

Measurements of the grip level and the water film depth for real accidents of the German In-Depth Accident Study (GIDAS).

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ABSTRACT

The grip between the road surface and vehicle tires is the physical basis for the moving of all vehicles in road traffic. In case of an accident the available grip level is one of the most relevant influence factors, influencing the causation and the procedure of the accident. However, the estimation of the grip level is not easy and therefore, is commonly not done on the accident scene. This is especially true for the measurement of the water depth. Until now, real accident databases provide no measurement data about the grip level and the water film depth and thus, the estimation of its influence is not possible yet.

From the tyre manufacturers point of view, it is important to know about the road conditions (namely grip level, macro-texture, water depth, temperature) at the accident scene, as well as the operating conditions of the vehicles (braking, loss of control, speed, etc). These data is necessary to define relevant tyre traction tests for the end-user and for regulations.

For this reason VUFO and Michelin developed a consistent method for the measurements of grip level and water depth for the accidents of the GIDAS database. The accident research team of Dresden, which documents about 1000 accidents with at least one injured person every year, is measuring the micro-roughness and the macro-roughness directly on the spot.

For the measurement of the micro-roughness a Skid Resistance Tester (British Pendulum) is used. The Mean Texture Depth (describing the macro-roughness) is measured by the Sand Depth Method.

Since June 2009, measurements for more than 700 accidents including 1200 participants have been carried out. In case of wet or damp road conditions during the accident, the water depth is measured additionally. Therefore VUFO and Michelin developed a special measurement device, which allows measurements with an accuracy of 1/10 millimetre. The measurement point at the accident

scene is clearly defined and thus, the results are comparable for all different accidents and participants.

The use of the GIDAS database and the accident sampling plan allows representative statements for the German accident scenario. With this data it is possible for the first time to have an accurate view of the road conditions at the accident scene. One possibility is a more detailed estimation of hydroplaning accidents using the actually measured water depths. The development of new testing methods and new tires can be based on the

real situation of the road infrastructure. Furthermore, the combination of the technical GIDAS data and the measured road surface properties can also be used for the estimation of effectiveness of several safety systems like the brake assist and/or emergency braking systems. The calculation of a reduced collision speed due to the use of a brake assist is only one example for the application of real measured grip level data.

INTRODUCTION

GIDAS is a joint project of the German Association for Research in Automobile Technology (FAT) and the Federal Highway Research Institute (BAST) of Germany. It started in 1999 with two research areas around Dresden and Hanover.



Figure 1. Research areas of Dresden and Hanover

The research area of Dresden covers about 3.000 km² with about 1 million people living there. The research area of Hanover comprises 2.289 km² and about 1.2 million inhabitants.

Facts about accident investigation

Each accident is encoded in the GIDAS database with about 3.000 variables. The database contains detailed information about:

- environment (meteorological influences, street conditions, traffic control),
- vehicles (deformations, technical characteristics, safety measures),
- persons (first aid measures, therapy, rehabilitation) and

- injuries (severity, description, causation).

About 100 photos are taken to document the accident scene, injuries, safety devices, traces and deformations of the vehicles. For each case the investigation team also draws a detailed sketch of the accident scene. This full-scale sketch shows the final positions of involved vehicles or persons and the positions of participants at the time of collision. Furthermore, view obstacles between the participants are measured and drawn into the sketch as well.

Reconstruction

On the basis of the full-scale sketch of the accident scenario and the vehicle deformations, every accident is reconstructed. The aim is to get information about the acceleration, deceleration, braking distance, collision speed, and initial speed for each participant and each single collision. To get this information for every involved vehicle it is necessary to reconstruct the pre-collision sequence, the impact and the post collision sequence for each participant. This can be achieved by using a reconstruction program called PC-Crash. After the reconstruction of the accident all information is coded into the GIDAS database as well.

Applications of GIDAS data

GIDAS offers important information regarding the optimization of vehicle safety for the automobile industry and their suppliers and is furthermore the basis for future ideas and concepts in research and development.

Using real accident data comparisons of the accident situation in reality and crash tests can be drawn and injury causing structures of vehicles can be identified very early. Analyses for legislators offer a close observation of the accident situation to discover negative developments immediately. The extensive documentation of the accident situation gives the possibility to work out legislative proposals and to analyse existing laws regarding their benefit for traffic safety.

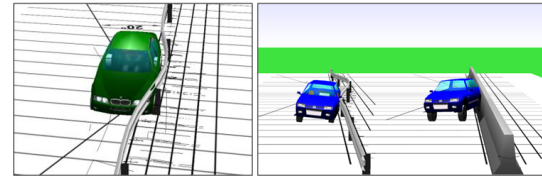


Figure 2. Simulation of steel- and concrete barriers

In the field of road traffic technology the GIDAS database allows the estimation of infrastructures and traffic control systems.



Figure 3. 3-D real accident simulation considering sensor-based safety system

The 3-dimensional simulation of the accident initiation phase is getting more and more important for the estimation of primary safety systems and thus, detailed information about the road surface is essential for precise results.

METHODOLOGY OF THE SKID RESISTANCE MEASUREMENTS

Aim of the cooperation between Michelin and VUFO was the development of a consistent method for the measurements of the grip level and the water depth directly on the accident scene. Therefore the definition of the measurement values, the measurement devices and the place of the measurement was necessary. The chronological implementation during the accident investigation and the education of the accident research team was one more important point in this process. For the measurements of the water depth it was additionally necessary to develop a new measurement device.

Measurement directly at the accident scene

The measurements of the grip level and the water depth are done directly at the accident

scene during the accident documentation of the research team and the police.



Figure 4. Measurements at the accident scene

The by the police blocked and secured accident scene allows secure and precise measurements of high frequently used roads, in urban as well as rural areas also. Normally the research team reaches the accident scene 20 minutes after the notification by the police. In case of rain, damp or wet road conditions the research team measures the water depth at first after arriving at the scene, so the variances can be reduced between the time of the measurement and time of the accident. By the reason that the measurement of the sand depth method is only possible on dry road surfaces, a re-work is necessary for wet and damp accident scenes. Furthermore a rework is needful in cases of high frequently used accident scenes where the closure is not possible by the VUFO. These accident scenes are measured another time, mostly by night. By the help of the previously marked measurement point, the re-work measurements are possible during low traffic times. Generally the measurements are done for each motorized vehicle that is involved in the accident. Measurements for bicycles, pedestrians, parking cars and trams are excluded.

Definition of the measurement points

To get comparable measurement values for all different kind of accidents a clear definition of the measurement points at the accident scene is absolutely essential. Therefore VUFO and Michelin define the following measurement points, which are explained by an example in the following figures.

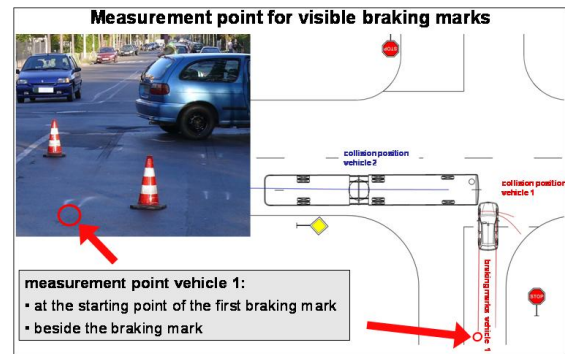


Figure 5. Measurement point for visible braking marks

In accidents where the braking mark of the participant is visible the micro- / macro-roughness and water depth are measured at the beginning of the first braking mark.

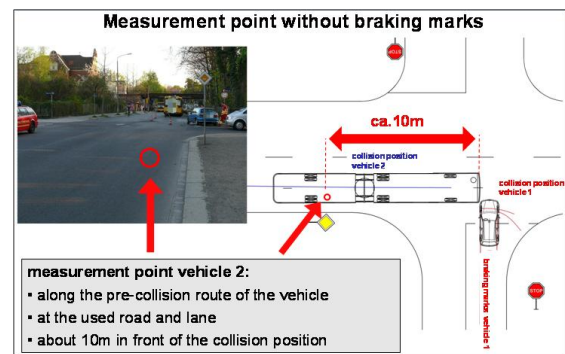


Figure 6. Measurement point without braking marks

If there are no braking marks at the accident scene, the measurements are done about 10 meters in front of the collision point in the right or left wheel track of the participant. The right or left wheel track means the track where normally the tires of the vehicles are rolling. For motorbikes the measurements takes place in the middle of the used lane.

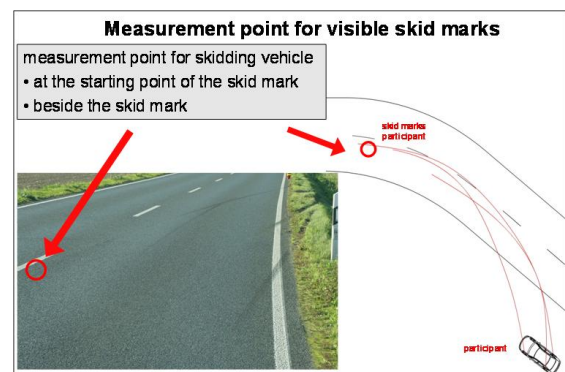


Figure 7. Measurement point for visible skid marks

In case of a skidding vehicle the measurements are done at the beginning of the first skid mark.

In general all the measurements are done on every kind of asphalt and concrete.

For roads with gobbles stones or a graveled surface the measurements are not possible with the used measurement devices. Apart from the measurement point the accident research team documents some more information at the accidents scene which is relevant for the analysis of the grip situation.

The most important information is the condition of the road surface. Here it is distinguished into dry, damp, wet, snow or icy condition. The distinction into damp or wet is done with the help of the water depth measurement device. If the device cannot measure a water depth value by the reason of too less water, the road surface condition is damp. Otherwise the condition is coded wet.

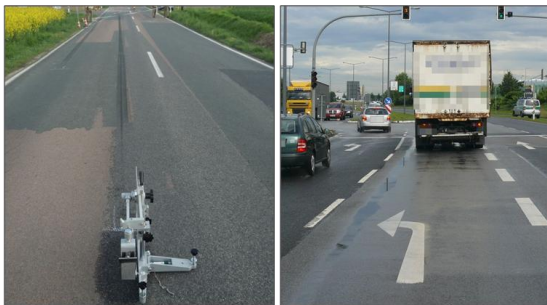


Figure 8. Changing material of road surface and influence of ruts

Furthermore changing materials of the road surface, the time of measurements, the influence of puddles or the influence of ruts at the accident scene are coded in the database. Here is also coded, if the measurement point is located in wheel track of the participant.

The Database includes the following information about the measurement point:

- position of measurement point
- condition of road surface
- time of the measurements
- changing material of road surface
- influence of puddles
- influence of ruts

Measurement values and measurement devices

For the definition of the useful measurement values it was important that the used devices are manageable by one person and the measurement time is less than maximum five minutes per participant. For this reason the following values were chosen.

Micro-roughness The micro-roughness is measured by the skid resistance tester (british pendulum).



Figure 9. Skid resistance tester

The functional principle of this device is quite simple, the pendulum is released from the horizontal position by a quick release button, it swings down with uniform force each time, and the rubber slider at the bottom of the pendulum contacts the road surface for a defined length. The degree to which the pendulum will rise up the calibration on the left-hand side of the image depends on the friction (resistance) of the rubber slider and the road surface. The more friction the less the pendulum will rise and the higher is the Skid Resistance Tester Value (SRT Value) of the road surface. For a better accuracy the measurements are done on wet road conditions only and dry road surfaces are watered.

At the accident scene five measurements are done for each participant and afterwards the mean value is calculated. The additional measuring of the road and the rubber temperature allows the correction of the temperature influence.

The Database includes the following measurement values for micro-roughness:

- five single SRT value
- mean SRT value
- rubber slider temperature
- road surface temperature
- temperature corrected mean SRT value

Macro-roughness For the measurement of the macro-roughness the sand depth method is used. The advantages of this method are the minor measurement time and the simple methodology.



Figure 10. Sand depth method

The necessary steps are: Spreading circularly a known volume of sand on dry road surface, measuring the area covered, subsequently calculation of the average depth between the bottom of the surface voids and the tops of surface aggregate particles. The result is the Mean Texture Depth which reflects the macro-roughness of the road surface.

The Database includes the following measurement values for macro-roughness:

- two diameters of sand covered area
- mean diameter of sand covered area
- calculated Mean Texture Depth (MTD)

Water depth For the measurements of the water depth a measurement device was developed which allows a measurement accuracy of one-tenth of millimetre.

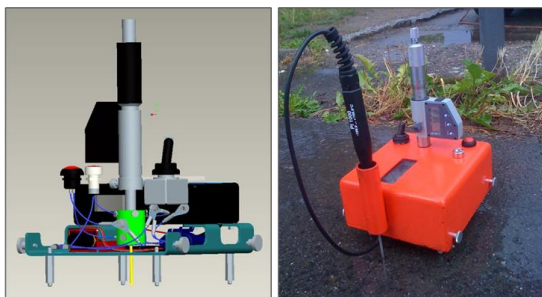


Figure 11. Water measurement device

The measurements are done at the same point where the micro- and macro- roughness is measured.

The principle of the measurement is very simple, easy to handle and very precise. The measurement prod of the device is coupled with the measurement screw. If the measurement prod has contact with the water film of the road an electric circuit is closed and an LED sign is shining. The digital display shows the measured water depth. The contact patch of the device is the zero level of the road surface and the measurement prod is calibrated of this surface level of the road. Depending of the volume of water positive and negative measurement values are possible. The following figure illustrates the correlation.

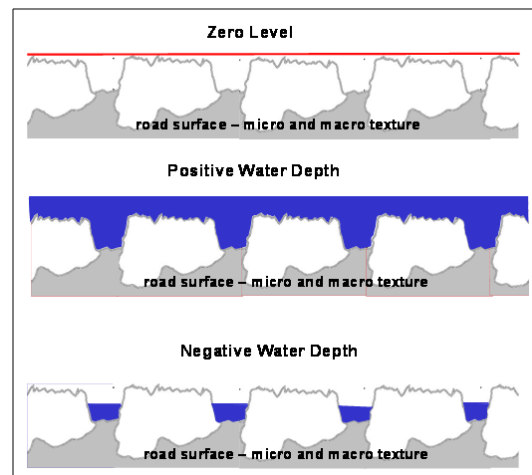


Figure 12. Explanation of positive and negative water depth

If the macro texture is completely covered with water, the water measurement device measures a positive water depth. In cases where the water only stands inside the macro texture the measurement value is negative.

At the accident scene the water depth is measured at the same point like the micro- and macro-roughness.



Figure 13. Water depth measurement at the accident scene

Therefore three separate measurements are done at this point and afterwards the mean water depth is calculated. Furthermore the temperature of the water on the road surface is measured and coded in the GIDAS database. In case of ruts at the accident scene the water measurement will be extended by the following method.

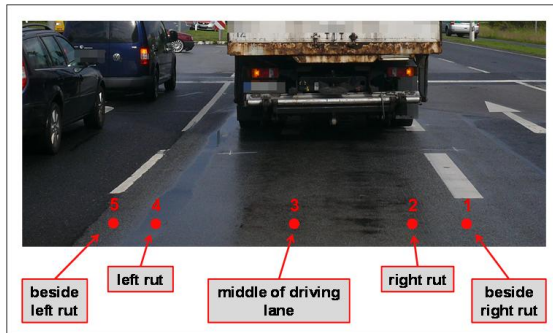


Figure 14. Additional measurements in case of ruts at the accident scene

For each of these five points one measurement value is measured and coded in the database. Therefore the analysis of the different water depths across the lane is possible and the influence of water filled ruts can be assessed.

The Database includes the following measurement values for water depth:

- three values for regular measurement point
- mean value for regular measurement point
- water temperature
- five measurement points for ruts across the lane

RESULTS

Since April 2009 the measurement team of the accident research unit in Dresden was at the scene of 639 accidents. In all 1002 participants (motorized vehicles) were involved in these accidents. Motorized participants means passenger cars, trucks, busses and motorbikes.

Analysis of representativity

The following diagrams show the comparison of accidents with measurement team and all accidents of the GIDAS database. At first the accident location is compared.

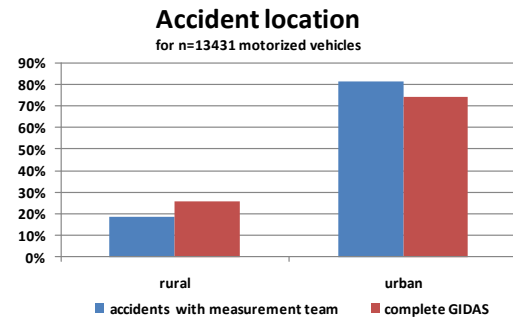


Figure 15. Distribution of accident location.

There are only small differences in the distribution of the accident location between the accidents with a measurement team and the whole GIDAS data-base of Dresden. The portion of accidents in rural areas amounts for the accident with a measurement team 19% and for the complete GIDAS database about 25%.

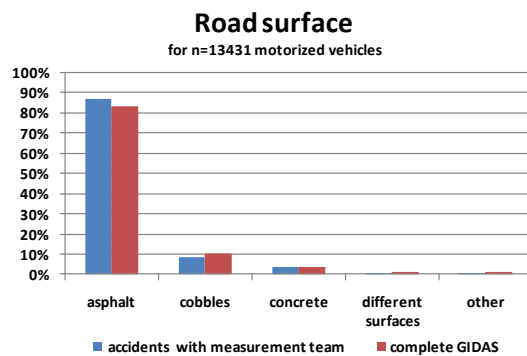


Figure 16. Distribution of road surface

The diagram of the road surfaces shows a similar distribution for both accident groups. Asphalt is the major road surface with a portion of approximately 85% in both groups. The portion of concrete surfaces is only 4% and is typical by used on highways. The coding different surfaces includes all accidents where the surface changes between the measurement point and the collision point.

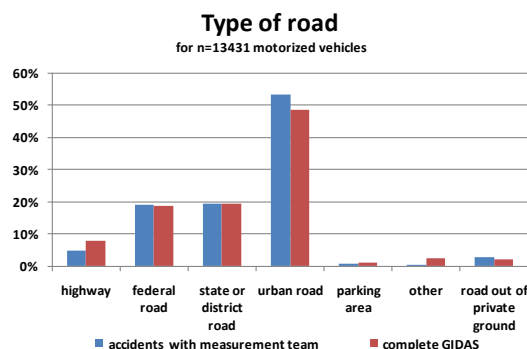


Figure 17. Distribution of type of road

The distribution of the road type shows a very good compliance between of the accidents with a measurement team and all motorized vehicles in GIDAS.

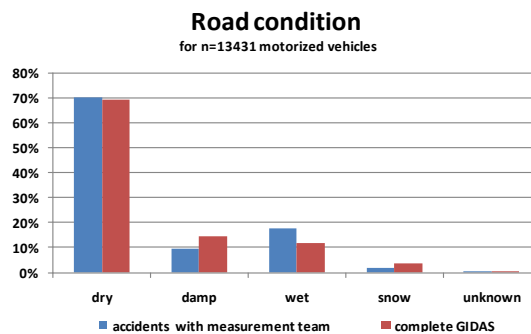


Figure 18. Distribution of condition of road surface

There are only small differences for damp and wet road conditions. The reason is the difficult distinction between wet and damp condition. The distinction criterion for the accidents with a measurement team is the functionality of the water depth measurement device. If the device is not able to detect a value by the reason of less water, the road surface is coded as damp. This possibility of distinction did not exist for the accidents before this measurement project. In sum the previous comparisons show that the accidents with a measurement team are a comparable and representative selection of the GIDAS database. Therefore the results of the skid resistance measurement are representative for the German accident scenario.

Results of Micro-roughness measurements

The measurement of the micro-roughness for 864 motorized vehicles by using a Skid Resistance Tester shows the following results.

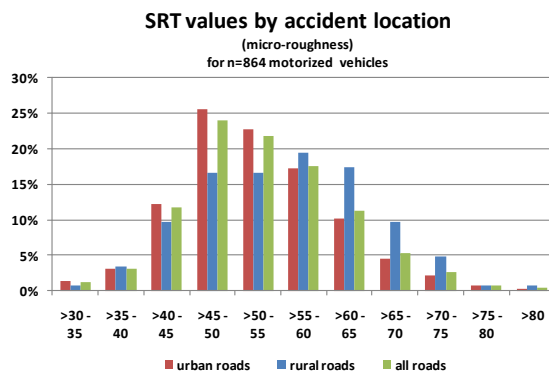


Figure 19. Distribution of SRT values

The distribution of the measured SRT values in wet conditions shows clear differences between the accident locations. In accidents in rural areas the measured SRT values (micro-roughness) are clearly higher than on urban roads.

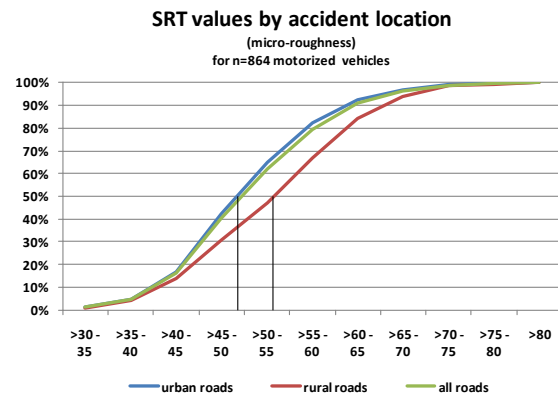


Figure 20. Cumulative distribution of SRT values

In about 50% of all accidents in urban areas the SRT values are less than 50 points. Compared to that, the SRT values of the half of all rural accidents is about 5 points higher on average. Only for 10% of all accidents (urban and rural) the SRT values are less than 40 points in wet conditions. It is assumed that the lower SRT value on the urban area can be explained by the impact of the higher traffic on the road wear which leads to lower micro-texture and therefore lower SRT values. In contrast, the evolution of the macro-texture due to the traffic is very small. This is consistent with the results shown on figure 21 and figure 22.

Results of Macro-roughness measurements

The macro-roughness of the road is important for the removal of the water for higher driving speeds. A high macro-roughness of the road surface allows a better displacement of the water by the tire.

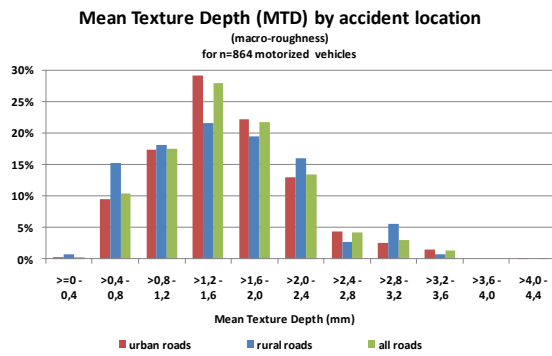


Figure 21. Distribution of Mean Texture Depth

In contrast to the SRT values, no clear differences between urban and rural accident locations can be noticed for the macro-roughness.

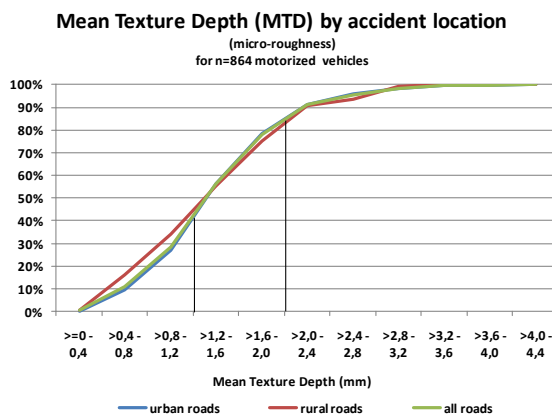


Figure 22. Cumulative distribution of Mean Texture Depth

For about 40% of all measured roads the Mean Texture Depth is lower or equal than 1,2mm and only in 25% the value is higher than 2,0mm. As mentioned the cumulative chart shows also the more consistent distribution of the rural accidents.

Result of water depth measurements

The water depth measurements take place directly after the arrival of the research team at the accident scene. Therefore minor changes of the water depth are possible from the time of accident to the time of measurement. The road of 67 motorized vehicles was only damp and thus a water depth measurement was not possible because of too less water. Altogether for 83 motorized vehicles a measurement of the water depth was possible. For seven (about 8%) of these vehicles the road surfaces were covered with ruts.

In 76 accidents the road was without ruts. The following figure shows the distribution of the water measurements at the regular measurement point.

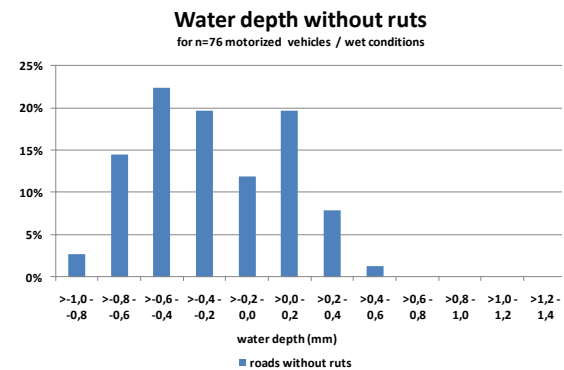


Figure 23. Distribution of water depth without ruts

The distribution of the water depth shows that for about 70% of all measured roads without ruts the water stands below the surface in the macro-texture. The water depth is never higher than 0,6mm.

The following figure shows the mean and maximum water depth for roads with ruts.

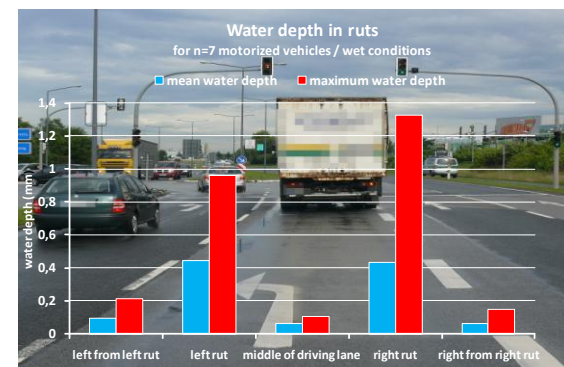


Figure 24. Distribution of water depth in ruts

The maximum water depth was measured with about 1,3mm, inside the right rut. In average the water depth is lower than 0,5mm for all measured accidents with ruts.

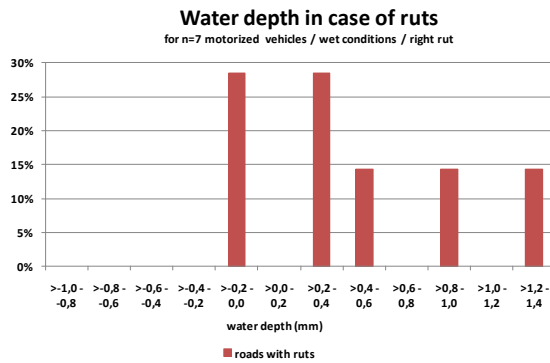


Figure 25. Distribution of water depth in ruts

The distribution shows the measurement values of the right rut. The diagram shows that for about 30% of all measured roads with ruts the water depth is higher than 0,50mm. It is important to remember that the existence of water filled ruts is very seldom in the accident scenario. Only in about 0,8% of all measured roads water filled ruts could be found and only in a thousandth of all roads the water depth inside the ruts is higher than 1,00mm.

The following figure shows the comparison of the water depth between roads with and without ruts.

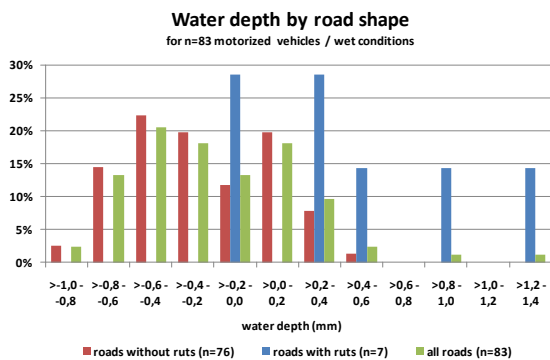


Figure 26. Distribution of water depth by road shape

The figure shows clear differences between roads with and without ruts. In general the water depth is clearly higher for roads with ruts compared to roads without ruts. For roads without ruts the maximum water depth was 0,60mm.

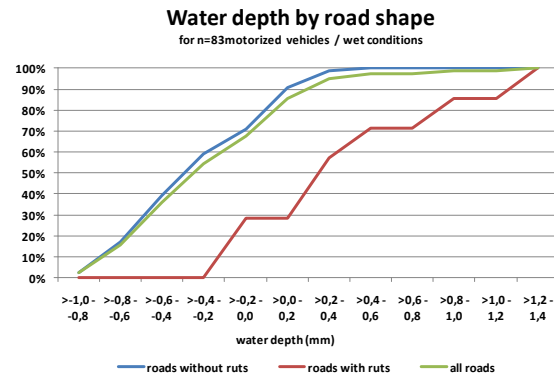


Figure 27. Cumulative distribution of water depth by road shape

For 80% of the roads without ruts the water stands below the surface inside the macro-texture. (resulting in a negative water depth) In case of ruts for 30% of the roads the water height is also below the road surface. On roads without ruts the water depth is never higher than 0,60mm.

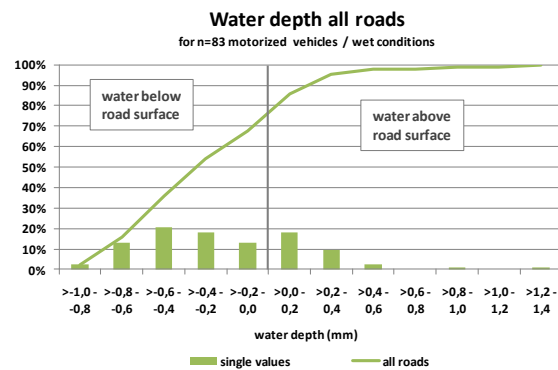


Figure 28. Distribution water depth of all roads

The water depth is lower than 0,00mm for about 80% of all motorized vehicles. In 80% of all measured accidents with wet conditions the water stands below the road surface only in the macro-texture. The following diagram is the result of the comparison of the water depth distinguished by the accident location for all roads (with and without ruts).

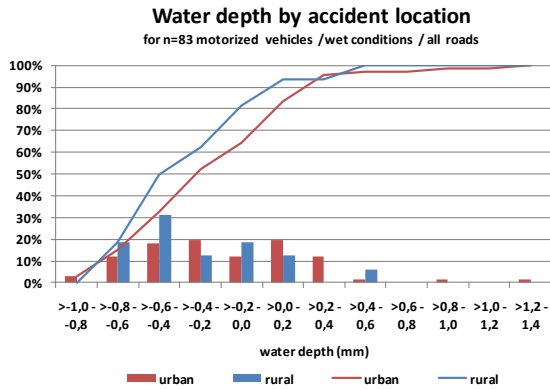


Figure 29. Distribution of water depth by accident location

In general the water depth in urban accident areas is slightly higher than in rural areas. In 50% of all measured roads in rural areas the water depth is lower than $-0,50\text{mm}$, contrary to the water depth in urban areas, where the 50% border amounts about $-0,30\text{mm}$. The reason for this difference is the distribution of ruts. However, the driven speed in urban areas (speed limit 50km/h) is clearly lower than in rural areas. The influence of the water depth on the tire road grip is not significant at a speed below 50km/h . Therefore the higher water depth in urban areas is noncritical for the tire road friction.

distribution of ruts by accident location
for n=13 motorized vehicles / wet conditions

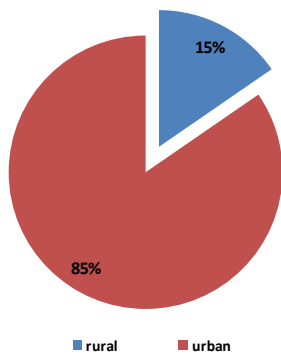


Figure 30. Distribution of ruts by accident location

Furthermore 11 of the 13 cases with ruts on the roads could be found in urban areas. Due to lower driving speeds of the vehicles in urban areas the influence of the higher water depth is also uncritical. In rural accidents where the driving speed is clearly higher the water depth is in 90% of all participants negative and thereby the water stands below the road surface inside the macro-texture.

SUMMARY AND CONCLUSION

The implementation of the consistent methodology for the measurement of the grip level and the water depth in real accidents scenarios is possible. The measurement of 639 accidents including 1002 motorized vehicles supplies revealing results.

The micro-roughness amounts more than 50 SRT points for 50% of all roads (urban and rural). Roads in rural areas have slightly higher SRT values than urban roads. In average the SRT value is three points higher for rural roads than for urban roads. Contrary to this there are no differences between rural and urban roads for the macro-roughness. Only for 30% of roads the Mean Texture Depth (macro-texture) is less than one millimetre.

The analysis of the water depth measurements shows clear differences between roads with and without ruts. For every road without ruts the water depth is lower than $0,5\text{mm}$ but for 30% of the roads with ruts the water depth amounts more than $0,5\text{mm}$. Nevertheless the relevance of water filled ruts is very low in the real accident scenario, only 0,7% of all measured participants had to deal with water filled ruts. In general the most frequent water depths in real accidents in wet and damp conditions are lower than 0mm . The following table shows a summary of water depth in different situations.

Table 1.
Summary of water depth measurements

condition of road surface	dry	damp	wet	snowy	icy
% of all roads	69,8%	14,7%	12,0%	1,9%	1,7%

water depth	< 0,0mm	0,0 - 0,5mm	>0,5 - 1,0mm	> 1,0mm
% of roads in wet and damp conditions	82,00%	16,70%	0,65%	0,65%

In wet and damp conditions the water depth is lower than $0,0\text{mm}$ for 82% of all participants. Only in 1,2% the water depth is higher than $0,5\text{mm}$. The consideration of the whole accident scenario (dry, damp, wet) shows only for 0,15% of the participants a water depth of more than $0,5\text{mm}$. For 96,8% of all participants the road was dry or the water stands below the road surface in the macro-texture.

PERSPECTIVES

The measurements of the grip level and the water depth are still going on and so the number of measured accidents and participants increases every day. At the same time the already existing accidents will be completely coded and reconstructed by the accident research unit of Dresden. After finishing this process it is possible to analyse the influence of the vehicle speed, the vehicle tire and the road curvature. Especially the analysis of the influence of the tire parameters like the tire width and the tread depth in wet accidents will be very helpful to detect critical situations on wet road surfaces. Furthermore, in combination with the driving speed the identification of hydroplaning accidents will be possible. In addition, it is planned to develop a methodology for the correction of water depth measurements based on the rainfall intensity and elapsed time between accident and water measurement.