ROAD SKID RESISTANCE INFLUENCE ON THE NUMBER OF CRASH ACCIDENTS

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SUMMARY

The international comparative measurements (using SCRIM, SKIDOMETER, GripTesters and Tatra Runway Tester (TRT)) were carried out in the Czech Republic in order to identify the correlations among these types of measurement devices and improve the Czech road surface skid resistance classification. The measured and classified skid resistance data of South Moravian road network and crash accidents were incorporated into the Pavement Management System RoSy®. It was found that on the road sections requiring the reduction of traffic speed or change of travel direction (cross sections, slopes and low radius of curves) the skid resistance was lower than on the adjacent sections. At the same time, an exponential increase of accidents depending on skid resistance occurred at these sections. The programme for decreasing the number of accidents on the main road network based on the identification and the improvement of skid resistance on dangerous road sections was proposed.

INTRODUCTION

The relative numbers of fatal road accidents in Central and East European countries of EU is several times higher then in the advanced EU countries. To address this problem a research project focusing on road skid resistance and its classification [1] has been launched in the Czech Republic.

The international comparative measurements focused on the comparison of results of Czech and other EU countries skid resistance measurements were carried out and the relations among the devices were found. The crash accidents and skid resistance levels were studied. Some of significant results dealing with preferred road maintenance and its cost-efficiency are presented.
SKID RESISTANCE CLASSIFICATION SYSTEM

The Czech skid resistance classification was developed on the basis of measurements in previous 35 years. At first the trailers with blocked wheel were used while at present the Tatra Runway Tester (TRT) [2] with optional wheel slippage is used. The skid resistance classification is presented in Table 1. The acceptable skid resistance value is used for planning the maintenance; in case of unacceptable level the maintenance should have to be carried out. The lowest level is supposed to be very dangerous for traffic safety.

To compare the classification system used in the EU states the comparative measurements have been prepared. The sections of pavements exhibiting different skid resistance were measured by SCRIM [3], SKIDDOMETER BV 11 [4], GripTesters [5, 6] and TRT at three speeds: 40, 60 and 80 km/h. The methodology and results of comparative measurements are described in the final report [1]. The correlations among mentioned devices were established. The skid resistance values in the Czech classification are included in Table 1.

The systematic SCRIM measurements for Road Databank carried out in the year 2004 signalized that 11.8 % of main road network length (Ist class road) exhibited an unacceptable and hazardous state. These results do not offer the base for regular planning of maintenance.

Table 1 – Czech skid resistance classification expressed as a friction coefficient at the speed 60 km per hour. The values given in the last 3 lines were determined on the base of results of comparative measurements [1]

<table>
<thead>
<tr>
<th>Friction Classification Measurement Device</th>
<th>1 Excellent</th>
<th>2 Good</th>
<th>3 Acceptable</th>
<th>4 Unacceptable</th>
<th>5 Hazardous</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRT (25 % of slid)</td>
<td>≥ 0,60</td>
<td>0,59 – 0,52</td>
<td>0,51 – 0,44</td>
<td>0,43 – 0,35</td>
<td>≤ 0,34</td>
</tr>
<tr>
<td>Skiddometer (16 % of slip)</td>
<td>≥ 0,76</td>
<td>0,75 – 0,67</td>
<td>0,66 – 0,58</td>
<td>0,57 – 0,47</td>
<td>≤ 0,46</td>
</tr>
<tr>
<td>SCRIM (lateral angle 20°)</td>
<td>≥ 0,69</td>
<td>0,68 – 0,59</td>
<td>0,58 – 0,50</td>
<td>0,49 – 0,39</td>
<td>≤ 0,38</td>
</tr>
<tr>
<td>GripTester 358 (15% of slip)</td>
<td>≥ 0,52</td>
<td>0,51 – 0,43</td>
<td>0,42 – 0,35</td>
<td>0,34 – 0,26</td>
<td>≤ 0,25</td>
</tr>
</tbody>
</table>

DETAILED SKID RESISTANCE MEASUREMENTS

In the frame of the project [1] TRT measurements of the whole road network of 2 South Moravian districts were carried out. The mean value of measured friction was calculated for each 20 m road subsection and the results were incorporated into road map.

It was found out that long time trafficked road sections requiring the reduction of vehicle speed or change of the travel direction is required (e.g. on sections where the vehicles load the surface by the horizontal forces) the friction coefficient is lower than on adjacent sections. On these sections called “dangerous” (cross sections, railway and pedestrian crossings, slopes exceeding 8 % and radius of curves being less than 250 m) it is necessary to offer greater skid resistance to eliminate possible driver mistakes in evaluation of traffic, distances or conditions of road.

We tried to find the real influence of these findings on the absolute crash accident numbers.
POLICE CRASH ACCIDENTS DATABASE IMPLEMENTATION INTO PMS

All the accidents causing personal injuries or physical damages (the costs of which exceed 700 €) are registered in Police Traffic Department Database. All accident data were installed into the RoSy® PMS [7].

The first step to import data from Police database to PM system was to set-up an interface enabling conversion of road section localisation to node-link system. Then the accident data with all details were imported to the database of the system for subsequent analysis. Basic and analysed data were also processed by RoSy® MAP module to generate geographical layers for presentation of accident local distribution, cumulated accidents in the „black-spots“ as well as pavement condition represented by skid resistance in relation with accidents location in ArcGIS application.

It has to be mentioned that localization of some accidents is not exact, but nowadays the accident localization starts to be based on the usage of GPS. An example of implementation of classified friction and crash accidents are presented in Figure 1.

![Figure 1 - An example of evaluation of friction and accidents in Road network map](image)

EVALUATION OF CRASH ACCIDENTS AND SKID RESISTANCE

All the accidents occurred on the roads of 2 districts were adjoined to the skid resistance range of classification. The results of that evaluation are presented in Table 2.

The total number of accidents on the main road (I\textsuperscript{st} class) network was 800 in the years 2003 and 2004. In total 24 % of accidents were localized on 6 % of the road length exhibiting unacceptable and dangerous skid resistance. Graphical evaluations of accidents per road kilometre in dependence on skid resistance classification are presented in Figure 2. The number of accidents on main road network according to skid resistance classification is growing exponentially. The annual average daily traffic intensity (all vehicles per 24 h) in the year 2000 traffic count varied from 4 000 to 13 500.

Compared with the I\textsuperscript{st} class road the number of accidents on II\textsuperscript{nd} class road does not depend on skid resistance classification to such an extent. Only 13 % of crash accidents happened on 8 % of road length. These roads exhibit worse geometrical characteristics; they are narrower and exhibit more failures. The number of accidents is influenced by traffic intensity (3 200 to 14 500 vehicles per 24 h). If the daily traffic on the II\textsuperscript{nd} class roads is equal to the one on I\textsuperscript{st} class roads, the number of accidents is approximately 2 times higher.
In the year 2005 the evaluation of friction and accidents continued. In total 382 km of roads (from which 305.5 km presented two-line roads) were measured and included nearly the whole main South Moravian road network (6 districts were included, only Brno-town network was excluded). The annual average daily traffic intensity was in the range from 1 600 to 20 000, the weighed mean was 7 540. The skid resistance measurements covered the whole scale of different wearing courses. The results are presented in Table 2 and Figure 2b).

Table 2 – Evaluation of the road accidents in dependence on road skid resistance classification

<table>
<thead>
<tr>
<th>Skid resistance classification</th>
<th>I\textsuperscript{st} class roads (2003-4)</th>
<th>II\textsuperscript{nd} class roads (2003-4)</th>
<th>I\textsuperscript{st} class roads (2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>L</td>
<td>A/L</td>
</tr>
<tr>
<td>Excellent</td>
<td>67</td>
<td>39.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Good</td>
<td>211</td>
<td>56.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Acceptable</td>
<td>330</td>
<td>38.3</td>
<td>4.3</td>
</tr>
<tr>
<td>Unacceptable</td>
<td>150</td>
<td>7.6</td>
<td>9.9</td>
</tr>
<tr>
<td>Hazardous</td>
<td>42</td>
<td>1.3</td>
<td>16.2</td>
</tr>
<tr>
<td>Total</td>
<td>800</td>
<td>143.5</td>
<td>2.79</td>
</tr>
</tbody>
</table>

Abbreviation: A – number of accidents in specified years, L – road length, A/L – mean year accidents number per kilometre of road

Figure 2 – Dependence of mean year number of accidents per kilometre of road on skid resistance classification: a) on I\textsuperscript{st} and II\textsuperscript{nd} class roads in the years 2003 and 2004; b) on I\textsuperscript{st} class roads in the year 2005.

The enlargement of road network and exclusion of the dual carriageways from the evaluation change the results when compared with measurements evaluation performed in 2 districts in the years 2003 and 2004. Traffic intensity influences the dependence of accident number on skid resistance classification; the roads with the low traffic intensity usually exhibit the worst characteristics and relative number of accidents is high, though the absolute number of accidents on that roads is low. 27 % of all accidents happened on 15.3 % of 305.5 km of main roads that did not fulfil the demanded value of skid resistance. The percentage of unacceptable and hazardous sections was nearly the same (if the whole measured main road network was evaluated) as the one was found in measurement of 2 500 km of road lines for Road Databank in the year 2004.

Nevertheless, detailed analysis of the first 2 districts evaluation was carried out to determine comparative accident rates and cost of accidents.
CRASH AND COST ANALYSIS

23 sections from the 2 districts road network were chosen. The sections were situated in places where the traffic loads the pavement surface by horizontal forces: cross sections, curves with low radius and high longitudinal slopes. The section lengths varied from 70 m up to 1,5 km. Three sections were chosen on dual carriageway for comparison.

All accidents that happened on chosen sections were evaluated. All losses due to accidents were calculated and causalities were registered on the base of the Police database.

Regarding the causes of accidents given in police reports it has been found that more than 50 % of accidents could have been supposed as the skid resistance can influence them (inadequate distance between cars, lower driver concentration, accidents on cross sections, vehicle speed not adapted to the condition of the road surface, etc.).

It was supposed that the antiskid road maintenance would decrease accident numbers on the section by 25 %. The benefits of the maintenance can include savings of social losses due to personal injuries and death and material losses; all these losses can be expressed in monetary units per year for the maintenance lifetime (dependent on traffic intensity).

The benefit/cost rates (B/C) were calculated for each section and following were found:
- Really dangerous places (cross sections, small diameter curves especially in greater slopes) with short distances of section (from 70 m to 200 m) with unacceptable and dangerous friction offer high B/C rates in range of 10 to 20; it means that if 1 monetary unit is invested to the maintenance 10 to 20 monetary units of social and material savings can be expected due to decrease in accidents.
- On long distance sections (300 m to 1 500 m) where several dangerous subsections are concentrated (several curves, different slopes), the mean section friction complies with an acceptable level, but some subsections with unacceptable or dangerous level of skid resistance have occurred and the B/C rates are from 2 to 10.
- On dual carriageways the B/C is lower than 0,5; on these roads the accidents do not depend on friction.

IDENTIFICATION AND MAINTENANCE PROGRAMME
OF ROAD ACCIDENT SECTIONS

Programme of identification of accident sections can be started by:
- Conversion of the Police Road Accidents Database into the Road PMS Database,
- Identification of the accidents sections (information about the worst sections can be advised by the Police Traffic Department directly),

Or
- Finding of all potential accident sections of used roads that require the reduction of traffic speed or the changing of direction (cross sections, railway and pedestrian crossings, slopes exceeding 8 % and radius of curves smaller than 250 m).

In both cases the selected sections need the consequent steps that will lead to analyses of the crash accident causalities and design of the improvements of sections:
- Measuring of skid resistance, unevenness (IRI), cross slopes and rutting.
- In simple cases only pavement diagnostics and design of maintenance can be performed.
- In case when more complex solution is required the analysis of the police reports dealing with accidents on the chosen section (diagram of vehicle movements, geometry of vehicles, accident causalities, etc.) is necessary.
- Evaluation of accident sections from the point of view of other factors influencing the crash accidents (drivers orientation in section, visibility of other traffic, radii of all edges or curbs, line widening, traffic sign visibility, etc.).
- Design of all possible changes that can improve the traffic safety.
- Realization of design and consequent evaluation of accident changes.

CONCLUSION

The conclusion is that the Czech skid resistance classification system is well calibrated and can capture the relevant differences in skid resistance. This classification, in combination with several other easily observable characteristics (cross sections, railway and pedestrian crossings, slopes exceeding 8% and radius of curves being less than 250 m), allows us to identify dangerous road sections that are prone to high levels of crash accidents. The corollary is that in dangerous sections the level of skid resistance should be increased in order to achieve the same level of safety as on the non-dangerous section.

This conclusion has clear policy implications. A programme for systematic identification of accident-prone sections and their preferred maintenance should be established. This would provide information necessary for much more focused and thus more efficient use of resources for road maintenance. Our research suggests that even under conservative assumptions 1 monetary unit spent on the improvements of skid resistance on relevant road sections can bring savings of up to 10 monetary units by preventing loss of lives, injuries and material losses due to accidents.

Currently, the Road Administration Authorities prefer a patchwork maintenance policy or, in more advanced cases, rely on PMS using cost benefit calculations for the road maintenance plan. The information about crash accidents and dangerous sections are not typically considered in these decision-making procedures. Our results suggest that more systematic research into the relationship between skid resistance and occurrence of crash accidents at certain road sections could form a basis for better maintenance policy that would not only be more cost-efficient, but could ultimately reduce the number of fatal accidents on the Czech roads.

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REFERENCES

1. Research project of the Ministry of Transport, No. 1F45B/064/120, Skid resistance of road surface characteristics according to European standard for traffic safety increase, 2003-7.
2. Tatra Runway Tester (TRT) – Skid Resistance Measurements, CZ.
3. SCRIM - Schniering Ingenieurgessellschaft mbH, D.
4. Skiddometer BV11 – Slovak Road Administration, SK.
5. GripTester 358 – CONSULTEST s.r.o., CZ.
6. GripTester 135 – Technical University of Vienna, A.