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Relating surface texture parameters from close range photogrammetry to Grip-Tester pavement friction measurements

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HIGHLIGHTS

- Asphalt pavement surface texture is measured using close range photogrammetry (CRP).
- CRP data processing methods and their impact on measured texture is investigated.
- The top 2 mm of the pavement surface gives the best texture-friction correlations.
- Identifies texture parameters that best correlate with GripTester-measured friction.
- The density of peaks is the most influential indicator of pavement surface friction.

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ABSTRACT

This study utilizes close range photogrammetry (CRP) to measure the texture of asphalt pavement surfaces with a view to explaining the variation of friction measurements obtained using a GripTester. A handheld camera was employed to capture images at different locations on both lanes of pavement sections using a scale rule for identification of control points. Proprietary software were employed for creation and analysis of 3D models from the images to determine pavement surface texture parameters. Different scenarios were considered including pavement surface analysis before and after filtering for micro- and macro-texture separation. Thresholding with respect to height to analyze the top 1–2 mm of the surface was also considered. Texture parameters were then related to friction measured at the image capture locations. The lane with higher friction values generally showed higher individual texture parameters across different scenarios. However, meaningful texture-friction correlations along the lanes were only obtained with the top 2 mm of the surface. Stepwise regression indicated that the density of peaks (Spd) and the peak material volume (Vmp) best correlate ($R^2 = 0.75$–0.76) with friction, but the Spd is more influential. These parameters can be used as indicators of pavement surface friction during its service life.

1. Introduction

Pavement surface texture is defined as the deviations of the pavement surface from a true planar surface [1]. It is typically divided to four different scales with different wavelengths, namely, microtexture (<0.5 mm), macrotexture (0.5–50 mm), megatexture (50–500 mm) and unevenness (500 mm–50 m) [2]. Pavement friction or skid resistance typically increases with an improvement in the microtexture and macrotexture scales, while megatexture and unevenness are undesirable [3,4]. The microtexture is the surface roughness that is related primarily to the fine-scale angularity and texture of aggregate particles. It helps cut through the water film between the aggregate particle and the tire rubber and needs to be present at any speed. The macrotexture is determined by the size, shape, spacing and arrangement of aggregate particles in the pavement surface. It governs pavement friction at speeds above 90 km/h on wet pavements [1,3,5].

Conventional measurement of the surface texture of asphalt pavements have focused on the macrotexture as it is a lot easier to measure than the microtexture. The most common techniques for macrotexture measurements include the volumetric sand patch method, circular texture meter and the outflow meter. More recently, laser-based, stereo photogrammetry, and microscopy

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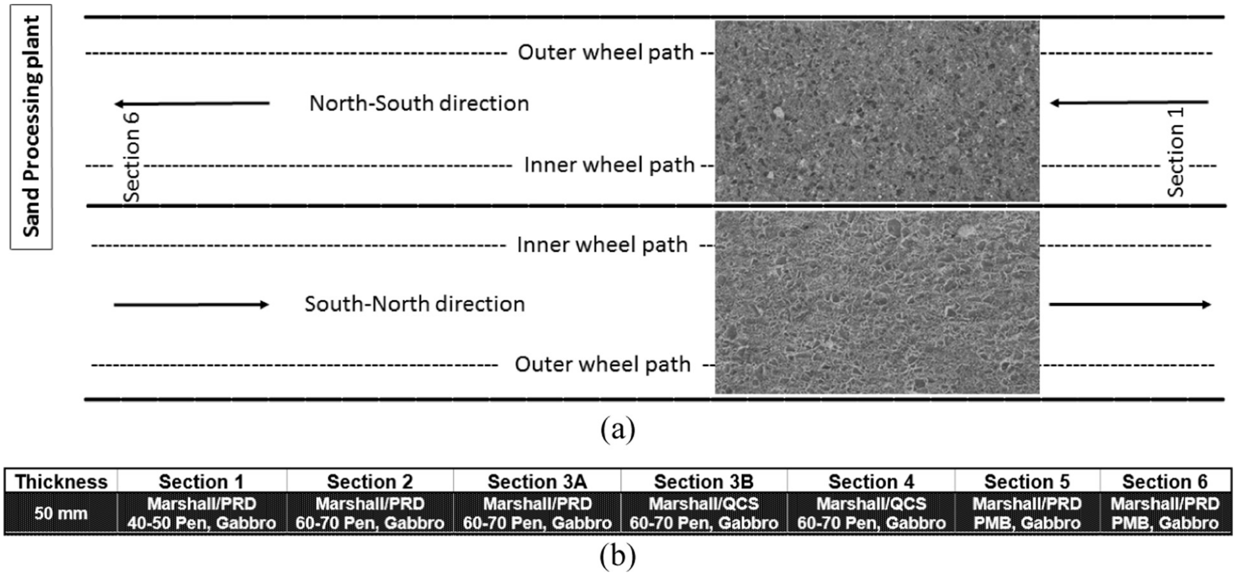
methods have also been employed for macrotexture measurement [3]. There is also a shift to 3D surface texture measurements, which provide a wide range of information and better represent the characteristics of the surface texture [6]. Some techniques for creation of 3D models of pavement surface texture include laser devices and close range photogrammetry (CRP). Nevertheless, laser devices are expensive, while an ordinary camera can be used for CRP [7]. CRP entails estimating 3D co-ordinates of points on an object using measurements from multiple images captured from different positions with an ordinary camera. From the images captured, 3D models of surface texture are created and analyzed using proprietary software such as 3D Flow Zephyr Pro, Digital Surf MountainsMap, etc [7,8]. The tools and resources required for the CRP method are minimal and easily available.

A range of parameters can be used for surface texture characterization. The mean texture depth (MTD), the mean profile depth (MPD) and estimated texture depth (ETD) from laser devices are the most common for 2D surface texture characterization [9]. Areal roughness parameters are used for 3D surface texture characterization. These include height (root mean square height, arithmetic mean height, skewness, etc), volume (material volume, void volume) and feature (density of peaks, arithmetic mean peak curvature, etc) parameters. Details of the above surface texture characterization parameters have been recently reviewed [3]. A number of studies have attempted to deduce correlations between some surface texture parameters and friction measured using different equipment. For instance, a study by Torbruegge and Wies found no correlation between the ETD and friction measured by the British pendulum tester [10].

Majority of the studies that investigated pavement texture-friction relationship used laser devices and the dynamic friction tester (DFT). A significant quadratic polynomial relation was shown to exist between macrotexture from a laser profile tester and DFT-measured skid resistance [11]. A number of parameters including the MPD were used as macrotexture indicators [11]. However, no clear positive relationship was observed between the MPD and DFT friction in another study [6]. The peak density and the arithmetic mean peak curvature of 3D macrotexture images from a 3D laser scanner were observed to have significant positive influence on friction. There was little influence from the arithmetic mean height and the root mean square slope [6]. Similarly, the density and sharpness of the peaks obtained after empirical decomposition of the texture profile from a circular texture meter showed good correlation with DFT-measured friction [12]. Another study also identified the peak density and core material volume from 3D laser scanner measurements as the most influential macro- and micro-texture parameters that exhibit fairly good correlation with DFT friction at high- and low-speed in wet conditions [13].

Only a few studies have considered the relationship between pavement texture and friction from continuous friction measuring equipment (CFME). CFMEs provide better detail about spatial variability of pavement friction and have gained increased attention in recent times [5]. A study by Kanafi et al. [14] evaluated the relationship between pavement texture measured using a 3D profilometer and friction measured using a portable CFME. It was observed that the full surface profile is subjected to change in macro- and micro-scales over time. Hence, spectral analysis cannot separately characterize aggregate surface texture polishing at actual road conditions. Moreover, the surface texture profile (macro- and micro-scales) did not correlate well with friction [14]. Another study investigated the relationship between macrotexture of an airfield runway from a photometric stereo system and friction from a CFME, the GripTester [15]. The photometric system uses a minimum of three pavement surface images illuminated from different directions and isolated from ambient lighting. The variation in intensity of lighting is then used for pavement surface recovery. The study showed reasonable correlation ($R^2 \sim 0.5$) between texture indicators (MPD, root mean square roughness and power spectrum energy) and friction [15].

In contrast to the above works, the present study investigates the relationship between texture measurements from a simple and readily available technique, CRP, and a portable CFME – the GripTester. The GripTester is an economical management device for pavement friction evaluation. An ordinary camera can be used to easily collect texture information in the CRP technique compared to more expensive laser devices used in previous studies. Hence, knowledge of the particular texture parameters determined from CRP measurements that influence friction would assist in design of asphalt pavements to meet skid resistance targets. The objectives of this study were to:



Thickness	Section 1	Section 2	Section 3A	Section 3B	Section 4	Section 5	Section 6
50 mm	Marshall/PRD 40-50 Pen, Gabbro	Marshall/PRD 60-70 Pen, Gabbro	Marshall/PRD 60-70 Pen, Gabbro	Marshall/QCS 60-70 Pen, Gabbro	Marshall/QCS 60-70 Pen, Gabbro	Marshall/PRD PMB, Gabbro	Marshall/PRD PMB, Gabbro

Fig. 1. Pavement test sections (a) schematic and (b) mix types. Note: PRD – Percentage refusal density, Pen – Penetration grade, QCS – Qatar Construction Specifications (essentially the Marshall method), PMB: Polymer modified bitumen.