Skid resistance measurements and motorcycles

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Summary

Loss of friction due to road slipperiness is an important factor in many road accidents. Nevertheless, little attention is paid to the skid resistance of road surfaces regarding motorcycling. The present ways of friction measurement are based on the use of two-track vehicles and pay no respect to one-track vehicles like motorcycles. Motorcycles have only one track, are balancing vehicles, ride on a different part of the lane, have different vehicle dynamics than cars and therefore motorcyclists have different needs for road friction than car drivers.

Also, because of the fact that motorcycles usually have only two wheels and are balancing vehicles, insufficient skid resistance forms a greater risk for motorcycles, even if this concerns only a small (tiny stretch) part of the road. There is no demand for different skid resistance measurement methods for cars and motorcycles. However, the way friction measurements are performed and reported should take the above mentioned different needs into account and follow-up actions should be more tailored to suit the needs of motorcyclists.

Introduction

Skid resistance (or friction) of road surfaces play a significant role in road safety as the friction between tire and pavement is a critical contributing factor in reducing potential crashes. When a tire is free rolling in a straight line, the tire contact patch is instantaneously stationary and there is little or no friction developed at the tire/road interface, although there may be some interactions that contribute to rolling resistance. However, when a driver or rider begins to execute a manoeuvre that involves a change of speed or direction, forces develop at the interface in response to acceleration, braking or steering that cause a reaction between the tire and the road (friction) which enables the vehicle to speed up, slow down, or track around a curve.

Many studies show a high correlation between pavement skid resistance and rate of accidents. The skid resistance of the road surface changes during the time and with the weather. A wet road surface has much less skid resistance than e dry road surface. These studies make no difference in the kind of vehicle. Many motorcycle accidents happen as a result of loss of control. The MAIDS report shows that 29.7% of the single vehicle accidents happen as a result of sliding.

Since lack of skid resistance is not mentioned as an accident cause in the report there is a good possibility that lack of friction is at least a contributing factor in many accidents that are allocated to other causes. In one of the RIDERSCAN surveys 79.6% of the motorcyclists answered that road surface (among which skid resistance) was the second most important infrastructure problem, after road maintenance (figure 1).

	No.	% cit.
Road works	**2 373**	**13.5 %**
Hazard signaling (black spot management)	**3 037**	**17.3 %**
Road structure and design (geometry, curve design)	**3 591**	**20.5 %**
Road signs, roadside equipment, urban furniture	**5 063**	**28.8 %**
Road markings (paintings)	**6 795**	**38.7 %**
Road surface (pavement, rutting, manholes, slabs joints, track trams, skid resistance)	**13 966**	**79.6 %**
Road maintenance (potholes, bituminous asphalt sealer, longitudinal roadway ridges, manhole covers, roadway debris)	**15 537**	**88.5 %**
Total	**17 556**	**100.0 %**

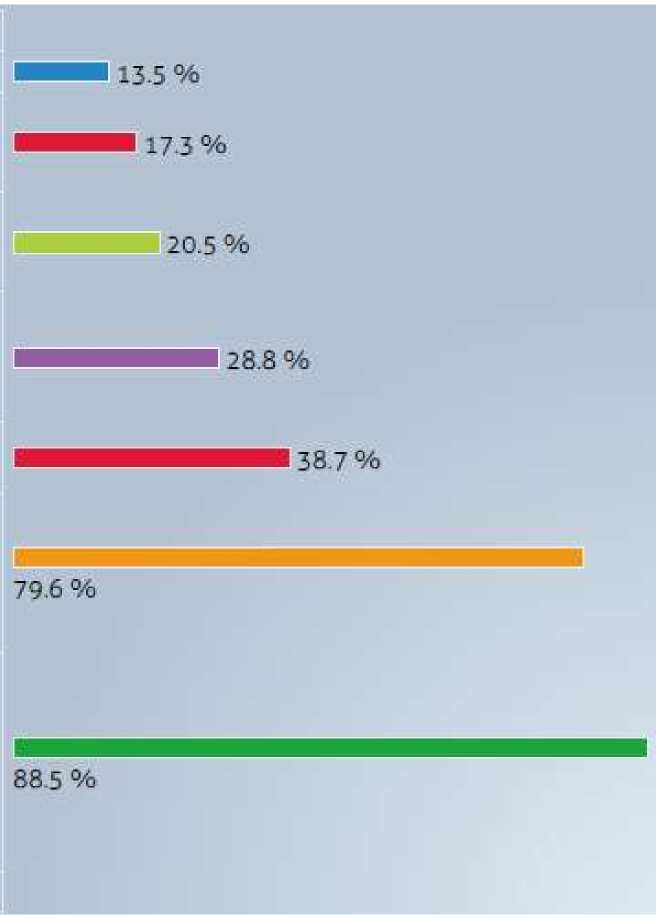

Figure 1 - Main infrastructure problems faced by motorcyclists (RIDERSCAN, 2015)

DEKRA states in the Motorcycle Road Safety Report that 27% of the motorcycle accidents are one-sided accidents, due to “Inappropriate reactions/errors, risky/unsafe driving, too high/excessive speed on the part of the motorcyclist”. In the report much attention is paid to possible defects of the vehicle and failures of the rider but very little to the infrastructure and none to the pavement. It seems, that the skid resistance of the road is a factor that needs more attention. If you don’t ask the question you will not get an answer, and in most accident reports and -studies no or little attention goes to the road surface. The relation between speed, friction and consequences is shown in figure 2.

Figure 2: Relation between speed, friction and consequences.

Although we do not know exactly which role friction plays in the cause of motorcycle accidents it is clear that it is an important factor in accidents in generally. Present road surface skid resistance measuring ways (longitudinal fixed slip and sideway force measurement) are developed with two-track vehicles in mind. The longitudinal fixed slip measurement effectively only measures the breaking skid resistance, while the sideway force measurement also measure lateral skid resistance, but only in the direction of the road. Also, in Europe, usually the skid resistance is only measured in the track that is closest to the hard shoulder in the most outside lane. This is not the place where motorcyclists ride. In fact, also for cars this way of measuring brings a risk, because cars can be confronted with differences in skid resistance between left and right wheels. In Sweden, this fact is recognized in the high level road safety standard IFS 2009:2, which not only states that wet friction must be measured on all new bituminous wearing courses (also on bicycling lanes and walkways), but also that friction is to be measured in two paths and split friction (the difference in friction number between the two measured paths) is restricted to a maximum 0.25 units of friction number.

However, in the practical asphalt paving documents in Sweden, it is per the choice of the road agency's project manager if friction is measured at all and when so, friction is normally measured in only one-wheel path. This shows how neglected road slipperiness can be in reality, despite ambitions. In the USA the measurements are usually done in the left track in the outside lane, because that is supposed to be more worn as a result of movements to the other lane. Also, motorcycle tires differ from car tires in shape and because motorcycles are balancing vehicles lateral skidding has other consequences than with cars. The common measurements work with reported average skid resistance on lengths of 20 to over 100 metres. The measurements are done on 5- or 10-centimetre-long pieces of road pavement. In the Netherlands these are added and averaged on 5 metre tracks, and later to 100 metre

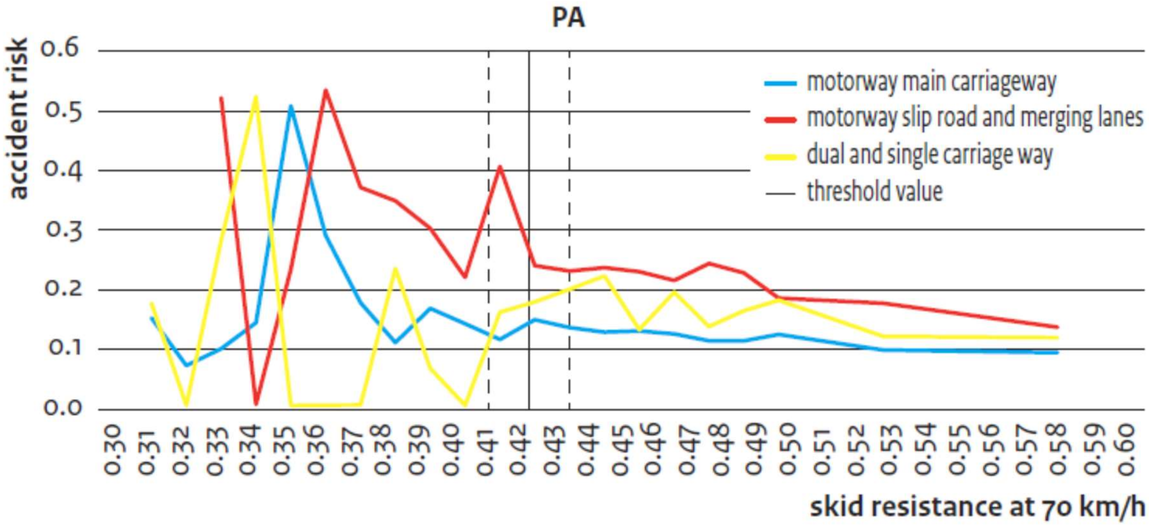

Figure 3: Relationship wet skid resistance current method of measuring and accident probability (number of accidents wet per million vehicle kilometres) for motorway main carriageway, motorway slip road and merging lanes and dual and single carriageway (RWS, 2015).

tracks. Tracks of 5 metres with a skid resistance below the standard are also reported to the client (contractor or road authority). A motorcycle can get out of balance on road lengths of only several decimetres, so a proper follow-up on these reports is important. Finally, motorcycle wheels are tilted in curves, where wheels of two-track vehicles are not. Although the physical laws do not make this distinction, it could make a difference, because of other rubber compound, the shape of the tire and the pressure on the spot where the tire and the road surface meet.

Skidding

Vehicular skidding can be distinguished in two types. One type of skidding is when the wheels of a vehicle are locked by braking and cease to rotate, but the vehicle continues to move. Another type is when the vehicle moves at an angle to the intended path, e.g. on horizontal curves. While a vehicle negotiates a horizontal curve, if the centrifugal force is greater than the counteracting forces (i.e. lateral friction force and component of gravity due to super elevation), lateral skidding takes place. The lateral skid is considered dangerous as the vehicle goes out of control leading to an accident. In case of motorcycles this could also lead to loss of balance, especially when the motorcycle is already oblique when cornering. The lateral skid resistance is generally equal to or slightly higher than the longitudinal skid resistance in braking tests. The measurement of this frictional resistance is called the coefficient of kinetic friction. Pavement skid resistance is primarily a function of the surface macro texture and micro texture.

Micro texture refers to small irregularities on the pavement surface (fine-scale texture), and it is related mostly to aggregate surface texture and the ability of the aggregate to maintain this texture against the polishing action of traffic and environmental factors. The friction coefficient decreases with skid speed, which in turn depends on the speed of vehicle and degree of brake application or the brake efficiency. The friction coefficient also decreases slightly with increase in pavement temperature and tyre/wheel pressure. Contrary to what many motorcyclists think, the tilting of the wheel is not relevant here.

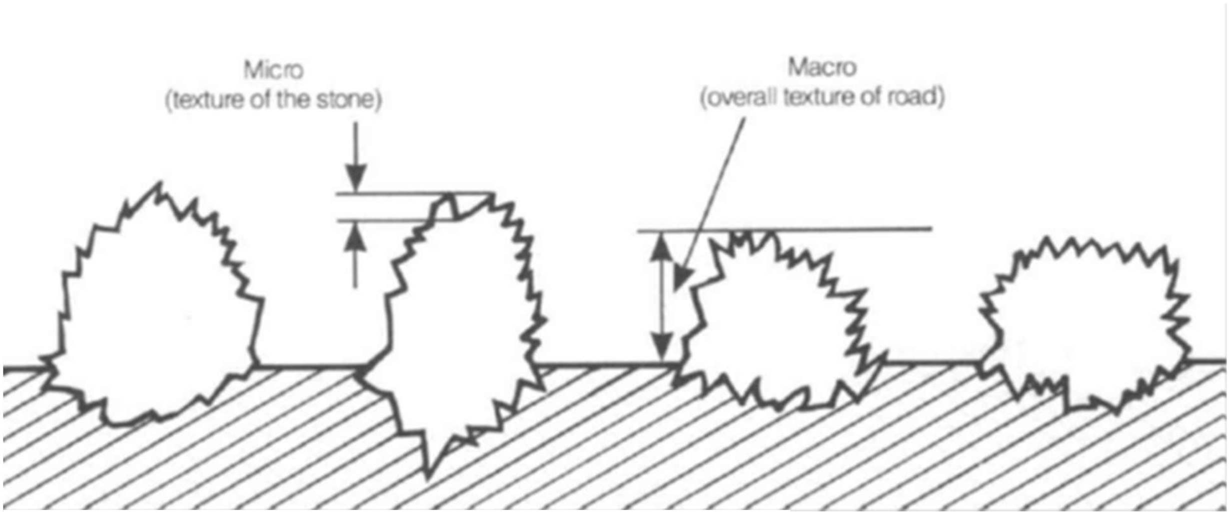

Figure 4: Micro- and macro texture

Macro texture refers to the large irregularities on the road surface (coarse-scale texture) that are associated with voids between aggregate particles. The magnitude of the macrotexture depends on the size, shape, and distribution of coarse aggregates used in pavement construction as well as the particular construction techniques used in the placement of the pavement surface layer. In wet circumstances both the micro-texture and the macro-texture are important. Micro-texture plays a considerable role in the road-tire contact in wet surfaces. The size of micro asperities has a significant trace in overcoming the thin water film.

Squeezing and overcoming the thin water film present in the pavement-tire contact area and generating friction forces requires the existence of micro-texture [22]. Moreover, to maintain a confident contact between tire and pavement, the micro-texture has a great role to penetrate into thin water film present on the surface of the pavement. The shape of micro asperities controls the drainage process. Macro-texture is important for the drainage of water at higher speed. Too little macro-texture may cause a too thick water film, which the tyre cannot force away. In time, as a result of the wear by the tires, the gravel in the pavement that provides the structure get polished in the direction of the traffic and gradually loses its skid resistance.

Figure 5: Slick texture due to bleeding bituminous binder. Photo J.Granlund

Measuring skid resistance

Skid resistance (friction) on road sections is usually measured by moving a (partially) braked wheel along the pavement, either fitted on a trailer or on a measurement truck. The wheel can be fitted in line with the direction of the measuring vehicle or on a yaw angle of 20 degrees. The wheel is usually braked with a slip of 20% or less. The average skid resistance is calculated on road sections of 20 to 100 metres and either on the wheel track that is nearest to the roadside or in the middle of the lane that is nearest to the roadside. For wet road surfaces the loss of skid resistance tends to increase progressively with increasing speed. Statistics show that the accident risks are much larger on wet roads. Therefore, the measurements are usually done on wet roads. To this aim water is sprayed before the testing wheel.

method	speed	toplayer	
	in km/h	porous	dense
SWF	40	0,57	0,63
	60	0,54	0,58
	80	0,51	0,53
RAW	50	0,45	0,44
	70	0,42	0,39

Figure 6: Dutch skid resistance standards with the currently used methods (source: rijkswaterstaat)

Present measure methods

Projects like TYROSAFE and Rosanne where aimed at harmonisation of measuring methods in Europe. They focussed on the two in Europe most common methods with a braked test wheel, a.k.a. the Skiddometer principle. In Europe braked-wheel or fixed-slip testing methods are still standard (described in CEN/TS 13036-2). Here a braked wheel is attached square to the roadside (in the same direction as the other wheels) to a trailer that is towed by a van. The lateral position is in the middle of the trailer. Because the car-trailer combination drives to the upmost right side of the lane (on European continent) the test wheel is effectively situated in the track that is closest to the roadside. No added weight is used and the pressure of the testing wheel to the road surface is limited to 200 kg. The road surface in front of the braked wheel is made wet with a water film of about 0.5 mm. This way, the braking force on a wet road is simulated. The outcomes consist of measurement results of 5-10 cm road lengths that are added to calculate an average on a length of the road between 20 and 100+

metres. However, in the Netherlands, and possibly also in other countries, tracks of 5 metres or less that have a skid resistance that is below the standard are also reported to the client.

The above mentioned CEN/TS 13036-2 also defines the Skid Resistance Index (SRI) and its Speed Parameter S0. The speed parameter shows how the road friction on slippery sections decreases with increasing speed. S0 is calculated based on texture data from laser scanning. SRI is calculated based on friction data at any speed[1] , along with texture based Speed parameter S0. In order to determine friction at e.g. 120 km/h, both data on texture and braking friction at f.x. 60 km/h are required. This calls for measurement systems that combine friction measurement wheels and texture-measuring lasers.

Figure 7: Braked-wheel testing trailer (photo: Rijkswaterstaat)

Figure 8: Braked wheel testing trailer (detail) (photo: Rijkswaterstaat)

Figure 9: Pendulum skid resistance tester

For local measurements, like measuring the skid resistance of road markings, cycle paths etcetera, a Pendulum Skid Resistance Tester is normally used. For this method the road has to be closed for traffic. It also measures just a small piece of the road.

In Norway, Denmark and Sweden, road slipperiness is measured with the ViaFriction device, as per CEN/TS 15901-14. Both Denmark and Norway use two ViaFriction sensors; one in each wheel path. The measurement trailer used in Sweden (see figure 9b) is constructed so the ViaFriction unit can be easily moved between different lateral positions, so a measurement in left wheel path can within few minutes be followed by a measurement in the right wheel path. The measurement wheel on

[1] Note: A friction meter mounted on a towed trailer or in a heavy vehicle may be subject to a lower legal operating speed, than set by the roads maximum speed limit.

ViaFriction is mounted in a suspension similar to a motorcycle rear suspension, making the wheel following the road profile very good even at undulating road sections. Thereby the instrument shows good measurement performance also on uneven road surfaces. ViaFriction is as standard equipped with a reference tyre for friction measurement as per ASTM E1551 and the vertical mass on the wheel is about 106 kg.

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Figure 9b: A ViaFriction trailer operated in Sweden and Norway. Photo: L Karlsson,

Another way of measure skid resistance is being used in more and more countries these days. This method is called Sideway-force Coefficient Routine Investigation Machine (SCRIM or SWF) or Seiten Kraft Messverfahren (SKM) in German. There are some very small differences between the SCRIM/SWF and SKM, but they are essentially the same.

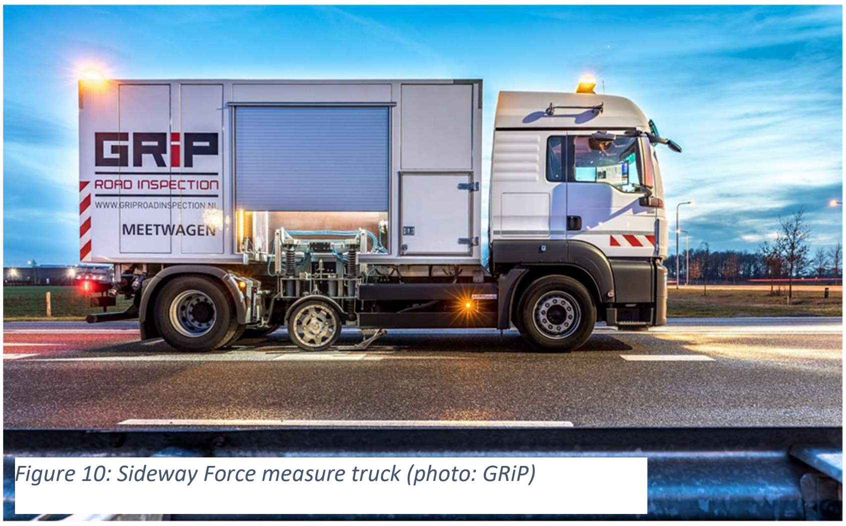

Figure 10: Sideway Force measure truck (photo: GRiP)

With this way of measuring the skid resistance a measurement truck is supplied with an extra wheel between the right front and rear wheels. This extra wheel is fitted on an angle of 20 degrees to the driving direction. This way of measuring the skid resistance is described in the European technical test description CEN TS 15901-8.

The SWF/SKM method is now used in ten countries in Europe: United Kingdom, Germany, France, Spain, Belgium, Portugal, Italy, Switzerland, Slovenia and the Netherlands. In the last method with the braked wheel beneath a trailer is also still in use. The tests are done on wet roads (the truck is equipped with a water tank) with speeds between 50 to 80 km/h and on longer distances. The SWF/SKM method to the measures – to a certain extent – also the lateral forces. This has the additional effect that in left-hand curves the skid resistance shows other values than in right-hand curves.

Figure 11: detail of Sideway-forces testing wheel (photo: Rheinland Schniering)

Figure11: Braked wheel and laser measuring (photo: AIT)

A new way to do measurements is to use laser. With laser the macro-texture can be measured, which gives an indication of the skid resistance. More important is that with laser the whole width of the lane can also be assessed on potholes, cracks, flatness, ruts. In Austria AIT works with trucks from RoadSTAR that combine the braked wheel method (with a braked test wheel that is positioned in line with the other wheels) with laser measurements and high-speed video camera's. The laser is attached in front of the truck and measures transverse and longitudinal evenness of the lane and the macro-texture of the pavement on a width of 3.3 meters. The trucks of Kiwa KOAC in the Netherlands are also equipped with laser measurement devices and a photo camera. These are integrated in the measurement system of the braked wheel, but register a smaller part of the road.

Outside Europe also some other methods are used. First the spin-up tester method, which works opposite to the locked-wheel method. Here the test wheel is locked until the test speed is reached and then it is unlocked and runs free. Another method is the Surface Texture Measurement. Because pavement skid resistance is tied to surface macrotexture, some methods seek to measure a pavement's macrotexture then correlate it with skid resistance as measured by some other, more traditional method. The simplest surface texture measurement is the sand patch test (ASTM E 965). The test is carried out on a dry pavement surface by pouring a known quantity of sand onto the surface and spreading it in a circular pattern with a straightedge. As the sand is spread, it fills the low spots in the pavement surface. When the sand cannot be spread any further, the diameter of the resulting circle is measured. This diameter can then be correlated to an average texture depth, which can be correlated to skid resistance. A texture depth of about 1.5 mm (0.06 inches) is normally required for heavily trafficked areas

Figure12: Prototype ROSAN device (circa 1998)

Motorcycles

Motorcycle tires have a different shape and have to deal with different forces than car tires. The present way of measuring can lead to results that are sufficient for cars, but not always for motorcycles. It is obvious that motorcycles, because of their lower weight (not because of the tilting!), have less (gravitational) force and therefore less grip than cars. Because of the lower weight (leading to less friction), the different shape of a motorcycle tire and because the motorcycle being a balance vehicle, the effect of the lateral forces, especially on the front tire, play a bigger role. More important however, is the fact that motorcyclist use the whole width of the lane, depending on the circumstances.

According to some operators the measurement of only the most outside track would be sufficient, this being the part of the road with the most wear. However, this is disputed by others, which is important for both cars (different skid resistance between the left and right track can lead to a rotating car when it breaks hard) and motorcycles: when only one track is measured and this track is not the one with least skid resistance this could lead to situations where parts of road used by motorcyclists (especially the left track) is more slippery than the measurements indicate. The skid resistance in this track(s) is supposed to give an indication of the skid resistance of the whole width of the road. The situation can change however when repairs, especially with bitumen, are being performed, like on the Belgian roads is common practice. The present way of inspection does not take this kind of deviations into account

Conclusion

The present methods for measurement and reporting road friction do not meet the needs of motorcyclists. The position of the wheel in only one-wheel path on the road is too different from daily motorcycle practice. Also the present way of calculating average skid resistance on road sections of 20 to 100 metres may work well for cars, but not for motorcycles. The fact that motorcycles have only two wheels in one track make them much more vulnerable than cars for slippery road surfaces. Even a spot of a few decimetres can be enough for a motorcyclist to lose grip and subsequently lose balance and crash. Motorcyclist normally do not ride on the part of the road that is measured, but use the whole lane, depending on the circumstances. The whole width of the lane can be assessed using laser technology, like PaveVision3D Ultra or the technique used in the RoadSTAR vehicles.

However, with laser technique the macro-structure is measured, and also damages to the road surface, potholes, cracks, flatness, ruts. It does not measure the micro-structure and therefor also not polishing. It does not measure the skid resistance, but gives only an indication, based on the macro-texture. A feasible measurement method could be to do friction testing in both wheel paths, and make an integrated analysis with measurement data also from (laser scanned) texture profiling in several parts of the lane (or continuous across the lane width). The analysis should not only compute average values over 20 metres or longer intervals, but also identify local slippery spots within lengths down to no longer than 5 metres.

Recommendations

- Motorcyclists use the whole width of the lane; therefore, the whole width of the lane should comply to the minimum skid resistance standards.
- These standards should be harmonized throughout Europe, preferably to the highest currently used standards as used in the Netherlands (see figure 6). To ensure this, road authorities should regularly have the skid resistance of the whole width of the lane measured.
- A method that takes motorcycles into account should also be part of the reviewed Road infrastructure safety management regulation (2008/96/EC). The current used methods with a braked (or locked) wheel, often even in just one track, do not completely fulfil this demand, but could be extended with laser measures and of photos.
- Also, reporting the average skid resistance over lengths of 20, 50 or even more metres may be good for cars, but does not meet the needs of riders of powered two-wheelers. Reporting smaller distances, 5 metres or less, when these do not comply to the standards and an adequate follow-up by the road authorities would be a large improvement to the current practice in most countries.
- With camera- and laser devices slippery spots, differences in skid resistance, potholes, cracking and rutting could also be measured and reported. Measurement trucks that can work this way already exist (e.g. Kiwa KOAC and AIT), but are not used this way by lack of demand from the road authorities.

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This paper does not does not reflect the opinion of the above mentioned persons, interpretations and conclusions are that of the author.

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