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Deterioration trends of asphalt pavement friction and roughness from medium-term surveys on major Italian roads

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Abstract

Deterioration models are the key factor for effective Pavement Management Systems, helping out road agencies to assess the actual pavement condition and forecast future performance of the asset. Among pavement condition characteristics, friction should be taken into account due to its important effect on user safety, while roughness could be used to express user comfort. The purpose of this study was to provide a reasonable case study for future improvements of Italian road management, even if the length of the analyzed highways was not intended to be representative of the overall Italian network.

This research studied the friction trend (Side Force Coefficient) depending on traffic levels (ESALs) and pavement aging for Italian highways, combining the data with roughness and macrotexture. Surface characteristics were monitored during a seven-year time span. A selection of different road sections with homogeneous traffic levels, similar environmental conditions and surface material was performed and high-speed/high-quality road surveys were used for distress data collection. Pavement deterioration models for Italian road sectors were developed at project level, as starting point to advance pavement management practices in Italy. Degradation curves showed the same trends for similar pavement structures, materials and traffic levels; on the other hand, differences in pavement characteristics, increased ESALs and various maintenance treatments significantly altered those trends.

Keywords: Pavement Management System; Deterioration models; Friction; Roughness; MPD; High-speed monitoring

1. Introduction

The lack of knowledge about condition of the assets does not allow road agencies to clearly identify the required funds for proper maintenance at the required time. As a result, a large amount of money is often wasted on emergency maintenance interventions, which have been proved to be less effective than preventive and corrective maintenance operations. To improve the current practice, a Pavement Management System (PMS) should be developed to address road network critical issues and plan for the best strategies and optimal timing for interventions, relying on updated inventory and database of the actual geometric features, functional and structural conditions of the road network. Due to limited available resources and in the context of global financial crisis, a pavement degradation model could be an essential tool for road authorities and agencies to describe past and present situation of the infrastructure, choose among the best suitable maintenance treatments and support budget allocation scenarios.

Currently, a number of countries already developed degradation models for roads; however, many of them can only be used within the boundary conditions they were developed on and no performance curve can be used for other road networks without proper calibration.

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2. Background and goals

In the available scientific literature, several pavement degradation models can be found, using different approaches and analytical methods: regression equations based on historical field data [1], probabilistic models [2,3], Bayesian statistics with a Markov chains and Monte Carlo simulations [4,5]. Different prediction time spans (forecast horizon) were commonly selected, allowing for short term and long term condition assessment, and several variables were taken into account such as road functional classification, pavement age, traffic loading (ESALs), environmental parameters (temperature and precipitation, for instance), layers thickness, Structural Number (SN); however, an effective and comprehensive model which includes all factors is very difficult to be implemented [6,7]. Moreover, performance assessment and treatment performance models for preventive maintenance on asphalt pavements were studied after several years of monitoring activities. Treatment life and extended pavement service life of thin Hot-Mix Asphalt (HMA) overlays and surface treatments (seal coats, chip seals, etc.) were estimated, according to different pavement condition data (rutting, roughness, macrotexture, etc.) [8–10].

One of the most critical issues regarding Pavement Management Systems is that prediction models do not match actual pavement conditions [11] and, in order to update deterioration curves, pavement performance must be monitored over consecutive years [12,13].

Recently, equipment able to quickly estimate road conditions were developed and high-performance (dynamic) measurements are performed with high-speed vehicles, avoiding traffic interruption or lane closures [14,15]. However, dataset needs to be detailed and reliable because errors can influence maintenance strategies if data collection does not ensure accuracy and precision. For these reasons, analysis techniques based on robust statistics should be performed [16].

Other problems related to road inspections are the lack of knowledge about maintenance history such as treatment applied to pavements without being recorded, the need to remove outliers in the data and pavement sections with unusual performance [13]. To help road managers, software based on Bayesian approach are also adopted to process and automatically analyze pavement data, computing averages, homogeneous section transition and other statistical analyses [17,18].

Several predictive degradation models describe friction behavior of road pavements. Friction data, along with macrotexture, were proved to be effective indicators to monitor pavement conditions [14] and equations were used to describe the degradation trend [19,1].

Roughness is commonly used to determine the comfort of road users running on a road and is useful to provide a general assessment of pavement conditions. Several studies [20–25] dealt with degradation curves of International Roughness Index (IRI) for both new pavements and existing sections [26–28], focusing on the relationships between age, traffic, rut depth, cracking, temperature and type of intervention.

Some studies [29] also proposed linear and exponential IRI performance curves, but these models often included detailed site-specific measurements and, thus, formulas could not be tailored to other local conditions.

In Italy, PMS applications with specific performance curves were developed in the past years [30]; included Side Force Coefficient, IRI and percentage of cracked area into degradation models, although no distress data collection was continuously performed using high-speed/high-quality road surveys.

Data analysis is currently conducted using a clustering approach to identify homogeneous sections and removing all outliers through median, upper and lower quartile calculations.

In this context, the present study shows the results of a seven-year monitoring campaign to evaluate how friction (by means of Side Force Coefficient), International Roughness Index and Mean Profile Depth were influenced by traffic (ESALs) and pavement aging. To this end, two Italian highways were considered by performing a selection of different road sections with homogeneous traffic levels, similar environmental conditions and materials; performance prediction models at project level were finally estimated as described in the following sections.

3. Field survey and research method

Road survey was conducted during spring season from 2008 to 2014; data were collected by adopting high-speed vehicles on two main arterials of the Italian road network in a coastal area (namely, Highway I and Highway II in this paper).

Data monitoring campaigns were carried out annually, from mid-March to mid-May, at least three days after the last rain event. Table 1 shows a range of weather parameters during the analysis period of each year.

Friction, macrotexture and roughness values were collected on the slow traffic lane, along left and right wheel paths; a 10-m spatial frequency was adopted to gather data from a Side Force Coefficient Road Inventory Machine (SCRIM), while a 20-m spatial frequency was used to get International Roughness Index (IRI) values from an Automatic Road Analyzer (ARAN).

The SCRIM measured at the same time both the macrotexture of the pavement, in terms of Mean Profile Depth (MPD, mm) according to ASTM E1845, and the pavement friction Side Force Coefficient (SFC) (ASTM E670) under wet conditions (0.5 mm of water film depth); the ARAN was used to get International Roughness Index (IRI) results according to ASTM E950 and ASTM E1926.

The SFC was computed as follows:

$$\text{SFC}\ (S) = 100 \cdot (FS/W) \tag{1}$$

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