SLIPPERINESS ON CONTAMINATED ROAD SURFACES

– DIESEL SPILLAGE AND LOOSE GRAVEL ON BARE ASPHALT

Investigation for the Swedish Motorcyclists Association, SMC

Final Report

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Cover photo: *Allt Om Bilen*.

INNEHÅLL

SUMMARY

Annually, several hundreds of motorcyclists in Sweden are injured after crashing on roads that are slippery due to contamination of loose gravel or diesel fuel on the asphalt surface. The vast majority of loose gravel come from winter gritting, from bad road repair or have been scattered from unbound material at the asphalt edge. Heavy vehicles with full tank are the main sources to diesel spillage. Motorcycle-crashes on contaminated road surfaces have a pronounced concentration to horizontal curves, ramps and roundabouts. The Vision Zero pays special attention to vulnerable road users, a group that in fact include motorbikers. There is a wide consensus on that loose gravel as well as diesel spillage on bare asphalt makes the road slippery and thus unsafe. The objective of this study was to investigate what road friction numbers can occur, when asphalt pavements are contaminated by loose gravel or by diesel fuel spillage. Road friction numbers were measured on a test section with dry asphalt (reference condition), then with contamination of winter grit 2 - 6 mm fine gravel, and finally with contamination of 10 liter diesel fuel. The results showed that the dry bare asphalt had friction numbers 0.75 to 0.80, but after contamination the friction was reduced to less than half. Loose gravel reduced friction down to 0.35, while diesel fuel spillage reduced friction down to 0.30. The conclusion is that in contaminated condition, the dry asphalt may become about as slippery as hard packed snow in the winter season. Motorbikers riding a warm summer day on dry asphalt should not expect the road to be as slippery as when driving on snow during the cold winter season. Therefore, it is important that management of contaminations is made with high alertness. Warning signs must be quickly erected, and as soon as possible loose gravel as well as diesel must be cleaned up. The recommendations are that road agencies should seek to improve practices for road repair in order to better prevent excessive loose gravel on the asphalt. Furthermore, unbound material are to be replaced by stabilized material at the asphalt edge. Road agencies should also improve friction management so it becomes more relevant for PTW safety; examples are given. Heavy vehicle operators should seek to implement technologies and practices to prevent diesel spillage from their vehicles.

SAMMANFATTNING (SWEDISH SUMMARY)

Årligen skadas flera hundratals motorcyklister i Sverige efter att ha kraschat på vägar som är hala på grund av förorening av löst grus eller diesel på asfaltytan. Större delen av lösgruset kommer från vinterns halkbekämpning, från dåliga vägreparationer eller genom att trafiken rivit upp och spritt ut obundet material från stödremsan utanför asfaltkanten. Fulltankade tunga fordon är de vanligaste källorna till dieselutsläpp. Motorcykelolyckor på förorenade vägytor är tydligt koncentrerade till horisontalkurvor, ramper och rondeller. Riksdagens Nollvision har särskilt fokus på oskyddade trafikanter, vilket inkluderar motorcyklister. Det finns en bred samsyn om att löst rullgrus liksom dieselutsläpp gör asfalterade vägar hala och därmed trafikfarliga. Syftet med denna studie var att undersöka vilka vägfriktionstal som kan uppstå, när asfaltbeläggningar är förorenade av löst grus eller med dieselbränsleutsläpp. Vägfriktionsantal mättes på en provsektion med ren asfalt (referensförhållande), sedan på samma asfaltyta efter förorening av vintergrus 2 - 6 mm fint grus, och slutligen på samma asfaltyta efter förorening av 10 liter dieselbränsle. Resultaten visade att den torra asfalten hade friktionstal 0.75 till 0.80. Efter förorening sjönk vägfriktionen till under hälften. Löst grus gav vägfriktion ned till 0.35, medan spill av dieselbränsle sänkte vägfriktionen ned till 0.30. Slutsatsen är att i förorenat skick blev den torra asfalten ungefär lika hal som hårdförpackad snö under vintersäsongen. Motorcyklister som kör en varm sommardag på torr asfalt förväntar sig knappast att vägen ska vara så hal som vid snöföre under den kalla vintersäsongen. Det är viktigt att hantering av föroreningar sker raskt och utan dröjsmål. Varningsskyltar sätts upp snarast, och vägbanan rengörs fortast möjligt från löst grus och dieselspill. Rekommendationen är att väghållare vässar rutiner och metoder för vägreparation, så att inte överflödigt grus ligger på och bredvid lagningarna. Obundet material i stödremsan utanför asfaltkanten ersätts med stabiliserat material. Väghållare bör också förbättra vägförvaltningen så den blir mer relevant för MC-säkerhet; rapporten ger flera exempel på hur det kan ske. Lastbilsåkerier och bussbolag uppmanas utrusta sina tunga fordon med spillskyddande teknik och införa rutiner som förebygger trafikfarligt dieselspill från fordonen.

1. INTRODUCTION

Annually more than 600 motorcyclists in Sweden are injured after crashing on roads that are slippery, due to loose fine gravel contaminating the asphalt surface[1]. According to the Swedish Traffic Accident Data Acquisition STRADA, these crashes constitutes one fifth of all severe MC-crashes in Sweden. Low or varying skid resistance could cause the motorcycle to lose traction. Loose gravel can in fact cause wheels to suddenly lock, which may capsize the motorcycle. Surely, there is a great need to reduce occurrence of loose gravel on bare asphalt roads. Hence, a first question is "*-Where does the loose gravel come from?*"

While Sweden is a cold climate country with icy winter road conditions, road agencies use fine gravel[2] with up to 6 mm large grains for gritting in order to maintain acceptable road friction in the winter season[3]. As the winter ends, remaining loose grit must be swept up and taken away from the public roads no later than June 1st. However, about 50 % of the mentioned 600 motorcycle crashes on loose gravel leading to human injury have occurred after the date June 1st. This fact is a strong indicator of that the cleanup of grit is not performed within the specified date limit June 1st. Two other sources to contaminations by loose gravel are excessive gravel from simpler asphalt patch repair, as well as gravel being scattered by traffic (particularly in sharp curves on narrow roads) from the unbound material at the pavement's edge.

Another significant cause of motorcycle crashes is low road friction due to diesel spillage on the asphalt. A literature study, see FEMA (2002), reports values up to twelve percent of all MC-crashes as caused by diesel spillage. Typical sources of diesel spillage are heavy buses and trucks, particularly when cornering while having the fuel tank about full. Police inspections in Gothenburg found ten percent among hundreds of buses were causing diesel spillage, see Karlsson (2011).

The combination of most contaminations being in curved road segments and that motorcycles highest demand for side friction occur when cornering, is an obvious reason to why crashes on contaminations are concentrated to curvy segments of the roads; horizontal curves, ramps and roundabouts.

2. OBJECTIVE: SLIPPERINESS ON CONTAMINATION

There is a wide consensus on that contamination by loose gravel as well as diesel spillage on bare asphalt makes the road slippery and thus unsafe. The traffic safety hazard due to diesel spillage is in fact part of the background to Directive 2000/8/EC: "*The accidental spillage of fuel (especially diesel) on to the road is a significant hazard for riders of two-wheeled motor vehicles and pedal cycles*."

There are law firms specialized on accident claims due to road slipperiness caused by contamination, for example *Bike Lawyer* in the UK. Single cases have been settled at over €1 Million.

However, there is a lack of knowledge on the typical degree of slipperiness at contaminated pavements. The objective of this study was to investigate what levels of road friction number that are recorded by a road friction measurement device on asphalt pavements, when contaminated by loose gravel and by diesel fuel spillage.

[1] Source: The insurance company Svedea.
[2] Soil materials are classified by grain size according to the SS-EN ISO 14688-1 (2002) standard. 2 - 6 mm grains are fine gravel, while 60 µm - 2 mm grains are sand.
[3] The Swedish national standard for road maintenance and operation: *Standardbeskrivning för Basunderhåll Väg, SBV*.

3. DEFINITIONS

Friction is "*the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other*." Hence, friction between a tyre and the road is depending on properties of the road surface as well as of the tyre. It is possible to isolate the friction-creating properties of the road itself, by measuring the friction with standardized friction testing devices with reference tyres, and slip percentages and following standardized practices. This has paved way for the concept of "*road friction*" (a.k.a. "*road slipperiness*"), being used by road agencies worldwide to enhance road safety.

Vision Zero. The basic starting point for Vision Zero is the ethical standpoint that no-one should be killed or suffer lifelong injury in road traffic (zero killed or severely injured, KSI's). Vision Zero stresses the fact that the road transport system is an entity, in which different components such as roads, vehicles and road users must be made to interact with each other so that safety can be guaranteed. In order to prevent serious results from accidents, it is essential for the roads, and the vehicles they carry, to be adapted to match the capabilities of the people that use them. Vision Zero emphasizes that responsibility is shared by transportation system designers and road users. Vision Zero was adopted by the Swedish Parliament in 1997.

Vulnerable Road Users. Vision Zero particularly addresses improved road safety for vulnerable road users (VRU's). The European Commission has defined VRU's as "*non-motorised road users, such as pedestrians and cyclists as well as motorcyclists and persons with disabilities or reduced mobility and orientation*."

4. METHOD AND INSTRUMENT

Road friction numbers were measured 2017-03-23 at a test section with bare asphalt in three conditions:

1. Dry asphalt (reference condition).
2. Contaminated by winter grit 2 - 6 mm fine gravel.
3. Contaminated by diesel fuel spillage, created by 10 liters of diesel fuel.

Spilling several liters of diesel fuel by intention is due to environmental reasons prohibited on normal paved surfaces. Furthermore, a fenced and gated area is needed to make this kind of road test in a safe and undisturbed way. Hence, the test was conducted at a facility used for harsh rescue and police outdoor training; the Bysjön Rescue Education Centre near Borlänge City. An aerial photo[4] of the facility is showed in Figure 1, with the 50 m test section marked by a red oval ring. The asphalt pavement was old with many cracks and high variance in macrotexture and roughness condition, just as on many rural county-roads in Sweden.

Figure 1 Bysjön Rescue Education Centre with the friction test section in red

[4] Aerial photo provided by Google Maps

Both air and road temperature were +6 °C, the relative humidity was RH 30 %, and the wind was blowing at about 8 m/s during the measurements.

The road friction numbers were measured with a car-towed device "*ViaFriction*", see Figure 2. ViaFriction is annually calibrated and certified by the Norwegian Public Roads Administration. The test tyre was a 4.00 - 8 smooth tread reference tyre as specified in the American ASTM E1551 standard. The trailer was pulled by a 4WD Polestar-modified Volvo XC90, with good acceleration performance also on slippery road surfaces. The target operating speed was 35 km/h. Slip was set fixed at 20 %.

Figure 2 The ViaFriction trailer for measurement of road friction. Photo: J Granlund

The project wanted to register is any significant lock occurred of the friction measurement wheel when testing slipperiness on the loose gravel. Therefore, the measurement trailer was equipped with a TomTom Bandit Action Camera, see Figure 3, filming at 30 frames per second.

Figure 3 The HD Action Camera. Photo: P Holmlund

Preparation of the 20 m section for testing on diesel spillage is showed in Figure 4.

Figure 4 Spilling 10 liter diesel in the 20 m test section. Photo: P Holmlund

An example of action photo, taken when measuring on diesel spillage, is showed in Figure 5.

Figure 5 Action photo taken during measurement on diesel spillage

5. RESULTS: DRAMATIC LOSS IN ROAD FRICTION

At the test facility, all asphalt areas were contaminated by winter grit. A short test section of about 50 m length was cleaned with a sweeping machine, especially for the friction test. Outside the test section, there were loose gravel on the asphalt. Note: The diesel test was made only on some 20 m.

Measurements were made in two directions, one bound East and one bound West. Due to the measurement wheel being located in the left wheelpath, there was a lateral offset of 1.5 m between measurements in the two directions. The test ground had old asphalt with numerous cracks and patches, resulting in variance in texture and roughness condition. Outside the East end of the test section, there was a decimeter deep "ditch-shaped" settlement in the asphalt, straight across the driving direction of the test section. This ditch affected the acceleration and braking behavior, in order to avoid mechanical shock damages to test personnel in the car as well as to the car and the measurement trailer. For precision reason, results from repeated measurements are compared only in the same measurement direction. Data from eastbound direction were not directly compared to data from westbound direction.

The ViaFriction device samples friction with high frequency, corresponding to steps down to decimeter intervals. The ViaFriction software has been developed for everyday road friction management, meaning that averaging is made over 20 meter and measurement sections are longer than 100 m (often tens of km). This project targets the risk for skid and slip crashes with powered two-wheelers PTW:s. This group of vehicles may lose control due to slipperiness already within a handful of meters. For that reason, it was desirable to evaluate variance in friction within much shorter length than 20 m relevant for crash risk with cars. The analysis started with averaging within 1-meter step length. However, it turned out that 1 meter averaging could not be handled properly by the actual version of the ViaFriction software. The software gave results that indicated local wheel lock, but by studying the action videos this was confirmed not having occurred in reality. In order to overcome the software´s algorithm problem for the unique needs of extremely short averaging steps in this project, processing was tested with incrementally increased step length. It was found that also 2 m did not work, but from 3 m averaging step length the software gave proper results. With a longer averaging step length, i.e. 20 m as traditional among many road agencies, precision would be improved between repeated or reproduced measurement runs. However, the data are then smoothened so much that local low dips of low friction that are hazardous to motorbikers are not discovered in the results. Due to the short test section, 50 m for gravel and only 20 m for diesel, the software was also unable to plot length intervals in the graphs (at least 100 m is needed for that normal functionality of the software).

Note: The actual test sections were 20 m and 50 m long. Data from the acceleration part before the test section and from the braking part after the test section are to be disregarded. This is both due to contamination of gravel and due to extreme change in speed such as when braking in front of the decimeter deep pavement damage.

5.1 The Dry Asphalt had Friction 0.75 to 0.80

The tests commenced by reference measurements on dry asphalt. Three runs were made in each direction. It turned out that one measurement file from the westbound direction was corrupt, so no data from that run could be retrieved. Results from the three runs on dry asphalt in the eastbound direction are showed in Figure 6. Within the test section, friction numbers were in the range 0.75 to 0.80, with except for singular values (a few meters) down to 0.72 and up to 0.82. Results from the two runs on dry asphalt in the westbound direction are showed in Figure 7. Within the test section, friction numbers were in the range 0.70 to 0.80 with except for singular values (some meters) down to 0.60 and up to 0.83.

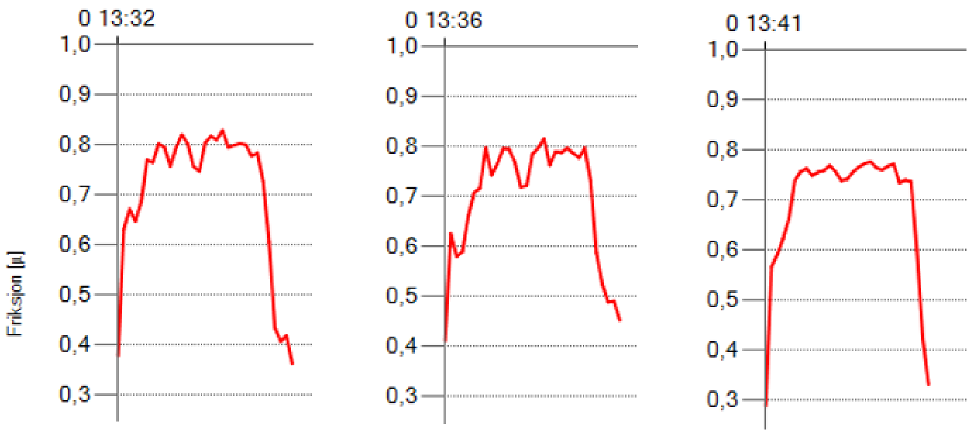

Figure 6 Friction numbers on 50 m dry asphalt, three eastbound runs

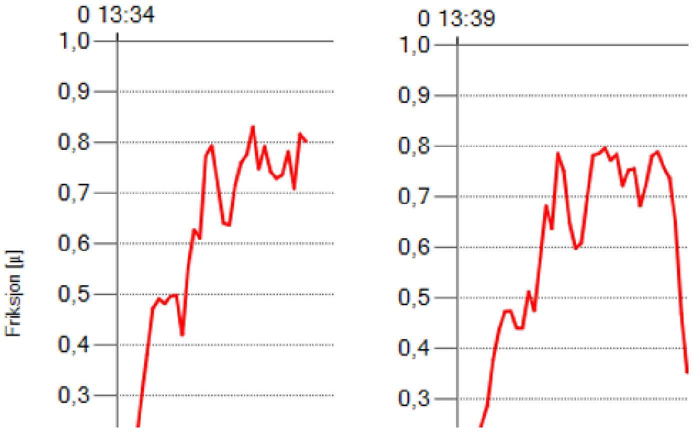

Figure 7 Friction numbers on 50 m dry asphalt, two westbound runs

5.2 Loose Gravel Reduced Friction to 0.35

Eight measurements were made on dry asphalt contaminated with a thick layer loose gravel with 2 - 6 mm grain size. Four runs were made in each direction. Results from the four runs on loose gravel in the eastbound direction are showed in Figure 8. Data from the 50 m test section is marked with a green circle in the first graph. Within the test section, friction numbers were in the range 0.40 to 0.45, with except for singular values (a few meters) down to 0.28 and up to 0.52. Results from the four runs on loose gravel in the westbound direction are showed in Figure 9. Within the test section, friction numbers were in the range 0.35 to 0.50 with except for singular values (a few meters) down to 0.27 and up to 0.54.

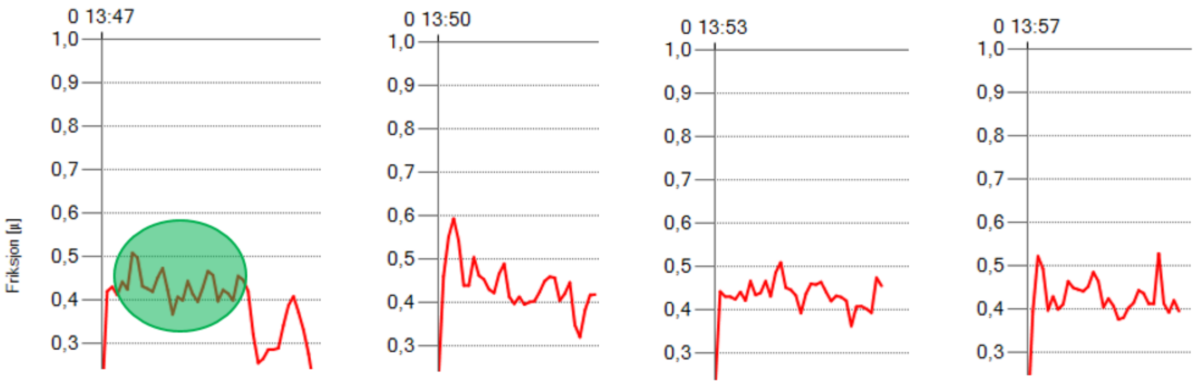

Figure 8 Friction numbers on 50 m loose gravel, four eastbound runs

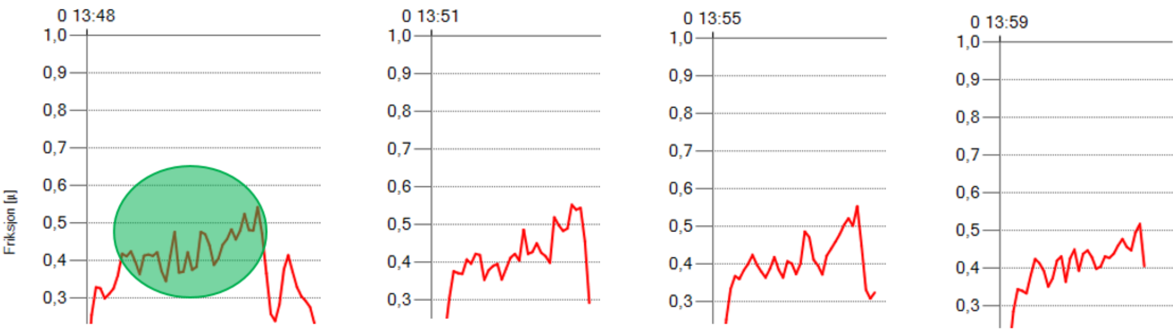

Figure 9 Friction numbers on 50 m loose gravel, four westbound runs

5.3 Diesel Spillage Reduced Friction to 0.30

Nine measurements were made on a 20 m short section of dry asphalt contaminated with 10 liter diesel fuel. Results from the five runs on diesel spillage in the eastbound direction are showed in Figure 10. Note: Only data in the middle along the graph is from the short test section. Data from the 20 m test section is marked with a green circle in the first graph. Within the test section, friction numbers were in the range 0.30 to 0.41. Results from the four runs on diesel spillage in the westbound direction are showed in Figure 11. Within the test section, friction numbers were in the range 0.35 to 0.41.

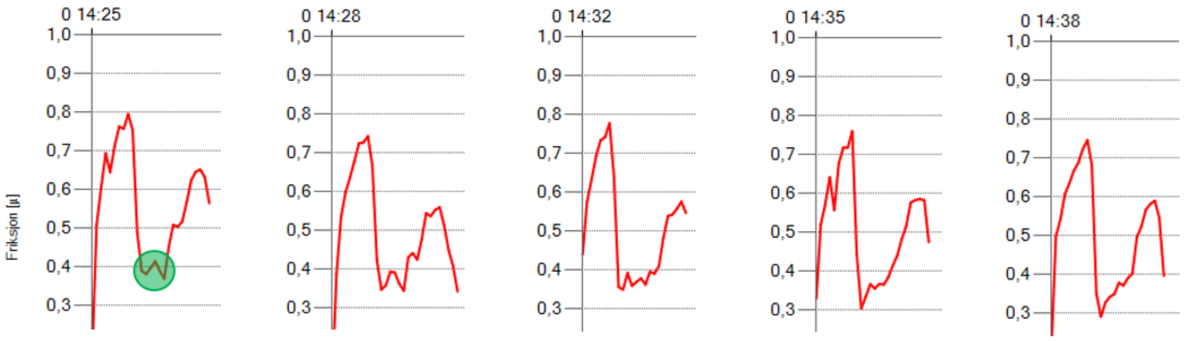

Figure 10 Friction numbers on 20 m diesel spillage, five eastbound runs

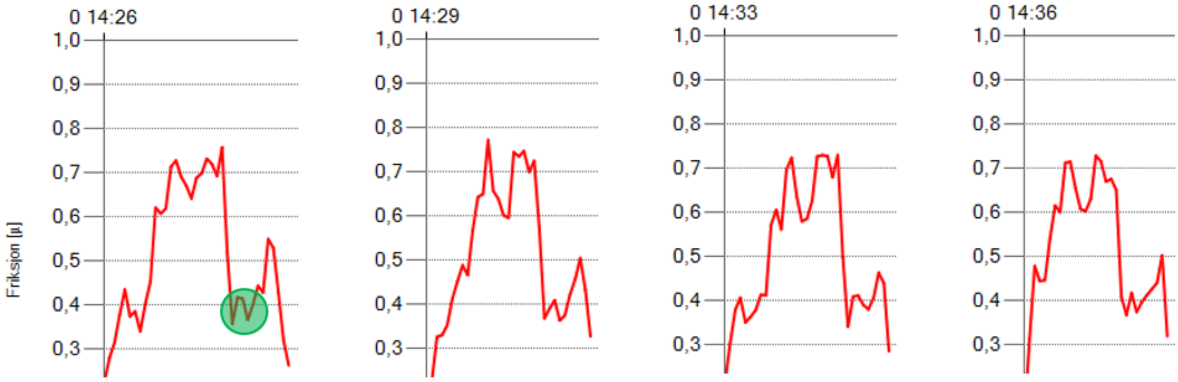

Figure 11 Friction numbers on 20 m diesel spillage, four westbound runs

5.3.1 Watering Didn't Increase the Diesel Slipperiness

The project team had an idea that diesel spillage may become even more slippery, if it rains on it. Therefore, the testing ended with a set up where the diesel spillage was gently watered from a water hose. After allowing the diesel to become diluted by the moisture for fifteen minutes, two finishing measurement runs were done; one in each direction. The results are showed in Figure 12. Within the test section, friction numbers were in the range 0.32 to 0.43. These results are within the variance of the above results for slipperiness on non-watered diesel spillage. These results therefore does not support the hypothesis that water can significantly increase the slipperiness on diesel spillage.

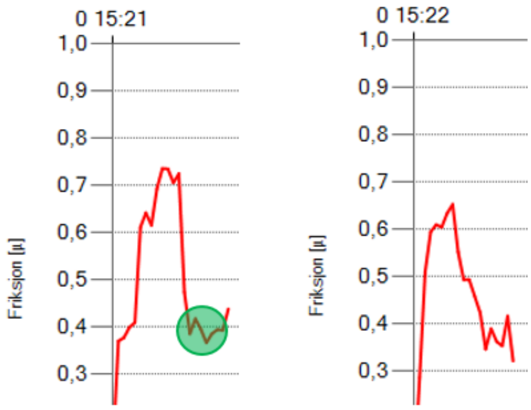

Figure 12 Friction numbers on 20 m diesel spillage, two runs

6. CONCLUSION AND RECOMMENDATION

Road friction numbers were measured with a ViaFriction device on a test section with dry asphalt (reference condition), then with contamination of winter grit 2 - 6 mm fine gravel, and finally with contamination of 10 liter diesel fuel. The results showed that the dry asphalt had friction numbers 0.75 to 0.80. Due to the contaminations, the friction dropped to less than half:

- Loose gravel reduced friction down to about 0.35.
- Diesel fuel spillage reduced friction down to about 0.30.

The above results can be compared to typical values of road friction on “winter-white” snowy road surfaces. Road surfaces of packed snow typically yield road friction numbers in the range 0.25 to 0.5. The low friction values results in much longer braking distance (often doubled or even longer), as well as reduced lateral stability. This is well known by road users, so they adapt their driving behavior to the low friction on winter-white road surfaces.

In-depth investigations of all fatal road traffic crashes in Sweden have clearly showed that loss of lateral stability is a worse risk factor than prolonged braking distance is. To motorbikers, road slipperiness may affect the risk for lateral instability more than it affects the braking distance. Furthermore, the difference in sensitivity for loss of stability and for braking distance may differ a lot, when comparing powered two-wheelers (PTW’s) and four wheeled passenger cars. It should therefore be highlighted that low road friction numbers can imply much higher crash risk to people on PTW’s than to people in cars. Despite this, limit values for lowest acceptable road friction are set with respect to cars rather than to PTW´s.

This study is quite small, made on a short test section with one single pavement type, only one type of grit material and diesel fuel from one supplier only. This calls for careful interpretation of the results. Precision for the repeated and reproduced measurement where not quantified, but god precision can be concluded already by ocular comparison of the graphs. Furthermore, the results are in line with intuition and experience of the author as well as among the SMC staff. Most important is that the results are in line with the numerous crashes registered for motorbikers on contaminated road surfaces.

The main conclusion is that in contaminated condition, the dry asphalt may become about as slippery as hard packed snow in the winter season. Motorbikers driving a warm summer day on dry asphalt should not expect the road to be as slippery as when driving on snow during the cold winter season. This highlights the importance of managing road surface contaminations with high alertness. Warning signs must be quickly erected, and as soon as possible loose gravel as well as diesel must be cleaned up. The recommendations are that road agencies should seek to improve practices for road repair in order to better prevent excessive loose gravel on the asphalt. Furthermore, unbound material are to be replaced by stabilized material at the asphalt edge. Road agencies should improve friction management so it becomes more relevant for PTW safety. An example is that current limit values for friction on bare asphalt are set for car traffic and relates to averaging over 20 m of road distance. Any averaging distance longer than 5 m seems to be too long, in order to be relevant for PTW safety; being able to “identify local slippery areas that are hazardous to PTW´s”. Therefore interim actions could be to cut the averaging distance from 20 m to 5 m, and to raising the limit value for low friction specifically in horizontal curves. Future research should seek to identify the shortest critical length of slippery road surface that is sufficient to cause significant crash risk for PTW’s. Could for instance an only 1, 2 or 3 m long slippery area be hazardous? Could a shorter averaging distance than 5 m be relevant, or should instead the limit value for 5 m be reduced? Future following studies on the topic slipperiness on contaminations should also investigate if a thinner layer of gravel on the asphalt may cause even worse slipperiness than the current study recorded. Also the effect on slipperiness of rounded gravel grains versus crushed macadam grains should be investigated.

Heavy vehicle operators should seek to implement technologies and practices to prevent diesel spillage from their vehicles.

7. ACKNOWLEDGEMENTS

The project is thankful to the rescue education organization at *Räddningstjänsten Dala Mitt*, for kindly giving access to their test facility at Bysjön, Borlänge. Thanks also for the kind assistance with sweeping the test section, and for closing it down for all the other people attending the facility on the measurement day. -*Thank you all very much!*

8. REFERENCES

ASTM E1551. *Standard Specification for Special Purpose, Smooth-Tread Tire, Operated on Fixed Braking Slip Continuous Friction Measuring Equipment*. American Society for Testing and Materials.

Considerations from the User regarding Regulation 34 Diesel Spillage. (2002). Informal document No. 11 by the UNECE Working Party on General Safety Provisions (GRSG), transmitted by the Federation of European Motorcyclists' Association (FEMA).
Internet 2017-07-05: https://www.unece.org/fileadmin/DAM/trans/doc/2002/wp29grsg/TRANS-WP29-GRSG-82-inf11.pdf

Directive 2000/8/EC of the European Parliament and of the Council of 20 March 2000 amending Council Directive 70/221/EEC on the approximation of the laws of the Member States relating to liquid fuel tanks and rear underrun protection of motor vehicles and their trailers.
Internet 2017-07-05: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0008&from=en

Geotechnical investigation and testing -- Identification and classification of soil -- Part 1: Identification and description. (2002). Swedish, European and International Standard, SS-EN ISO 14688-1:200
Internet 2017-07-04: https://www.iso.org/standard/25260.html

Karlsson, B. (2011). *Polisens fordonskontroller*. Tylösandsseminariet.
Internet 2017-07-05: http://www.mhf.se/client/files//content/projekt_vi_driver/Tylosandseminariet/Presentationer_2011/Tisd_10-45_Bengt_karlsson.pdf

Säkrare vägar och gator för motorcyklister – en självklar del av Nollvisionen. (2017). Sveriges MotorCyklister. Internet 2017-07-04: http://www.asfaltskolan.se/media/Sakrare_vagar_o_gator_for_MC.pdf

The Swedish national standard for road maintenance and operation: *Standardbeskrivning för Basunderhåll Väg, SBV.* (2014). Trafikverket. Internet 2017-07-04:
http://www.trafikverket.se/contentassets/dd3893424b90468e91c42359becb610d/standardbeskrivn_basunderhall_vag_140901.pdf

The Swedish national road geometric design code: *Krav för vägars och gators utformning (VGU).* (2015). Trafikverket och SKL. Internet 2017-07-04: https://trafikverket.ineko.se/Files/sv-SE/12046/RelatedFiles/2015_086_krav_for_vagars_och_gators_utformning.pdf

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Slipperiness on Contaminated Road Surfaces

– Diesel Spillage and Loose Gravel on Bare Asphalt

Annually, several hundreds of motorcyclists in Sweden are injured after crashing on roads that are slippery, due to contamination of loose gravel or diesel fuel on the asphalt surface. The vast majority of loose gravel come from winter gritting, from bad road repair or have been scattered from unbound material at the asphalt edge. Heavy vehicles with full tank are the main sources to diesel spillage. Motorcycle-crashes on contaminated road surfaces have a pronounced concentration to horizontal curves, ramps and roundabouts. The Vision Zero pays special attention to vulnerable road users, a group that in fact include motorbikers. There is a wide consensus on that loose gravel as well as diesel spillage on bare asphalt makes the road slippery and thus unsafe. The objective of this study was to investigate what road friction numbers can occur, when asphalt pavements are contaminated by loose gravel or by diesel fuel spillage. Road friction numbers were measured on a test section with dry asphalt (reference condition), then with contamination of winter grit 2 - 6 mm fine gravel, and finally with contamination of 10 liter diesel fuel. The results showed that the dry bare asphalt had friction numbers 0.70 to 0.80, but after contamination the friction was reduced to less than half. Loose gravel reduced friction down to 0.35, while diesel fuel spillage reduced friction down to 0.30. The conclusion is that in contaminated condition, the dry asphalt may become about as slippery as hard packed snow in the winter season. Motorbikers riding a warm summer day on dry asphalt should not expect the road to be as slippery as when driving on snow during the cold winter season. Therefore, it is important that management of contaminations is made with high alertness. Warning signs must be quickly erected, and as soon as possible loose gravel as well as diesel must be cleaned up. The recommendations are that road agencies should seek to improve practices for road repair in order to better prevent excessive loose gravel on the asphalt. Furthermore, unbound material are to be replaced by stabilized material at the asphalt edge. Road agencies should also improve friction management so it becomes more relevant for PTW safety, i.e. reducing averaging distance for friction numbers from 20 m down to 5 m (or in the future: even shorter) while also raising the limit value for minimum friction specifically in horizontal curves. Heavy vehicle operators should seek to implement technologies and practices to prevent diesel spillage from their vehicles.

Johan Granlund, M.Sc. in Civ. Eng. is an IPMA Certified Senior Project Manager, Thought Leader and Expert in Road Technology. Johan has been working on driving quality and traffic safety since 1991. He holds driving license for motorcycle since 1985. Johan has invented two patented methods for measuring road characteristics and led three projects within EU ROADEX. He is a member of the Nordic Road Forum committee "Traffic Safety and Transport", a member of the board of the International Forum for Road Transport Technology, and is working on standardization in road conditions. His client stock include road user organizations, road and traffic authorities and the Accident Investigation Board Norway. Johan teaches at the Asphalt School and at several universities, is a sought-after lecturer and has written articles in international scientific journals in vehicle technology as well as in road and aerospace technology. The Swedish National Society for Road Safety (NTF) awarded the 2017 honorary award in memory of Evert Warg to Johan, for his valuable road safety work during many years.