Calculation of an applicable friction coefficient for the reconstruction of traffic accidents with the aid of measured roughness on the spot and the GIDAS-database

Author: **Dipl.-Ing. Uli Uhlenhof**

Verkehrsunfallforschung an der TU Dresden GmbH
Zellescher Weg 24
01217 Dresden
Email: uhlenhof@vufo.de
Tel.: +49 (351) 43898931

The GIDAS-investigation team of Dresden (VUFO) has documented more than 11.500 accidents since 1999. The documentation of the accident includes beside vehicle-, injury- and environmental-data very detailed reconstruction data. Within this accident investigation the VUFO began to record the skid resistance of the accident site in 2009. The measurements are divided in macro- and microroughness (Sand depth method and Portable Skid Resistance Tester-SRT-by Munro-Stanley London©). Both methods are used to determine the skid resistance for more than 1000 passenger cars.
The aim of the present study is to find out a relationship between the measured skid resistance, the road conditions and the friction coefficient, which is used to calculate the maximum accelerations and decelerations during a reconstruction of an accident.
Basic approach to convert the SRT-value into the friction coefficient is the calculation of the theoretical absorbed energy of the spring rubber system of the swinging arm of lever. This absorbed energy is used to get the friction coefficient by using the equations for the work of friction.
To consider the road-behavior, in correlation to the friction coefficient, the results will be merged with existing literature.
Last step for this study will be a comparison between actual used friction coefficients all over the GIDAS-database and the theoretical results.
The study shows, if it is possible to use the SRT-Measurement for the estimation of a friction coefficient for the reconstruction of a traffic accident. As expected, the GIDAS-Database and the additional measurement of the roughness of the road directly on the spot are an enormous useful dataset.

MOTIVATION

The documentation of an accident in the German - In - Deph - Accident Study (GIDAS) includes the reconstruction of the accident as it really occurred. One of the most important challenges within the reconstruction process is the estimation of the friction coefficient. At the moment a reconstructor valuates this coefficient by the help of existing literature and the behavior of the road surface. For that reason the variation for the applied friction coefficient in a reconstruction is very high.

Since 2009 the GIDAS investigation team measures directly at the accident site the skid - resistance. The measurements consist out of two parts: the micro- and the macroroughness (Sand depth method and Portable Skid Resistance Tester (SRT) by Munro-Stanley London©).

Picture 1: measurement of the micro- and macroroughness at the accident site

The motivation of the study was, to use the measured SRT - dataset for a more exact estimation of the friction coefficient. The aim of study is to find out a relationship between the measured skid resistance, the road conditions and the friction coefficient, which is used to calculate the maximum accelerations and decelerations during a reconstruction of an accident.

Dataset

There are more than 11.500 real accidents since 1999 within the GIDAS-database. For 1588 vehicles a roughness measurement dataset of the street exits. The reconstruction is completed for 988 vehicles until now. The measurement is proceed in all cases of motorized vehicles, including passenger cars, trucks, busses and motorized two wheelers. This study applies only the dataset of the passenger cars. 684 passenger cars remained in the dataset.
The road surface is divided in asphalt, concrete and other road surfaces. Only the road surfaces of asphalt and concrete is defined. In that way the study excludes the datasets of other road surfaces. The calculation uses 674 datasets.
The time of the investigation is directly after the accident occurred, normally within a 1 ½ hour time gap.
At least the conditions at the accident sites were registered. The road surface could be wet or dry. A total of 241 datasets could be identified under wet conditions, 433 on dry roads (Table 1).

Table 1: conditions and road surface

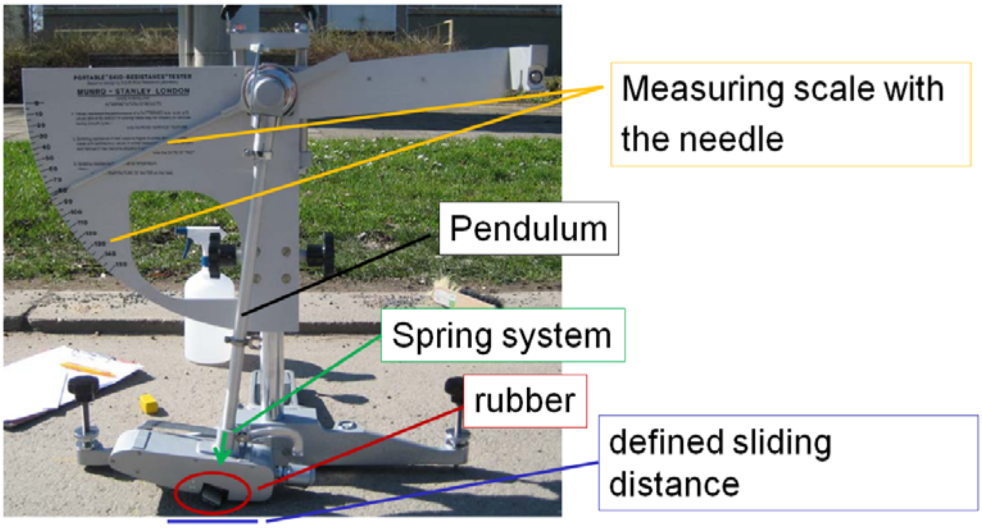
condition/ road surface	wet	dry
asphalt	241	420
concrete	0	13

The dataset is complemented by the measured temperature at the accident site.

Measuring method

1. Microroughness

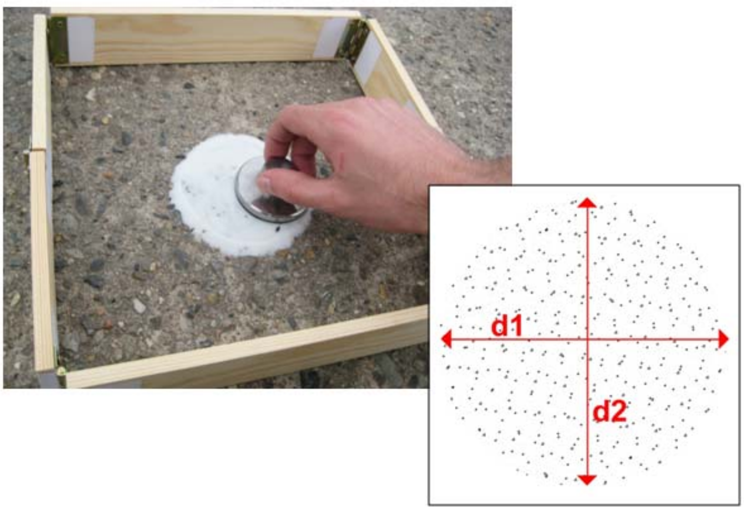
The GIDAS Team applies for the measurement of the micro-roughness the portable Skid - Resistance Tester by Munro - Stanley, London©. This instrument is also known under the label British Pendulum Tester. The portable Skid - Resistance Tester is based on the Izod principle. In operation, a pendulum of a known mass rotates about a vertical spindle. The head of the pendulum is fitted with a rubber slider. This slider is forced by a spring system. In that way the rubber touches a defined sliding distance of the surface by releasing the pendulum out of the horizontal position. After the pendulum process the skid - resistance - values are read directly from the measuring scale [4].



Picture 2: construction of the SRT - pendulum

2. <u>Macroroughness</u>

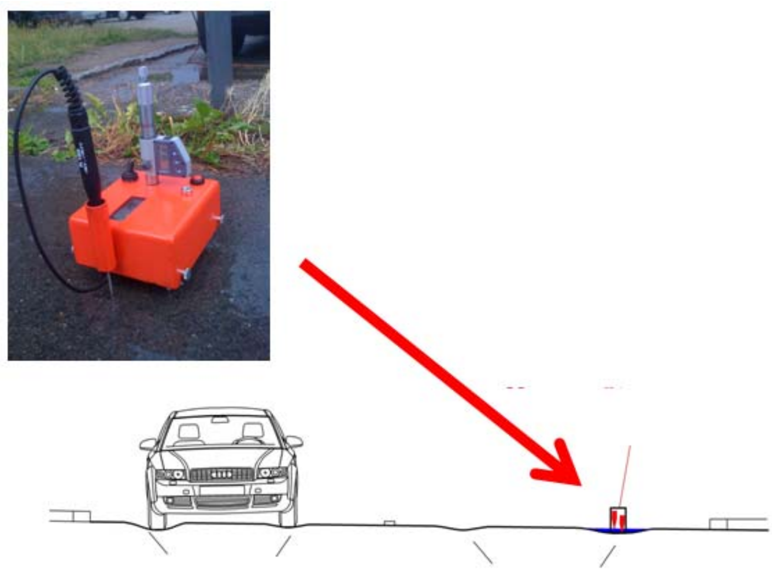
For all the datasets the macroroughness was measured at the accident site. The Dresden - GIDAS Team applies the sand depth method for this additional metering. The standard test method is to pour 50ml sand (-300 + 150 micron) on the surface and spread the sand over the surface. After that you have to work with a flat wooden disc with hard rubber disc in a circular motion so, that the sand is spread into a circular patch with the surface depressions filled with sand to the level of the peaks. The procedure is complete when no further distribution of sand outwards is achieved. Then there is to measure the diameter of the sand extension in two dimensions. A calculation of the texture depth follows [5]. In this study the dataset of the texture depth or macroroughness is not used.



Picture 3: sand depth method

3. Water depth

In case of wet accidents the Dresden - GIDAS accident investigation team measures directly after arriving at the accident scene the water depth on the street. We constructed a measuring instrument, which is able to meter the height of the water film on the surface of the road. In case of ruts exists a special measuring schema. . In this study the dataset of the texture depth or macroroughness is not used.



Picture 4: Measuring of the water depth

4. Measuring point

The location of the measuring point depends on the existence of marks. If there are marks of skidding or breaking the measuring has to be taken at the beginning of the mark (but not on the mark - falsification of the result through rubber on the surface).

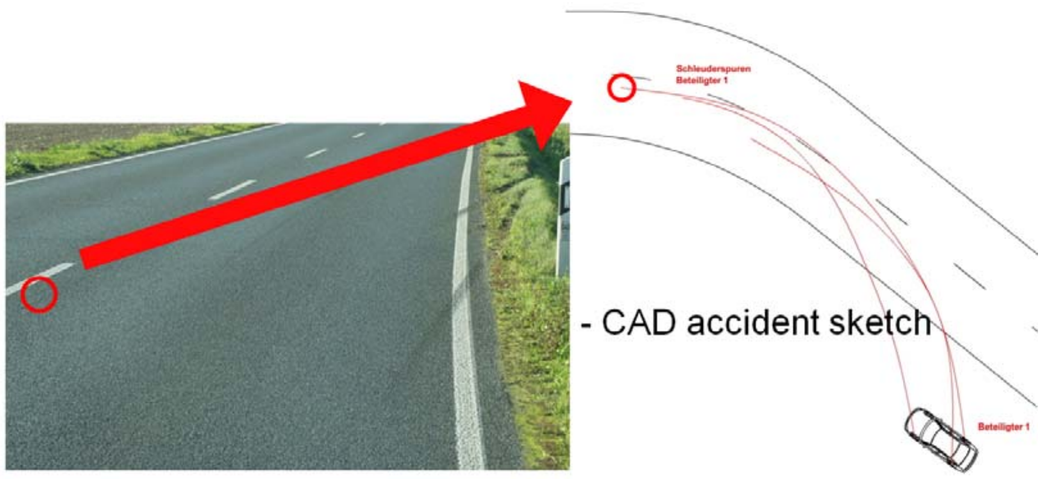


Figure 5: Measuring point in case of existing marks

If there are no marks on the street the measuring point will be estimated nearby the beginning of the incoming way of the involved vehicles.

Calculation of the friction coefficient - theoretical model

The basic idea for the calculation of a theoretical friction coefficient is, that the pendulum has less potential work at the end of the pendulum process than at the beginning. This difference is caused by the friction work between the rubber and the surface of the street. The difference between the starting height h_0 and the ending height h_n is important for the further calculation.

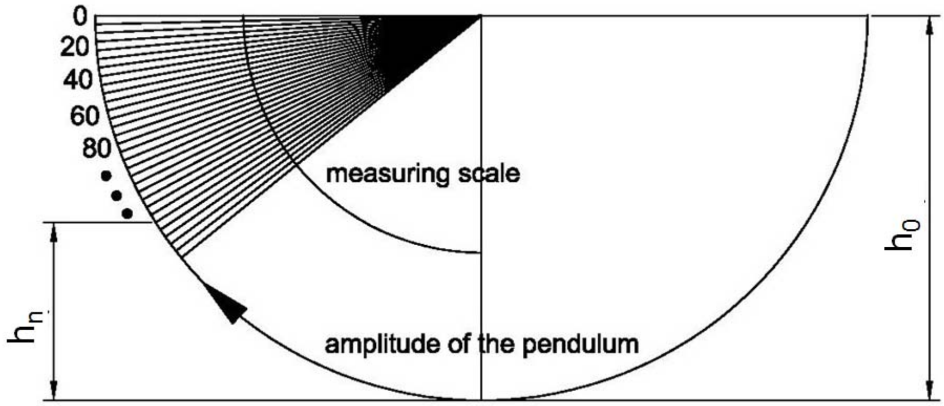


Figure 6: principle of the pendulum process

The detailed calculation of a theoretical friction coefficient for every value of the SRT - measuring could be taken with:

$$W_f = \Delta E_{pot} = E_{pot0} - E_{potn} \quad (6.1)$$

$$W_f = F_f \times s \quad (6.2.)$$

$$E_{pot} = m \times g \times h \quad (6.3.)$$

$$F_f = \mu_{theo} \times F_N \quad (6.4.)$$

with:

- W_f … friction work
- E_{pot} … potential energy
- F_f … friction force
- s … sliding distance
- m … mass of the pendulum
- g … constant of gravitation
- h … height of the pendulum
- μ_{theo} … theoretical friction coefficient
- F_N …normal force

$$\mu_{theo} = \frac{(m \times g) \times (h_0 - h_n)}{(F_N \times s)} \tag{6.5.}$$

With the aid of formula (6.5) a calculation of the theoretical friction coefficient dependent on the measured SRT - scale value is possible. Figure 1 shows the calculated theoretical friction coefficient:

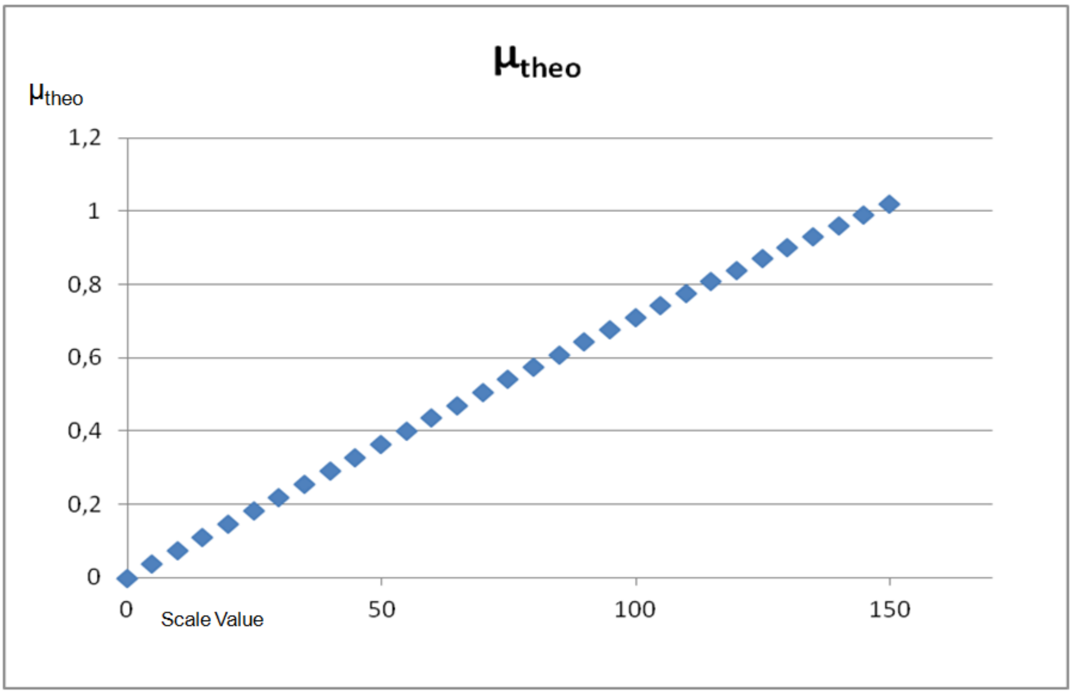


Figure 1: theoretical friction coefficient in dependence of the SRT - scale value

Validation

In a next step the theoretical friction coefficient for every measured value in the GIDAS - database out of the used dataset was calculated.

The effect of on rubber resilience exerts a perceptible influence in all skidding measurements. This influence is mentioned by a corrective factor for the SRT - value, shown in table 2. The temperature which is used is that one on the surface of the street [4].

Table 2: corrective factor for the influence of temperature

Temp (°C)	corrective factor
0	-7
5	-5
10	-3
15	-2
20	0
25	1
30	2
35	2,5
40	3

Following figure 2 shows the distribution of the calculated and corrected theoretical friction coefficient out of the used dataset, times 10. The minimum is at 0,35, the maximum at 0,8 and the average at 0,5.

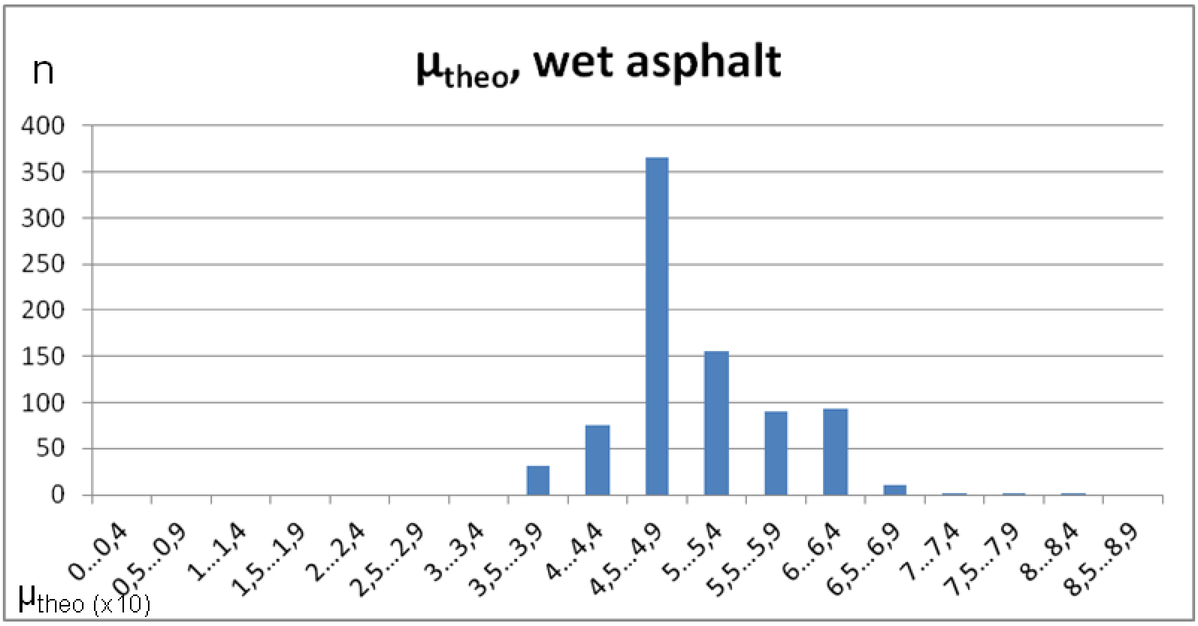


Figure 2: Theoretical friction coefficient calculated out of the measured SRT-values at the accident site

To compare the calculated values with common friction coefficients in the reconstruction a study of existing sources was realized. As a result there were found applied decelarations for asphalt in a range from $4m/s^2$ to $7{,}5m/\ s^2$ [1] and from $4m/\ s^2$ to $8{,}5m/\ s^2$.

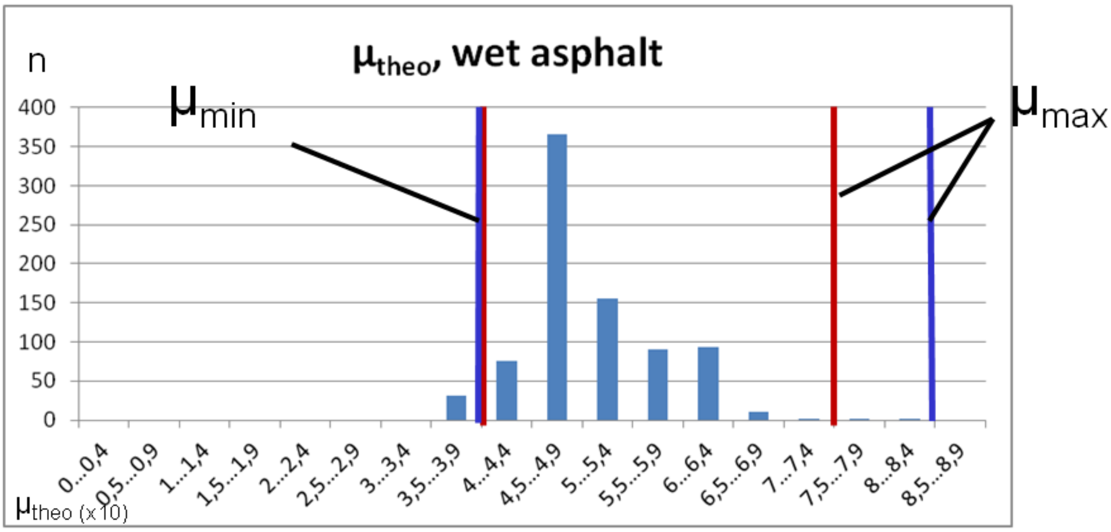


Figure 3: Theoretical friction coefficient calculated out of the measured SRT-values in comparison to applied decelerations

It is to be seen, that the distribution is to left sited, but in principle within the recommended range. The conclusion is, that if a lower measured and calculated friction coefficient exits, a higher deceleration could estimated, by a higher one a higher value could be applied.

But in fact it could only be rated as an advice for the reconstructor. In consideration of the existing situation without any information about the condition of the surface of the street at the accident site, it is an improvement for the reconstruction. At least he results of a reconstruction are getting similar to the real accident that happened due these additionally information.

SUMMARY AND CONCLUSION

As the results have shown, some further steps in analyzing the theoretical calculation of a friction coefficient have to be done.

- Extension of the study by the inclusion of the values of the sand depth method and the water depth measurement.
- Development of a calculation model for the dependence of the SRT - value and the applicable friction coefficient.
- To implement the influencing parts of speed and weight of the car, it is recommended to evaluate real friction coefficients by experimental tests on special defined roads with known cars.

The conclusion of the study is that it is possible to use the investigated dataset for a calculation of a theoretical friction coefficient. We think that the information of the SRT measurement could be used as a valuable addition during a reconstruction, but it will not replace a tire model.

Due the calculation of a theoretical friction coefficient a reconstructor can estimate the maximum accelerations and decelerations much more similar to the real conditions for an accident and that`s why we use these findings in the GIDAS reconstruction.

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