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Skid resistance determination for pavement management and wet-weather road safety

T.F. Fwa

Department of Civil & Environmental Engineering, National University of Singapore, 1 Engineering Drive 2, Singapore 117576, Republic of Singapore

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ABSTRACT

Road accidents during wet weather have been a topic of major concern of road engineers in regions of wet-tropical climate and in other parts of the world during the wet season of the year. Road safety studies indicate that approximately 20% of all road accidents occurred during wet weather, and that the skid resistance of wet pavements have a major influence on the occurrences of wet-weather accidents. Monitoring of wet pavement skid resistance has been an integral part of a typical pavement management system. However, because of the lack of prediction capability of pavement skid resistance under various rainfall intensities, the minimum skid resistance threshold for safe wet-weather driving has been specified by highway agencies based on either engineering judgement or past experience. It is shown in this paper that the single-point minimum skid resistance threshold is inadequate to offer a complete description of the skid resistance performance of the pavement sections in question for effective management of a road network. It is unable to assess the risk involved in an actual wet-weather condition where the pavement surface water-film thickness and vehicle speed are different from standard test conditions. This limitation of the current system of specifying a minimum skid resistance threshold can be overcome by adopting a theoretically sound approach to represent pavement skid resistance under different conditions of water-film thickness and vehicle speed. This paper describes the theoretical basis of the approach and the development of a mechanistically derived three-dimensional finite-element skid resistance simulation model to predict skid resistance. The application of the proposed approach and the skid resistance prediction procedure in pavement management system and wet-weather driving safety assessment is presented.

1. Introduction

Road accidents during wet weather have been a topic of major concern of road engineers in regions of wet-tropical climate and in other parts of the world during the wet season of the year. Road safety studies indicate that approximately 20% of all road accidents occurred during wet weather, and that the skid resistance of wet pavements have a major influence on the occurrences of wet-weather accidents (McGovern et al., 2011; Ivan et al., 2012). To minimize the occurrences of wet-weather road accidents, road agencies responsible for maintaining road pavement networks regularly monitor pavement skid resistance and activate preventive or corrective measures when necessary to keep pavements safe for wet-weather driving.

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E-mail address: ceefwatf@nus.edu.sg

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A common practice by road agencies in keeping pavements safe for wet-weather driving is to set a minimum skid resistance maintenance threshold (Highway Research Board, 1972; Hall et al., 2009). This threshold skid resistance value provides a convenient working reference for a highway agency to check against the skid resistance of the pavements under its charge, for the purpose of keeping the pavements safe for wet-weather driving. The minimum threshold skid resistance is a single-point control applied across either an entire road network or a given class of highway class. It is shown in this paper that the single-point threshold value is inadequate to offer a complete description of the skid resistance performance of the pavement sections in question for effective management of a road network, and it does not permit pavement engineers to evaluate the wet-weather driving risks for vehicles traveling at different speeds under various wet-weather conditions.

To overcome the above-mentioned limitation of the current system of representing pavement skid resistance and specifying the minimum skid resistance threshold, this paper presents an approach that offers a more complete representation of pavement skid resistance under different traffic operating conditions of water-film thickness and vehicle speed. The proposed approach includes a mechanistically derived three-dimensional finite-element skid resistance simulation model that is able to predict pavement skid resistance at different vehicle speeds and water-film thicknesses. The theoretical basis of the approach and the formulation and capabilities of the three-dimensional finite-element skid resistance simulation model is explained. The application of the proposed approach and the skid resistance prediction procedure in pavement management system and wet-weather driving safety assessment is presented.

2. Pavement friction management as a part of pavement management system

A key function of pavement management systems is to monitor pavement condition and perform necessary maintenance to provide a safe, efficient, comfortable and durable riding surface for vehicles in all weather. Maintaining pavements to achieve a high level of road safety is an integral part of a pavement management system. In practice, this is achieved by keeping the skid resistance of pavements at a sufficiently high level to minimize the risk of vehicle skidding and hydroplaning.

2.1. Concept of minimum skid resistance threshold

Skid resistance is the force developed when a tire that is prevented from rotating slides on a pavement surface (Highway Research Board, 1972). Skid resistance is an important pavement safety evaluation parameter because poor skid resistance can lead to skidding accidents and inadequate braking distance during emergency braking. For a known vehicle tire, the skid resistance available is given by the frictional force developed at the tire-pavement interface, which is governed by surface properties of the pavement. In general, the friction resistance of dry pavements is high and rarely presents any skidding risk. The main road safety concern is the significantly reduced skid resistance during wet-weather when there is a layer of water film on the pavement surface (Hall et al., 2009). Hence, it is common practice to measure and report the skid resistance of a pavement surface under wet condition for the purpose of pavement friction management.

The skid resistance of a wet pavement varies with the thickness of water film on the pavement surface. For a given test speed, the thicker the water film, the lower is the skid resistance. In pavement skid resistance survey of a pavement management system, a standard skid resistance test procedure and test equipment is adopted, and the test speed and water film thickness are fixed. It is a widely adopted practice in pavement management for a highway agency to specify a minimum skid resistance measured in a standard manner as the threshold for maintenance activation (Highway Research Board, 1972; Hall et al., 2009). Any pavement section that has its skid resistance equal to less than this threshold is deemed to be unsafe for wet-weathering driving.

Two forms of minimum skid resistance thresholds are commonly used by highway agencies for pavement friction management, namely the Investigatory Level and the Intervention Level (Hall et al., 2009; Rogers and Gargett, 1991; Henry et al., 2000). The Investigatory Level is the skid resistance at which an agency should start to monitor the pavement skid resistance and crash levels, and begin the process of planning for some preventive or restorative actions. The Intervention Level is the skid resistance at which an agency must take immediate corrective action, such as a maintenance or restorative treatment. It can be considered to be the skid resistance level below which the driving safety risk becomes unacceptable.

Since there is no analytical tool available for pavement engineers to derive theoretically the minimum skid resistance for safe driving in wet weather, the minimum skid resistance threshold has been specified by highway agencies based on one or more of the following considerations: engineering judgement, deterioration trend of skid resistance, records of crashes, or practice of other agencies for a similar type of pavement section. Based on the practices adopted by different highway agencies, Hall et al. (2009) recommended the following three methods for establishing skid resistance thresholds:

- Method 1 using historical skid resistance data – By plotting historical trends of skid resistance deterioration with time, the Investigatory Level is set at the skid resistance level when the deterioration rate of skid resistance begins to increase significantly. The Interventional Level is set at either a certain skid resistance magnitude or percentage (e.g. 10 percent) below the Investigatory Level.
- Method 2 using both historical skid resistance data and crash data – The Investigatory Level is determined by the same way as Method 1, but the Intervention Level is set at the skid resistance level when there is a significant increase in the rate of number of crashes.