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A study on the relationship between mean texture depth and mean profile depth of asphalt pavements

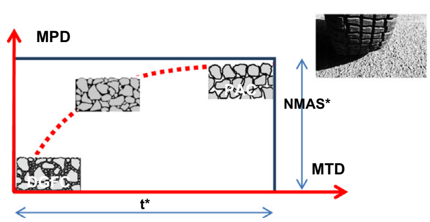
F.G. Praticò [a], R. Vaiana [b,*]

[a] DIIES Department, University Mediterranea of Reggio Calabria, via Graziella Feo di Vito, Italy
[b] Department of Civil Engineering, University of Calabria, Arcavacata Campus of Rende, Cosenza, Italy

HIGHLIGHTS

- Mean profile depth (MPD) and mean texture depth (MTD) of asphalt pavements were investigated.
- MPD is a purely geometric indicator.
- MTD is affected by dense granular flows.
- MTD–MPD relationship diverges from linearity when open-graded mixtures are considered.

GRAPHICAL ABSTRACT



Symbols.
MPD: mean profile depth (ISO 13473-1 [1]; ASTM E 1845 [2]).
MTD: mean texture depth (ASTM E 965 [3]; EN 13036-1 [4]).
NMAS*: fraction of the nominal maximum aggregate size.
t*: fraction of the thickness of the wearing course.
DGFC: dense-graded friction course. PAC: porous asphalt concrete.

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ABSTRACT

Safety, skid resistance and noise of roads highly depend on the characteristics of pavement surface texture, for both porous and dense-graded wearing courses.

In the light of the above facts, the objective of the study was to model the relationship between laser-based and volumetric-type measurements of the surface macro-texture of a pavement. In more detail, the study focused on the mean profile depth (MPD, as *per* ISO 13473-1:1997 and ASTM E1845-01) and on the mean texture depth (MTD, as known as sand patch texture, as *per* ASTM E965-96 and EN 13036-1). Different types of surface textures were considered: dense-graded friction courses (DGFC), splittmastic asphalts (SMA), open-graded friction courses (OGFC), porous European mixes (PEM).

A generalised simple model has been set up, calibrated and validated. The proposed model fits the data of many types of wearing courses without neglecting the basic achievements which refer to the curves previously derived.

1. Background

Surface texture has an outstanding importance in terms of road and airport safety [5]. It affects as well pavement performance [6]: (i) tyre/road friction [7–9]; (ii) noise emission [10–13] and driving comfort [14]; (iii) rolling resistance [15,16]; (iv) wear of tyres [17,18]; (v) particulate matter emission from paved roads [19,20]; (vi) operating costs [15]; (vii) greenhouse gas emissions [21]. Focused on macrotexture (MPD, MTD) impact on life cycle GHG (greenhouse gas) emissions. Indeed, macrotexture refers to the primary wavelengths that excite shock absorbers in vehicle suspension systems, cause deformation of tyre sidewalls for a moving vehicle, affect energy dissipation, waste heat, and rolling resistance by vehicles.

Surface macrotexture (wavelengths between 0.5 and 50 mm) can be assessed through intrinsic and extrinsic indicators [22]. In

* Corresponding author.
E-mail addresses: filippo.pratico@unirc.it (F.G. Praticò), vaiana@unical.it (R. Vaiana).

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more detail, the following main methods apply: volumetric methods ([3] procedure, with glass spheres; [4], with glass spheres), laser-based methods ([1,2,23–27]), and permeability-related methods ([28,29]). Note that volumetric methods and indicators (e.g., MTD) are based on the ratio between a volume and a surface area, while laser-based methods and indicators (e.g., MPD) rely on the ratio between a surface area and a length. Yaacob et al. [30], assessed pavement texture with variety of test methods, including sand patch test and multi laser profiler. They concluded that there were weak correlations between the results of these two measurement techniques. Rodriguez et al. [31], advised the use of 3D texturometer laser, as a method of measuring the surface macrotexture and MPD (mean profile depth) in order to estimate indicators derived by Sand and Grease Patch tests. Surface texture depends on mix components and construction process [32–39].

The sand patch method (see [3,4] and previous standards in which sand was used instead of glass spheres) is suitable for bituminous surface courses and concrete pavement surfaces with texture depth greater than about 0.25 mm and is affected by the surface and inner structure of the mixture (air voids distribution, shape, tortuosity). Sand patch method depends on dense granular (glass beads) flows. It is size-dependent and a complicated set of flow properties are involved, which differentiate them from ordinary fluids [40].

Laser-type measurements (see [2,1]) are affected by the complex shape of a pavement surface but they do not depend on what the laser cannot "see" from its position. In more detail, even when conoscopic holography is used (which presents several advantages), a laser beam is projected onto the surface and then the immediate reflection along the same ray-path are put through a conoscopic crystal and projected onto a CCD (charge-coupled device for the movement of electrical charge). The result is a diffraction pattern. This pattern is frequency analysed and the distance to the measured surface (pavement surface) is consequently derived. The main advantage with conoscopic holography is that only a single ray-path is needed for measuring, thus giving an opportunity to measure very deep pavement "valleys". Criticalities (as for all the laser-based techniques) relate to beam dimensions and to the fact that beams describe a family of straight lines, without any possibility to investigate pores properties outside the above plane.

Accurate sand patch testing on/and laser based testing cannot be carried out when road surface is sticky or wet. The equipment of the sand patch method costs around 0.1 k€ while the equipment of a laser-based texture equipment costs around 10–100 k€. The duration of the two tests ranges from less than one second (high-speed laser measurement), to a couple of minutes (sand patch method), to several minutes (high-precision, laboratory-type lasers).

Pavement macrotexture depth (herein termed MTD, [3,4]) and mean profile depth (MPD, [1,2]) are indicators which refer to macrotexture domain (wavelengths between 0.5 and 50 mm). Two main domains can be approximately observed with reference to macrotexture studies and analyses [41]: low macrotextures (MPD lower than about 1.5 mm) and high macrotextures (MPD higher than about 1.5 mm).

In the first dominion many linear relationships MTD (MPD) have been derived. The slope of the equation used to obtain MTD from MPD measurements takes values from about 0.5 to 1.2. In particular, values of 0.5–0.6 were found by [42,9], whereas [6] found a slope value of 0.7. According to [1,2,43–48], the range of slope was 0.8–1. Finally, [27] and [49] found slope values of 1.1 and 1.2, respectively.

The intercepts range from about −0.3 [50], to 0.0 [35], to 0.2 [1,2,42–44], to 0.3 [9], to 1 [51] with MPD based on microscopy evaluation.

It is noted that several lasers, due to their characteristics, yield other linear relationship [52]. For example, for the CTMeter, the slope is about 0.95 and the intercepts is about 0.07 [49].

In the second dominion (higher values of macrotexture) many authors have found results which do not comply with the previous equations (e.g. [35]).

According to [1], experience has shown that the sand patch texture may be not reliable if used in porous surfaces because some material may pour down into the pores [6].

According to [5], the prediction of MTD (mean texture depth, volumetric method) from MPD (mean profile depth [2]) is not valid for highly porous surfaces, as the glass spheres or sand flows into the pores, producing high values for MTD. Furthermore, at the same time, [5], found that the prediction of OFT ([28], outflow time) from MTD was very good also for highly porous surfaces. Note that the existence of a different relationship between MPD and MTD for porous asphalt concretes (PAC) or similar surfaces (open-graded friction courses, OGFC, porous European mixes, PEM; etc.) has been pointed out by many other authors (other data [35,50,53]).

Vilaça et al. [54] developed a scanning prototype to derive ETD and results obtained showed a certain difference between the predicted and the actual value of texture for "rough" porous asphalt concretes.

Praticò and Vaiana [55] studied the variability of MPD-related and ETD-related measurements for porous asphalt concrete. Their standard deviation and coefficient of variation resulted comparable.

Note that when comparing CTMeter and sand patch method, [35,56], found that the offset between the CTMeter and sand patch test results was insignificant when open-graded mixtures were excluded.

Freitas et al. [57]) focused on the variability of the mean profile depth and pointed out the necessity to further investigate the effect of the type of surface on data variability.

Finally, note that the inherent proportionality between MPD and the NMAS (nominal maximum aggregate size) has been partly proved by [58]. In contrast, this fact didn't happen when comparing MTD and NMAS. Note that Superpave defines NMAS as "one sieve size larger than the first sieve to retain more than 10% of the material" [59].

2. Objectives

Safety, skid resistance and noise of roads highly depend on the characteristics of pavement texture, for both porous and dense-graded wearing courses.

Consequently, there is a strong need to develop methods and algorithms to quickly estimate the characteristics of road surface textures, without traffic interruptions, over a wider range of pavement types. To this end, assessing relationships which are valid for different types of friction courses can have an appreciable impact, in a context in which porous asphalt concretes and other innovative wearing courses are widely used.

In the light of the above facts, the objective of the study was to model the relationship between laser-based and volumetric-type measurements of the surface macro-texture of a pavement. In more detail, the study focused on the mean profile depth ([1,2]) and on the mean texture depth ([3,4]). Different types of surface textures were considered: dense-graded friction courses (DGFC), splittmastic asphalts (SMA), open-graded friction courses (OGFC), porous European mixes (PEM). Modelling was followed by calibration and validation.