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
“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”...
ROAD/PAVEMENT DAMAGE...
Truck Tire Inflation Pressure in South Africa:

\[\text{Approximately 20\% Increase in 20 Years}\]

**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.

Van Vuuren (1974) - Average: 620 kPa
De Beer (1995) - Average: 733 kPa
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 suggest that this may be far from real-world conditions....
Tyre Loading, $P$ (kN)

Contact Stress, $q$ (kPa)

Design Tyre Loading (1D): ELSYM, RUBICON
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....
HEAVY VEHICLE SIMULATOR
(HVS Mk III) - [1975 - 1993]
HVS Mark IV+
NEW HVS MkIV (PLUS): TYPICAL DYNAMIC LOAD HISTORY

![Graph showing load cycle 1 and load cycle 2 with turn-around areas marked. The graph includes time in milliseconds (10800-16800) and load in kN (50-75).]
Dynamic Load (HVS Mk IV Plus)
Moving Dynamic Load (sinusoidal)
Uni-directional Load
Permanent Surface Deformation
Area of Interest:

DIRECTION OF TRAVEL OF TYRE
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

Test H2297 done at Heidelberg Dated 1/10/2003 Tyre: RO Axle:1

Vertical Stress (kPa)

Vertical Stress (kPa)

Length of Tyre Contact Patch (mm)

Tyre Width (mm)
Vertical Contact Stress – “m” Shape

Test H2306 done at Heidelberg Dated 1/10/2003 Tyre: RO Axle:5

Vertical Stress (kPa)

Length of Tyre Contact Patch (mm)

Tyre Width (mm)
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
Tyre Load = 18 kN

INFLATION PRESSURE:
- 420 kPa
- 520 kPa
- 620 kPa
- 720 kPa

Tyre width: 220 mm

CONTACT STRESS (kPa)

PIN NUMBER ACROSS VRSPTA

FIGURE 11

Maximum vertical stress at CONSTANT LOAD and various inflation pressures
Tyre Load = 49 kN

Tyre width: 220 mm

CONTACT STRESS (kPa)

PIN NUMBER ACROSS VRSPTA

FIGURE 12

Maximum vertical stress at CONSTANT LOAD and various inflation pressures
INFLATION PRESSURE = 420 kPa

WHEEL LOAD:  
- 20kN
- 30kN
- 40kN
- 50kN

Tyre width: 220 mm

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

CARAVAN SIDE CONTINENTAL 11R22.5 TREDDED

LOAD

INFLATION PRESSURE
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 Caravan Side (Tyre 11R22.5 Treaded)
SIM - HVS04 Inflation Pressure = 800kPa ; Load = 30kN (Tyre 11R22.5 Treaded)
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)
MANTSOLE TRAFFIC CONTROL CENTRE (TCC) ON NATIONAL ROAD NR 1 (N1)

Full Axle SIM

North
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
TEST 765: NKR 9519 - 09/10/2003- STEERING AXLE

Across the SIM pads

Counts

216 mm; 1.778 Ton

203 mm; 1.402 Ton

Across the SIM pads
STEERING AXLE

Data Points

Vertical Load (newtons)

PAD 1
PAD 2
PAD 3
PAD 4

Test No.
765

Registration No
NKR9519
REAR AXLE – UNEQUAL LOADING


- 277 mm; 2.609 Ton;
- 303 mm; 1.390 Ton;
- 257 mm; 2.675 Ton;
- 254 mm; 2.131 Ton;

Counts

Across the SIM pads

REAR AXLE – UNEQUAL LOADING


- 277 mm; 2.609 Ton;
- 303 mm; 1.390 Ton;
- 257 mm; 2.675 Ton;
- 254 mm; 2.131 Ton;

Counts

Across the SIM pads

REAR AXLE – UNEQUAL LOADING


- 277 mm; 2.609 Ton;
- 303 mm; 1.390 Ton;
- 257 mm; 2.675 Ton;
- 254 mm; 2.131 Ton;

Counts

Across the SIM pads
Tyre barely in contact with surface

TEST 768-09/10/2003: DDT235N AXLE 2

189 mm; 0.037 Ton
297 mm; 4.312 Ton
202 mm; 1.874 Ton
194 mm; 1.223 Ton
MAXIMUM VERTICAL STRESS

TYRE barely in contact with surface
Test 174 done at Heidelberg: Date 10/09/2003 (overload) 6-AXLE TRUCK
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)
Design Tyre Loading (1D): ELSYM, RUBICON
Single tyre load: 20 kN; 520 kPa
Modified (1D): ELSYM, RUBICON

Tyre (CENTRE) Loading, $P$ (kN)

Tyre Edge loading, $P$ (kN)

Contact Stress, $q$ (kPa)
SIM: VERTICAL (NORMAL) STRESS, \( \sigma_{zz} \)

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)

40mm ASPHALT LAYER

Maximum SED = 606 MPa/m^3

PAVEMENT BASE LAYER
I/3 – BULK STRESS IN ASPHALT

**KEY:**

(I/3) BULK STRESS

C(kPa) = 2000, 1150, 150

Linear Elastic Solution

Three Layer Pavement

Asphalt Surfacing = 40 mm thick

Static Loading

0.142 (Max. I/3 Bulk Stress)

0.106 (Max. I/3 Bulk Stress)

0.0888 (Max. I/3 Bulk Stress)
SQRT (J2) - SHEAR POTENTIAL IN ASPHALT

SIM - 600 kPa, 35 kN

0.277 (Max. SQRT(J2) Stress)

0.14 (Max. SQRT(J2) Stress)

KEY:

SQRT (J2) Stress:
C(kPa) = 2000, 150, 150
Linear Elastic Solution
Three Layer Pavement
Asphalt Surfacing = 40 mm thick
Static Loading

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 ZAR millions, if effectively employed...
I Thank You all