Evaluation of Tire/Surfacing/Base Contact Stresses and Texture Depth

W. J. vdM. Steyn and M. Ilse
Department of Civil Engineering, University of Pretoria, Lynnwood road, Hatfield, South Africa. Wynandsteyn@up.ac.za

ABSTRACT
Tire rolling resistance has a major impact on vehicle fuel consumption. Rolling resistance is the loss of energy due to the interaction between the tire and the pavement surface. This interaction is a complicated combination of stresses and strains which depend on both tire and pavement related factors. These include vehicle speed, vehicle weight, tire material and type, road camber, tire inflation pressure, pavement surfacing texture etc. In this paper the relationship between pavement surface texture depth and tire/surfacing contact stress and area is investigated. Texture depth and tire/surfacing contact stress were measured for a range of tire inflation pressures on five different pavement surfaces. In the analysis the relationship between texture and the generated contact stresses as well as the contact stress between the surfacing and base layer are presented and discussed, and the anticipated effect of these relationships on the rolling resistance of vehicles on the surfacings, and subsequent vehicle fuel economy discussed.

1. INTRODUCTION
Tire rolling resistance has a major impact on vehicle fuel consumption with between 7 and 10 % of the total energy consumption of a vehicle being consumed through rolling resistance. It is estimated that a 10 % reduction in tire rolling resistance will lead to a 2 to 3 % improvement in vehicle fuel economy [1]. Rolling resistance is the loss of energy due to the interaction between the tire and the pavement surface. The tire/pavement surface interaction is a complicated combination of stresses and strains which depend on both tire and pavement related factors, including vehicle speed and weight, tire material, type and inflation pressure, and road camber and surfacing texture. Shear mechanisms develop tractive and lateral forces which create a friction coupling between the tire and pavement surface. This friction coupling depends on surface adhesion (between the rubber and the pavement surfacing) and hysteresis

(rubber deformation when it interacts with pavement unevenness) [2]. Thus the pavement surface texture plays an important role in tire rolling resistance. Pavement texture is classified into roughness, mega-texture, macro-texture and micro-texture, and the focus of this paper is on the effects of macro-texture and tire / pavement contact stresses.

The objectives of this paper is to demonstrate the effect of tire and surfacing conditions on contact stresses generated between a car tire and a range of surfacing types, as well as the subsequent contact stresses developing between the bottom of the surfacing and the top of the base layer. The resultant effect on relationships between texture depth, rolling resistance and fuel economy is also discussed.

2. TIRE / PAVEMENT INTERACTION

Vehicles travel on pavement surfacings through a complex interaction between the tire rubber and the surfacing material, and these interactions are affected by the vehicle properties, tire properties and surfacing properties.

2.1. Rolling Resistance

Tire rolling resistance is influenced by variations in vehicle, pavement surface, environmental and tire properties. These include:

- Vehicle size, weight, static and dynamic weight distribution, suspension system characteristics, kinematics, speed, wheel slip and acceleration;
- Pavement surface material, slope variations, roughness, texture and compliance;
- Ambient air temperature, and
- Tire construction material, ply rating and structure (radial/bias), chemical composition, elastic properties, hardness, tread depth, wear, age, side wall design, inflation pressure and pressure distribution over tire / pavement contact area.

Rolling resistance is caused by the viscoelastic properties of the tire rubber and the constant deformation of the internal components of the tire during use. Rolling resistance is typically calculated using Equation 1. In Equation 1 the importance of the texture depth, pavement roughness (through IRI) and structural condition (through deflection) as pavement-related factors are visible [1].

$$Fr = CR2 \, . \, FCLIM \, . \, ((b11 \, . \, Nw) + (CR1 \, . \, ((b12 \, . \, M) + (b13 \, . \, v^2)))) \qquad (1)$$

and

$$CR2 = Kcr2 \, . \, (a0 + (a1 \, . \, Tdsp) + (a2 \, . \, IRI) + (a3 \, . \, DEF))$$

where
Fr – Rolling resistance [N]
CR1 – Rolling resistance tire factor
CR2 – Rolling resistance surface factor
FCLIM – climatic factor
Nw – Number of wheels
b11, b12, b13 – Rolling resistance parameters