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A new and simplified approach to assess the pavement surface micro- and macrotexture

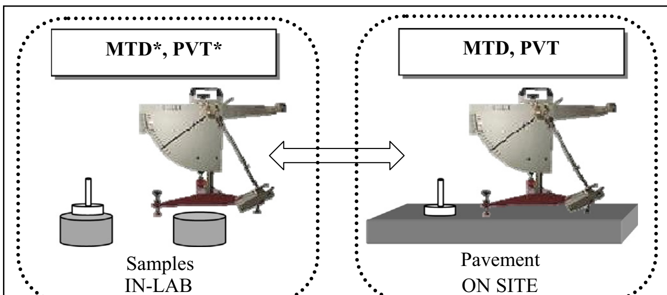
Filippo G. Praticò [a], Armando Astolfi [b,*]

[a] DIIES Department, University Mediterranea of Reggio Calabria, Italy
[b] DICAM Department, University of Palermo, Italy

HIGHLIGHTS

- Miniaturised tests of skid resistance and texture are proposed.
- Experiments provide insights about the transportability of the miniaturised tests.
- Physical-based models help understand and explain the results of miniaturised tests.
- Theoretical aspects can benefit researchers and practitioners.

GRAPHICAL ABSTRACT



Symbols. MTD: mean texture depth; MTD*: miniaturized mean texture depth; PTV: Pendulum Test Value; PTV*: miniaturized Pendulum Test Value.

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ABSTRACT

Road safety depends on pavement skid resistance and surface texture. Skid resistance mainly depends on micro-texture and macrotexture. Skid and texture measurements on samples, in the laboratory, at the preliminary stage of the design, would enhance the design in terms of timing, costs, and reliability. Consequently, this study aims at setting up and validating simple methods for assessing surface texture and skid resistance based on core/sample measurements. Experiments were carried out and predictive relationships were set up to explain and predict results. Under given conditions, miniaturised macro- and microtexture tests (modified EN 13036-1 and modified EN 13036-4, respectively) prove to be a reliable tool to optimise texture design. Results highlight the suitability of the proposed methodology and can benefit both researchers and practitioners.

1. Introduction

Pavement texture is a continuum which includes different scales, as a function of the wavelength: micro, macro, mega-texture and unevenness [1–4]. Micro-texture refers to wavelengths, λ, lower than 0.5 mm and peak-to-peak amplitudes, A, in the range 10^{-3}mm–0.5 mm. Macrotexture refers to λ = 0.5–50 mm and A = 0.1 mm–20 mm.

Macrotexture can be assessed through laser-based methods [5–9], sand-patch-like methods [10–14], or other extrinsic methods [15]. Methods above differ based on a number of parameters: the "material-method" used to "fill" the texture (sand, glass beads, or laser), the number of points on the surface investigated (1–10), and the number of diameters measured *per* point (2–4) [11]. The mean texture depth (MTD, [10]) pertains to the macrotexture domain. It usually ranges from 0.3 mm to 0.7 mm for dense-graded friction courses (DGFC) and from 1 mm to 6 mm for porous asphalt concretes (PA) and it requires a surface diameter that is usually between 50 mm and 300 mm [16].

* Corresponding author.
E-mail address: armandoastolfi@gmail.com (A. Astolfi).

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Micro-texture pertains to the roughness of the surface of the exposed aggregate chips that can be felt by one's fingertips. It interacts with the tire rubber on a molecular scale and provide adhesion (one out of the two key mechanisms of tire-pavement friction, cf. [17]. Research shows that the evolution of the asperity-peak curvature of micro-texture follows that of the surface friction coefficient [18].

Micro-texture values are indirectly estimated in terms of pendulum test value (termed PTV in the standard EN and termed BPN in ASTM and CNR standards), using low speed friction measurement devices such as the British Portable Tester [19,20]. PVT values usually have to be greater than 45–65 (based on pavement type and road relevance), with measurements baselines which are about 125 mm [21,22]. Furthermore, surface texture affects friction, in terms of both macrotexture and micro-texture [23–26,19].

Pavement micro- and macrotexture are a vital requirement of a pavement because they impact road safety, [1,17,27–32] and greatly affect the state of play of the transportation infrastructure [33]. It turns out that the design of pavement texture at an early stage, in the laboratory, is crucial because of many reasons: i) concurrent requirements have to be satisfied: volumetric properties [34], "premium" properties [35], variations over time [17,36–38], and production requirements [39]; ii) the ability of laboratory specimens to reproduce real pavements may be sometimes controversial (cf. [40–42]) and methods and studies are needed to link field and laboratory results; iii) laboratory experiments enforce scientific control by testing hypotheses in the artificial and highly controlled setting of a laboratory and imply considerable savings. Unfortunately, MTD and PTV measurements require extended surface areas and this hinders from having MTD and PTV estimates based on laboratory samples.

Understanding and deriving relationships between MTD (/PTV) tests carried out on samples and on real pavements is crucial: 1) to asses if mixes with identical volumetrics and components may have surface properties which are significantly different based on on-site vs. in-lab compaction [43,44]; 2) given the above, to help carry out a realistic design of surface characteristics during the so-called prequalification of the mix friction course. This research gap calls for research and investigation.

2. Objectives

The main objective of the study described in this paper is to provide a theoretical and practical framework to carry out micro- and macrotexture measurements at the design stage, on samples or small slabs, in the laboratory. In more detail: i) standardized measurements were carried out on several friction courses according to the sand patch method [10] and to the British Pendulum Method [21]; ii) both dense-graded and open-graded friction courses were considered; iii) in-lab and on-site tests were carried out; iv) the tests were both modelled. Algorithms were set up and finally applied to explain results and predict further developments. This paper illustrates the results obtained in terms of miniaturization of macrotexture measurements and micro-texture measurements. Section 3 refers to experiments while a Section 4 focuses on modelling, calibration, and validation. Finally, in Section 5, conclusion are drawn and main contributions are pointed out.

3. Experiments

In task 1, in the aim of gathering practical information and data about the potential of the two tests to be used in the laboratory, experiments were carried out on pavements and on cores extracted. Six reference friction courses were considered: three dense-graded friction courses (DGFC), herein termed DG1-DG3, and three porous asphalt concretes (PA), herein termed PA1-PA3. On average, for DGFCs, specific gravity was 2.32 and asphalt binder content was 5.1% (by weight of mix), while for PAs, specific gravity was 2.11 and asphalt binder content was 5.0% (by weight of mix). Two types of indicators were derived: Mean Texture Depth (MTD, [10]) and Pendulum Test Value (PVT, [21]). The volume used to measure MTD and the length of the contact path were the ones set up in the concerned standards (UNI EN 13036-1 [10] and UNI EN 13036-4 [21]) and the ones needed in order to make it possible to perform them on samples, in the laboratory.

3.1. Macrotexture

For macrotexture, note that a volume of 25,000 mm^3 is required by the traditional, current methods [1,11,12], while a smaller volume (4500 mm^3, [45]) is required by the diameter of Marshall [46] or gyratory specimens [47]. By referring to the miniaturization of the MTD test, it appears relevant to observe that when sample, sand patch, and spreading tool are considered: the sample diameter varies from "infinity" (pavement), to about 100 mm (Marshall specimen), while the spreading tool has a constant diameter of 63.5 mm, and the sand patch diameter varies based on mix type, compaction and volume.

After the preliminary tests, in which different volumes were considered (cf. Fig. 1A), two volumes were considered: 25,000 mm^3 (as per the abovementioned standard) and 4500 mm^3 (miniaturised test).

In each point of each surface (e.g., point B of surface DG1), multiple repetitions of the MTD measurement were carried-out (up to 31, Table 1). For V = 4500 mm^3, note that each measurement was followed by compressed air jet blasting in order to clean the surface and that this procedure is not usually required because both CNR and EN-ASTM standards do not require to repeat the measurement in the same point of the surface. Table 1 illustrates the averages obtained for the six pavements under analysis. Values in the range 0.5 mm–1.9 mm were obtained for DGFCs. On the contrary, values between 1.6 mm and 2.9 mm were obtained for PAs. Note that the standard deviation ranged from 0.01 mm to 0.22 mm for DGFCs, while it ranged from 0.00 mm to 0.10 mm for PAs. Note that DG1 differs from DG2 and DG3 and this may be due to the fact that DG1 corresponds to a dense-grade friction course that is older than DG2 and DG3. This partly complies with Iuele [43] and Do [48] and refers to the fact that surface texture deterioration is greater than for the other two types of surface. Many factors, including aggregate properties, binder properties, aggregate-binder combination, road geometry, traffic, weather, rainfall, and environmental conditions can be responsible for this [43,48–52]. Table 1 also illustrates the coefficients of variation (CV, ratio of standard deviation to mean) for each mix (with V = 4500 mm^3 and V = 25,000 mm^3). DGFCs have CVs lower than 14%, while PAs have CVs lower than 4%. It is possible to observe that:

- the higher the volume is, the higher the MTD becomes;
- the standard deviation decreases when the volume used increases from 4500 mm^3 to 25,000 mm^3;
- the coefficient of variation (CV) decreases when the volume increases;

R_{MTD} is the ratio $MTD_{25}/MTD_{4.5}$, i.e., the ratio between the value of MTD obtained when using a volume of 25,000 mm^3 or 4500 mm^3. By referring to $R_{MTD} = MTD_{25}/MTD_{4.5}$ (Table 1), note that this ratio ranges from 103% to 121% for the dense-graded friction courses considered, while it ranges from 102% to 123% for porous asphalt concretes.

It is noted that high values of MTD (e.g. PA2) may be linked to sand percolation into the interconnected pores "under the surface",