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New findings regarding the significance of pavement skid resistance for road safety on Swiss freeways

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Abstract

Introduction: The significance of the influence of poor pavement skid resistance values on accident frequency in wet pavement conditions has been the object of many studies over several years. The various investigations have produced very diverse findings. Only seldom, however, has detailed consideration been given to the central question of whether pavement skid resistance is a decisive parameter in the occurrence of local accident "black spots." Until now, the focus has been more on describing a relationship between pavement skid resistance and accident frequency. *Method and results:* In the course of the network-wide survey of the states of pavements and of accident occurrence on Switzerland's freeways from 1999 to 2003, it emerged that a relationship with inadequate pavement skid resistance was provable for only a small proportion of accident black spots. These findings were used to frame a guideline for authorities and highway operators about how to treat skid resistance when assessing pavements and accident occurrence on freeways.

Keywords: Road safety; Skid resistance; Accident analysis; Influence of poor skid resistance on accident black spots; Evaluation of safety measures

1. Introduction

1.1. Background

Investigations into the relationship between pavement skid resistance and accident occurrence have been carried out over many years. Until about 1993, a wide variety of research projects (Kamplade, 1995; Rizenbergs, Burcheit, & Warren, 1977; Wehner, Schulze, Dames, & Langer, 1975) documented indications of a relationship between accident frequency and pavement skid resistance. Recently, however, various researchers (e.g., Hirsche & Tenzinger, 1990; Mayer, Van Der Sluis, & Steinauer, 2002; Rogers & Gargett, 1991; Tiefenbacher, 2001) have quantified such relationships — above all for highways with fast traffic, such as freeways — as insignificant.

If the relationship between accident frequency and pavement skid resistance can no longer be described in functional terms, it becomes more difficult to assess the influence of skid resistance characteristics on accident occurrence. Without a quantifiable relationship, it is no longer possible to specify or determine limits for minimum requirements relating to skid resistance.

1.2. The assignment

The first uniform, network-wide inspection and assessment of the pavement characteristics and safety level (ZEB-NS) of Switzerland's National Highways (Swiss Federal Roads Authority, 2003) provided an opportunity for a recently completed follow-up investigation, which analyzed afresh and in greater depth the relationship between accident occurrence and pavement skid resistance, as a very large dataset was now available for the first time. Its aim was to clarify the influence of pavement skid resistance — and poor skid-resistance in particular — on accident occurrence. Note that in Switzerland the term "National Highways" refers specifically to the country's network of express routes, but not all National Highways are true freeways.

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2. Research aims and methodology

2.1. Aims

The research had the following aims:

- To identify pavement segments with pavement skid resistance levels below the limit for freeways and also with higher accident frequency under wet pavement conditions.
- To investigate the frequency of such segments in the context of the network as a whole.
- To describe analytically any relationship between accident frequency and pavement skid resistance.
- To derive procedural recommendations for evaluating pavement skid resistance in the context of the evaluation and assessment of road safety on freeways.

2.2. Basic principles

The collection and evaluation of accident occurrence data was based on the police records of highway accidents on the National Highway network over five years (1995–1999). Accidents were allocated to 500-m route-intervals with segment limits that tallied with those of the 100-m intervals for the skid resistance investigation. This ensured that linkage would be possible. To calculate the accident and injury rates, the traffic volumes from the cross-section counts of the automatic traffic counters (ASTRA, 1995–1999) were applied to all the 500-m intervals through the relevant aggregations.

The evaluations of accident occurrence involved the following parameters:

- Accidents according to highway conditions - dry and wet (wet = damp/wet)
- Accidents according to type of accident (as specified in the Bfs-Code [Swiss Federal Office For Statistics (Bfs), 1992] Code)
- Accidents according to severity (damage to property, injuries, fatalities)
- Accident rate Ar (number of accidents per 10^6 veh. km)
- Accident rate wet Ar (proportion of wet accidents)
- Injury rate (number of injured persons per 10^8 veh. km)

The status inspection of skid resistance was undertaken with the SCRIM (Sideway Force Coefficient Routine Investigation Machine) on all traffic lanes of the national highways, generally using a measurement speed of 80 km/h. Around junctions and on stretches with speed limits of 80 km/h, a measurement speed of 60 km/h was used.

The usual procedure for SCRIM measurements was followed in order to evaluate the skid resistance measurements. The readings were then aggregated to mean values for 100-m route-intervals. These intervals form the basis for the comparison with accident occurrence.

Table 1 gives an overview of the scope of both the measurements and the evaluation of accident occurrence and pavement skid resistance.

2.3. Research methods

The method of critical accident rates (Swiss Association of Road and Transportation Experts (VSS), 1999) was used to identify accident black spots, while the pavement segments with pavement skid resistance levels below the limit for freeways according to the official Swiss standard (Swiss Association of Road and Transportation Experts (VSS), 1991; i.e., with $\mu < 0.32$) were sorted from the data collected through the SCRIM measurements.

2.3.1. Evaluation procedure for "accident black spots"

Accident black spots were identified by means of the method of critical accident figures (Swiss Association of Road and Transportation Experts (VSS), 1999). It is defined as: accident black spot is present wherever the number of accidents in a certain interval is greater than the critical accident figure.

The accident figure in relation to vehicle mileage (i.e., the accident rate) was used to determine the accident black spots on Swiss freeways.

To qualify instances of statistically notable accident occurrence in wet conditions, reference was made to the wet accident rate and critical wet accident rate, respectively. The equations to execute critical rate calculation were:

$$A_{rcit} = A_{rm} + k\sqrt{\frac{A_{rm}\cdot 10^6}{ADT_i\cdot 365\cdot T\cdot L_i}} - \frac{10^6}{2\cdot ADT_i\cdot 365\cdot T\cdot L_i}$$

$$\text{with} \quad A_{rm} = \frac{10^6}{T\cdot 365}\cdot\frac{\sum_1^n Z_i}{\sum_1^n (ADT_i\cdot L_i)}$$

where:

n	Number of intervals
k	1.645 with 5% level of significance
A_{rm}	Mean accident rate for the whole route length per highway category
Ni	Number of accidents during the time period T in interval i
L_i	Interval length [km] in interval i
ADT_i	Average daily traffic in vehicles in interval I
T	Time period in years

Table 1
Scope of the research

Parameter	Interval length	Number of intervals					
Accident occurrence	500 m	without accidents		with accidents		total	
		683	14%	4,358	86%	5,041	100%
Skid resistance	100 m	inadequate		adequate		total	
		784	1.3%	59,503	98.7%	60,287	100%