L'exploitation
et la maintenance
des infrastructures

PN - ANR MOVE
DVDC
DURÉE DE VIE DES CHAUSSÉES

IREX
Institut pour la recherche appliquée et l'expérimentation en génie civil

TRIBOLOGICAL APPROACH TO ROAD PAVEMENT SURFACE BEHAVIOUR

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MINISTÈRE
DE LA TRANSITION
ÉCOLOGIQUE
Liberté
Égalité
Fraternité

Public presentation of results
7 November 2023, ENTPE, Vaulx-en-Velin

AGENCE NATIONALE DE LA RECHERCHE
ANR

Position of the problem, contribution of tribology

- Surface and sub-surface problems (5 cm): cost 15 billion euros / year
- Scientific and practical solutions to surface pathologies (not affordable with current methods or very heavy calculation tools)

  Top down cracking TDC; rutting; polishing

- Realism of tyre-road pavement contact - better mechanical quality in design and repair

Multiplication of singular points; Reduction in course thicknesses; Materials (new formulations)

- Tribology (science of contact, friction, wear, lubrication, etc.)

  Tractive rolling, braking and cornering are not taken into account

  Rapid calculation accessible to manufacturers



GET AS CLOSE AS POSSIBLE TO THE REALITY OF SURFACE CONTACT

CALCULATE THE STRESSES AND DEFORMATIONS ON A ROAD PAVEMENT SURFACE, TAKING FRICTION INTO ACCOUNT

Semi-analytical contact calculation since 1990

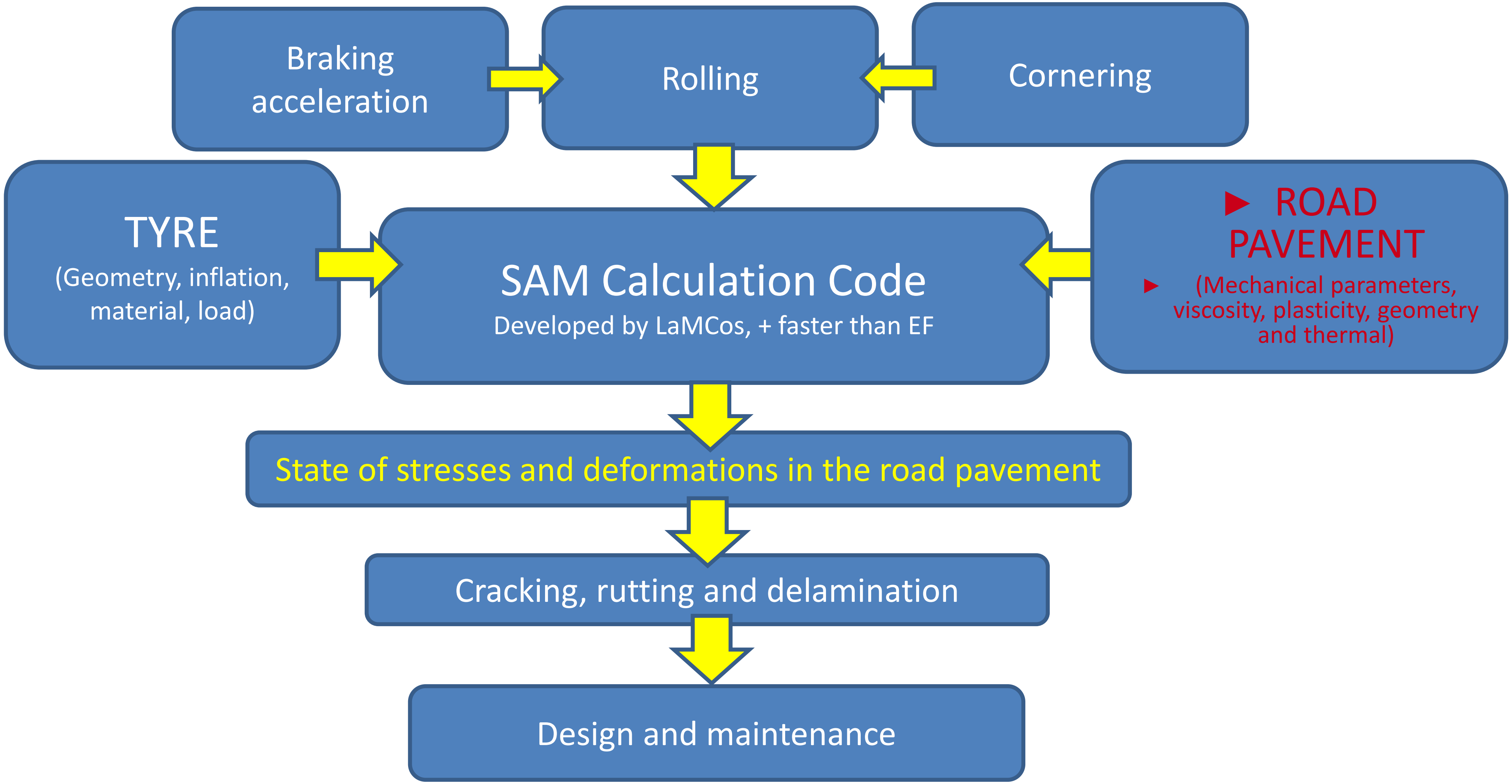
Similarity of the contact problem (only the materials and dimensions change)

Geometry
Kinematics
Loading
Materials
Friction

Calculation of stresses and deformations at any point

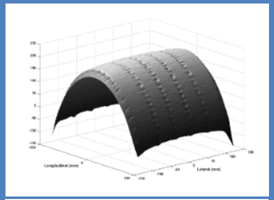
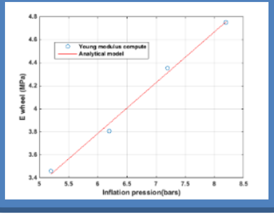
OUR APPROACH: ADAPT THE ROLLING CALCULATION CODE (SAM) TO THE TYRE-ROAD PAVEMENT CONTACT

STUDY PARAMETERS

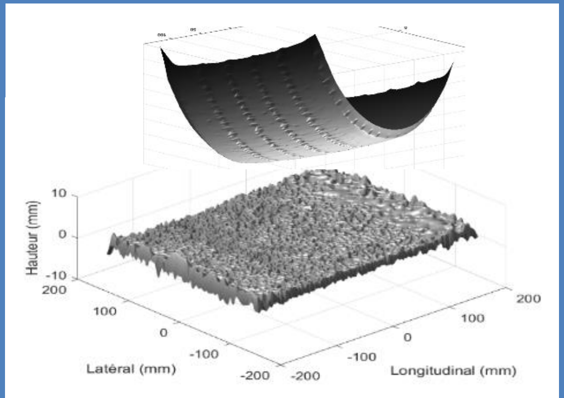


HOW SAM WORKS

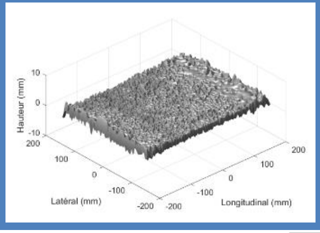
TYRE

CONTACT

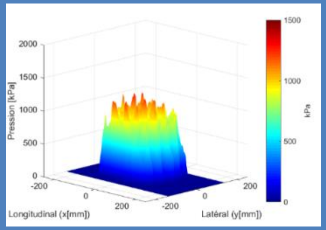


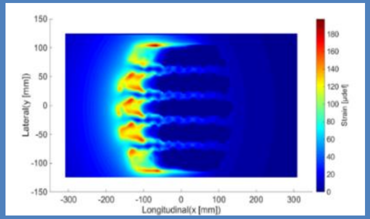
ROAD PAVEMENT

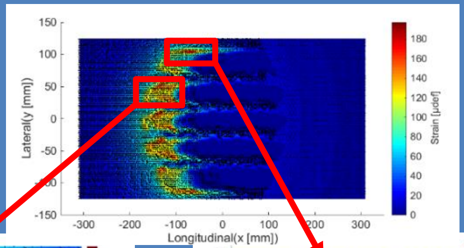


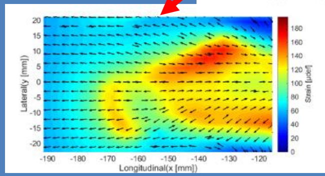
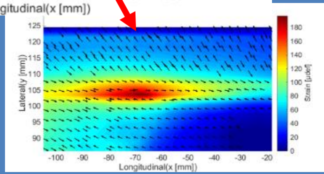
Effort normal W	32 kN
Effort tangentiel longitudinal F_x	[-10, 10] kN
Effort tangentiel latéral F_y	10 kN
Module d'Young du pneu E_w	2,92 MPa
Coefficient de Poisson du pneu ν	820
Pression de gonflage du pneu	820 kPa
Module d'Young du BBSG (15 °C, 10 Hz) E_c	5 400 MPa
Coefficient de Poisson du BBSG ν	0,35
Coefficient de frottement μ	0,7

RESULTS

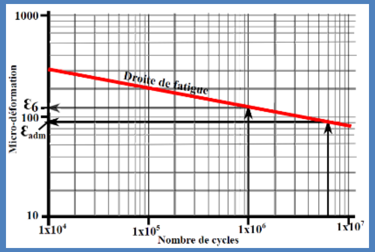






CRITERION

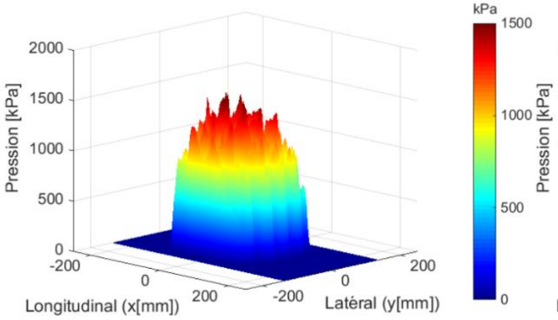


NEED FOR FATIGUE RESULTS ON SURFACE COURSES DESIGN

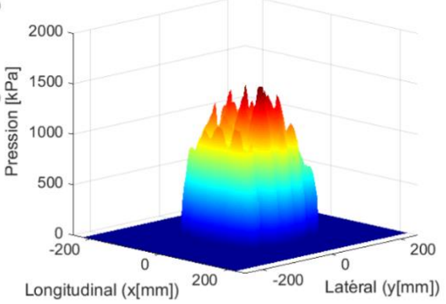


CALCULATIONS WITH THE STATIC SAM CODE (DVDC PHASE 1)

TYRE LOAD W= 32.5 kN

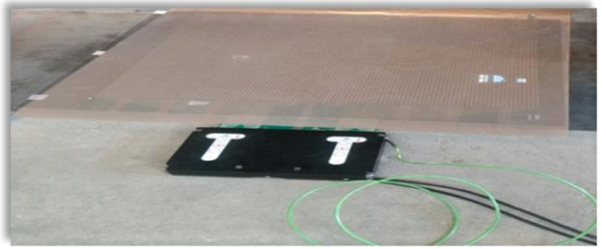


Pressure field calculated by SAM



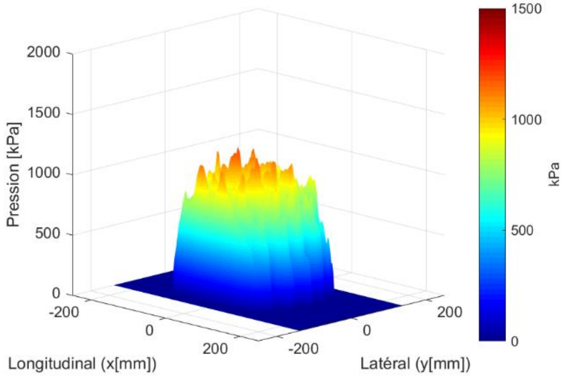
Pressure field measured by Tekscan

Maximum pressure 1.5 MPa

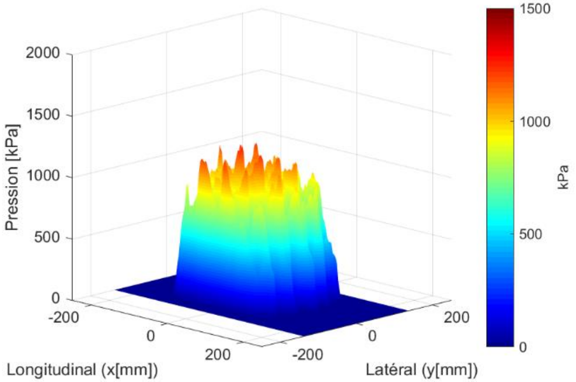


Validations by measurement with a Tekscan resistive pressure sensor

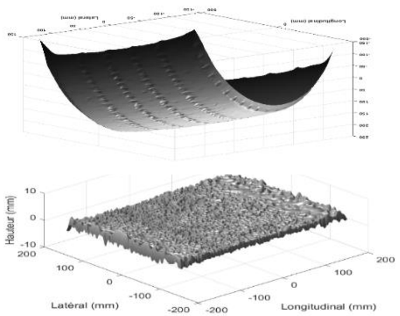
Good agreement between SAM and Tekscan measurements



Pressure field calculated by SAM
On smooth road pavement Pmax = 1.5 MPa



Pressure field calculated by SAM
On digitised actual road pavement Pmax = 1.5 MPa



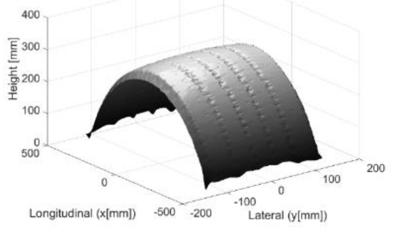
Negligible influence of the consideration of an actual road surface on the contact pressure
The tyre profile is decisive

Mesh size: 3x3x3 mm

CPU time (Core i5 2×2.5 GHz – 8 GB RAM): **7 sec**

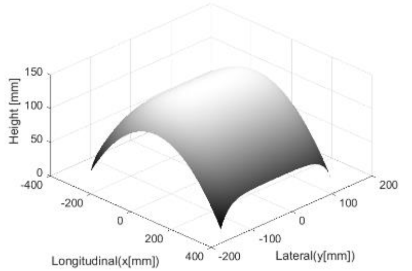


Evolution of the normal stress field at depth



Profile with real tyre (inflation pressure 8 bar, load 35 kN)

Profile with smooth tyre (inflation pressure 8 bar, load 35 kN)

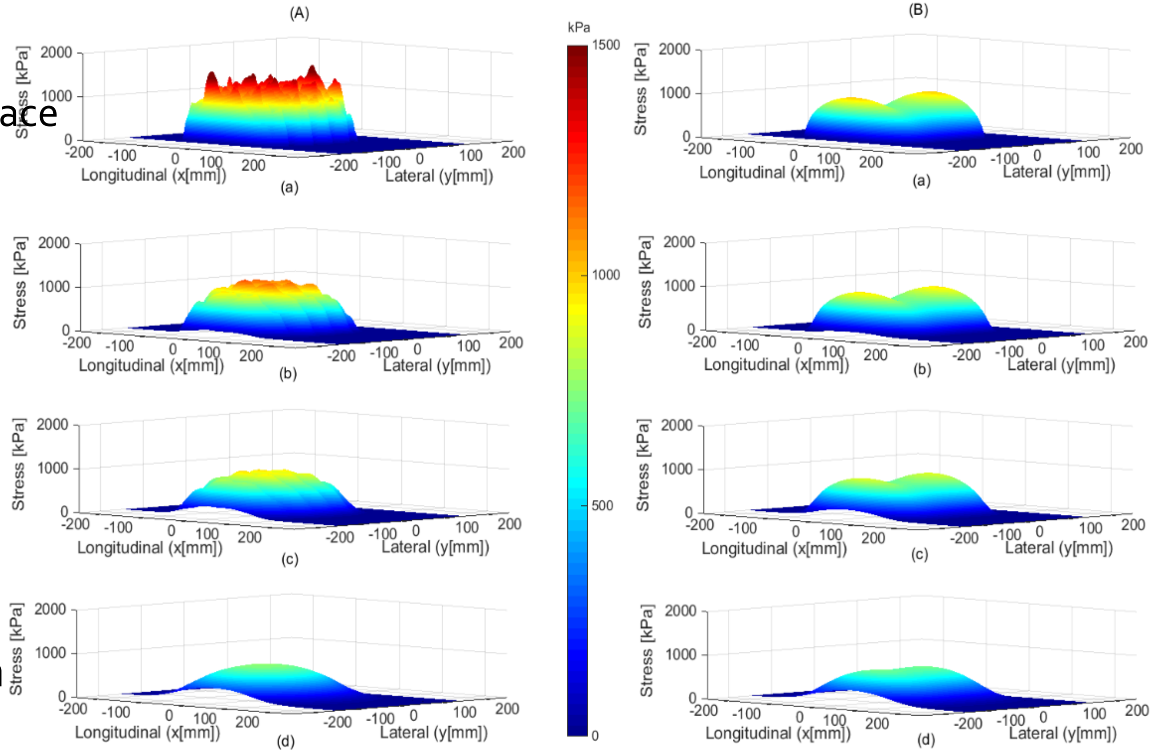


At the Surface

At 1 cm

At 2 cm

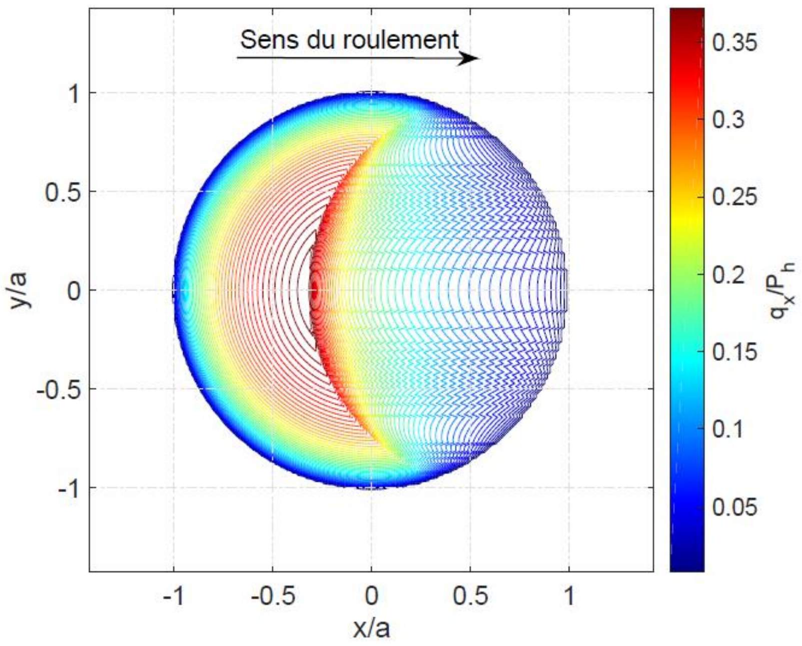
At 5 cm

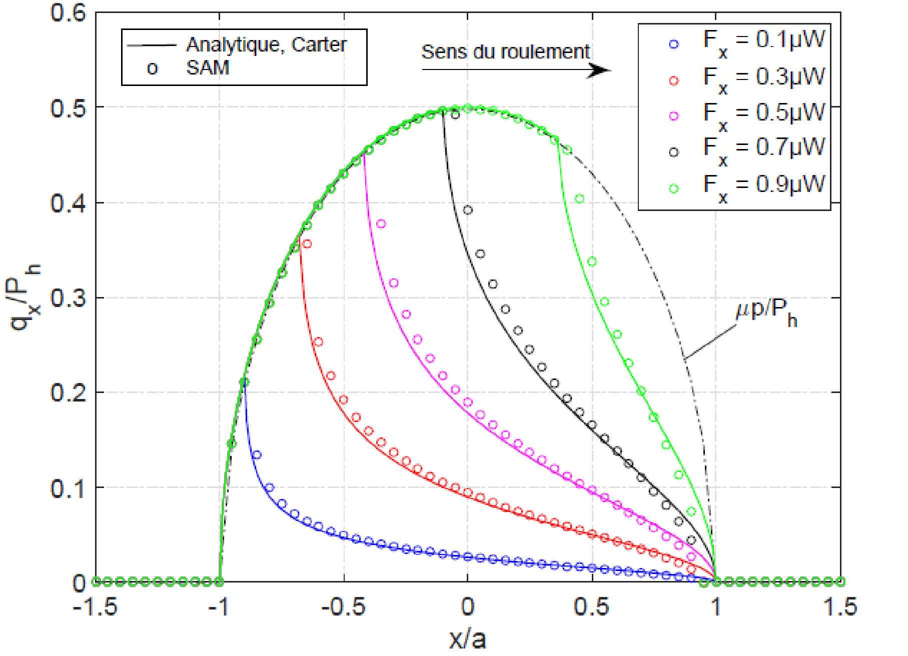


At the surface
With real tyre Pmax =1.5 MPa
With smooth tyre Pmax =1.0 MPa

For a study in the first few centimetres, a real tyre must be used

TAKING INTO ACCOUNT CONTACT AND FRICTION THEORY





Tyre grip at the front of the contact
Slippage at the back of the contact

Surface shear increases with the coefficient of friction

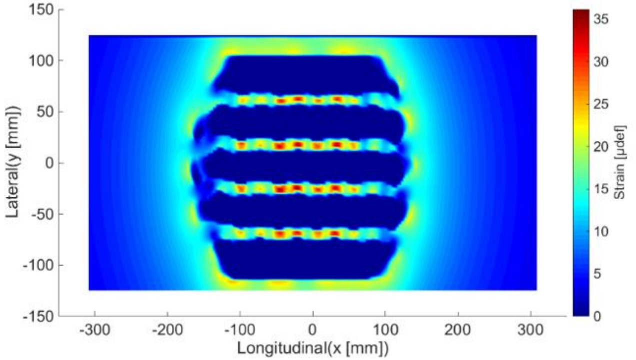


CALCULATIONS WITH THE SAM CODE (DVDC PHASE 2)

Free rolling (TRAILER WHEEL)

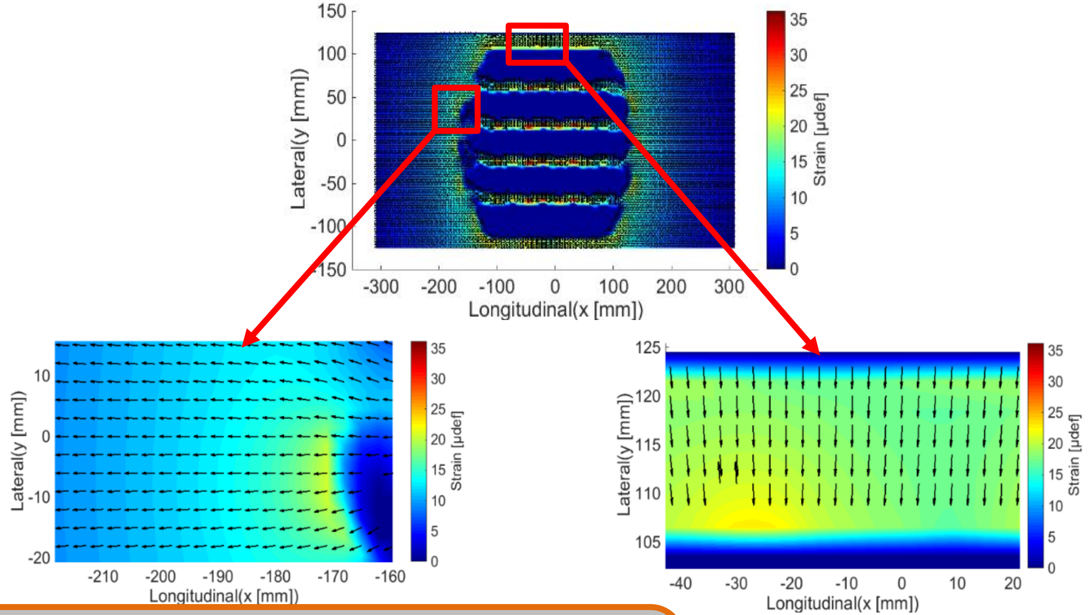
μ (*coefficient of friction*) = **0.7**; *W(load on tyre)* = **32.5** kN;
F_x (*tractive effort*) = 0
Contact on SCAS

Surface shear



Deformations and main directions

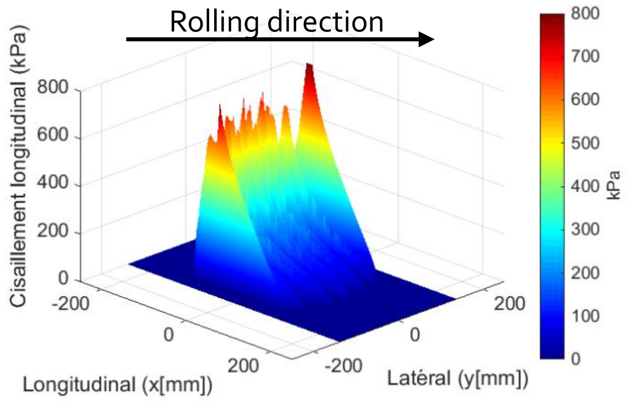
Maximum main deformation field by surface extension



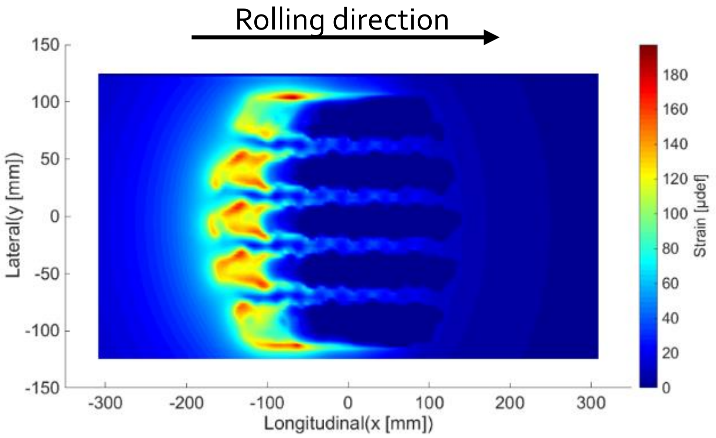
35 micro-def, value less than **ε 6**
low risk of surface-initiated cracking

$\mu = \mathbf{0.7}$; W = **32.5** kN; F_x = 10 kN

Surface shear



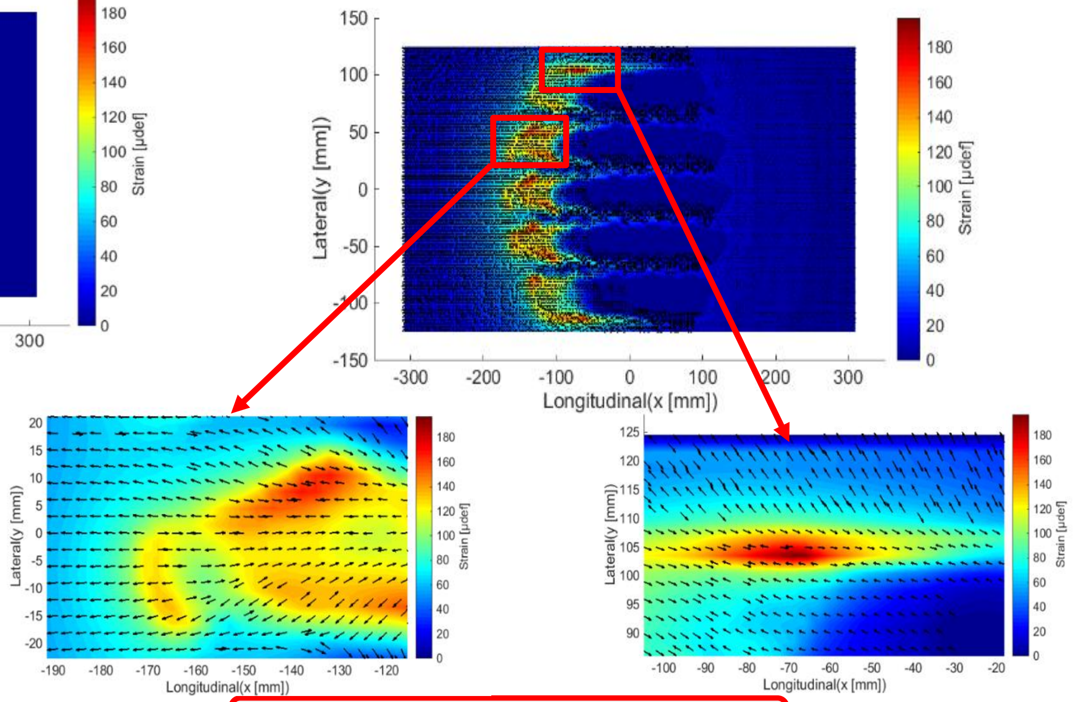
3D Profile



Projected view

Deformations and main directions

Maximum main deformation field by surface extension



Main directions of extension

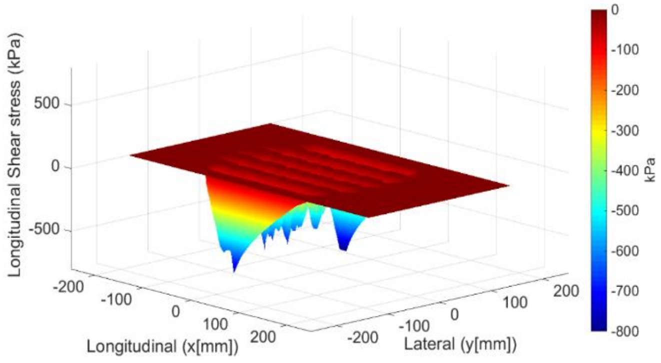
$$\varepsilon_t = 190 > \varepsilon_6$$

Risk of surface cracking (longitudinal crack on the rear edge of the tyre-road contact patch)

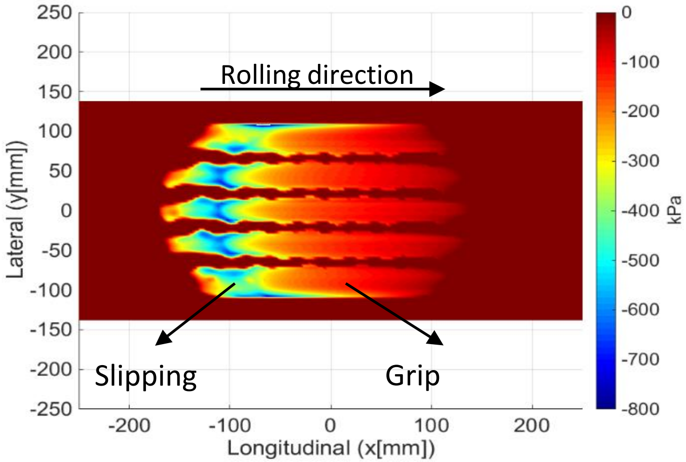


μ= **0.7**; W= **32.5** kN; $\mathbf{F_x}$ **=−10 kN**

Surface shear



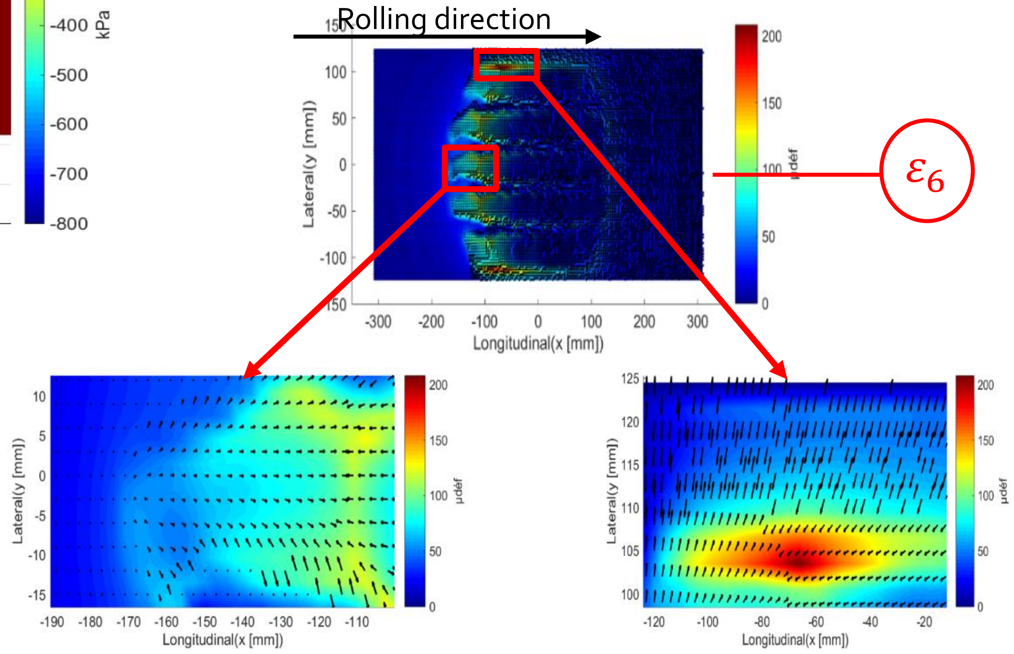
3D Profile



Projected view

Deformations and main directions

Maximum main deformation field by surface extension

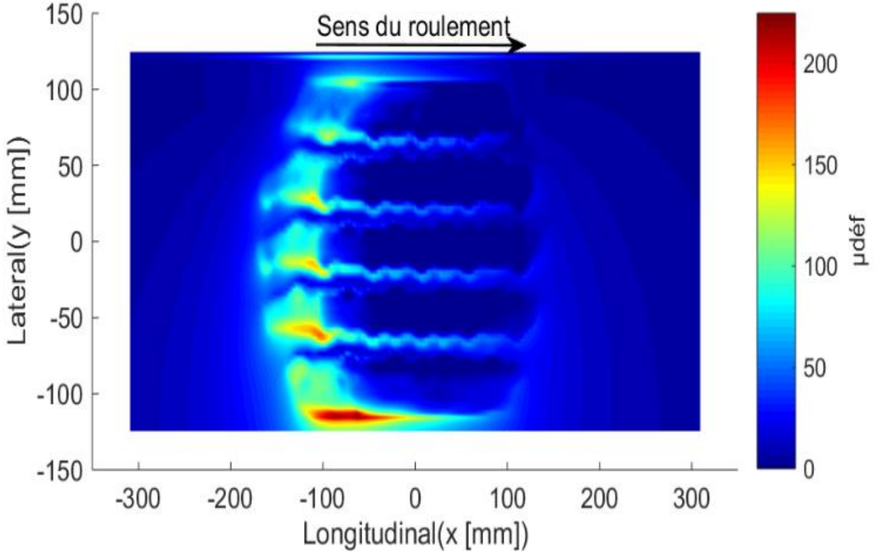


$\boldsymbol{\varepsilon_t = 210 > \varepsilon_6}$

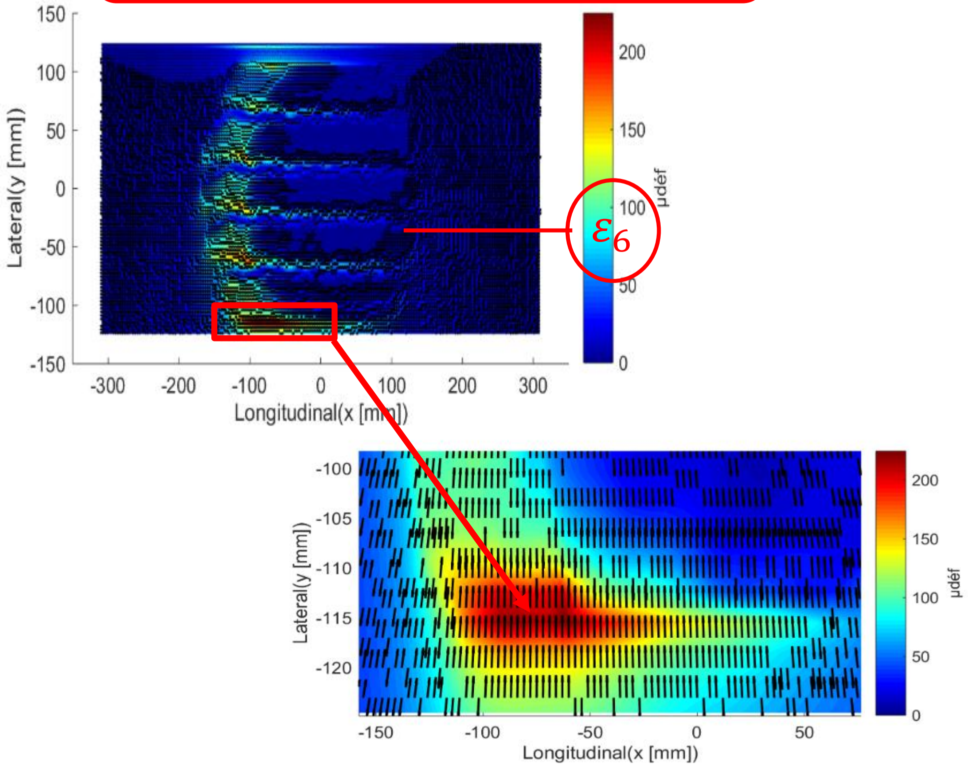
Risk of surface cracking (longitudinal crack on the rear edge of the tyre-road contact patch)



- **Surface shear**



Maximum main deformation field by surface extension

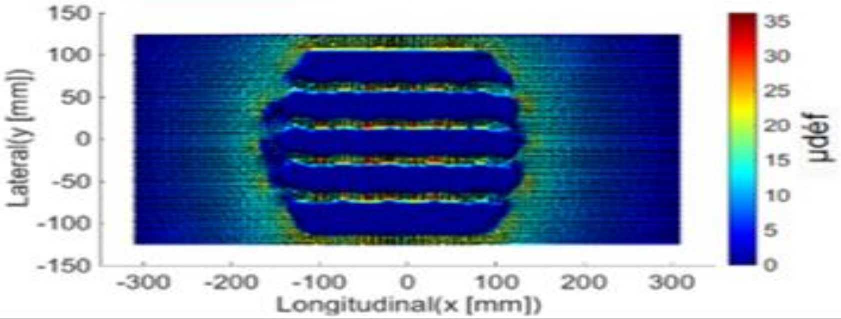
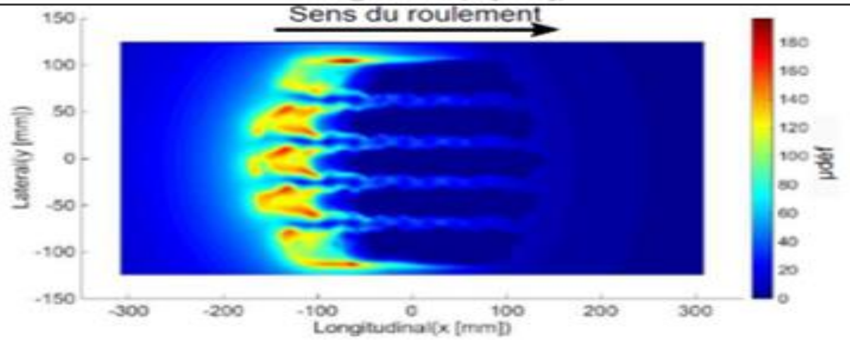
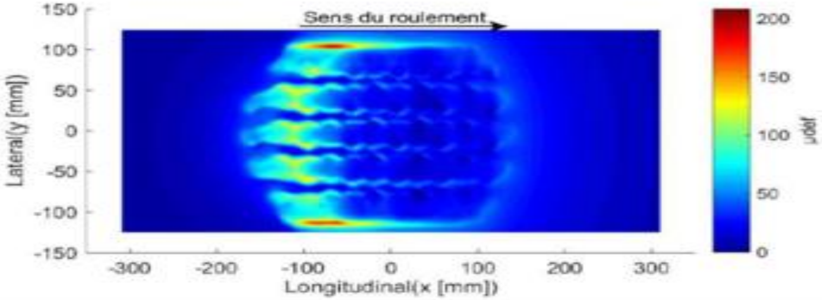


$$\varepsilon_t = 270 > \varepsilon_6$$

Risk of surface cracking (longitudinal crack on the rear edge of the tyre-road contact patch)

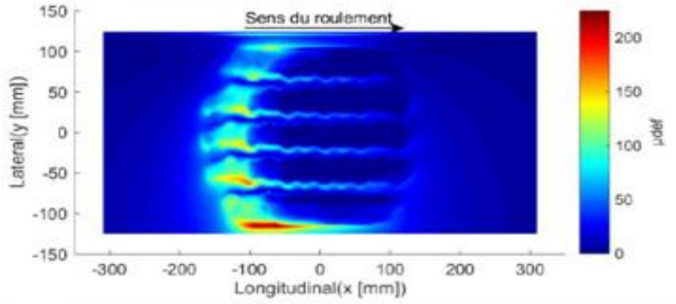
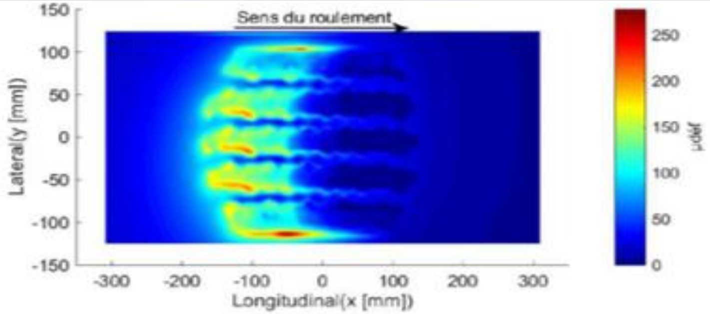
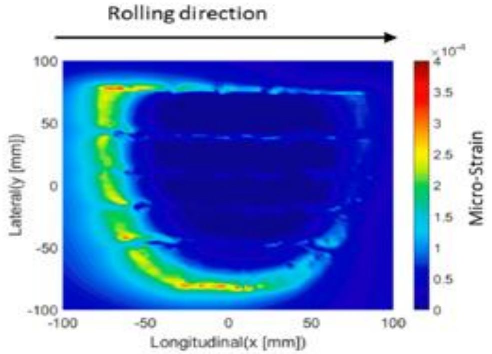


SUMMARY OF SAM CALCULATIONS IN STRAIGHT SECTION

	Application des efforts	Déformations principales et directions principales d'extension	$\varepsilon_{6\,max}$ (µdef)
ROULEMENT PUR			**35**
ROULEMENT TRACTIF			**200**
ROULEMENT FREINAGE			**200**

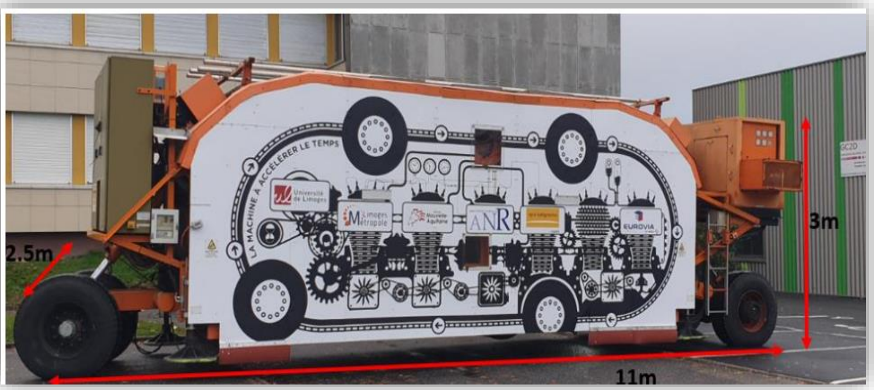


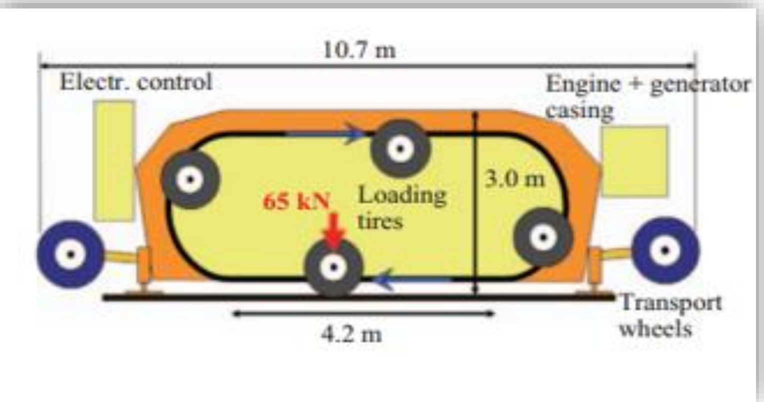
SUMMARY OF SAM CALCULATIONS IN CURVED SECTION

	Application des efforts	Déformations principales et directions principales d'extension	$\varepsilon_{6\,max}$ (µdef)
VIRAGE PUR			**250**
VIRAGE TRACTIF			**280**
VIRAGE PNEU INCLINE			**360**



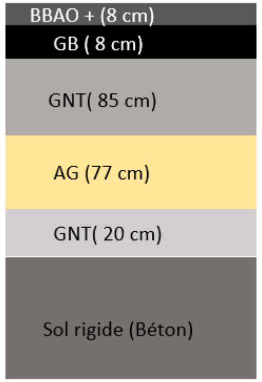
EXPERIMENTAL VALIDATIONS OF SAM CALCULATIONS (DVDC PHASE 4)

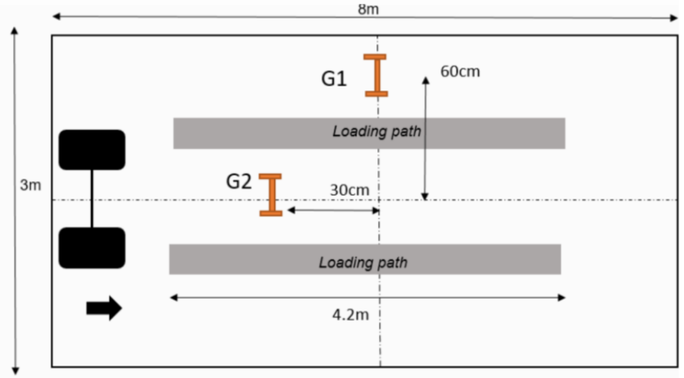




MLS 10 pure rolling simulator

d)





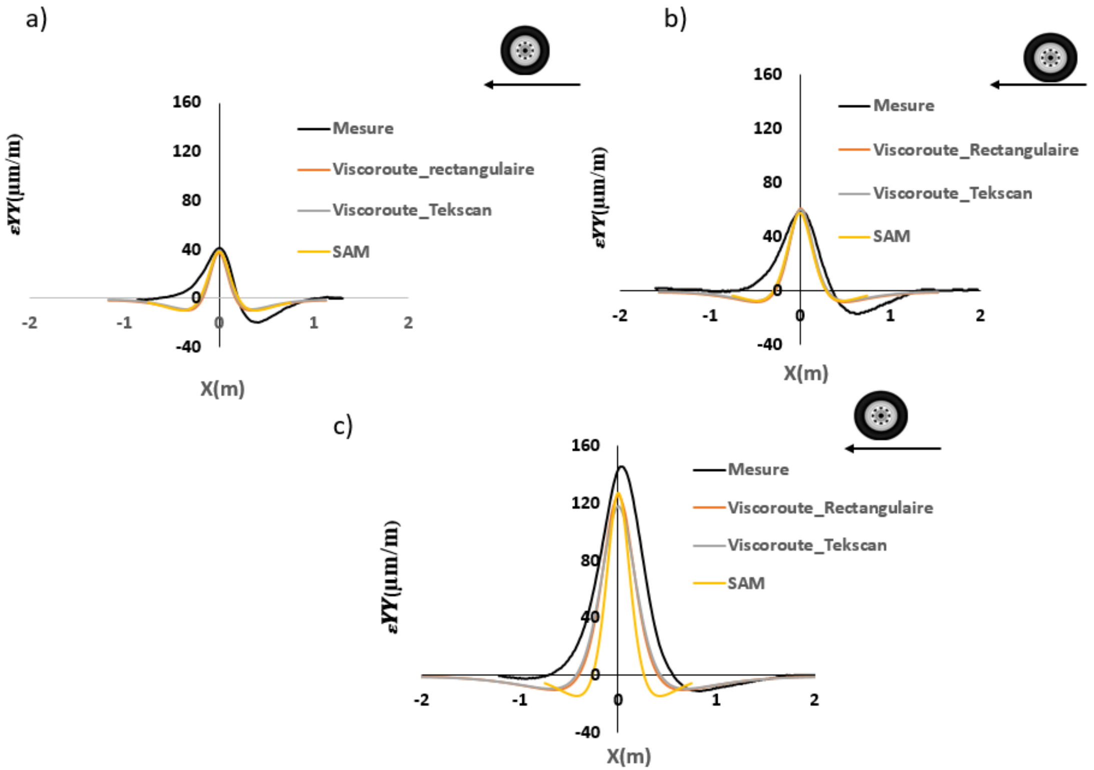
Example of road pavement
Malet (spie Batignoles)

- Location of sensors on the road pavement surface



SURFACE MEASUREMENTS AT 0.6 M FROM THE CENTRE OF THE PAIRING

•

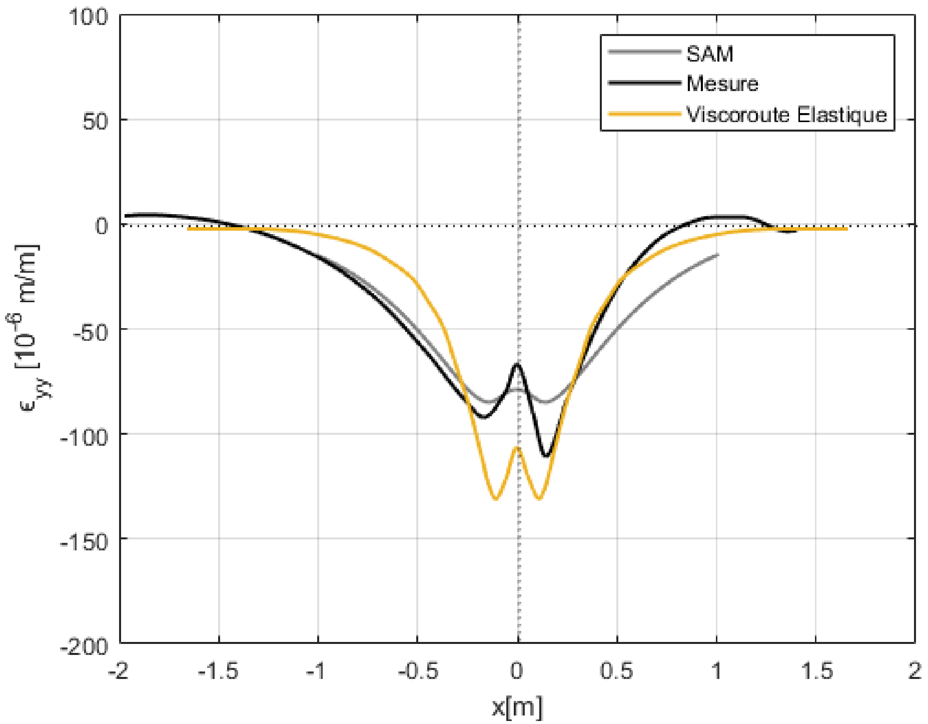


Transverse deformation signals at 20°C, (at h = 0; y = 60).
a) BBAO+, b) BBAO, c) Agreco

Good correlation between measurements and SAM calculations

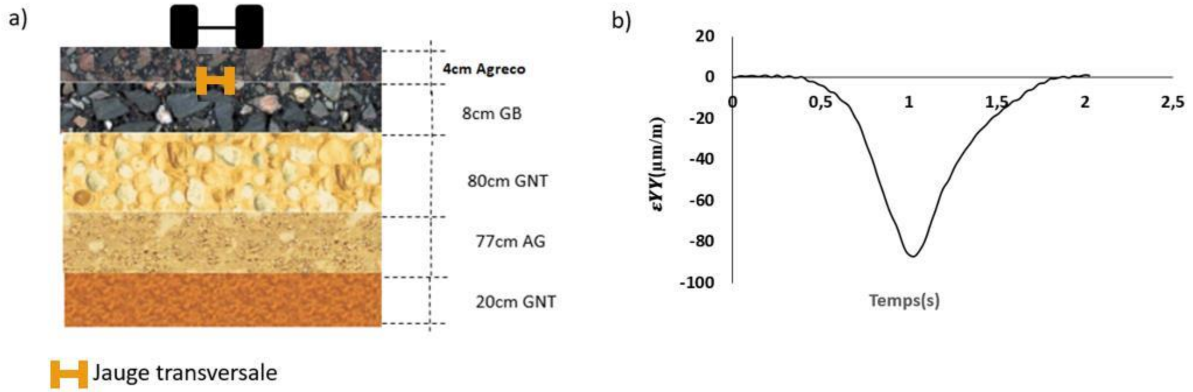
SURFACE MEASUREMENTS AT THE CENTRE OF THE CONTACT PATCH

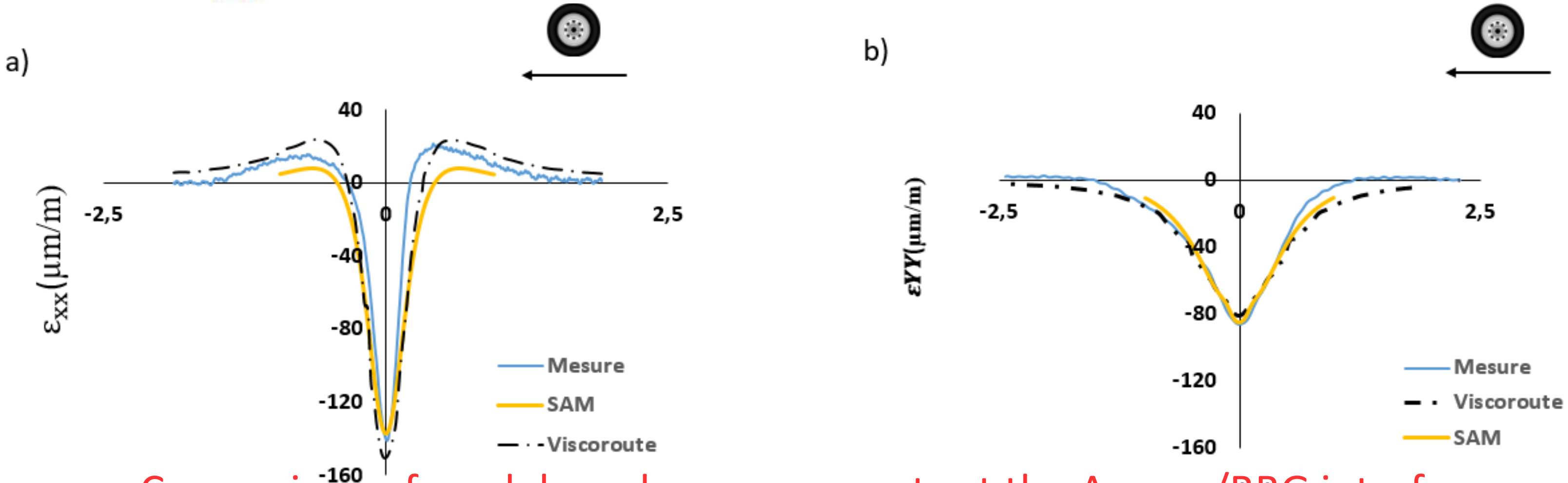
•



Transverse deformation signals for BBAO+
20°C; h = 0; y = 0 (on the surface at the centre of the pairing)

Good correlation between measurements and SAM calculations
On the surface, SAM is closer to the measurements than viscoroute
integration of tribological parameters





Comparison of models and measurements at the Agreco/BBG interface:
a) longitudinal deformations; b) transverse deformations

Good correlation between measurements and SAM calculations

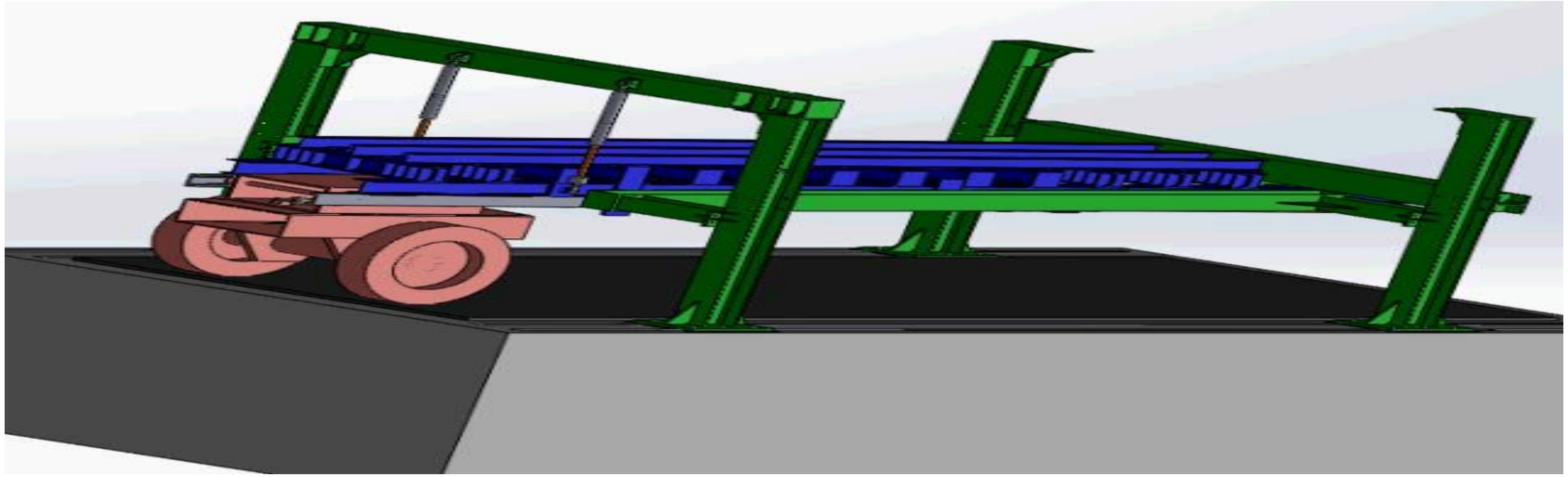
CONCLUSIONS

- Reliable surface calculation of tyre/road pavement contact by a model using a very fast semi-analytical method incorporating friction
- Application to actual tyre/road pavement contact, highlighting the aggressive effect of the tyre structure
- Surface calculation of stresses and deformations in free rolling, tractive rolling and braking conditions
- Detection of deformations greater than ε 6 in tractive rolling, braking and cornering



OUTLOOK

- Development of the elasto-plastic and visco-elastic aspects of the surface coating (underway at the LaMCoS)
- Development of the SAM tool towards probabilistic aspects (risk coefficient)



- Construction (in progress) of a simulator (MACADAM) reproducing braking, acceleration and cornering in controlled environments (0 to 40°C)
- Assistance with the design of pavement surface courses (SAM ROUTE).