IS THE CORRELATION BETWEEN PAVEMENT SKID RESISTANCE AND ACCIDENT FREQUENCY SIGNIFICANT ?

L. Seiler-Scherer, dipl. Bau-Ing. ETH
IVT-ETH Zürich

Conference paper STRC 2004

STRC 4rd Swiss Transport Research Conference
Monte Verità / Ascona, March 25-26, 2004

IS THE CORRELATION BETWEEN PAVEMENT SKID RESISTANCE AND ACCIDENT FREQUENCY SIGNIFICANT?

L. Seiler, dipl. Ing. ETH
ETH Hönggerberg
HIL F 12.2
8093 Zürich

Phone: 01 633 31 93
Fax: 01 632 10 57
e-Mail: seiler@ivt.baug.ethz.ch

Abstract

Questions concerning the effect of skid resistance on traffic accidents, particularly by wet pavements, have been investigated in various researchs for many years. Apart from separation of the influence of skid resistance from other influence factors, one of the main issues in all these studies has repeatedly been the quantifying of the correlation between skid resistance and accident occurrence. The goal was finding a threshold or minimum value for the skid resistance.

Whereas elder studies show quantified correlations between skid resistance and accident occurance, recent research results tended to put these in question.

Based on a large data set regarding freeways and a pilot study regarding main roads the present study shows that it was not possible to identify any such relation between skid resistance and accident occurrence for either wet or dry pavements. It was not possible to formulate no quantifiable correlation in this regard.

It could, however, be find out that a systematic search for notable areas where very low skid resistance values with high accident frequencies by wet pavement coincide is extremely worthwhile, as it serves to identify individual, randomly distributed danger zones. These can then be subjected to more detailed investigations.

Keywords

Skid resistance – accident occurrence – 3rd Swiss Transport Research Conference – STRC 2003 – Monte Verità

1. Introduction

To minimise accidents due to skid resistance and to provide legal certainty for concerned authorities researches regarding a possible relationship between skid resistance and accident occurrence have been carried out for many years. Thereby it is desirable to specify requirements for skid resistance of different pavements or to define guidelines for minimum skid resistance values.

1.1 Standard

For the time being valid standard SN 640 511 b came out in 1984. It specifies guide values on the one hand for the Skid Resistance Tester (SRT – Pendulum) and the outflow measuring device and on the other hand for the Skiddometer. These guide values were defined at that time on the basis of a representative distribution of 280 routes of the Swiss roadnetwork [1]. It was supposed that vehicle drivers based on their experience adapt their driving behavior on wet roads to the current skid resistance. This guide value corresponds to the 95 % curve. However, the above guide value has not to do with effective correlation between skid resistance and accident occurance. Furthermore, this valid guide value specifies no obliging minimum for the pavement skid resistance.

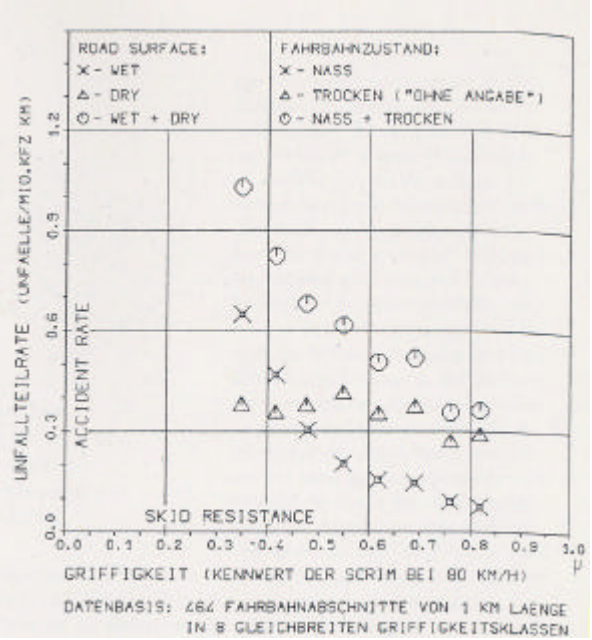
1.2 Literature

Various research results have been published over many years and have tried to quantify the influence of skid resistance on accident occurrence by wet conditions and to characterise a correlation between skid resistance and accident frequency. Whereas a wide variety of investigations and findings from research projects affirm more ore less such a correlation; there exist other researches, which could not find any statistically significant results to confirm a possible one.

Practically, all measures taken to improve skid resistance indicate a positive effect on reducing accident occurrence in form of a general increase in traffic safety. Between 1963 and 1993 often quantified relations were reported (for example in [2],[3],[4],[5]).

For example the figure right shows such a correlation from 1983. 464 intervals each 1 km length were measured and evaluated with an English SCRIM. As the graphic shows there exist a clear correlation between wet accident rate and skid resistance.

Figure 1: Correlation skid resistance – accident rate



J. Kamplade, H. Schmitz,
Erfassen und Bewerten der
Fahrbahngriffigkeit; Mai 1983

During the last 10 years the results of investigations regarding a correlation between accident occurrence (by wet pavement) and skid resistance have been assessed more critically; sometimes they were even considered as unproved [2][6][7][8]. Compared to earlier researches, in the last years, databases with substantially larger data were evaluated. An example of recent investigations comes from Germany [2], which is based on the data from the states Bayern and Nordrhein – Westfallen each of them with about 4'000 km national routes. This investigation came to the following results:

- Firstly, it could be shown that evidently the level of skid resistance of areas with wet accidents differs only slightly from the level of skid resistance elsewhere in the highway network.
- Secondly, at areas with significant accident occurrence no evident correlation, either by dry or by wet condition, was found between any accident parameters and skid resistance.
- Finally, it could be shown that the average skid resistance over all accident-remarkable intervals was lower than the one over the rest of the network.

2. Research results

To analyse the question regarding the effect of skid resistance on accident occurrence both freeways and main roads were examined more closely in course of the research „ Besoin en adhérence“ [10] VSS 2000/360. For freeways owing to the inspection and assessment of the state of national freeways (ZEB-NS) [9] between 1999 and 2002 an extensive database for the skid resistance as well as for the accident was available. At present no such database exists for main roads. The ETH Zurich developed its own pilot study in the course of the research project.

2.1 Freeways

2.1.1 Bases

Skid resistance

One element of the inspection and assessment of the state of national freeways (pavements) ZEB-NS [9] between 1999 – 2002 was a survey of the skid resistance on all the traffic lanes on Switzerland's national freeways, evaluated at 100 m intervals. The status inspection of skid resistance was undertaken with the SCRIM (Sideway Force Coefficient Routine Investigation Machine). The measuring speed was in general 80 km/h. By around junctions and on routes with speed limitations, a measuring speed of 60 km/h was used. The performance data were aggregated to mean values for intervals of 100 m. These intervals provide the basis for the comparison of skid resistance with accident occurrence.

For the comparison of skid resistance with accident occurrence, freeway categories 2 x 2 as well as 2 x 3 lanes were evaluated. In addition to those accidents, which take place on freeways with direction separation, on 2 lanes freeways without direction separation and on mixed traffic roads with two – way traffic (M), other types of accidents are possible.

The following table shows the scope of skid resistance measurements:

Table 1: Scope of skid resistance measurements [9] 100% = 6077.374 km

Freeway category	All lanes		Passing lane		Cruising lane		Crawler/truck lane	
	km	%	km	%	km	%	km	%
Whole network	6027.539	99.19	2691.061	44.28	3228.908	53.13	107.570	1.77
1 (2x2)	4796.871	78.93	2415.756	39.75	2381.115	39.18	-	-
2 (2x3)	441.825	7.27	173.205	2.85	160.443	2.64	107.570	1.77
3 (2)	539.671	8.88	89.945	1.48	449.725	7.40	-	-
4 (M)	249.172	4.10	12.155	0.20	237.625	3.91	-	-

Accident

Another element of the inspection and assessment of the state of national freeways (pavements) ZEB-NS [9] the safety level of the Swiss national freeways was also determined across the network for 500 m intervals. Based on recording police reports accidents of a five years period (1994 – 1998) were collected and classified according to number, severity (injured persons), accidents on dry pavement, accidents on wet pavement and accident type. The average daily traffic volume (ADT) was aggregated on the basis of traffic measurements from the automatic traffic counters [11] for all 500 m intervals. In a further step, based on these data accident rates as well as wet accident rates were determined. Due to not completely available accident data approximately 77 % of the national freeway network could be evaluated.

Assignment of skid resistance and accident occurrence

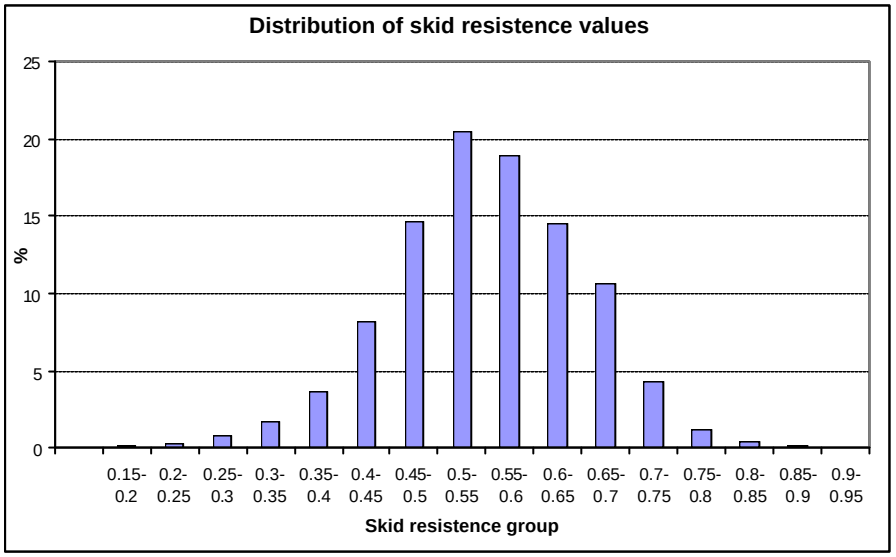
To define a possible correlation between skid resistance and accident occurrence an appropriate skid resistance value had to be assigned to each accident interval. As the values of skid resistance were measured for each traffic lane and 100 m intervals separately, the smallest skid resistance value in each 500 m interval (accident intervals) was assigned to that accident interval.

2.1.2 Evaluation

Skid resistance

The following figure shows the distribution of skid resistance values for 500 m intervals.

figure 2: Distribution of skid resistance values

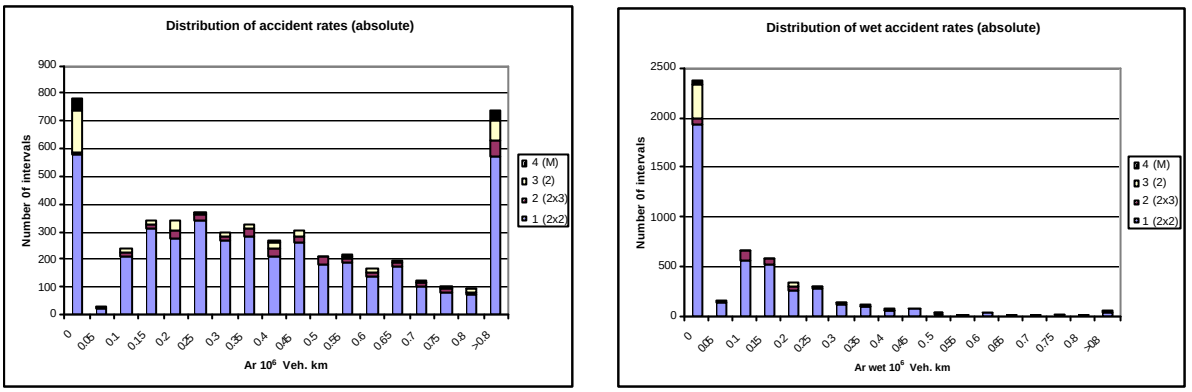


The figure shows a slightly shifted distribution of skid resistance values with a major part assessed as adequate to good values. Skid resistance values under the valid guide value of 0.32 are very rare. This picture confirms the statement in [9] that regarding the pavement skid resistance the condition of the national freeway network can be classified as good to very good, a fact, which is probably a consequence of specific and careful maintenance of the network.

Accident

For a correlation between skid resistance and accident occurrence is particularly the wet accident rate of importance. The distribution of the wet accident rate makes it clear that there are almost no sites on the national freeway network where a notably high number of accidents in wet conditions are recorded. The following figure shows the distribution of the accident rates and the wet accident rates of all evaluated intervals (500 m):

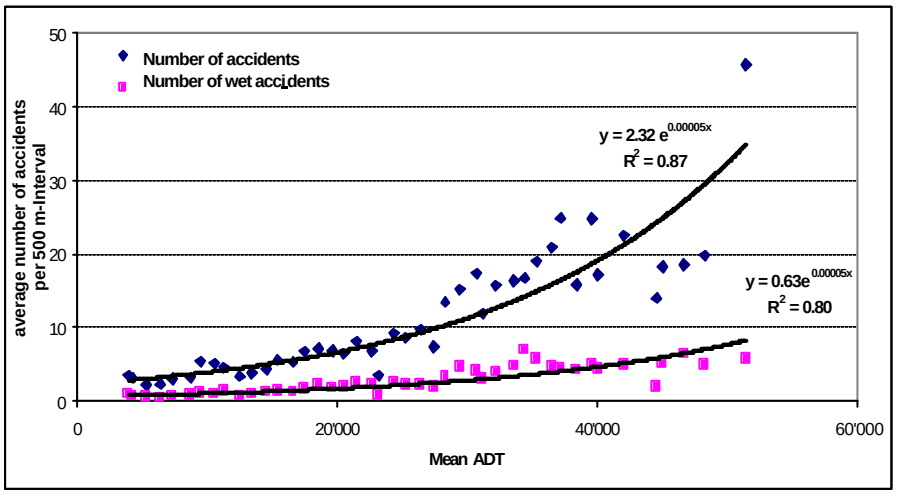
Figure 3: Distribution of accident rates and wet accident rates



Correlation between number of accidents and ADT

The analysis of accident occurrence resulted in a fundamental confirmation of the correlation between the number of accidents per interval and the average daily traffic (ADT). The following figure shows this correlation, whereby the intervals were summarised in each case in ADT-groups with a range of 1000 vehicles per day and the average number of accidents of different ADT-groups.

Figure 4: Correlation between number of accidents and ADT



Correlation between skid resistance and accident frequency

To analyse any possible correlation between skid resistance and accident occurrence, all intervals of skid resistance values and accident rates were grouped into 16 skid resistance

classes, each with a bandwidth of 0.005 in the process. For each these groups mean accident rates and mean wet accident rates were determined from single values.

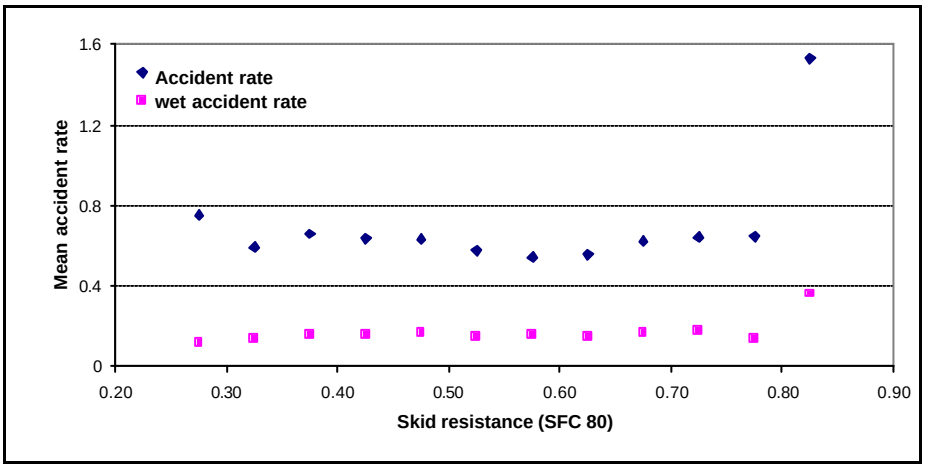
The following table shows these basic values.

Table 3: Basic data: Skid resistance and accident frequency

Skid resistance group	Number of intervals	Mean accident rate	Mean wet accident rate
0.15-0.2	3	1.340	0.529
0.2-0.25	8	0.724	0.109
0.25-0.3	25	0.752	0.116
0.3-0.35	51	0.592	0.141
0.35-0.4	105	0.660	0.160
0.4-0.45	237	0.635	0.162
0.45-0.5	425	0.632	0.171
0.5-0.55	590	0.580	0.150
0.55-0.6	546	0.543	0.155
0.6-0.65	419	0.560	0.150
0.65-0.7	306	0.624	0.168
0.7-0.75	124	0.642	0.174
0.75-0.8	34	0.647	0.138
0.8-0.85	12	1.530	0.362
0.85-0.9	4	0.959	0.205
0.9-0.95	1	0.277	0.000

The investigation of a possible correlation between the grouped skid resistance values and accident frequency expressed through the accident rate / wet accident rate, was undertaken by means of various regression analyses. Various curve adjustments and analytical functions were tested to correlate the data, but not definite relation with an acceptable coefficient of correlation could be derived.

Figure 5: Correlation between skid resistance and accident rate / wet accident rate



The figure shows that no quantifiable correlation with skid resistance emerges either for the accident rate or for the wet accident rate.

Intervals with remarkable Skid resistance

Since no quantifiable correlation could be identified or proved by the analysis of the correlated date, the database for low skid resistance values $\mu \leq 0.32$ was subjected to more detailed examination.

By Taking the full data set for accident occurrence into account, in this case including all freeway categories, it was possible to sort out and analyse more closely a total of 147 intervals with $\mu \leq 0.32$. The analysis of these 147 intervals on the basis of the critical wet accident rate [12] led to 19 accident – remarkable intervals. That means that only 13 % of the intervals of national freeway with skid resistance $\mu \leq 0.32$ are also notable for wet accidents. Therefore no regularity is identifiable. This randomness is further underlined when the geographical positions of these intervals in the network are examined more closely. The identified intervals are located variously at curves, on straight sections, on stretches of open freeway and in tunnels. Neither do they coincide with those intervals, which have other pavement surface problems involving characteristics such as longitudinal or transverse evenness or damages of the surface. In this connection it is important to remember that the condition of Switzerland's national freeway is generally good to very good with regard to pavement characteristics.

2.1.3 Results freeways

This for the first time and in such a large scale carried out study of the influence of pavement skid resistance on accident occurrence, in particular when the pavement is wet, covers the whole Swiss national freeway networks. The fundamental conclusion of the study is that no quantifiable correlation could be found. The analysis of the database shows however that single remarkable areas can be located where skid resistance could play a determining role.

2.2 Main roads

2.2.1 bases

Skid resistance

By main roads the pavement skid resistance, the intervals were aquired in the accident database of the canton Zurich, were measured with the SRM (Stuttgarter Reibungsmesser) of the ETH Zurich in 2002. The interval length amounted to 100 m and the measuring speed was 40 km/h. Altogether 55 intervals were measured. The measured data were aggregated to average values for intervals of 100 m. These intervals formed the basis for the comparison of skid resistance with accident occurrence.

Accident

The accident database of the canton Zurich from November 1997 until October 2002 served as basis. All intervals on main roads without the city of Zurich and without Winterthur were considered. The database contains the number of accidents, the number of wet accidents, the number of sliding accidents and the number of wet sliding accidents per 100 m intervals. In this database all intervals with above average amount of accidents (more than 2 accidents in 5 Years) and above average amount wet accidents as well as an above average number of sliding accidents were segregated. 55 intervals corresponded to these criteria.

Assignment of skid resistance and accident occurrence

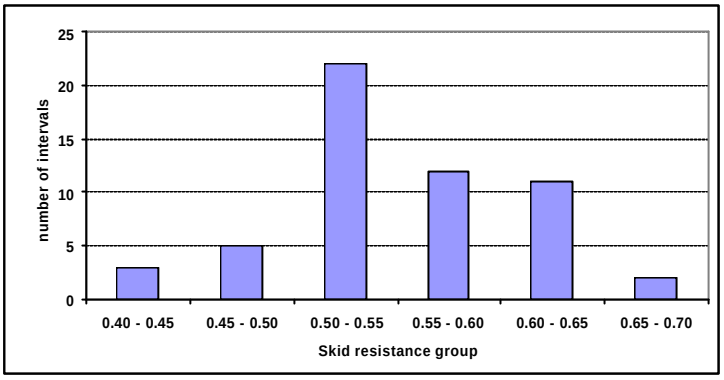
For the correlation between skid resistance and accident occurrence the appropriate skid resistance interval of 100 m was assigned to the accident interval of 100 m in each case.

2.2.2 Evaluation

Skid resistance

The opposite figure shows the distribution of skid resistance of these intervals. Only 6 intervals point a skid resistance value under the valid guide value of $\mu \leq 0.48$.

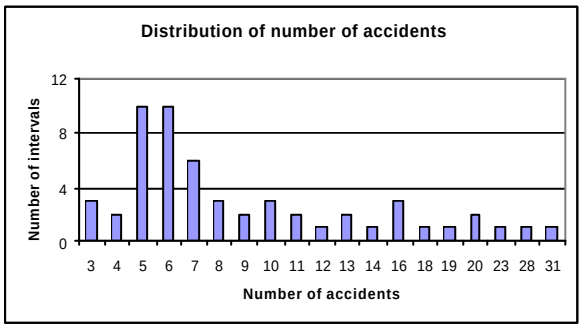
Figure 6: Distribution of skid resistance values

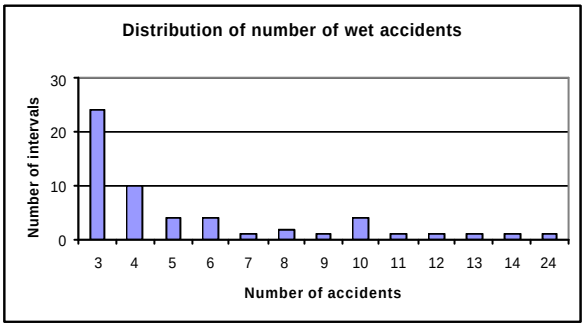


Accident

The following figure shows the distribution of number of accidents for all evaluated intervals.

Figure 7: Distribution of number of accidents and number of wet accidents

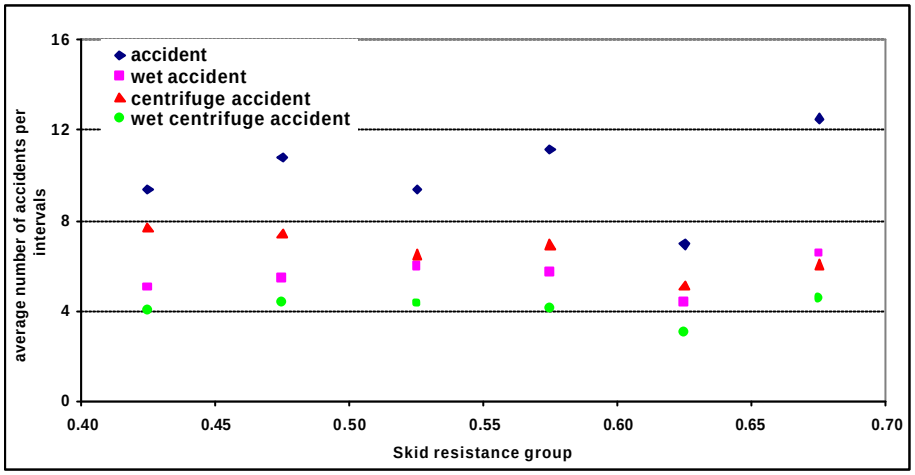




Correlation between skid resistance and number of accidents

To analyse any possible correlation between skid resistance and accident occurrence, skid resistance classes were formed again and average number of accidents, wet accidents, sliding and wet sliding accidents were determined.

Figure 8: Correlation between skid resistance and number of accidents



The figure shows that neither for all accidents nor for wet accidents, sliding and the wet sliding accidents an evidence correlation exists.

Influence of curvature

To judge the influence of the alignment, the intervals were grouped in three categories, on the one hand into the group with intervals with a weak to no curvature, and on the other hand into the group with intervals with a middle to a strong curvature. In addition, all intervals in junctions were separated in a special group. For these intervals different criteria for accidents (collision with other vehicles) are decisive. For these categories the middle skid resistance, the average number of accidents and wet accidents were evaluated. In addition the percentage of wet accidents as a part of all accidents was calculated.

The following table shows that with an almost constant average value of skid resistance in these three categories the average number of accidents rises from the weak to the strong curvature category and the average number of accidents in junctions is the largest. Regarding all accidents the percentage of wet accidents is almost constant by all three categories (about 58%).

Table 4: Influence of curvature

	weak curvature	middle/strong curvature	junctions
Average value of skid resistance	0.56	0.54	0.55
Number of intervals	22	20	13
Average number of accidents per interval	6.2	9.6	14.9
Average number of wet accidents per interval	3.6	5.8	8.3
Percentage wet accident [%]	58	60	56

2.2.3 Results main roads

Based on the pilot study provided by the ETH Zurich at 55 selected intervals in the canton Zurich a direct correlation between skid resistance and accident occurrence could not be determined. However for a given skid resistance, an increase in the number of accidents by more strongly curvatures could be observed. As the database is very small, for main roads further investigations are necessary.

3. References

[1] Bühlmann, F. Beurteilung der Griffigkeit auf Fahrbahnen, Institut für Strassen-, Eisenbahn- und Felsbau an der ETH Zürich, *Mitteilung Nr. 53*, Zürich, März 1983

[2] Mayer, G.; Van der Sluis, S.; Steinauer, B., Griffigkeit von Fahrbahnoberflächen, Forschung Strassenbau und Strassenverkehrstechnik, *Heft 841*, Bonn, 2002

[3] Wehner, B.; Schulze, K.-H.; Dames, J.; Langer, H., Untersuchung über die Verkehrssicherheit bei Nässe, Forschung Strassenbau und Strassenverkehrstechnik, *Heft 188*, Bonn 1975

[4] Rizenbergs, R.; Burcheit, J.C.; Warren, L.A., Relation of accidents and pavement friction on rural, two-lane-roads, *Transportation Research Report 296*, Washington D.C, 1977

[5] Kamplade, J., Schmitz, H. Erfassen und Bewerten der Fahrbahngriffigkeit mit dem Messverfahren SRM und SCRIM, Bundesanstalt für Strassenwesen, Bergisch Gladbach, Mai 1983

[6] Hirsche, E. – U.; Tenzinger, B., Untersuchung des ursächlichen zusammenhangs zwischen Unfallgeschehen und Griffigkeit, Forschung Strassenbau und Strassenverkehrstechnik, *Heft 587*, Bonn 1990

[7] Rogers, M.P.; Gargett, T., A skidding resistance standard for the national road network, *Highway an Transportation*, 38/1991

[8] DACH-Workshop 2001, München 25/26.06.01

[9] Lindenmann H.P., Schiffmann F., Weber T., Mäder J.J., Bär D., Fontana M., Zustandserfassung und –bewertung Nationalstrassen, Fahrbahnen (ZEB-NS), Schlussbericht, Bundesamt für Strassen ASTRA, Zürich 2003

[10] Lindenmann H.P., Seiler, L., Schiffmann, F., Shojaati, M., Besoin en adhérence, Teilbericht Griffigkeit und Unfallgeschehen, IVT-ETH Zürich, 2004 (in Vorbereitung)

[11] Strassenverkehrszählung auf den Nationalstrassen (1994-1998), ASTRA, Bern

[12] Verband Schweizerischer Strassenfachleute (VSS), SN 640 009, Lokalisierung und Rangierung von Unfallschwerpunkten, Zürich, 1999