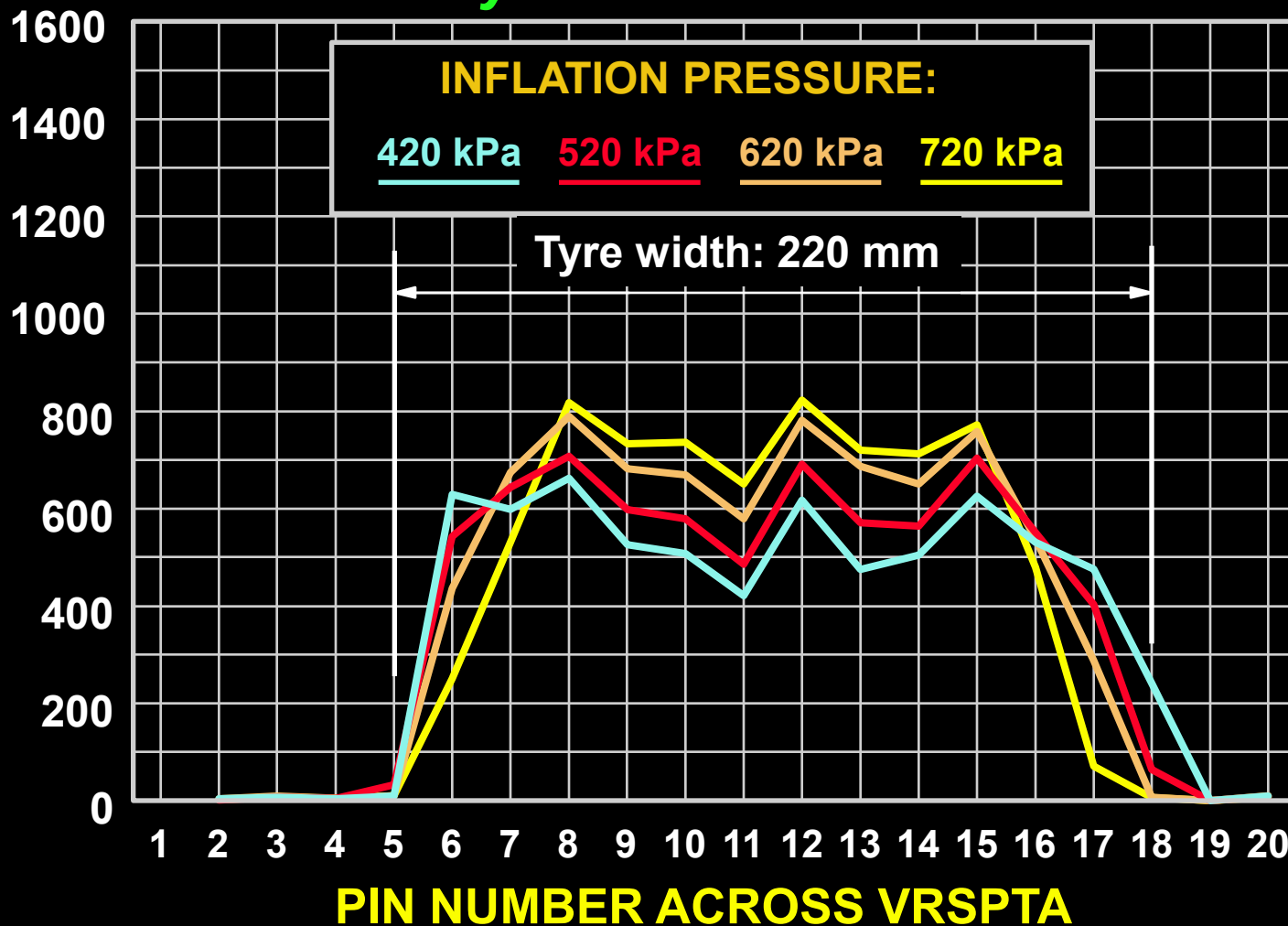


FIGURE 11

Maximum vertical stress at CONSTANT LOAD and various inflation pressures

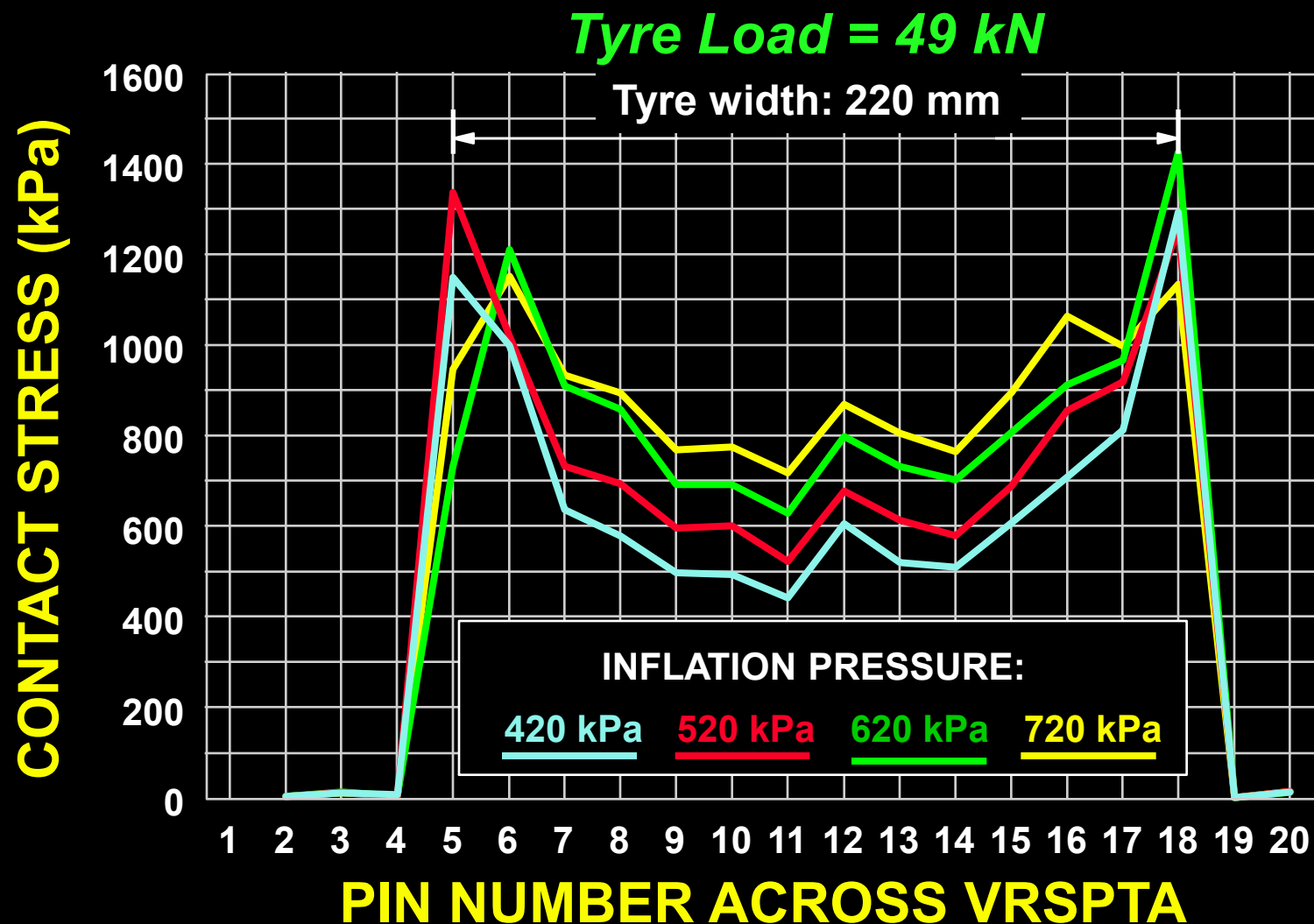


FIGURE 12

**Maximum vertical stress at CONSTANT LOAD
and various inflation pressures**

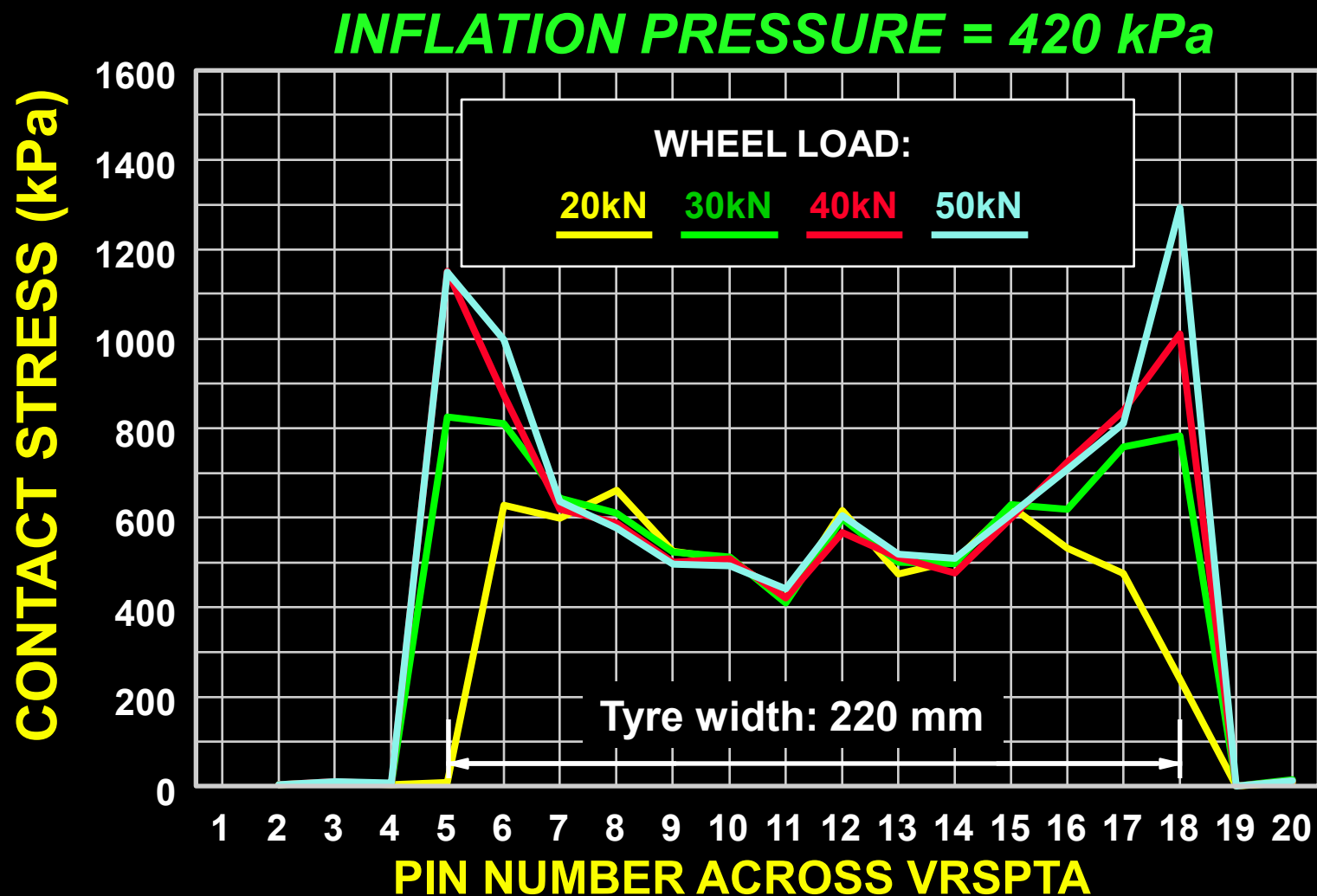
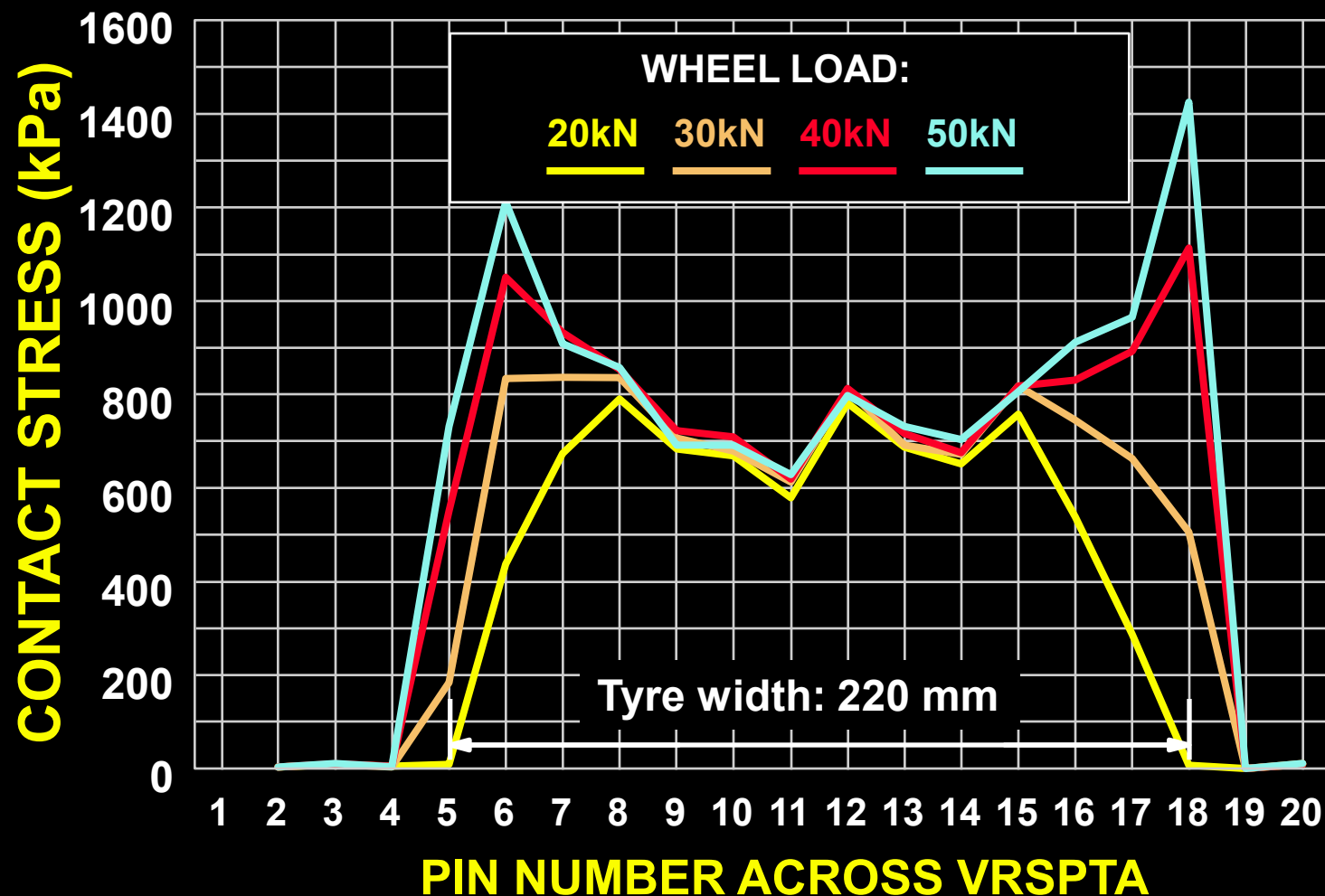
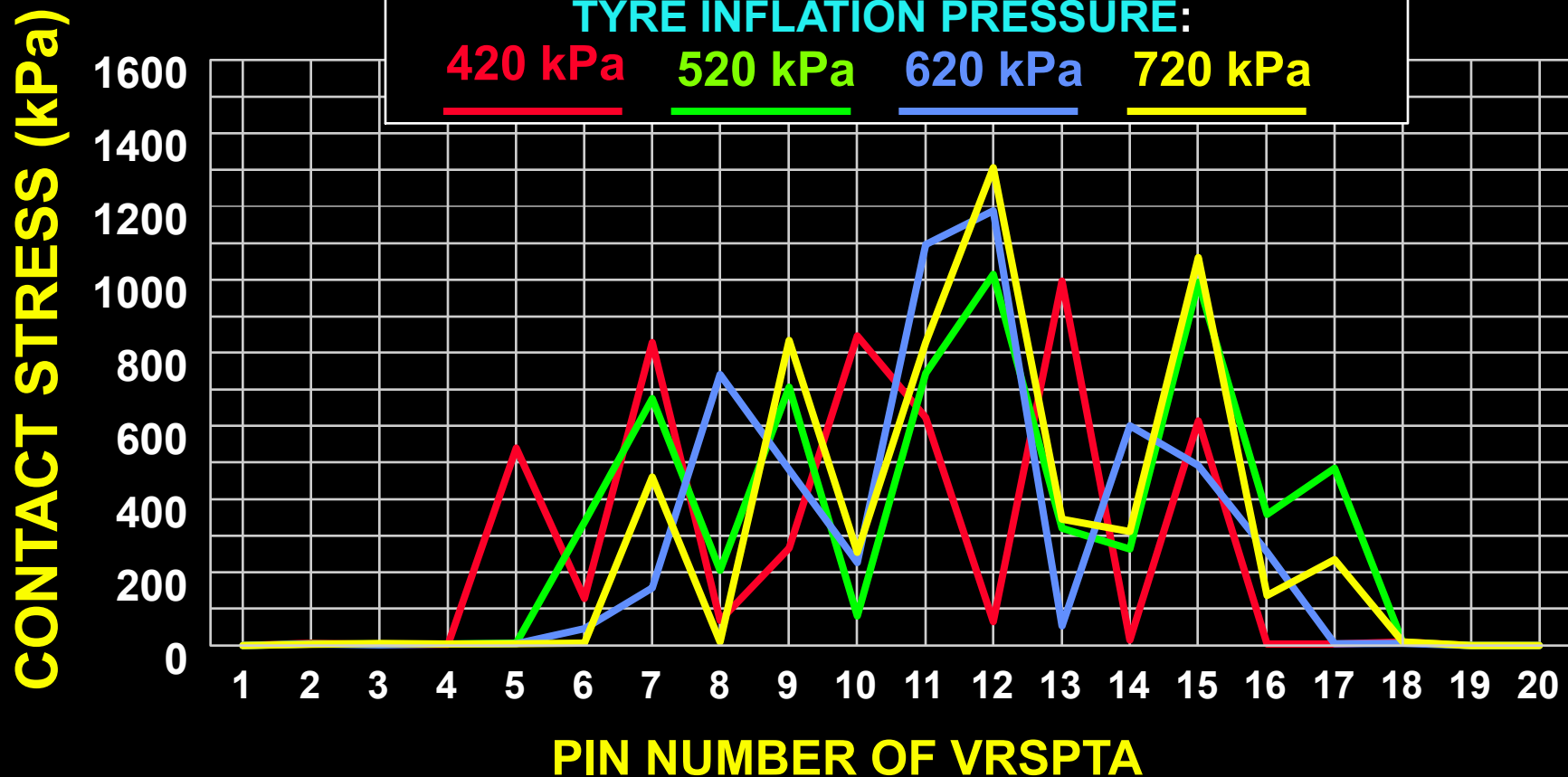


FIGURE 13
Maximum vertical stress at CONSTANT
INFLATION PRESSURE at various loads

INFLATION PRESSURE = 620 kPa**FIGURE 14**

**Maximum vertical stress at CONSTANT
INFLATION PRESSURE and various loads**

Tyre Load = 20 kN



FIGURE

**Maximum vertical stress¹⁶ of tyre with tread grooves
at CONSTANT LOAD and various inflation pressures**



CSIR

INFLATION PRESSURE = 520 kPa

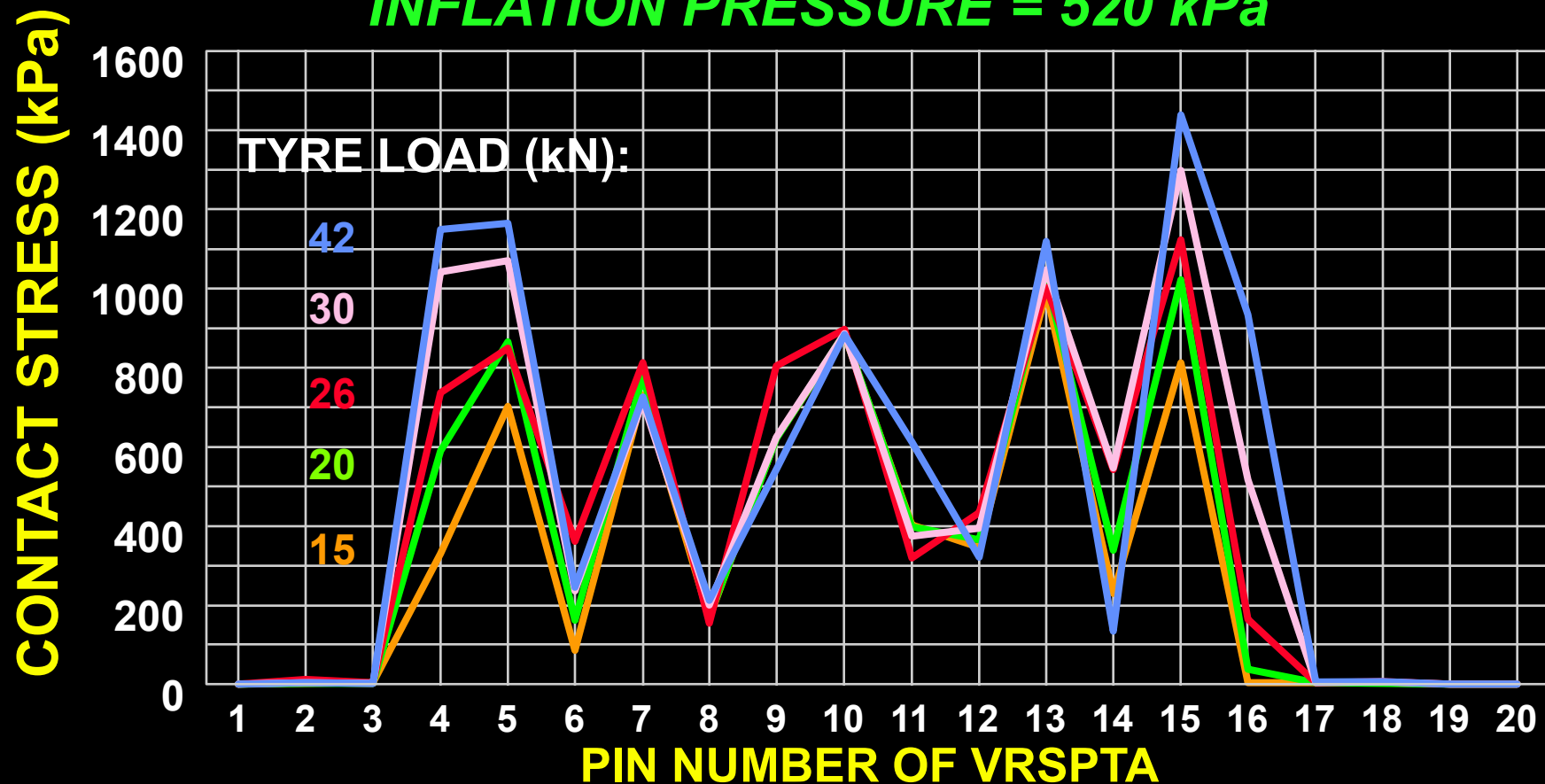
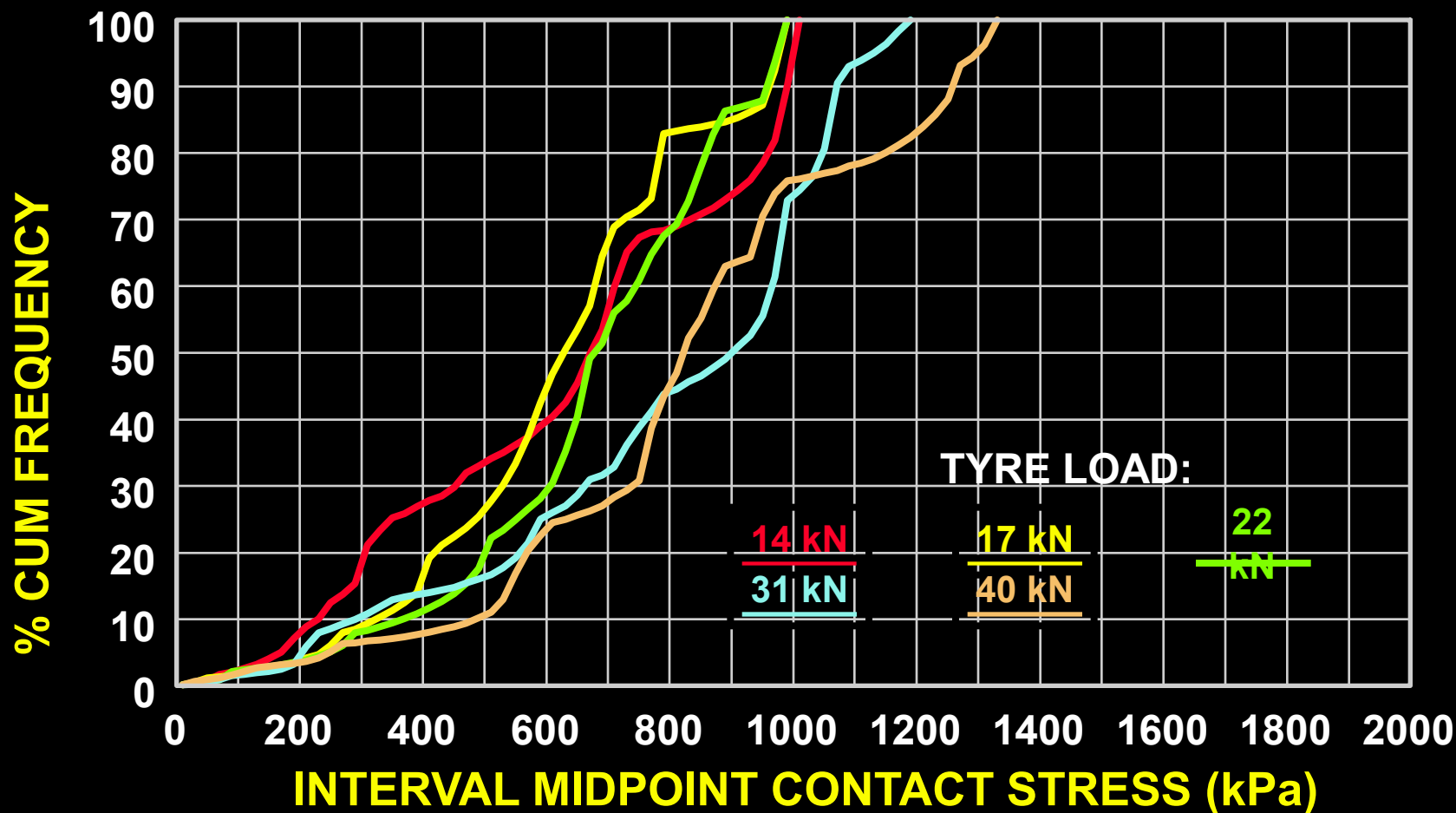


FIGURE 17

Vertical stress of tyre with tread grooves at CONSTANT INFLATION PRESSURE and various loads

10.00 X 20 14 PLY TYRE WITH TREAD**FIGURE 19****Cumulative frequency of maximum vertical stress**

MEASURED VERTICAL
CONTACT STRESS
VALUES

DIRECTION OF TRAVEL

Patch area = 74 028 mm²

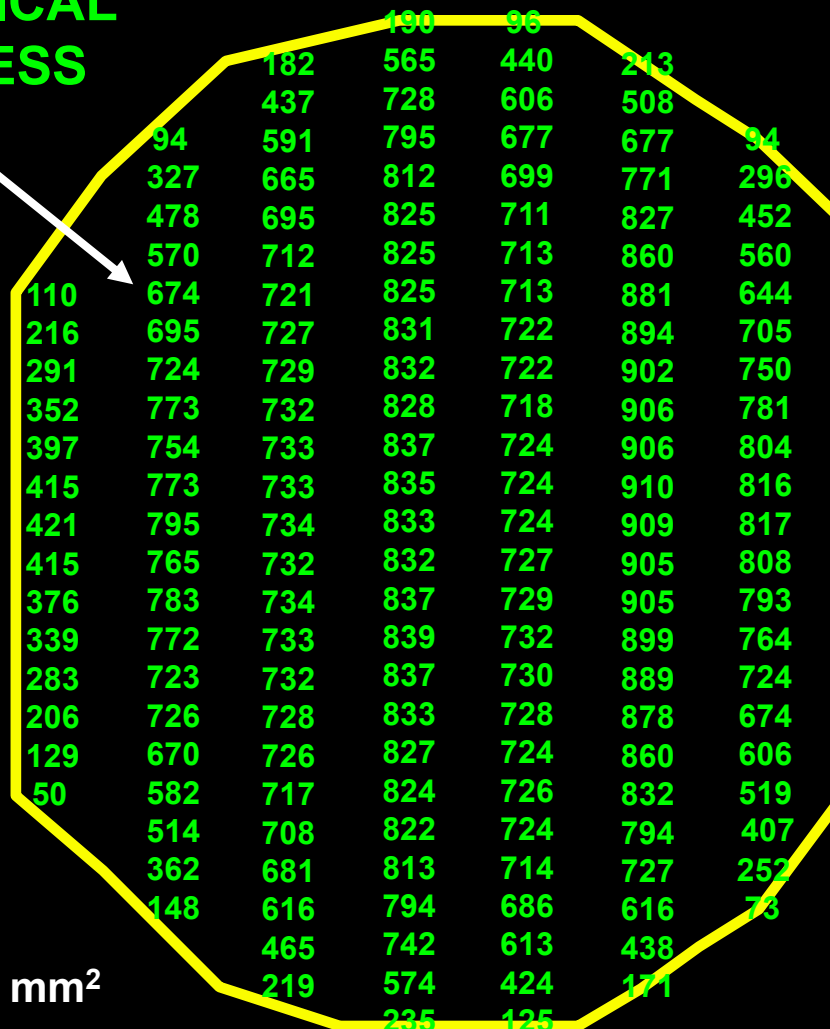


FIGURE 25d

Typical measured tyre contact patch



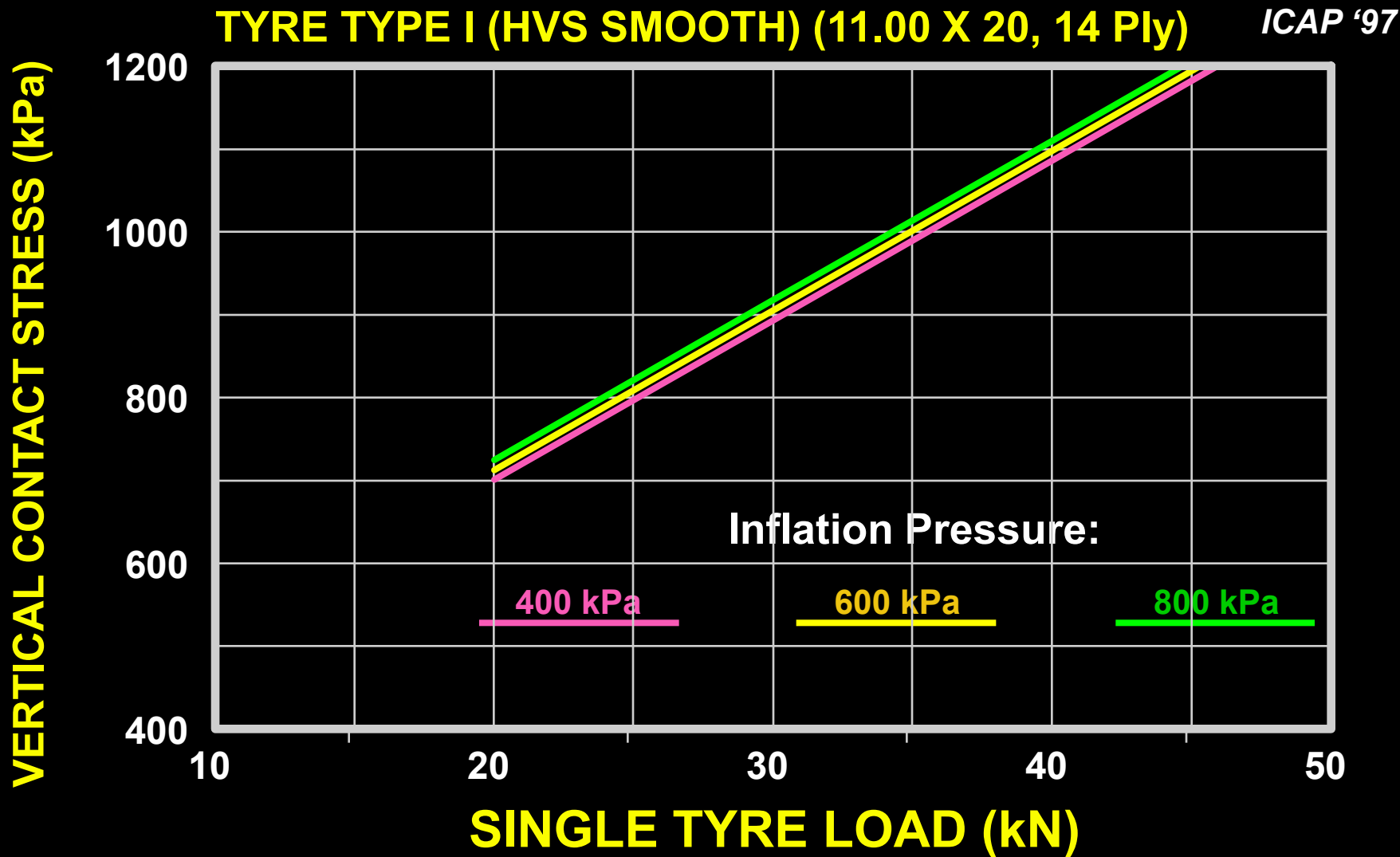


FIGURE 26a

Maximum vertical stress vs tyre load

TYRE TYPE II (HVS - WITH TREAD) (11.00 X 20, 14 Ply)

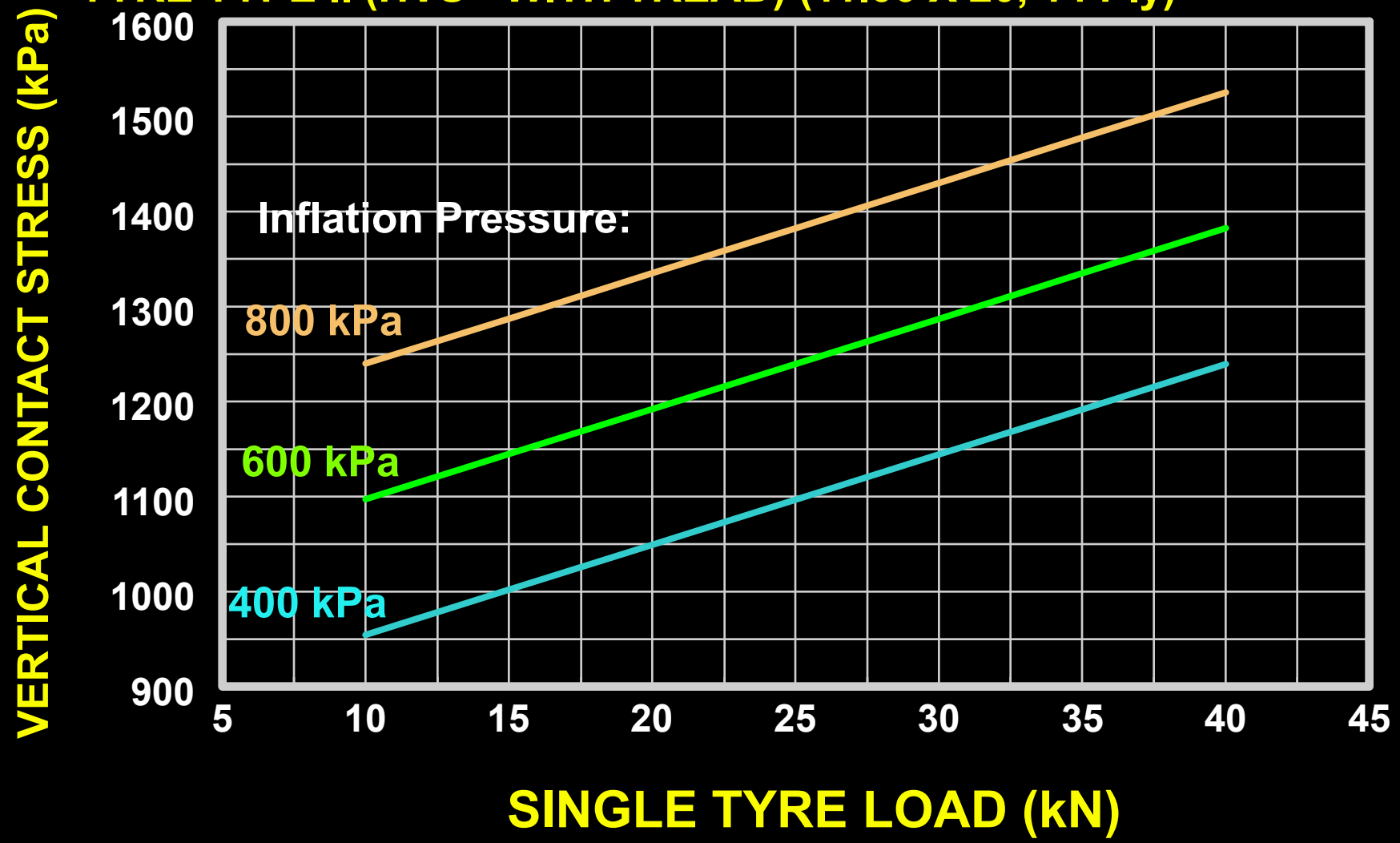


FIGURE 26b

Maximum vertical stress vs tyre load

TYRE TYPE III (AIRCRAFT TYRE)

ICAP '97

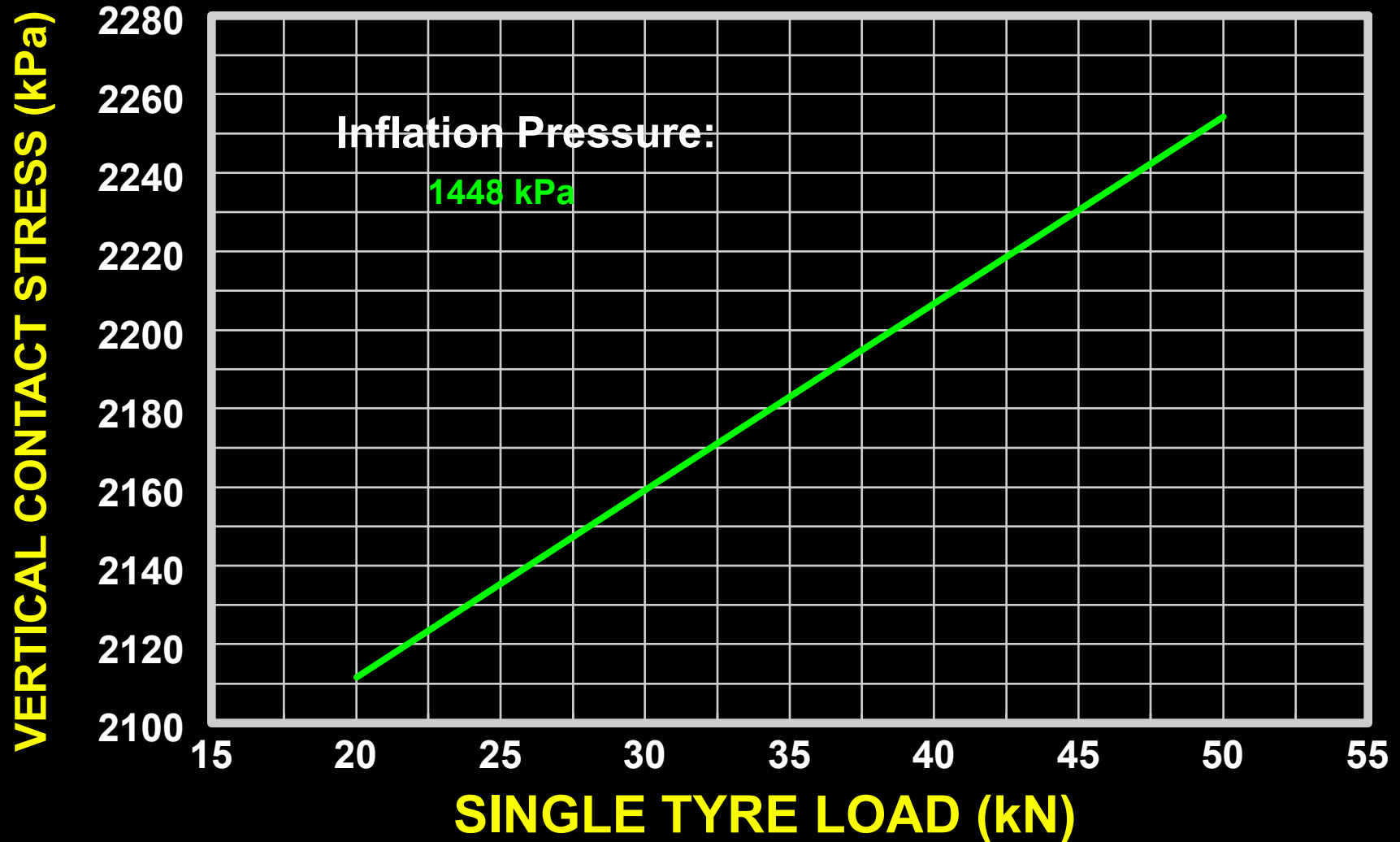


FIGURE 26c

Maximum vertical stress vs tyre load



CSIR

TYRE TYPE IV (315/80 R22.5)

ICAP '97

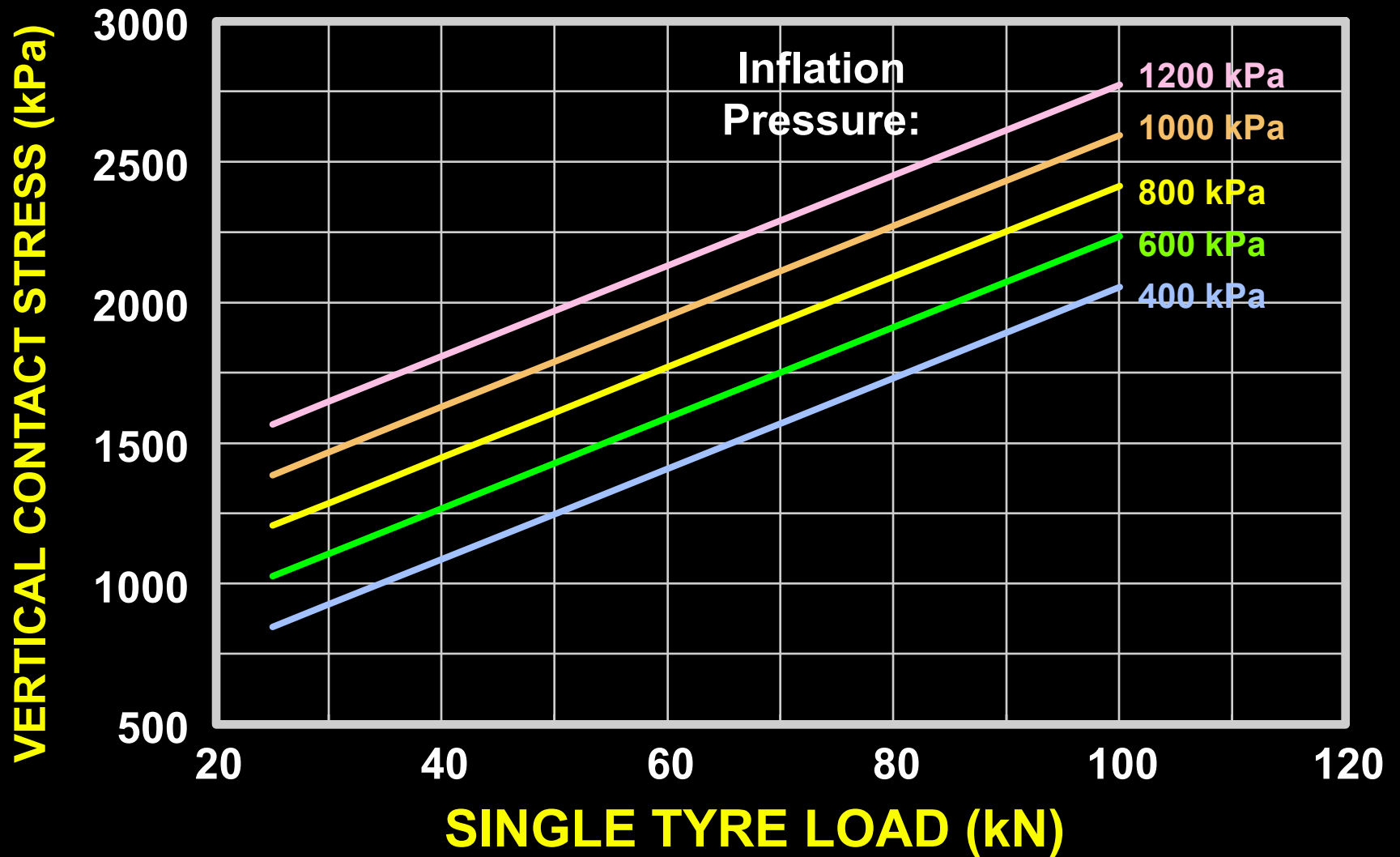


FIGURE 26d

Maximum vertical stress vs tyre load

TYRE TYPE V (425/65 R22.5 - WIDE BASE)

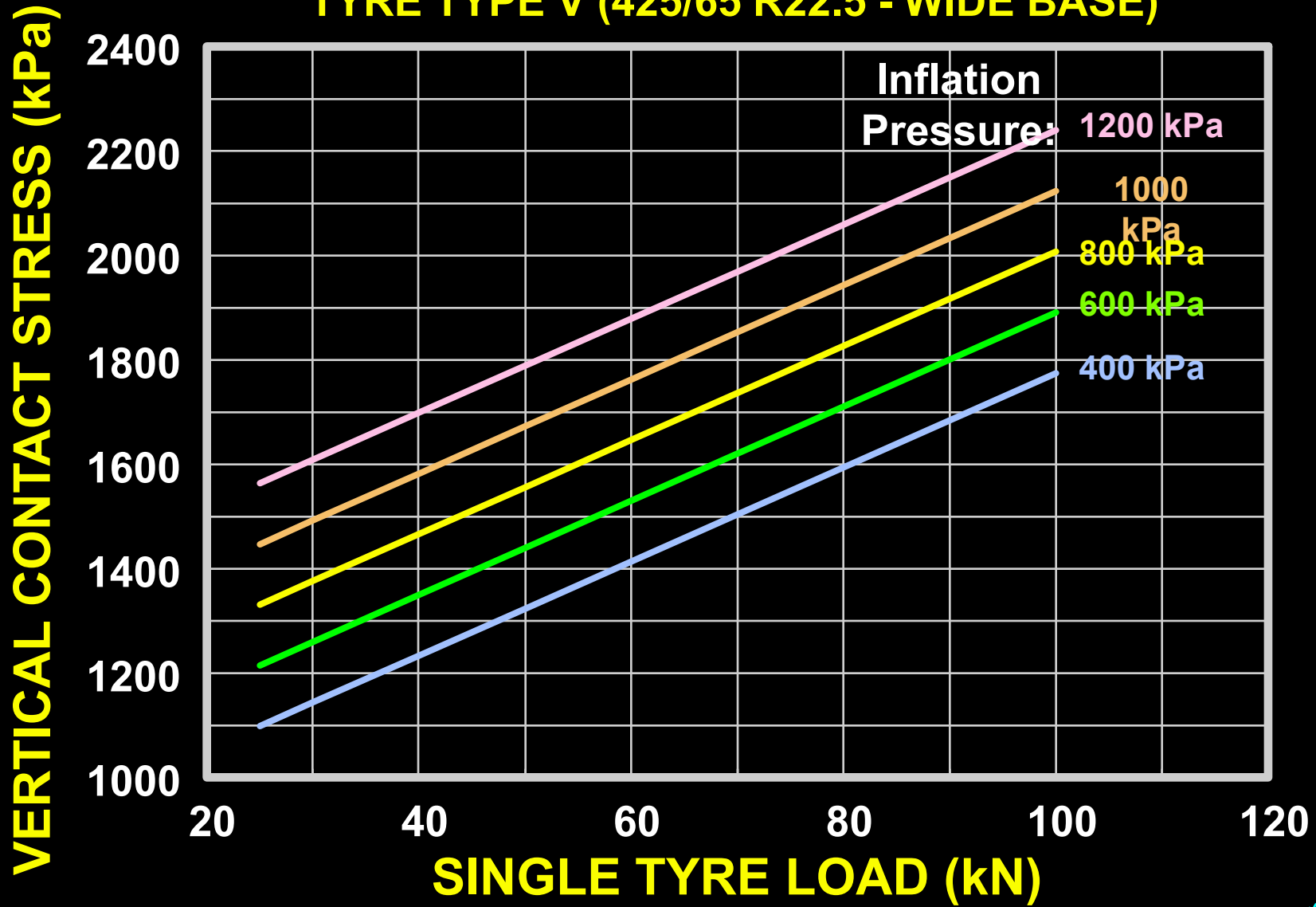


FIGURE 27a

Maximum vertical stress vs tyre load

TYRE TYPE VI (425/65 R22.5 - R160AZ WIDE BASE)

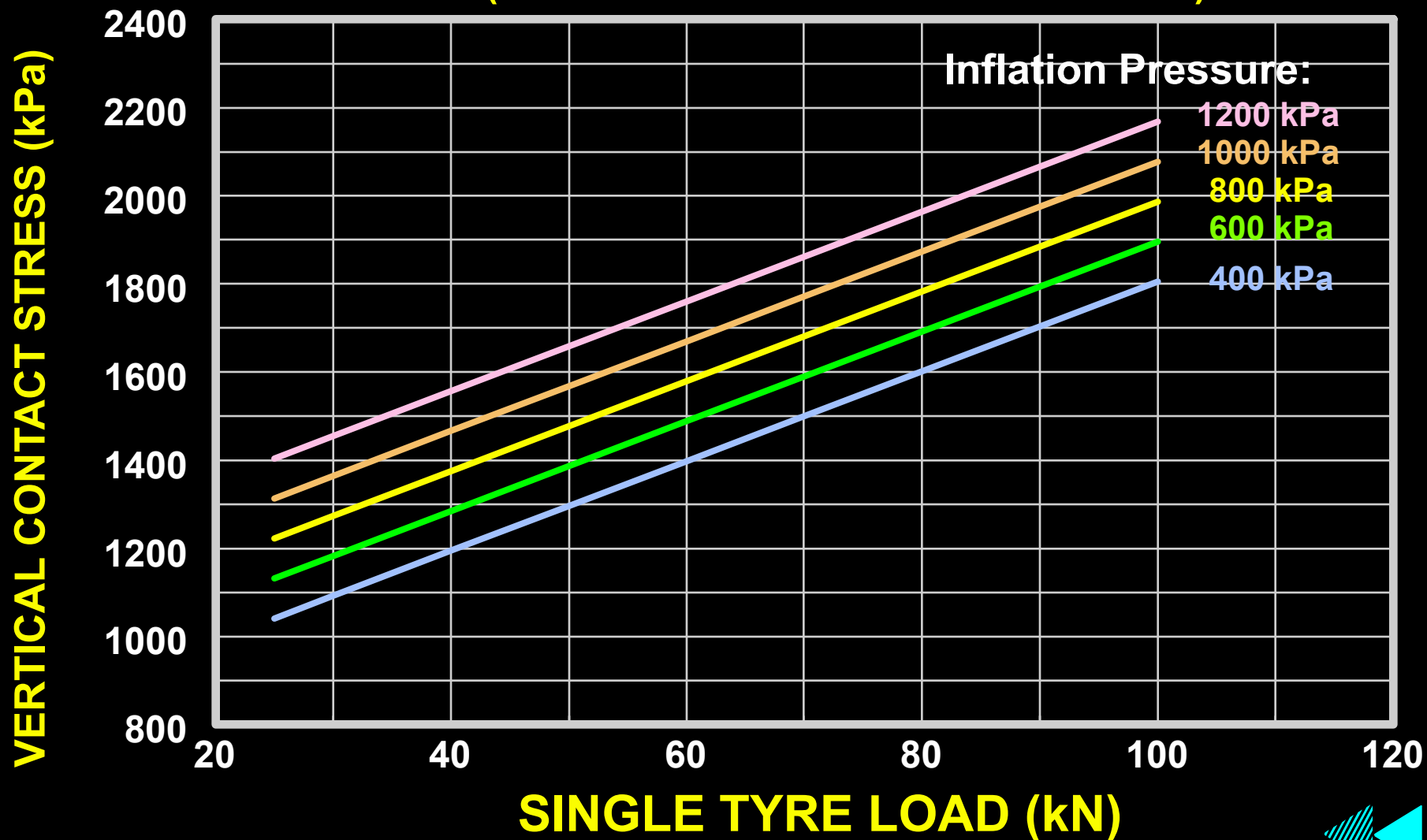


FIGURE 27b

Maximum vertical stress vs tyre load



**TYRE TYPE VII (425/65 R22.5 - R160BZ - WIDE
BASE)**

ICAP '97

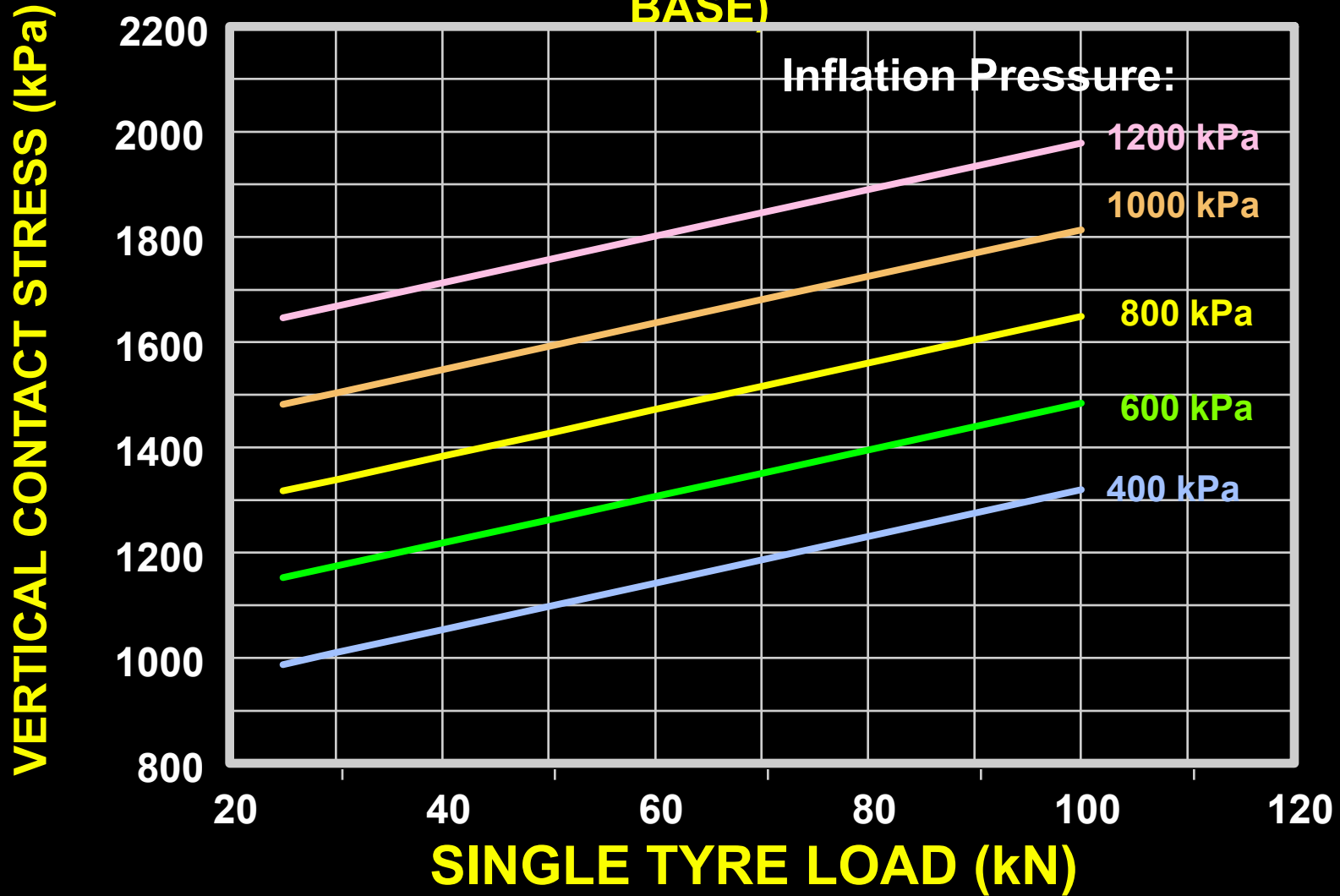


FIGURE 27c

Maximum vertical stress vs tyre load

DEPTH (mm)

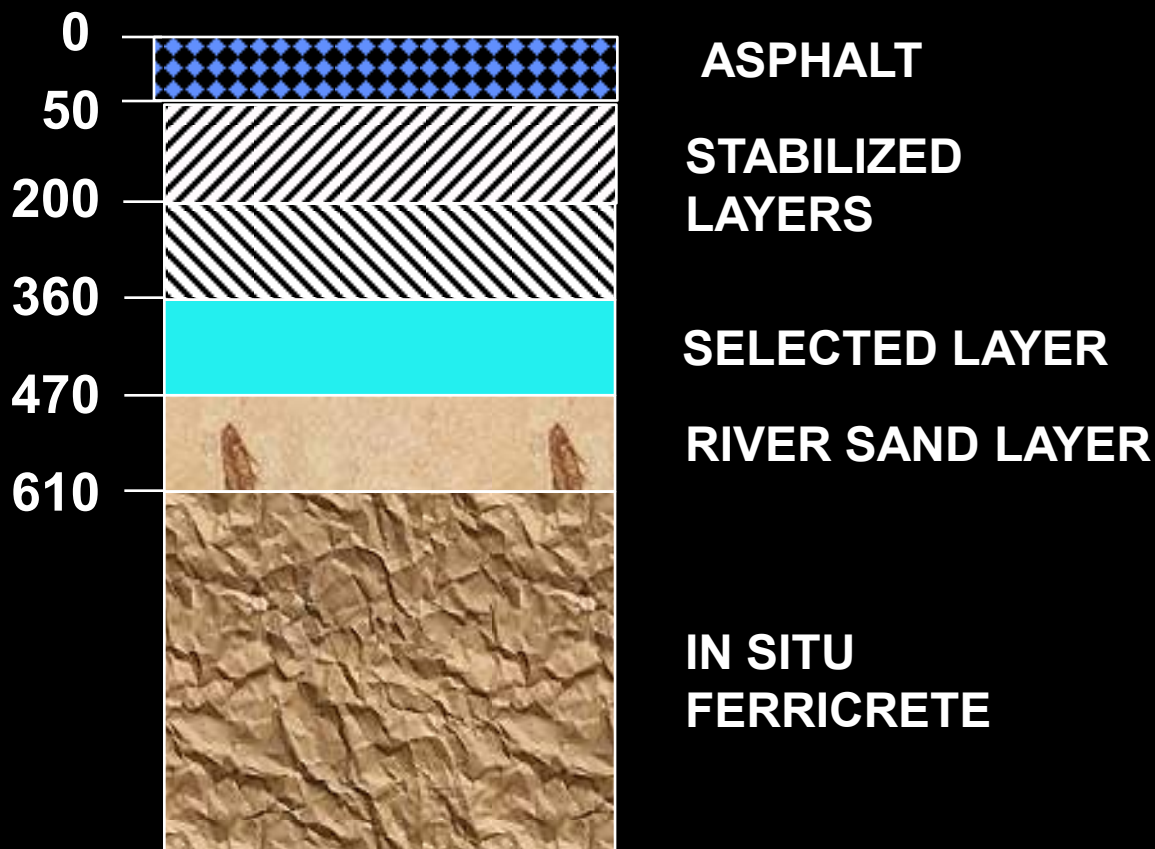


FIGURE: 28

**Pavement structures evaluated
with the HVS**

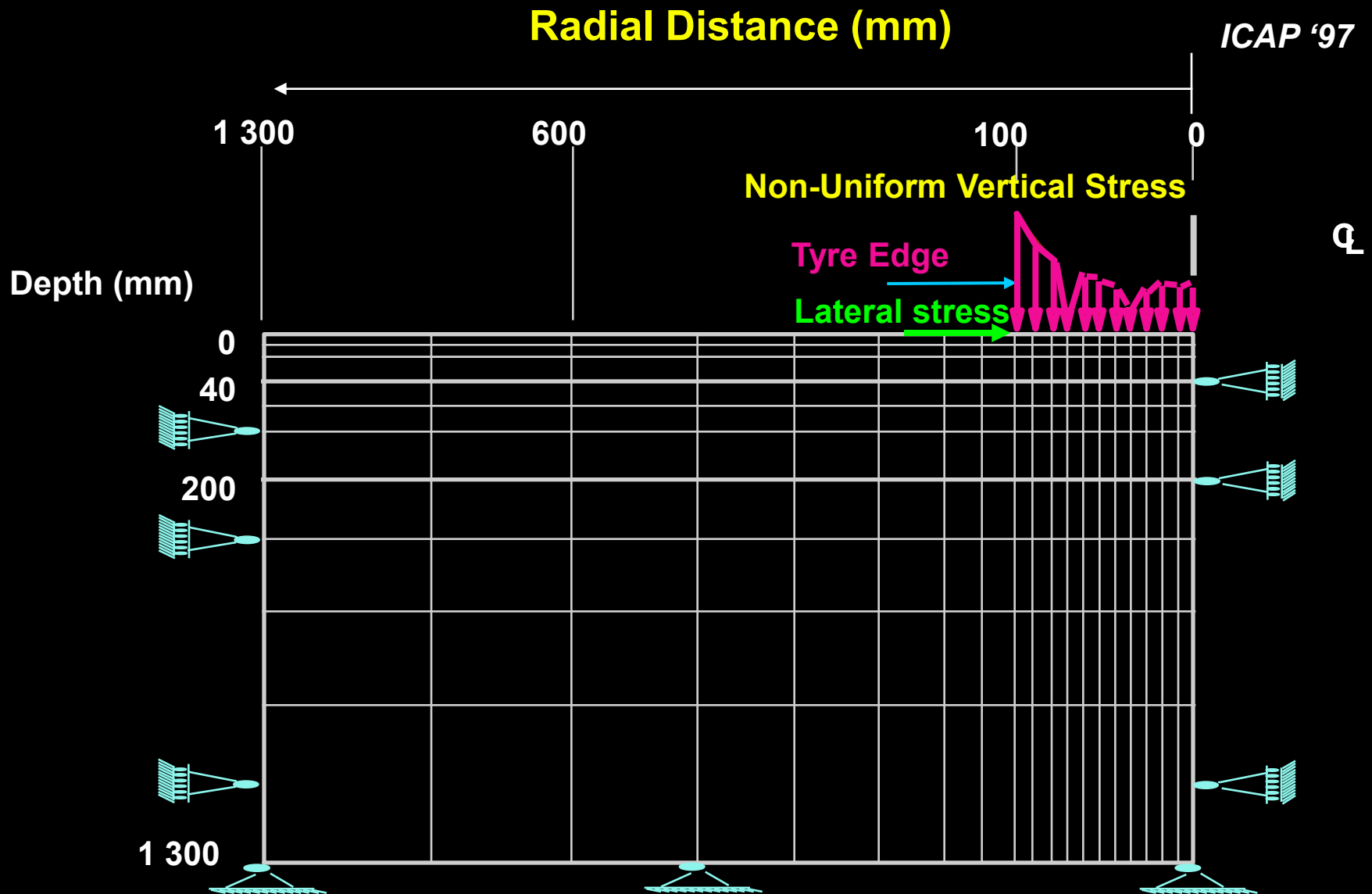


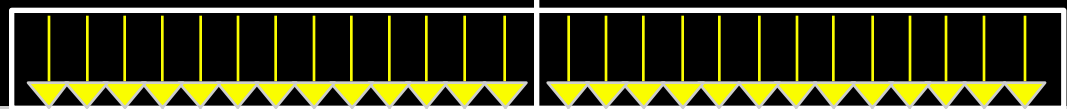
FIGURE: 29

**Axi-symmetrical Finite Element Model
used in this study**

TYPE
I

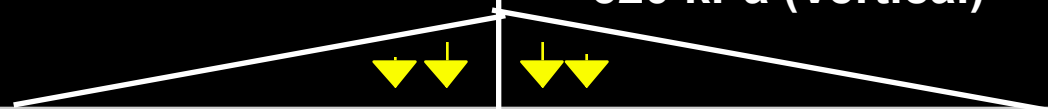


520 kPa (Vertical)



II

520 kPa (Vertical)



III

520 kPa (Vertical)



IV

520 kPa (Vertical)



260 kPa
(Inward Shear)

V

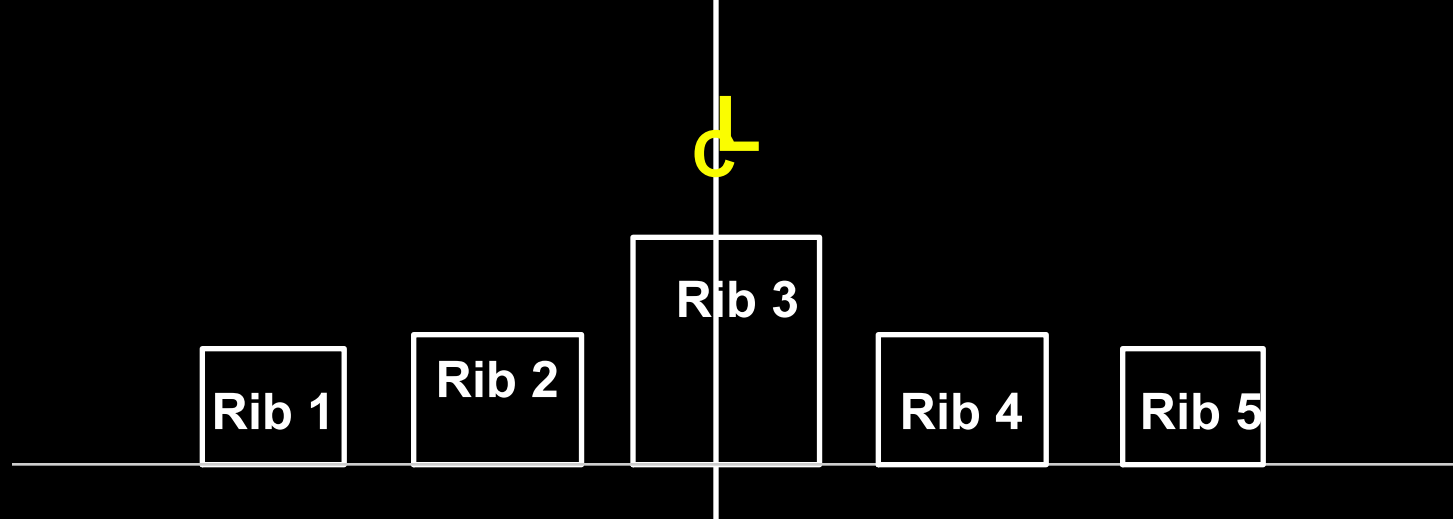
520 kPa (Vertical)



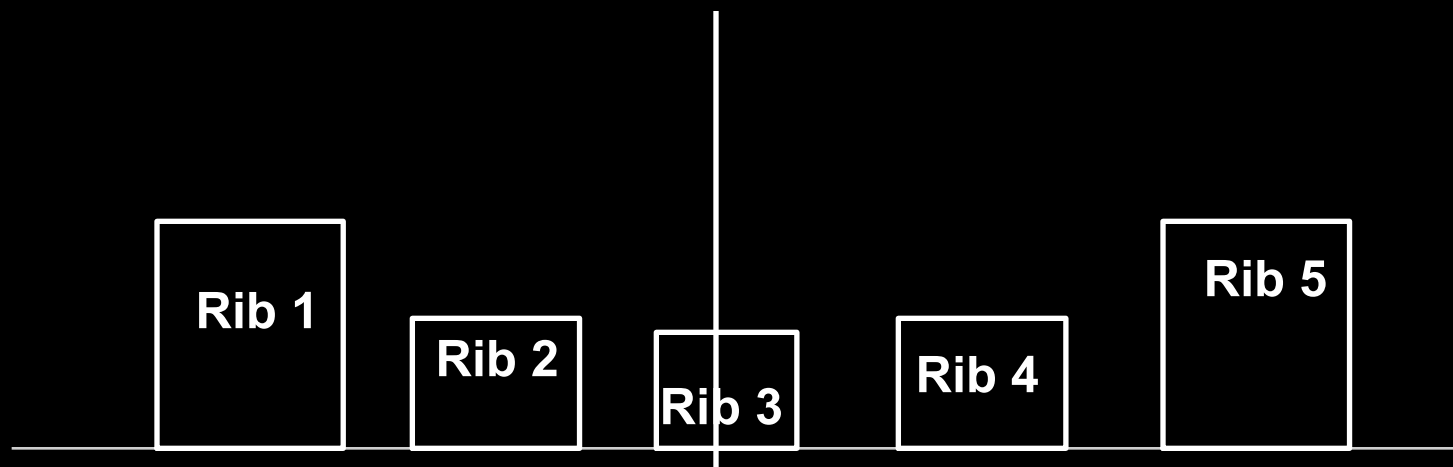
260 kPa
(Outward Shear)

FIGURE: 30

Load/Contact Stress Idealizations used for the analysis in this study

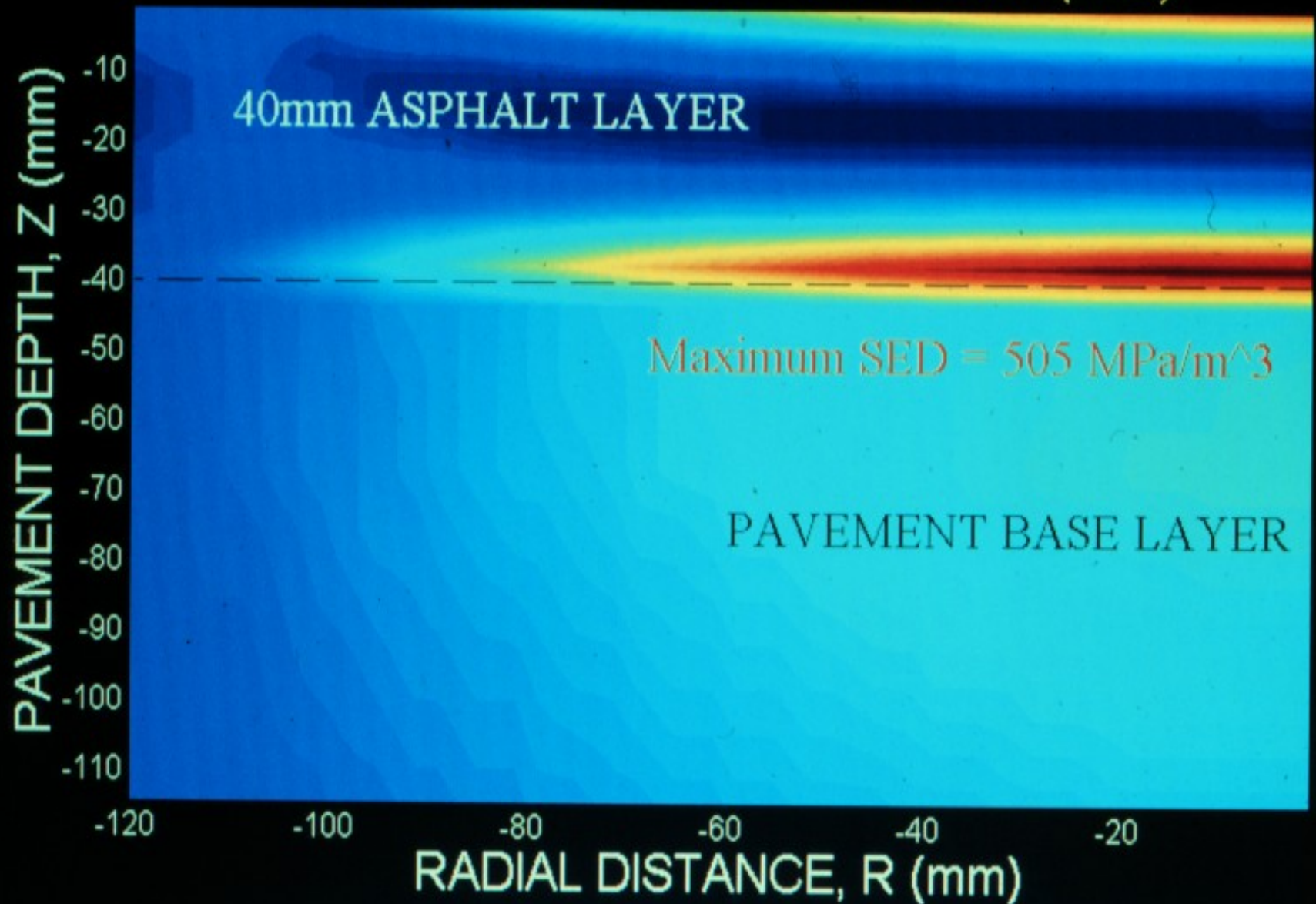


TYPE VI - TYRE CENTRE
(Vertical and lateral)

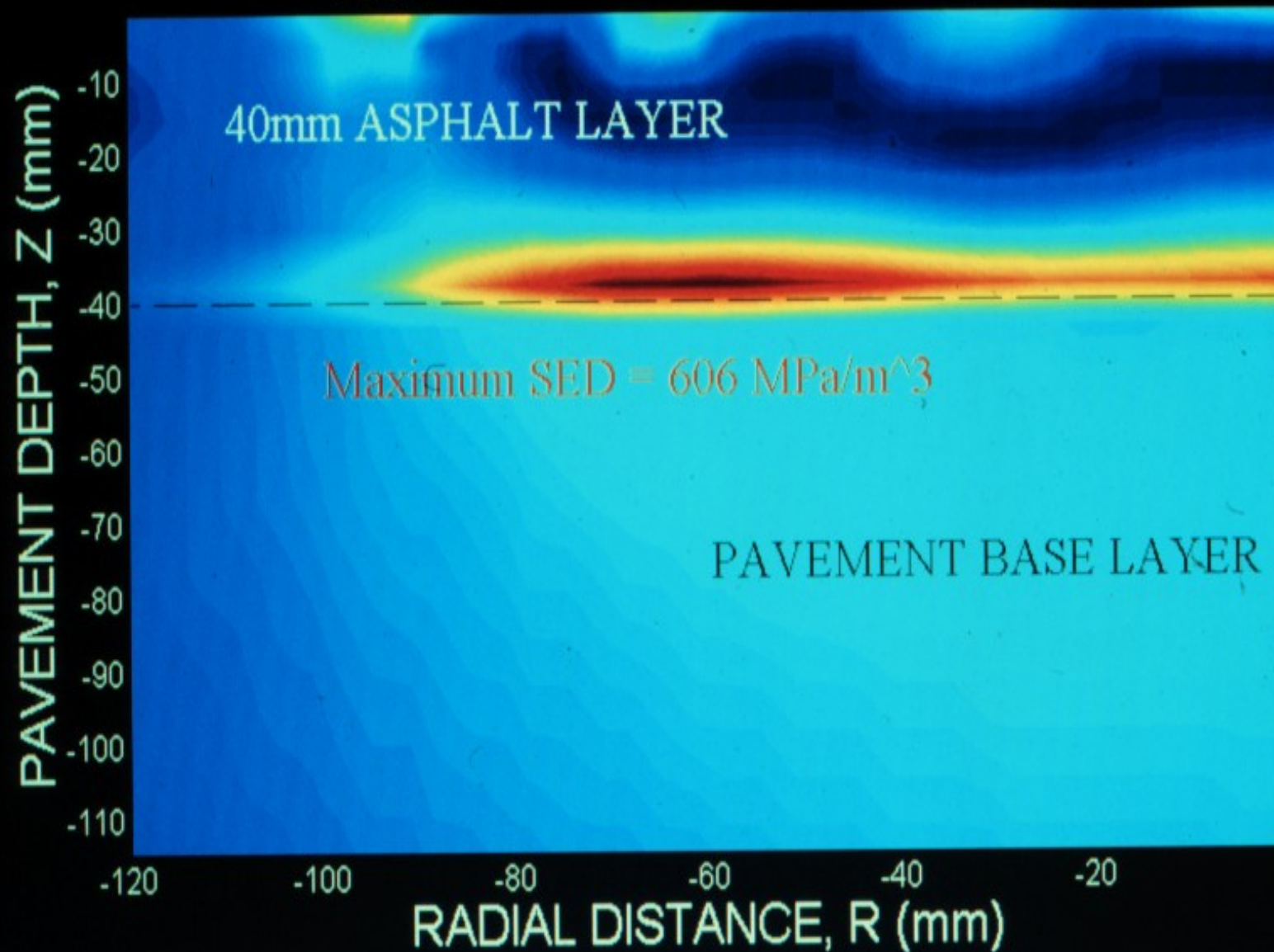


TYPE VII - TYRE EDGE
(Vertical and lateral)

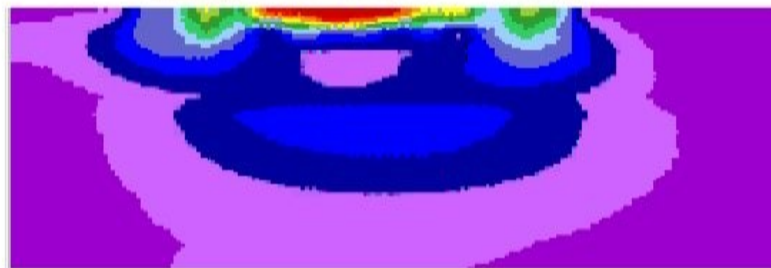
UNIFORM VERTICAL STRESS (520 kPa)
STRAIN ENERGY OF DISTORTION (SED)



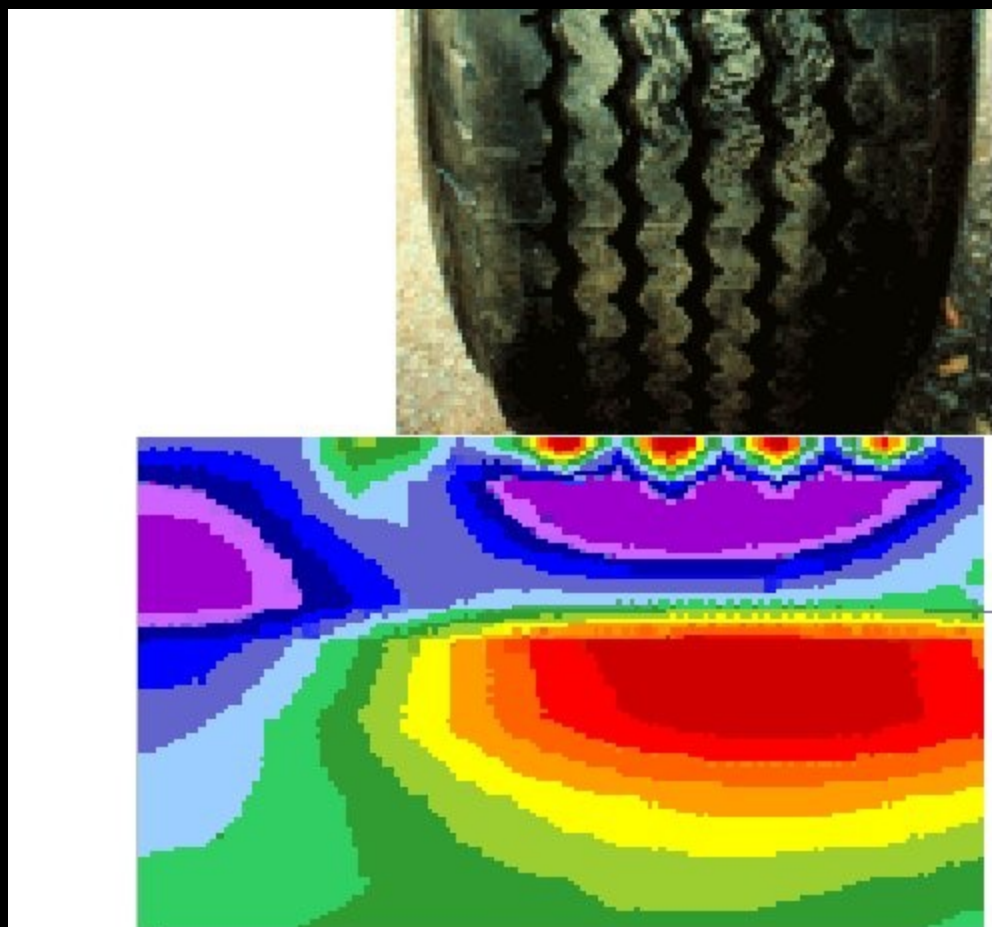
NON-UNIFORM STRESS (EDGE) (420 kPa)
STRAIN ENERGY OF DISTORTION (SED)



Pseudo-Energy under non-uniform contact stress conditions (Symplectic Engineering Corporation, USA)



Colour maps of Shape distortion (Symplectic Engineering Corporation)



TRUCK AXLE WITH DUAL TYRES
(DEFLECTOGRAPH - TYRE TYPE: 11.00 X 20, 14 Ply India Supertex 238)

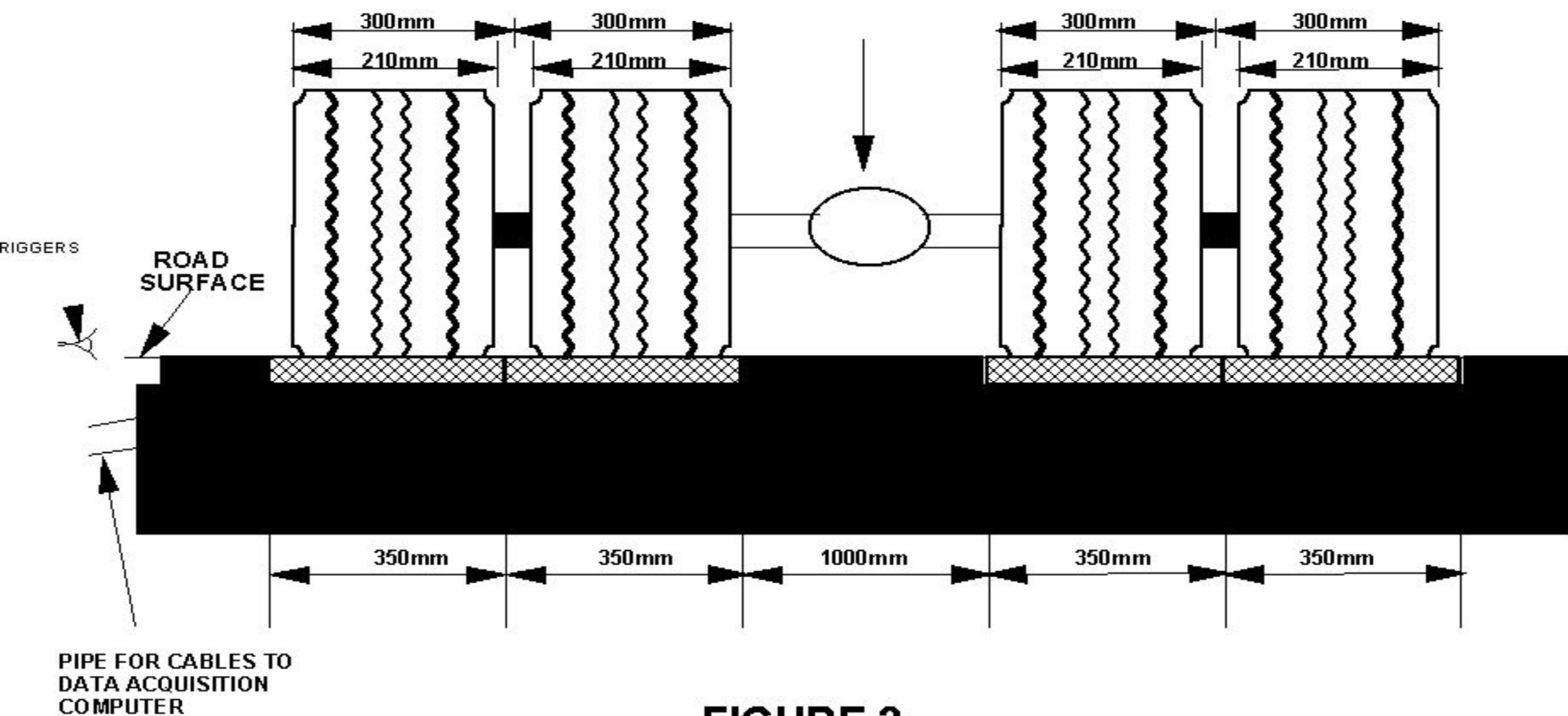


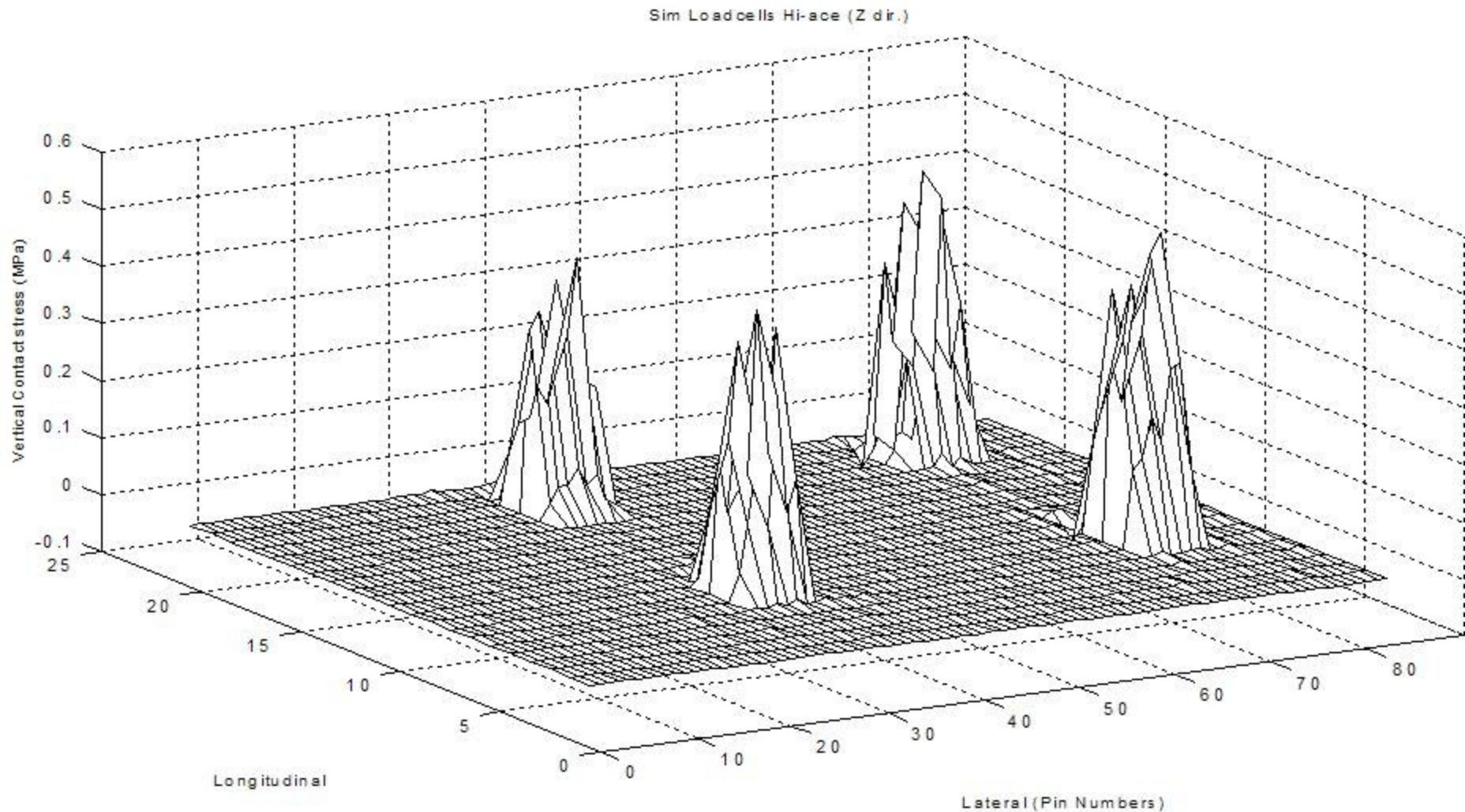
FIGURE 2

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

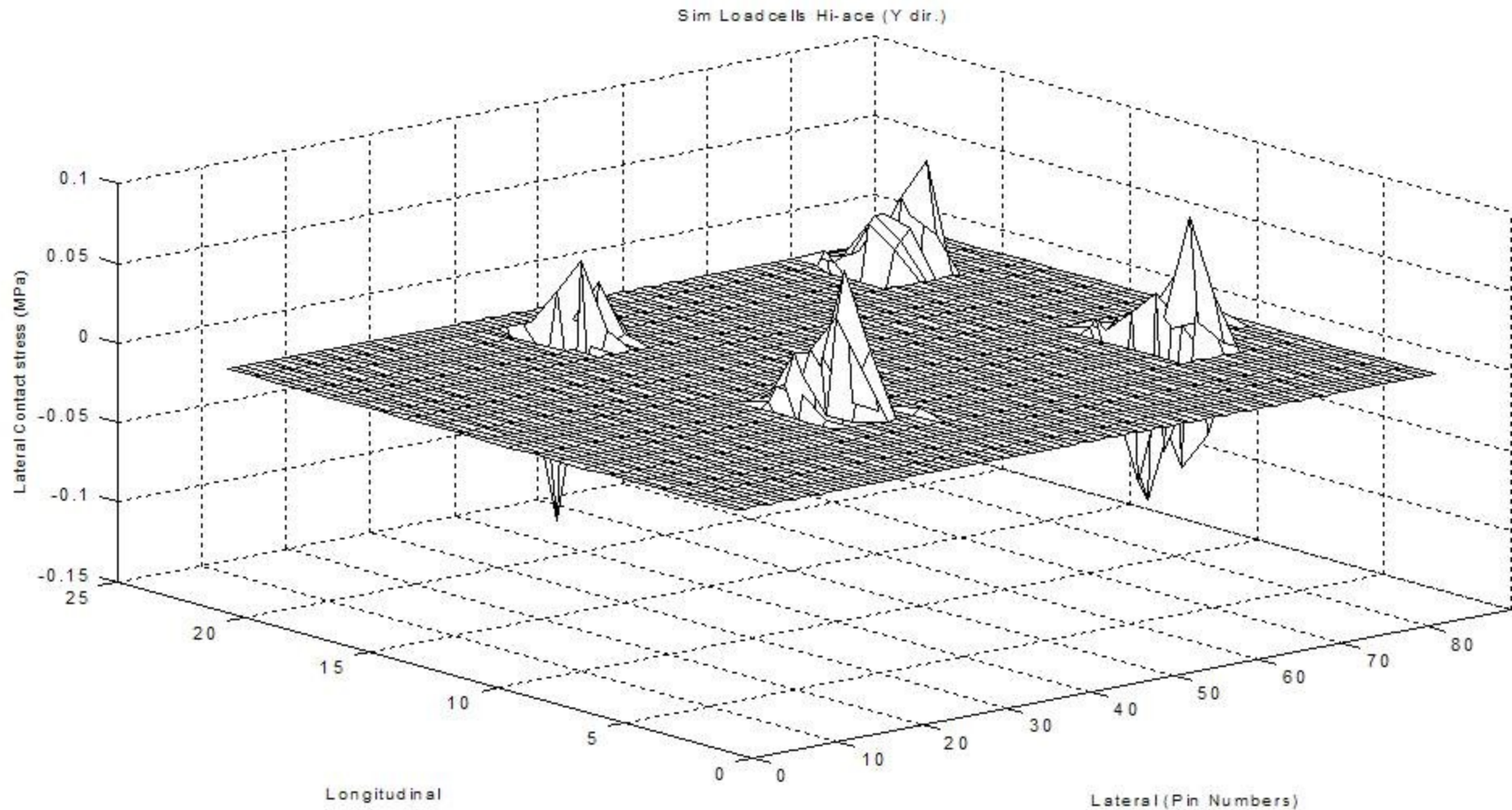
VRSPTA Mark III



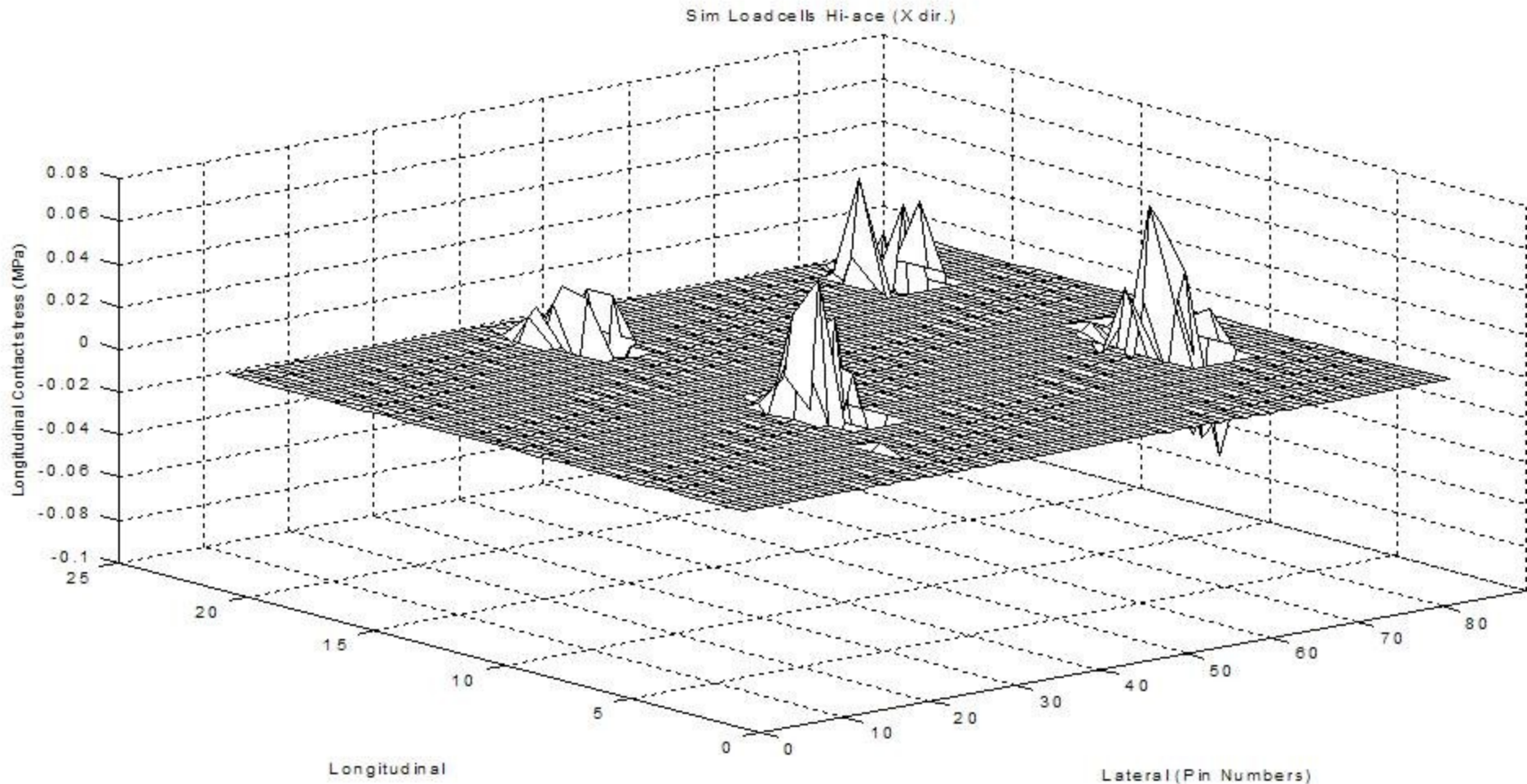
Light Passenger Vehicle: Vertical Contact Stress



Light Passenger Vehicle: Lateral Contact Stress



Light Passenger Vehicle: Longitudinal Contact Stress





WARNING



PASOP
STADIGE
TOETS
VOERTUIG



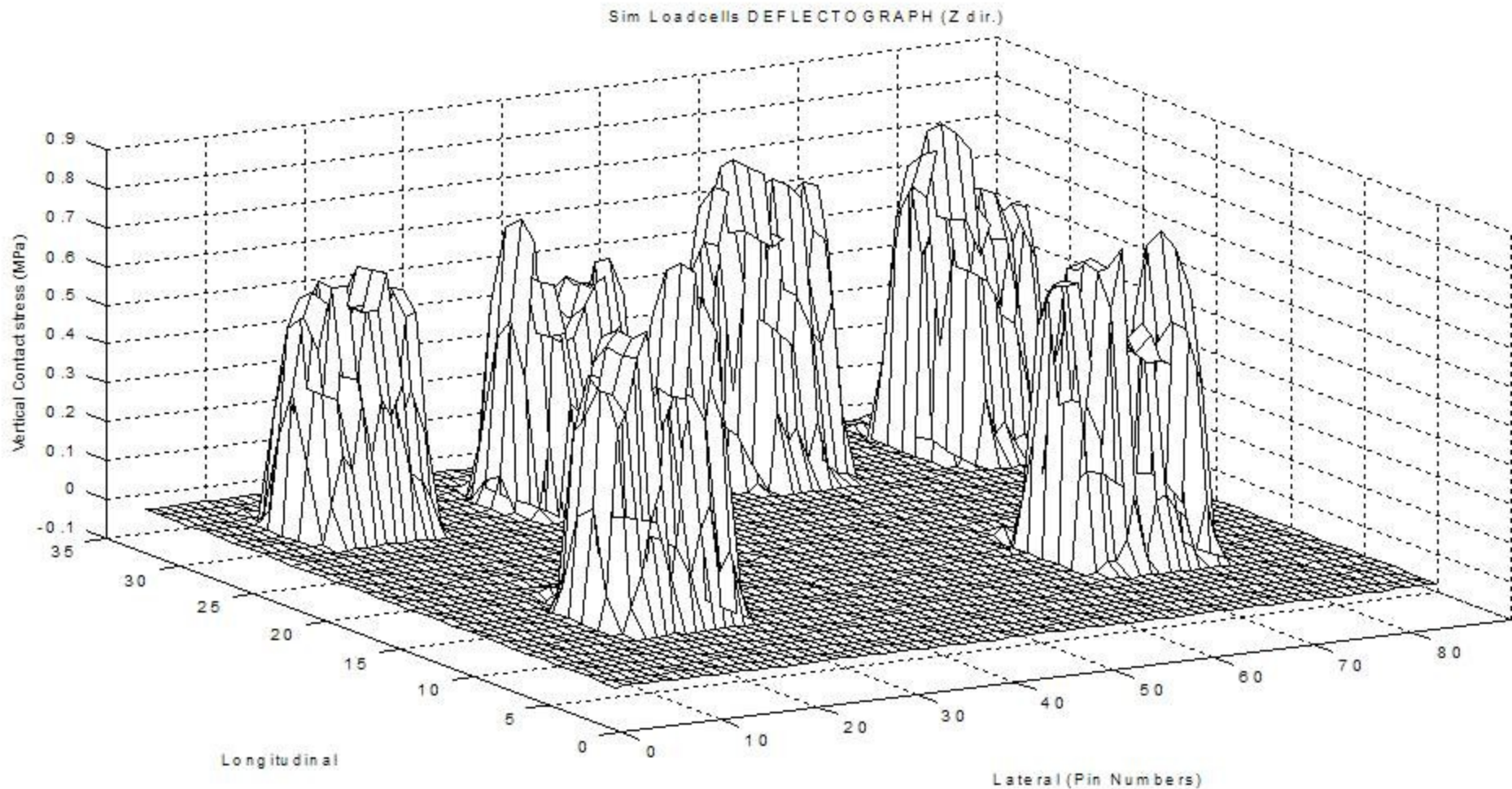
CAUTION
SLOW
TEST
VEHICLE

80

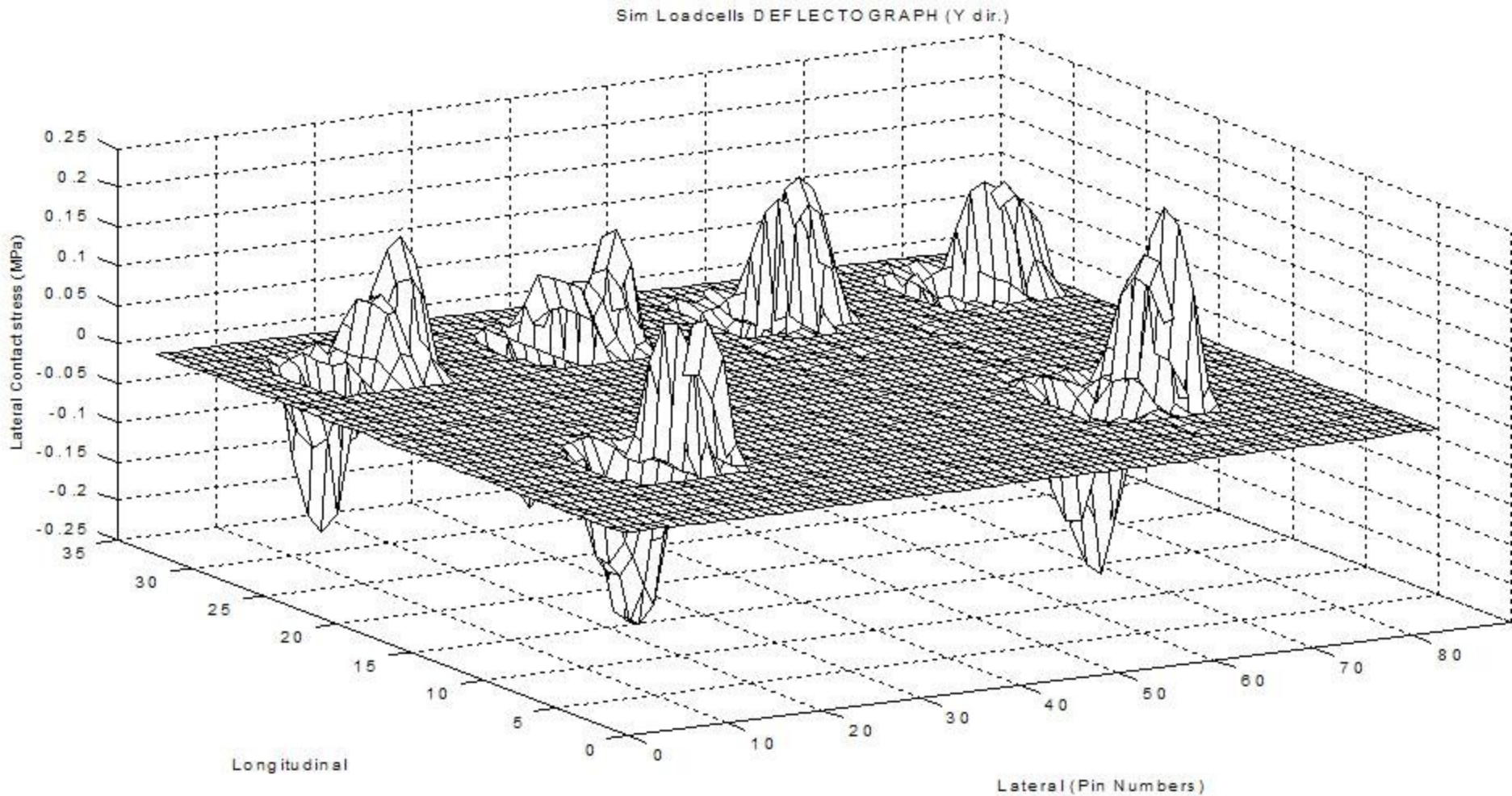
KMP270T



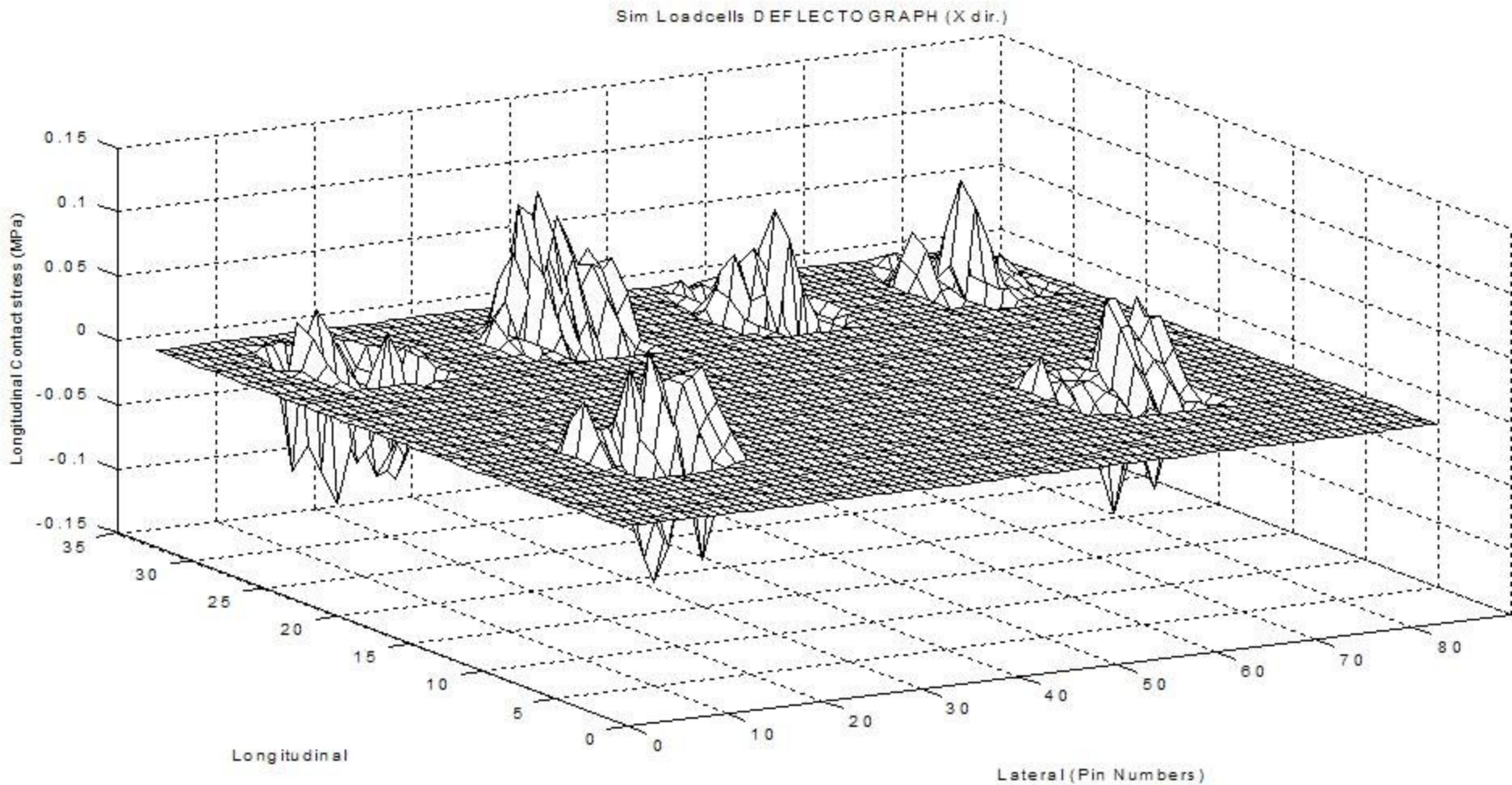
Deflectograph Truck (80kN, 650 kPa): Vertical Contact Stress



Deflectograph Truck (80kN, 650 kPa): Lateral Contact Stress

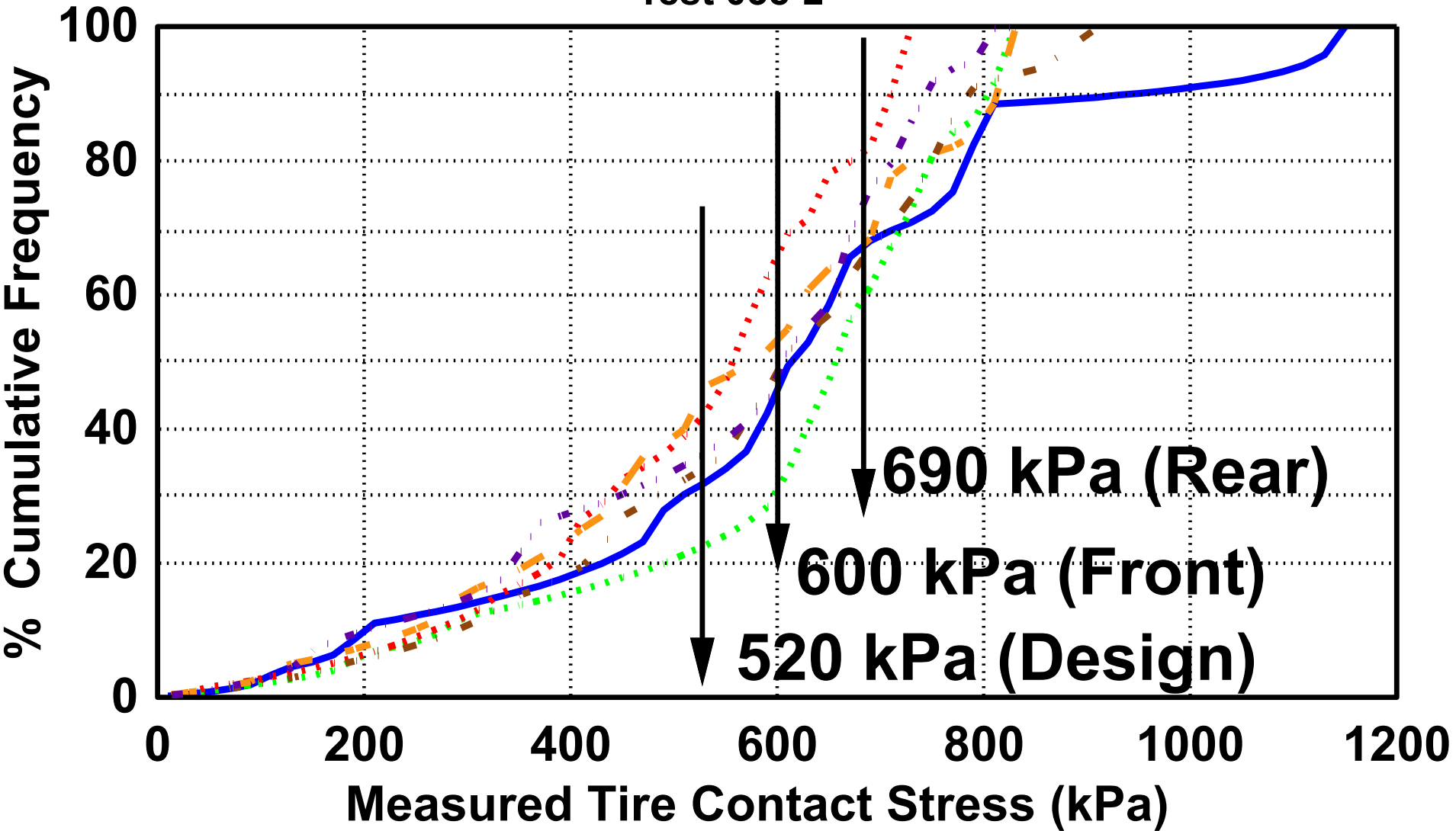


Deflectograph Truck (80kN, 650 kPa): Longitudinal Contact Stress



DEFLECTOGRAPH (OCTOBER 1998)

Test 038-z



Tyre	Front Left	Front Right	Rear Left Outer	Rear Left Inner	Rear Right Outer	Rear Right Inner
Inflation Pressure	600 kPa	600 kPa	690 kPa	690 kPa	690 kPa	690 kPa



N1 Mantsole Weighbridge

12 11'97



12 11 '97

Maximum axle load legally allowed on South African Roads from 1996

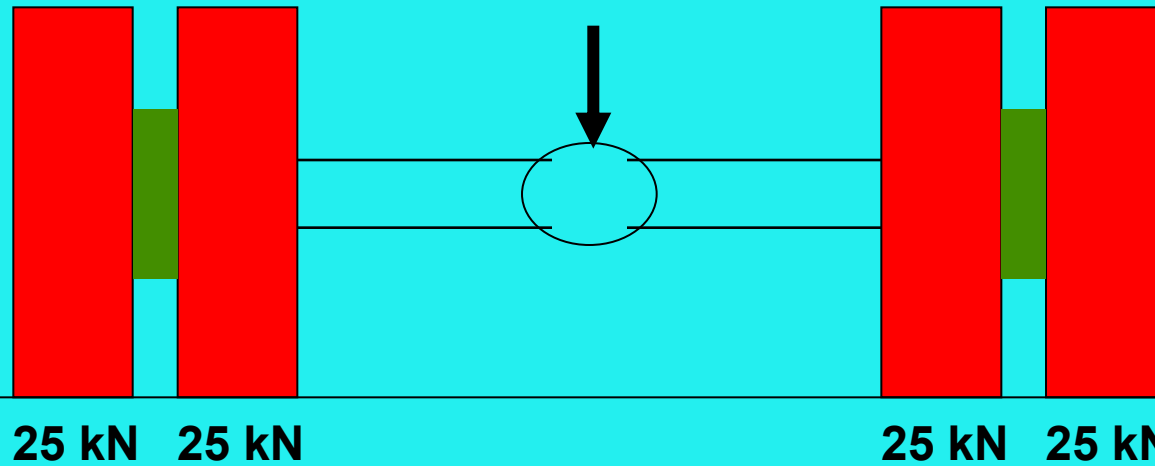
Type of axle	No of tyres per axle	Axle Mass (kg)	Load per Axle (kN)*
Single axle (steering)	2 or 3	7 700 (7 700)	76
Single axle (non-steering)	2 or 3	8 000 (7 700)	78
Single axle	4 or more	9 000 (8 200)	88
Tandem axle	4 or more	18 000 (16 400)	88
Tridem axle	4 or more	24 000 (21 000)	78,3

() Previous legal load limits

* $g = 9,8 \text{ m/s}^2$

100 kN Axle

**WHEEL
LOAD**



Road Category [TRH4 (1996)]	Percentile Values (%)	Contact Stress (kPa)	Load Radius (mm)
D	50	660	110
C	80	865	96
B	90	975	90
A	95	985	90

**RECOMMENDED (INTERIM) TYRE
CONTACT STRESSES**

Test 038-z

