Wear 332-333 (2015) 907–917

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

# Quantifying aggregate microtexture with respect to wear—Case of New Zealand aggregates

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ARTICLE INFO

*Article history:*
Received 14 September 2014
Received in revised form
12 November 2014
Accepted 27 November 2014
Available online 13 December 2014

*Keywords:*
Polishing
Microtexture
Surface friction
Curvature

ABSTRACT

Quantifying road surface microtexture (wavelengths shorter than 0.5 mm) and relating it to surface friction help to better understand mechanisms involved in the evolution of skid resistance. In this study, a three-step methodology was developed to systematically measure and analyse aggregate profiles and compare the evolution of surface friction and roughness parameters. Criteria used for the three steps (selection of the areas to be measured, filtering of the profiles to keep only the relevant part for analysis, selection of roughness parameters) are presented and justified by considering on the one hand polishing and abrasion mechanisms and, on the other hand, the contact between a viscoelastic solid and a rough surface. The methodology is applied to three different New Zealand geologically sourced aggregates and polished by using the Wehner/Schulze device. Three-dimensional images of the samples were taken periodically during the test to record the microtexture changes due to polishing. Results show that roughness parameters expressing local shape, such as curvature of asperity tips, can reasonably explain the surface friction variation; height parameters such as the standardised profile root-mean-square are also explanatory but to a lesser extent. Relevance of the studied roughness parameters is discussed and interpretation in terms of physical change of surface texture is provided.


## 1. Introduction

Pavement surface texture is an important road surface feature as it determines the interaction between the tyre and road surface, including wet skid resistance, noise, rolling resistance, spray, and tyre wear. Pavement surface texture can be divided into four scales according to the wavelength: microtexture, macrotexture, megatexture, and unevenness [1].

Microtexture is the roughness of the surface of the exposed aggregate chips that can be felt by one's fingertips (wavelengths less than 0.5 mm). Macrotexture is the roughness of the road surface due to the arrangement and size of aggregate chips that can be seen by the naked eye or felt by a human hand (wavelengths between 0.5 and 50 mm) [1]. Both microtexture and macrotexture are required to provide skid resistance when the road surface is wet. The macrotexture is needed to evacuate the bulk water and the microtexture is required to penetrate the remaining water film. Once direct contact between the tyre and the road is restored, both texture scales contribute to the generation of surface friction forces. Macrotexture is important in providing hysteretic friction and microtexture in the development of adhesion between the tyre and the pavement surface.

Road surfaces are polished by traffic and microtexture is the most affected texture scale as it is the highest part of the road surface to be in contact with the tyre. Several attempts have been made to characterise road surface microtexture in such a way that it can be directly related to surface friction [2–4], in particular to explain the variation of surface friction with polishing [5,6]. Authors of references [2–4] showed that parameters characterizing the shape of microtexture asperities are the most related to surface friction. They confirm results obtained from experiments conducted by Sabey [7] on single spherical and conical asperities. In addition, Dunford et al. [6] highlighted the need, while analyzing texture profiles, to consider only the highest part of the profiles that can be in contact with the tyre. Despite progress made by the mentioned studies, there has been no consensus on a method to analyze and characterize microtexture profiles.

This paper introduces a three-step methodology to systematically measure and analyse aggregate profiles and compare respectively the evolution of surface friction and roughness parameters.

## 2. Background

### 2.1. State of the art

Skid resistance deteriorates over time due to traffic polishing. It is desirable for road engineers to be able to predict this evolution

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http://dx.doi.org/10.1016/j.wear.2014.11.028
0043-1648/

so that skid resistance can be maintained at a safe level. There are a number of factors that affect skid resistance and these can be grouped into four categories [8]:

- Surface aggregate factors (e.g. geological properties of the aggregate, surface microtexture and macrotexture, chip size and shape, and type of surfacing);
- Load factors (e.g. cumulative traffic loading, traffic intensity, composition and flow conditions, and road geometry);
- Environmental factors (e.g. water film thickness, surface contamination, temperature, seasonal and short term rainfall effects); and
- Vehicle factors (e.g. vehicle speed and suspension system, angle of tyres, wheel slip ratio, tyre characteristics, tread depth and patterns).

Aging of bituminous materials is another important factor. Works conducted by Kane et al. [9] helped to better understand the aging mechanisms and to simulate these mechanisms in laboratory. Out of all the listed factors, only the surface aggregate factors, and partially the load factors, are controllable [10].

There are a number of laboratory tests used to predict the skid resistance performance of aggregates, such as the Polished Stone Value (PSV) test. This test has been standardised [11] and is the most commonly used laboratory test to assess and rank the polishing resistance of aggregates. However, the ability of the PSV test to assess the skid resistance of road surfaces has been questioned by a number of researchers [12–14]. Therefore, several alternative devices and laboratory test methodologies have been developed with the aim of providing a more accurate long term skid resistance performance prediction. An example is the Wehner/Schulze (WS) device, which was developed in Germany and is now standardized to be used worldwide [15].

Do et al. [5] used the WS device to polish aggregate specimens and a laser sensor to measure microtexture profiles. The texture measurements were taken at three stages of polishing (at 0, 90,000 and 180,000 polishing passes) and three parameters were used to characterize the surface texture: the profile height root-mean-square ($R_q$) and two angular parameters developed by Zahouani et al. [4] characterizing the angularity of surface asperities (a more detailed description is included in Section 4.3.3). These authors found that the surface friction evolution of a limestone can be explained by $R_q$ whereas the surface friction evolution of a sandstone depends on that of the angular parameters. In addition, one has to consider two scales while analyzing the sandstone: the measured profile and its envelope which is constituted by a line linking all of the profile summits.

Chen and Wang [16] also assessed the microtexture evolution of aggregates that were polished by the WS device. Seven stages of polishing were observed and two dimensional surface profile measurements were analysed using fractal and spectral approaches. It was found that geologically different aggregates are polished at different rates, depending on the hardness of their mineral content. This finding is similar to what Do et al. [5] has found. Additionally, previous study undertaken by Wilson and Black [12] found that not only mineral hardness, but also rock matrix toughness are important to determine the ability of an aggregate to resist polishing action.

Dunford et al. [6] reported a similar study and made use of three dimensional (3D) measurements. They used the WS device to polish aggregate specimens and measured surface friction at 0, 90, 900, 9,000 and 90,000 passes. To obtain 3D measurements, a device called the Infinite Focus was used. Two aggregates were randomly chosen from the polished part of the specimens and the whole aggregate surface was assessed. Three areas at the highest parts of each aggregate (six areas in total) were chosen to be scanned with 5, 10 and 20 times magnifications. The data gathered with 20 times magnification was then used to calculate the parameter $S_a$, which is the arithmetic mean of absolute departure of the surface from a mean plane within a defined area. The wide range of $S_a$ values of the six areas suggested that there was high variability among the data, and hence, more data need to be included in the analysis. To reduce the variability, a 0.08 mm Gaussian filter (high pass filter) was applied to remove wavelengths above 0.08 mm. The study concluded that $S_a$ could explain the changes on the aggregate surface during the polishing process.

### 2.2. Scope of the study

The research reported in this paper discusses a methodology to assess polishing of New Zealand aggregates by quantifying the changes in their microtexture. This complements previous work that has been undertaken at IFSTTAR in France [4,5] and at the Transportation Research Laboratory (TRL) in the UK [6]. Attempts were made to systemize the process of measurement and analysis of microtexture profiles which were divided into three steps: selection of the areas to be measured, selection of the relevant part of the profile, and the selection of roughness parameters. Previous research work had highlighted the necessity of analyzing only the highest part of a profile but without further clarification. This led to new objective research analysis methods to be developed in this research particularly for step 2, by quantitatively determining the profile depth to which microtextural change due to polishing by vehicle/polishing device tyres occurs.

## 3. Experiments

### 3.1. Materials

Three different New Zealand geologically sourced aggregates were used in this research, which are Greywacke, Basalt and Andesite aggregates. They were sourced from different quarries around the North Island of New Zealand and were chosen due to the popularity in their usage on New Zealand roads.

The three aggregates are all composed of different mineral compositions. The Greywacke (sedimentary rock) consists of fine grain minerals that are supported by a matrix that is rich in very angular shaped Quartz, which is a hard mineral, and hence, it is not easily broken. The Basalt, which is an igneous rock, contains large crystals of Augite and colourless Olivine. The matrix is entirely composed of needle-like crystals of Feldspar with granules of brown Augite and black Iron Oxide crystals. Finally, the Andesite, which is also an igneous rock, consists of large crystals of Feldspar and Pyroxene. The matrix is composed of small needles of Pyroxene, Iron Oxides and glassy material that seems to have devitrified to Cristobalite or Tridymite.

### 3.2. Specimens

Circular discs (Fig. 1b) are prepared for polishing tests on aggregates. The preparation steps are as follows:

- place manually the aggregates (fraction 7.2/10 mm) in a single layer as closely as possible, with their flattest faces lying on the bottom of a circular mould of 22.5 cm diameter;
- fill the interstices between the particles with silica sand called “Fontainebleau sand” (fraction 0.16/0.315 mm);
- fill the mould with resin and remove any excess from the edges of the mould;
- when the resin has completely set, remove the specimen from the mould.