OVERRUN TEST
TASK FORCE INVESTIGATIONS
REPORT

March 2018

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1. INTRODUCTION

Overrun test method is used to characterize road wear caused by studded tires. The test has been developed over the years and it is used as part of the regulation for stud type approval.

In 2014, Trafi presented a study about the variation of the results. The study concluded a sort of variation of the results which could affect the confidence of the test in terms of reproducibility and repeatability.

As an effort to increase the accuracy of the test, Trafi invited all accredited laboratories to join a Task Force. The purpose of this group was to analyze and identify the potential sources of variation of the test in order to analyze them and to provide recommendations to Trafi. The goal was to increase repeatability and reproducibility in each laboratory and between the different ones.

The entity members of this Task Force group were: Tikka Spikes & Continental, Nokian Tyres plc, BD Testing, Test World, Goodyear and Trafi as observer.

This report summarizes the investigations and findings achieved by the group and the proposed recommendations.

2. BRIEF TEST DESCRIPTION

15 stones of Kuru Grey granite are overrun 200 times at 100 km/h by the studded test tires. The mass lost by the stones (difference between their mass before and after the test) determines the level of wear that the test tires produce.

The order of magnitude of mass loss is about 2 tenth of gram. Due to this very small weight loss, it is necessary to follow the same preparation process of the stone before each weighing (before and after the test). The stones are washed and dried at high temperature, so the stones are in the same humidity and cleanliness conditions to be weighed before and after the overrun passes.

Apart from the 15 stones mounted into the frame (Test stones), there are 5 other stones which are not overrun but kept under water at the same place as the test stones during the 200 passes. These reference stones are processed together with the test stones for the mass measurement and in the same way. They are used to identify the mass loss due to the process but not to the overrun passes.

3. INVESTIGATIONS

The test has been analyzed and reviewed at its different steps. Investigations have been carried out during 2015, 2016 and 2017, and they are summarized in the following sections.

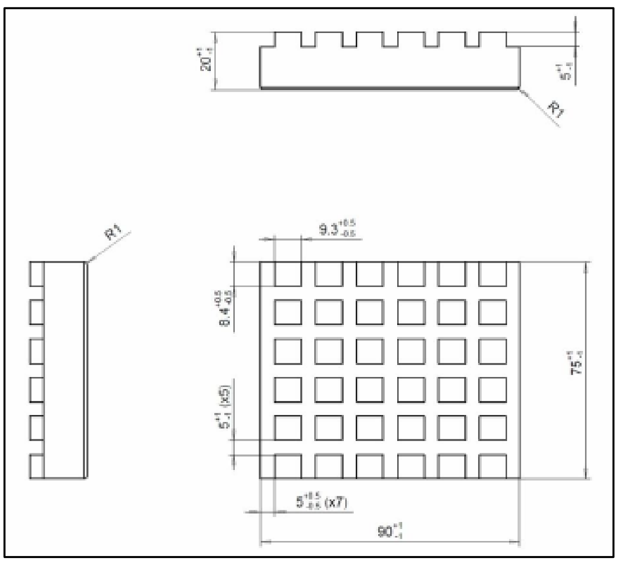
a. 2015

Following investigations were carried out during 2015:

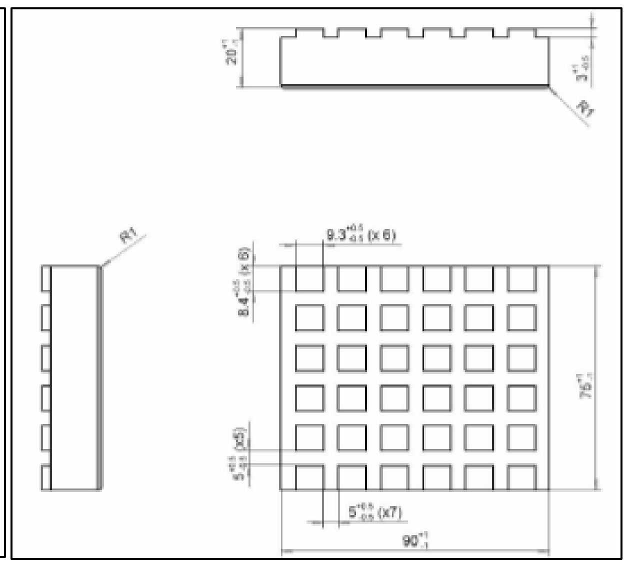
1. Sample geometry: Groove depth

The geometry of the stones used during the test has been analyzed. The groove depth is one of the influencing parameters on the mass loss, as it provides strength to the small blocks. Two geometries were tested to see the wear of each stone:

Labra-0058



K05



Both geometries have the same dimensional specifications, except the groove depth: 5 mm for Labra-0058 and 3 mm for K05. They were tested under the same conditions and the average mass loss was:

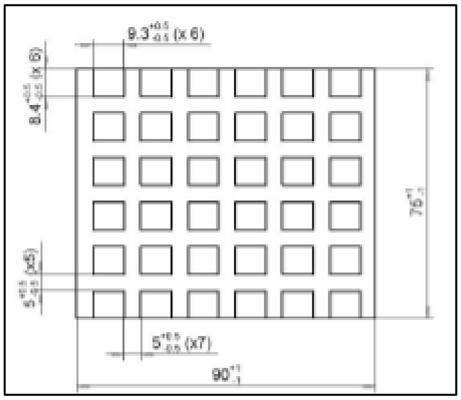
Geometry	Mass loss
Labra-0058	1.043 g
K05	0.844 g

The lower wear of K05 was probably caused by the fact that block edges are less fragile when they are supported better with less block height.

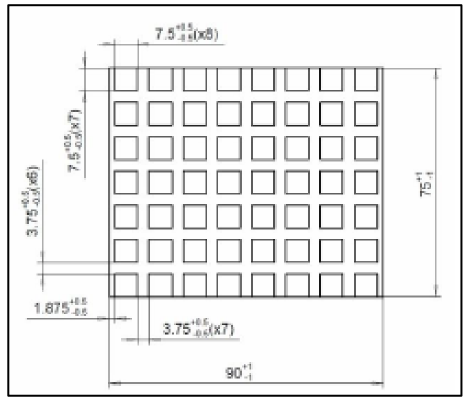
So, the groove depth of the samples seems to influence the mass loss.

2. Sample geometry: Groove width and block size

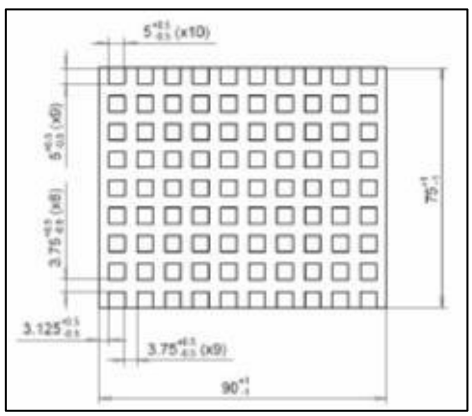
The geometry of the small blocks could be defined in different ways. The blocks of the stones could present different total edge length and different number of corners, depending on the geometry.
To check if mass loss is affected by these parameters, three geometries are tested. They all have the same dimensional specifications (same groove depth) except the size of the blocks (wide or narrow) :



K05



K03

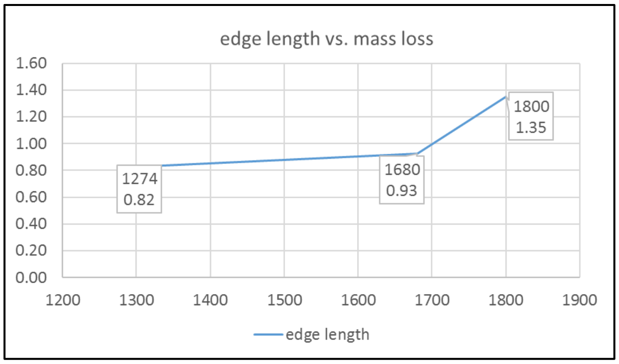


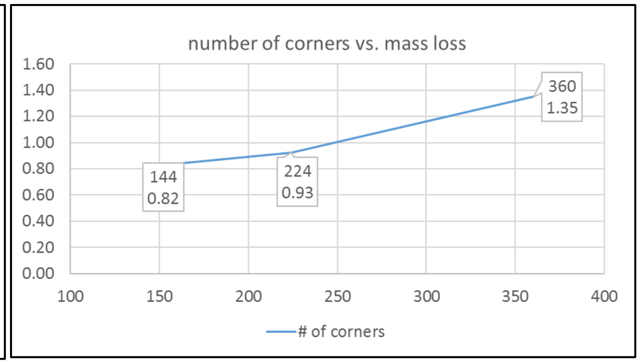
K01

The edge length, number of corners and mass loss are:

Geometry	Total edge length	Number of corners	Mass loss
K05	1274 mm	144	0.82 g
K03	1680 mm	224	0.93 g
K01	1800 mm	360	1.35 g

The following graphs show the relation between mass loss versus number of corners and edge length:

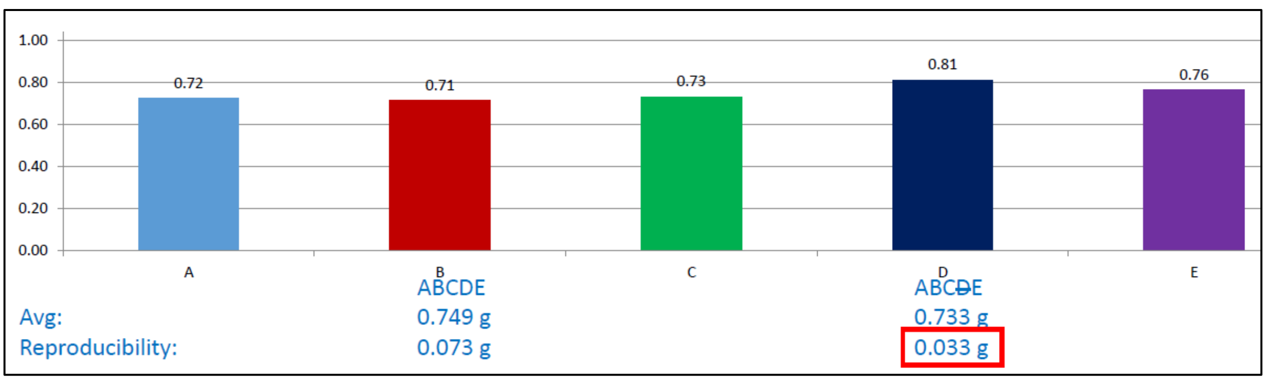




The mass loss increases with edge length and number of corners, so the groove width of the samples seems to influence the mass loss.

3. Stone preparation and weighing

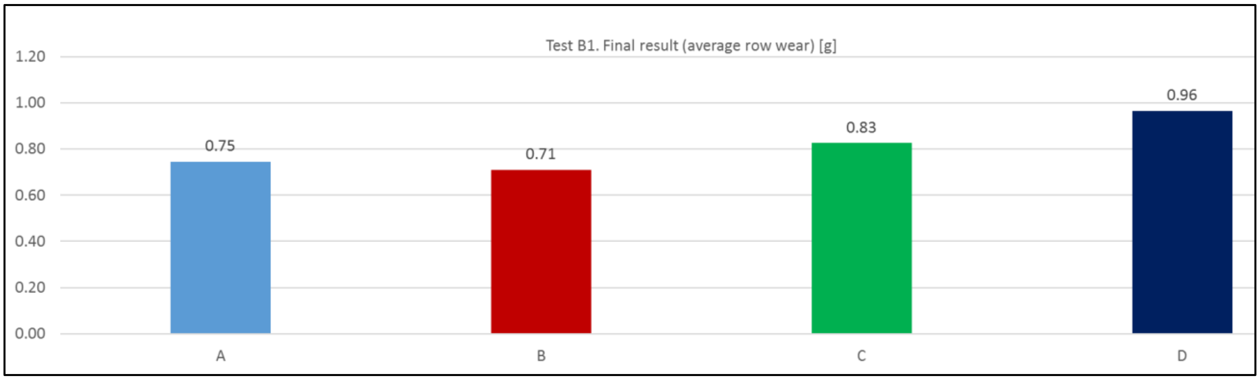
The purpose of this exercise was to check the reproducibility of the laboratory part of the process: Stone processing for getting stone mass. Each laboratory prepared stones to get the mass before the overrun passes. Once mass was measured, each laboratory sent the stones to the same laboratory (laboratory E) for overrun passes. After overrun passes were done for all the sets of stones, laboratory E sent them back to the laboratory who handled stones originally for the final measurements. The exercise was done with K05 stone geometry.



Results showed that one laboratory got slightly different wear result than others. This laboratory was not filling the remaining capacity of the oven with “dummy” stones (practice so far not specified in the method), but only with the 20 stones of the set. So, the conclusion is that the oven capacity should always be fully used.

4. Round Robin test

A round robin test is carried out between four laboratories. The geometry of the stones used by all laboratories was K05. Two sets of the same tires were tested by laboratory with the same type of vehicle (VW Golf type or similar). The average results were:

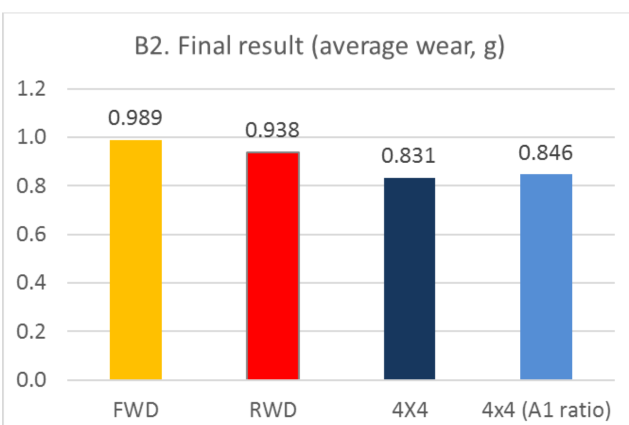


As a first analysis, the measurement system variation is 0.234 g and the reproducibility is 0.198 g.

Nevertheless, it is noticed that lab D was watering the full track. This practice was so far not specified in the test method description. If the result of this laboratory is not considered, the measurement system variation is reduced to 0.152 g and the reproducibility to 0.088 g.
Reproducibility can be further improved through technical alignment and more specific description of test method. The potential source of variation would need to be confirmed.

5. Vehicle influence (propulsion type: FWD, RWD, 4x4)

This exercise was to check differences on results due to different driving axles of the vehicle. All three sessions (Front-Wheel Drive, Rear-Wheel Drive, All-Wheel Drive) were performed with old Toyota Hilux. With this vehicle, it was possible to switch propulsion type easily so the vehicle was the same in all sessions.
4 or 5 results were obtained for each propulsion type, and the chart below shows the average of them:



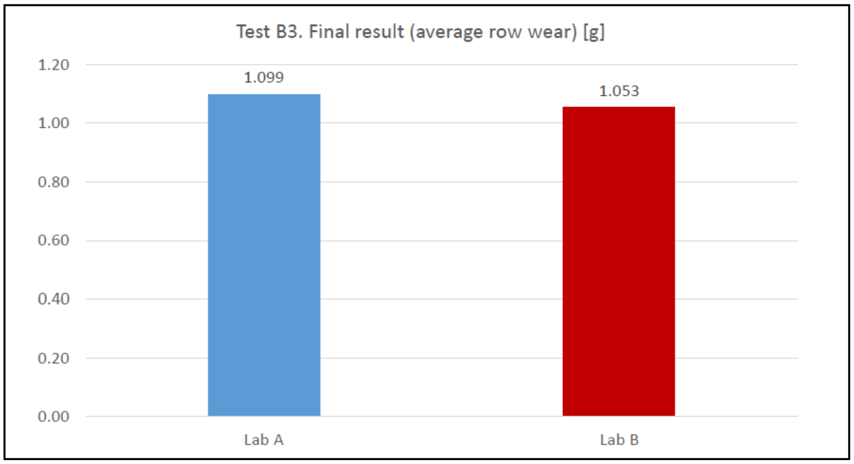
Propulsion type	stdev (g)
FWD	0.024
RWD	0.041
4x4	1 sample
4x4, using wear ratio found in A1	0.028

The stones used for the tests were mainly K05. As remark, during All-Wheel Drive (4x4) session, there were K05 stones only for 1 set. Standard stones were used for the other 4 sets of 4x4, and a correction factor from the previous investigation "*Sample geometry: Groove depth*" was applied to these results (1.2358, ratio between Standard/K05 results).

6. Different stone manufacturers

It was noted in Task Force meetings that laboratories where using different suppliers for stones. Stone material where the same Kuru grey granite and the stone design where the same for all, but manufacturing supplier and equipment could be different.

To study this further, one laboratory performed 2 tests with similar candidate tires, on same track with same vehicle, but stones (Labra-0058) from different suppliers used by laboratory A and laboratory B.



Difference of the test results where 4.37%, which can be considered inside normal variation of the test.

It was also notified, that even though same stone geometry (drawings) where used by all suppliers, laboratories had small differences for internal stone preparation work.

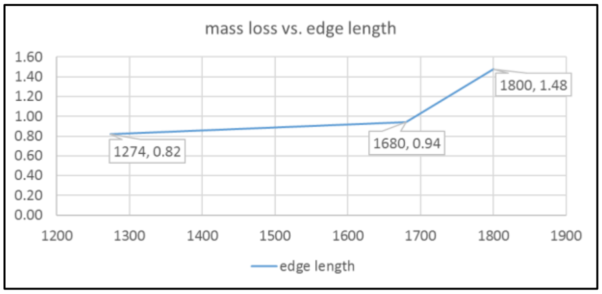
Therefore, common understanding was that one common supplier would eliminate one source of variation. That initiated discussion towards a unique supplier to be the common one for stones. This is still valid for all the laboratories. It was also agreed to include a chamfer at the cutting edge of stone back and sides.

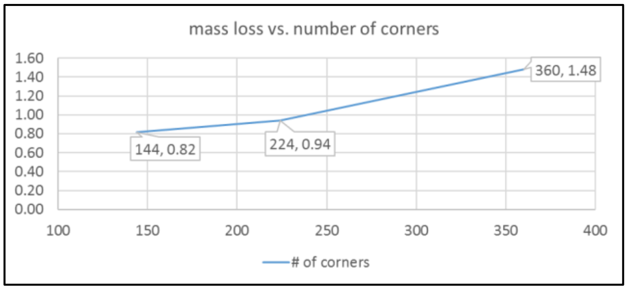
7. Confirmation of Sample geometry: Groove width and block size

As in the previous investigation about groove width and block size, K01 and K03 are retested to get additional data:

Geometry	Total edge length	Number of corners	Mass loss
K03	1680 mm	224	0.96 g
K01	1800 mm	360	1.61 g

This data is added to the previous investigation, and the conclusions are confirmed:

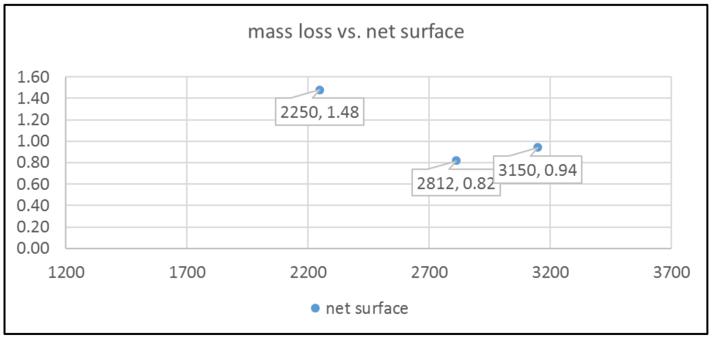




Additionally, the net surface is checked versus the mass loss. The net surface is the total top area of the stones.

Geometry	Net surface	Mass loss
K05	2812 mm^2	0.82 g
K03	3150 mm^2	0.94 g
K01	2250 mm^2	1.48 g

Despite the clear correlations with the other parameters, no relation is found with the net surface:



Nevertheless, it is confirmed a link between mass loss and geometrical parameters of test samples, as shown previously.

8. Influence of sprinkling the entire surface vs. samples only

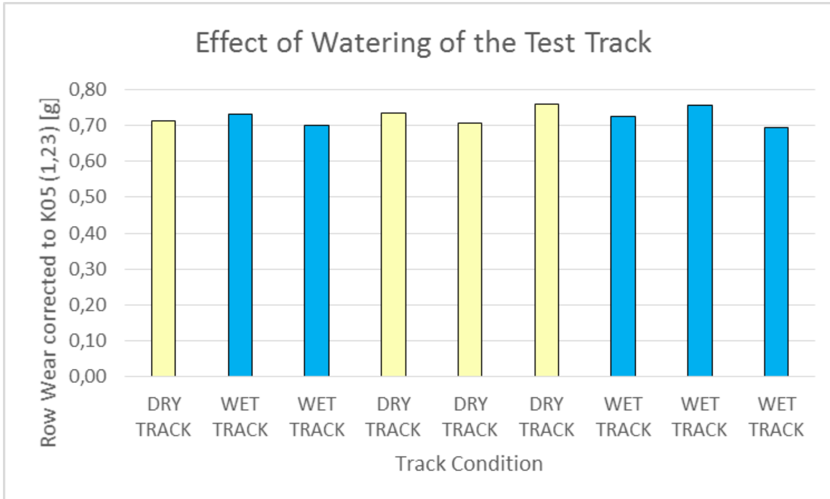


Figure: Effect of Watering of the Test Track

According the trials made in several days, with the reference tyre of Task Force of 2015, the watering of the entire track surface had no effect to the wear results. The watering was done by spreading the water with a tank trailer pulled by a tractor. The watering renewed always when the track seemed to have dry spots. The full temperature scale trials could not be performed, and the influence of cooling may vary depending on properties of tread components of a tyre.

b. 2016

Following investigations were carried out during 2016:

1. Influence of test speed, K0058 and K01

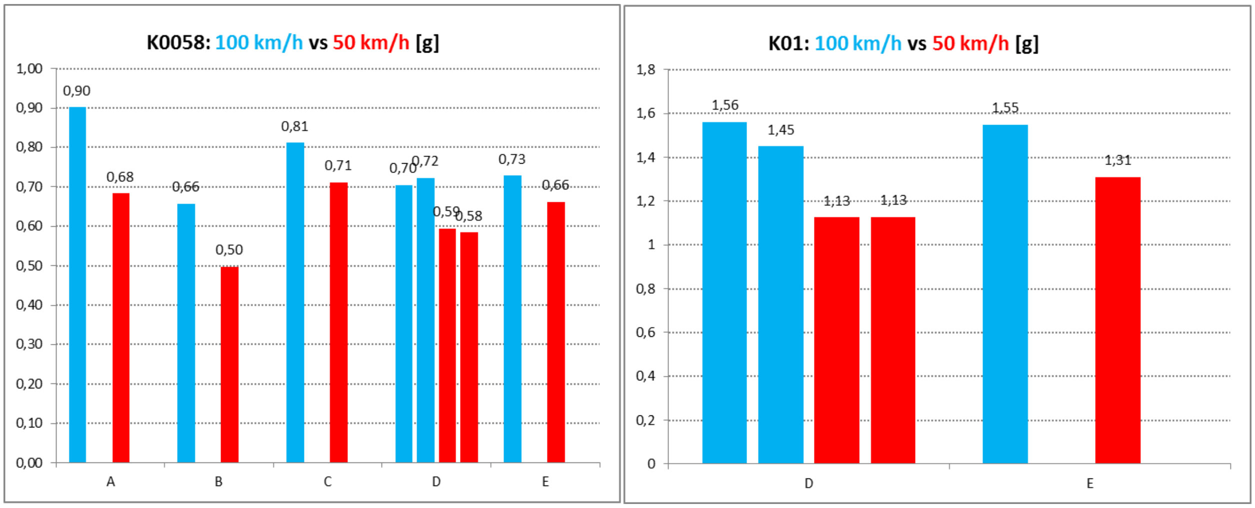


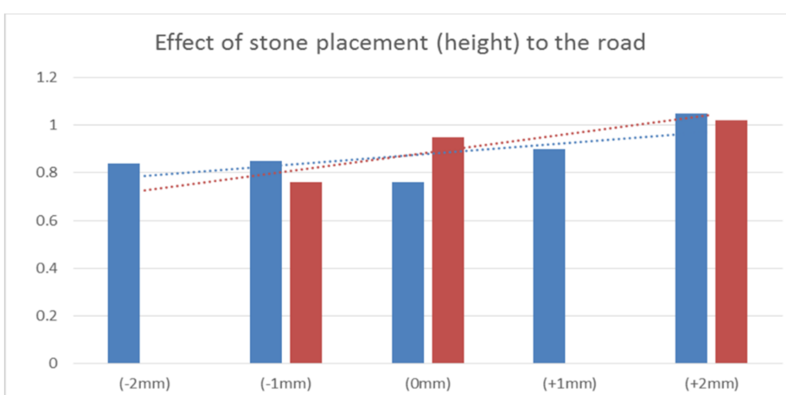
Figure: Test Results of stone type "K0058" and "K01" at 100 km/h vs 50 km/h

The test shows clearly a reduction of the wear in both test stone types as result of lower test speed. It was also assumed that speed will influence in the scraping length of the stud at contact patch, some stud marks observed at the stones show that at higher speeds the impact of the stud is dominating element of wear, when at lower speed the scratching of the studs may cause more wear. Therefore, the stud and tyre design may have a different effect on the road wear behaviour at different speeds.

2. Influence of the height of the test stones

Influence of the height position of the test stones in relation to the mounting frame was tested. The assumption was that frame and stones position in relation to the ground may be different.

It was observed that an increased offset of the samples leads to an increase in mass loss. The same observation was valid for both Labs which performed the tests. Overall standard deviation for the entire sample population (8 results) was 0.11g. So, as conclusion, the placement of the sample sets might have an impact on the test results. This is validated in another exercise later.



3. Influence of tire pressure

Influence of the tire pressure was tested with 75% load with Nordman tires and result is:

Pressure	Mass loss
250 kPa	0.72 g
200 kPa	0.60 g

Lower tire pressure means smaller wear result due to smaller stud force. Lower pressure means also higher rolling resistance, which means that tire temperature is higher.

4. Influence of load of the vehicle

Influence of the tire load was tested with 65 and 75% load with Nordman tires and result is:

Load	Mass loss
65%	0.68 g
75%	0.72 g

Load has not so big influence in wear result. Presumably all laboratories load the vehicle as little as possible. In some cases, vehicle can be heavier, which may lead to slightly higher result.

5. Influence of watering of the track – repeat with Nordman 4

Track watering experiment was repeated at different test track. Result is:

Condition	Mass loss	Pr.change
Dry	0.82 g	11.3 %
Wet	0.94 g	-0.2 %

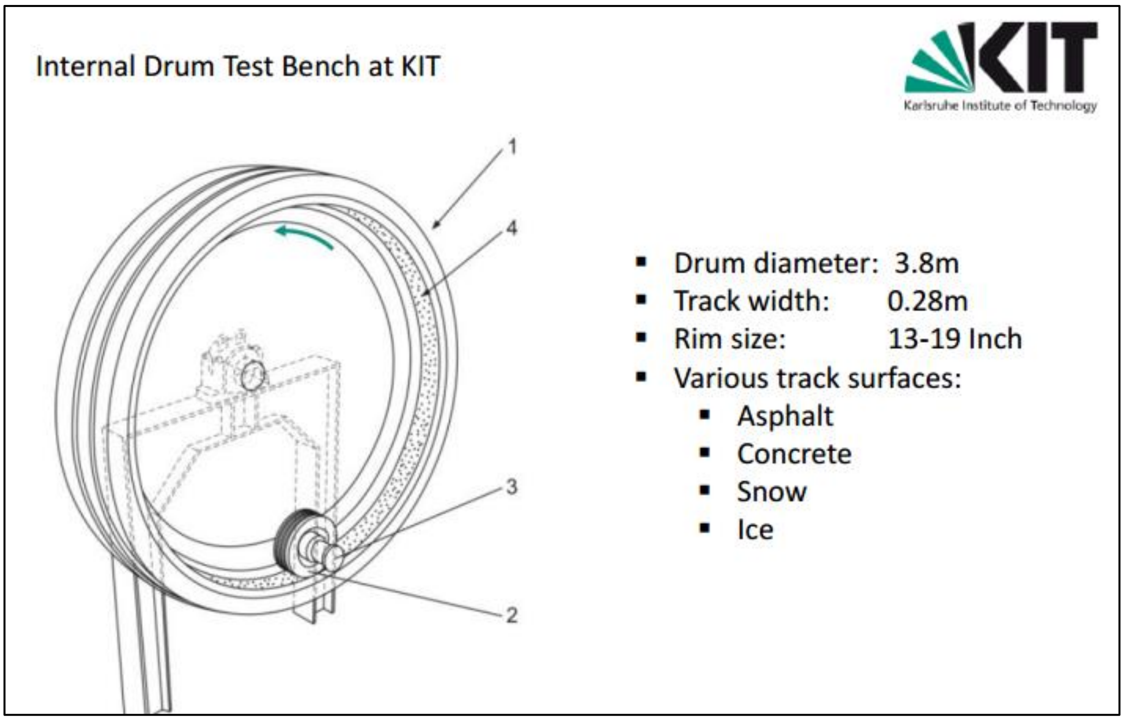
Wear result was higher on wetted track in this case. Watering reduced protrusion change as also in previous experiment. However, protrusion change on dry surface is much smaller than in previous experiment. It is probable that watering cools down the tire, which makes stud force and hence wear result higher.

c. 2017

Following investigations were carried out during 2017:

1. KIT carrousel test campaign

Karlsruhe Institute of Technology has an indoor drum designed for indoor tire tests. One of the capabilities is to perform overrun test over the 2 rows of 6 stone plate platform. A campaign of different tests was planned with this drum. Purpose was to be able to test under more controlled conditions (as an indoor installation can provide). Additionally, the drum can provide very high number of passes in very short time, making the studies more feasible.



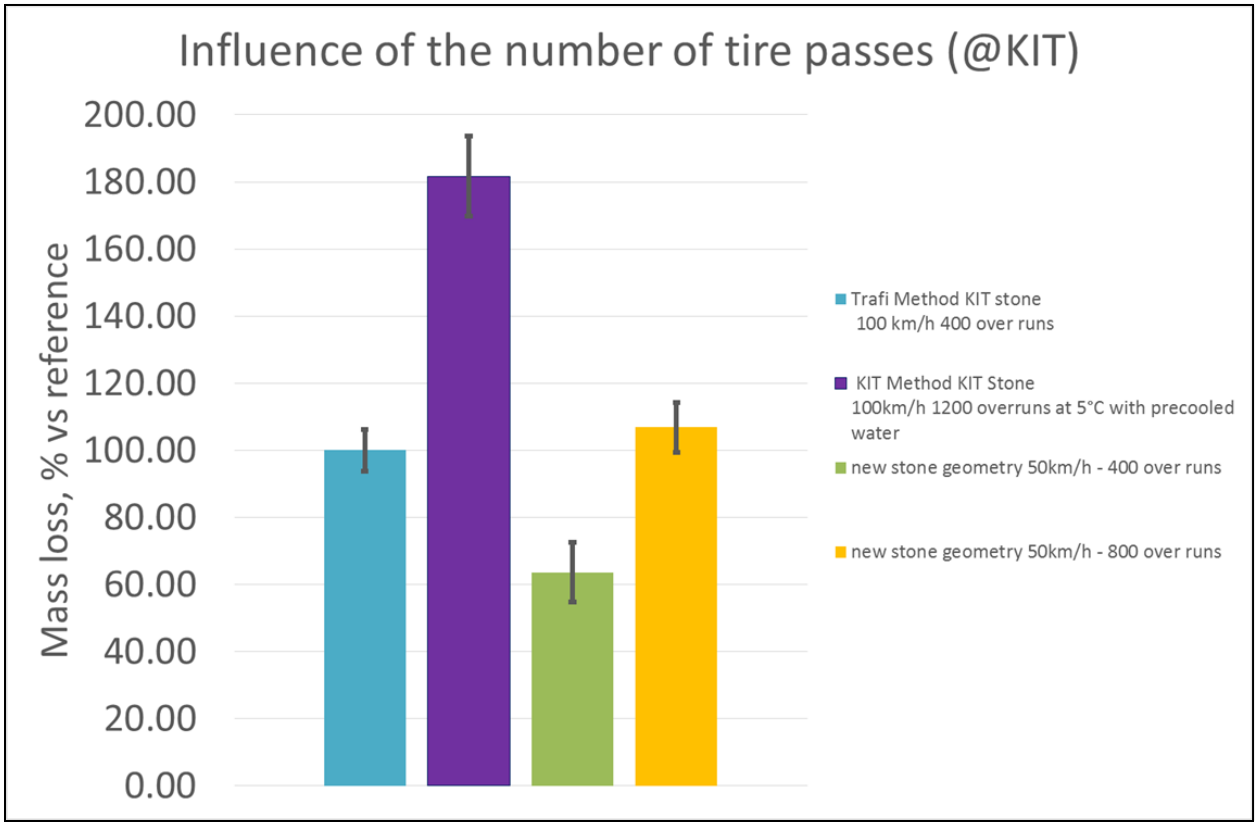
There is a specific method of overrun test followed in KIT which is slightly differently than Trafi method. Main difference is in stone handling: In KIT method, test stones are kept under water for 24 hours, and then, they are dried with compressed air and weighed. This process is followed just before and after the overrun passes in the drum.
Other differences of KIT method are also in stone geometry, only 6 stones plate, 1200 overrun passes and test temperature remains constant (adjustable). For comparison, Trafi method was also followed for some of the tests, meaning the oven drying was followed and using reference stones (the overrun passes were done in the drum).

The test plan of the campaign was:

Test Set	Test Tire	Tyre ID	KIT Method KIT Stone 100km/h 1200 overruns at 5°C with precooled water	Trafi Method KIT stone 100 km/h 400 over runs at 5°C with precooled water	New Method 1 new stone 100 km/h 400 over runs at 5°C with precooled water	New Method 2 new stone 50 km/h 400 over runs at 5°C with precooled water	New Method 3 new stones 50km/h 800 over runs at 5°C with precooled water
Individual tire variability	Nordman 4	1	x	x			
	Nordman 4	2	x	x			
	Nordman 4	3	x	x			
	Nordman 4	4	x	x			
	Nordman 4	5	x	x			
Size influence	CiC2 14"	6	x				
	CiC2 16"	7	x				
	CiC2 18"	8	x				
Stone variability	Nordman 4	1	x				
		1	x				
		1	x				
New test method development	Nordman 4	2		x	x	x	x
		2		x	x	x	x
		2		x	x	x	x
new test method - size influence	CiC2 14"	6			x		x
	CiC2 16"	7			x		x
	CiC2 18"	8			x		x
Temperature test	Nordman 4	3	-5°C dry				
		3	10°C wet				
		3	20°C wet				

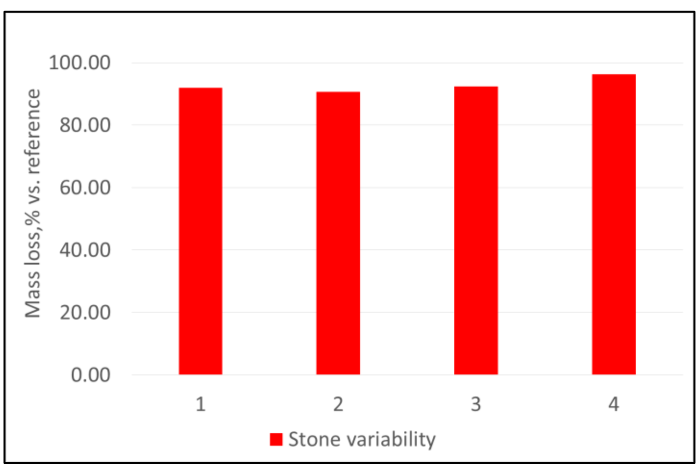
i. Number of tire passes

Similar methods were tested with different number of passes. The chart shows the average of the results obtained with the different sessions. The results are shown as relative versus a reference at 100%. The difference between the sessions of the two first bars was the number of passes (400 and 1200 respectively), and similar difference for the last two bars (400 and 800 over runs). As shown, an increased number of tire passes leads to an increased wear rate:

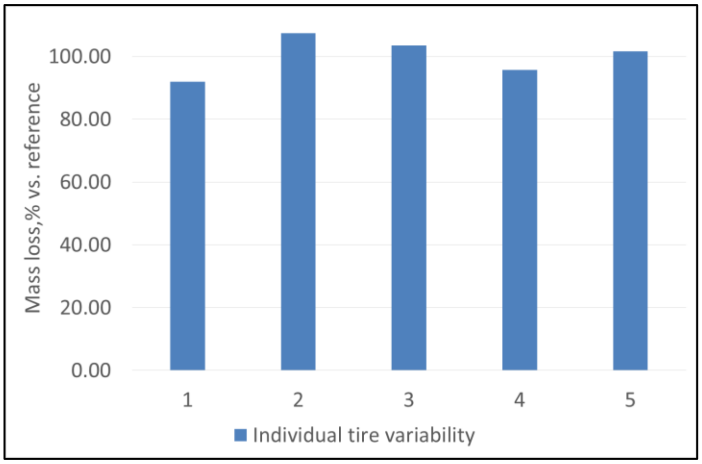


ii. Stone and tire variability

During the test campaign, it was possible to check the variability of the results due to both stones and tires. As these elements are never physically the same, they may introduce some variation in the test results.
For stone variability, same physical tire was tested several times. The results relative to a reference are shown in the chart. The average of the results was 92.72% and the standard deviation was 2.45%, so stone variability has a low impact on overall results:

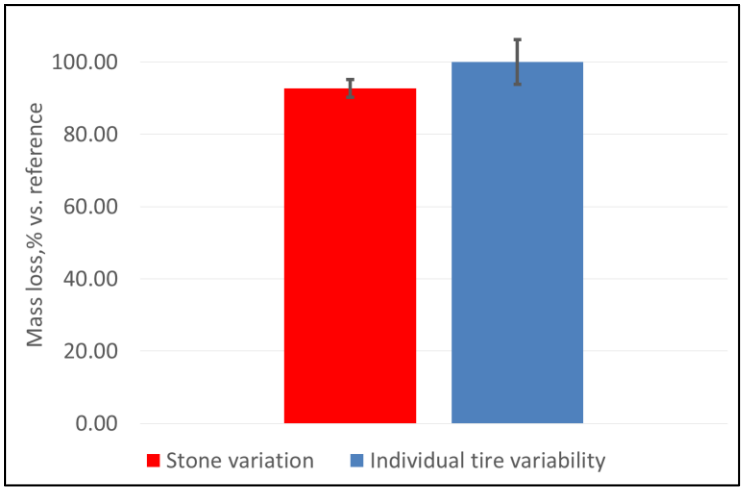


Regarding the tires variability, different physical tires of the same model were tested under similar conditions. Considering the reference of 100% as average of the results, the standard deviation was 6.18%, which includes the 2.45% coming from the stone sample variability:



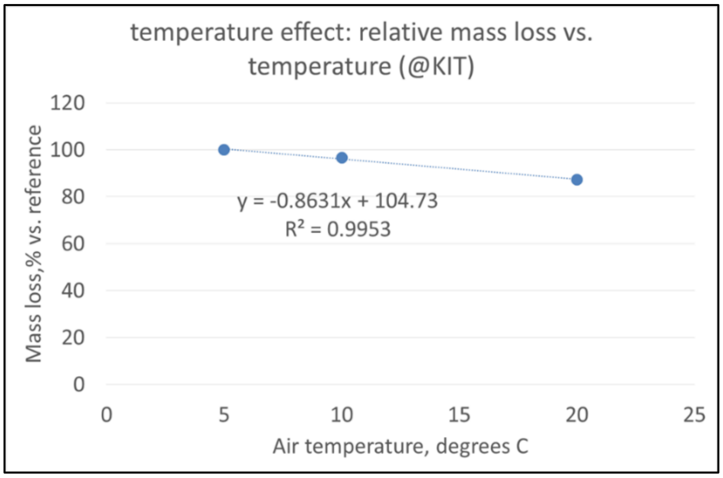
So, individual tire variability exists even under Lab conditions. The potential origin may be tire manufacturing variations.

With the results of these exercises, it is concluded that the variation caused by individual tires (6.18%) is higher than the variation caused by the test stone samples (2.45%):



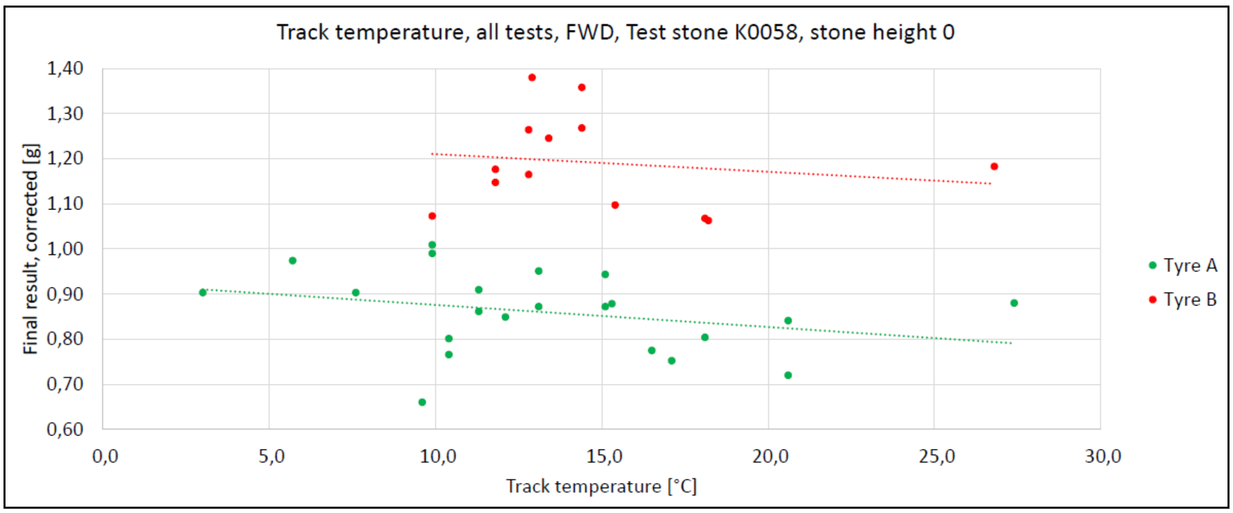
iii. Impact of air temperature

In the laboratory, it was possible to set a specific temperature during the test. The results of tests with same tire and method at 5°C, 10°C and 20°C showed that the measured temperature impact corresponds to -0.86% / °C (for KIT conditions):



So, as an initial conclusion, the temperatures of ambient air and ground seem to have an impact on the test results, but it would need further data to validate it.

2. Outdoor: Corrected results by track temperature



All comparable test results have been collected to determine the influence of temperature to test results. This diagram presents results of all task force tests performed during 2017, all laboratories with same type of vehicle, standard stone design and stone height set to 0 level, and for tire A and tire B. Tests results which have exceeded quality parameters or other test requirements (for example stud protrusion change…) except track temperature, have been excluded.

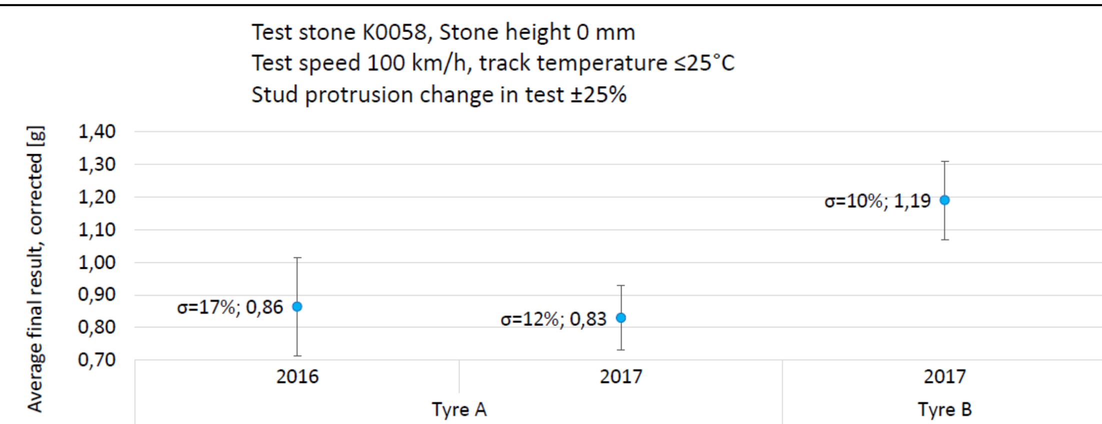
Trendline shows that higher track temperature could influence to lower road wear. Even though, track temperature is not directly influencing to the road wear, but indirectly influencing to one or more mechanisms influencing the road wear.

3. Outdoor: Corrected results by year

Round Robin tests were performed during 2016 and 2017 used same tire A, which could be used to compare total variation of tests after improvements for 2017. In addition, tests at 2017 used also tire B, with a slightly higher road wear.

2016 Round Robin tests total variance, including all laboratories, was 17% (13 measurements).

At 2017, same tire A was tested 19 times by task force participants with 12% of variance. Tire B was tested 10 times with total variance of 10%.

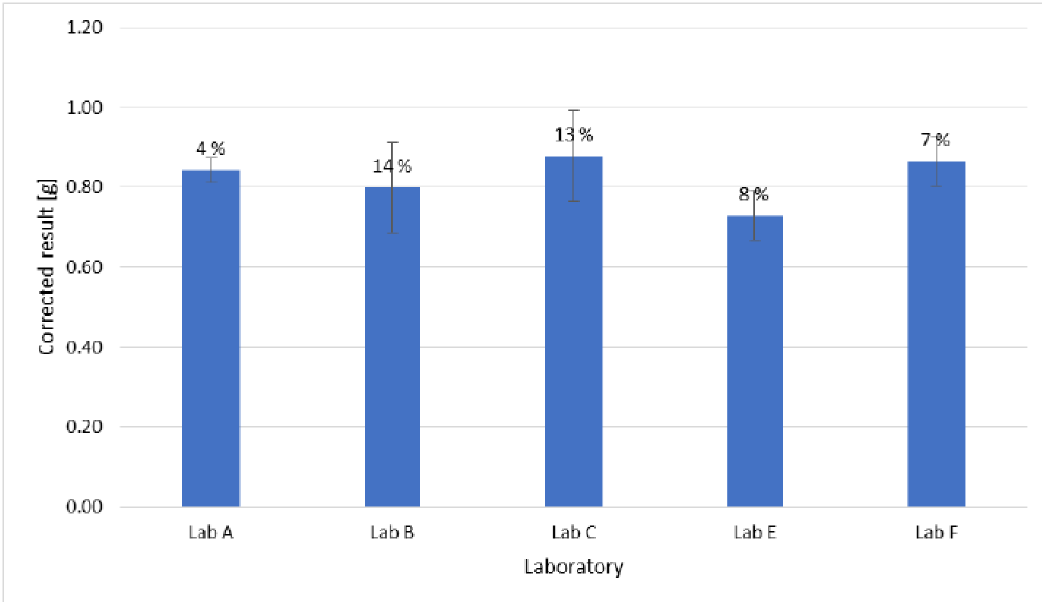


	2016 (Tyre A)	2017 (Tyre A)	2017 (Tyre B)
Average result, corrected	0,86	0,83	1,19
StdDev of result	0,15	0,10	0,12
Count of measurements	13	19	10

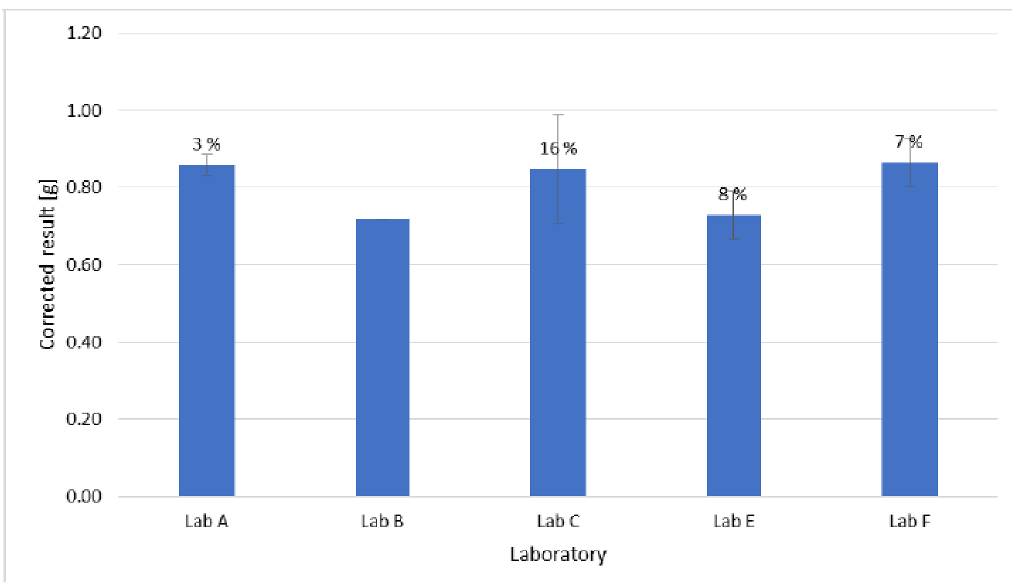
Based on the data shown in above diagram, the actions of the Task Force group have decreased total variability of the test method.

4. Outdoor: Corrected results by lab

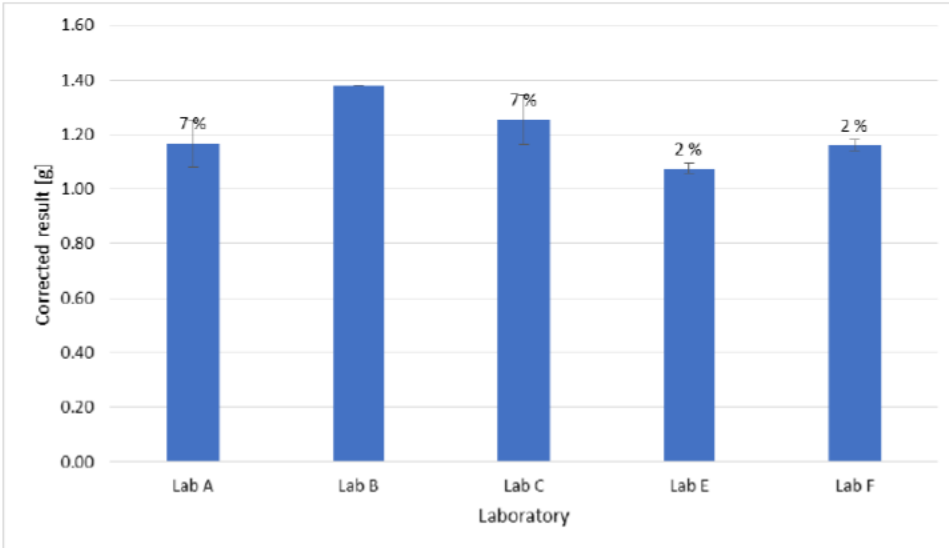
Based on Round Robin tests performed during 2017, it was also clear to analyze possible differences between laboratories, in this case with tire A and tire B. For the analysis, 2 different approaches were selected: 1st to include all test data and 2nd to include only those results which fulfill the required test parameters. It is to be highlighted that in this comparison, results represent both, laboratory and track, as all laboratories performed these tests on their own test tracks.



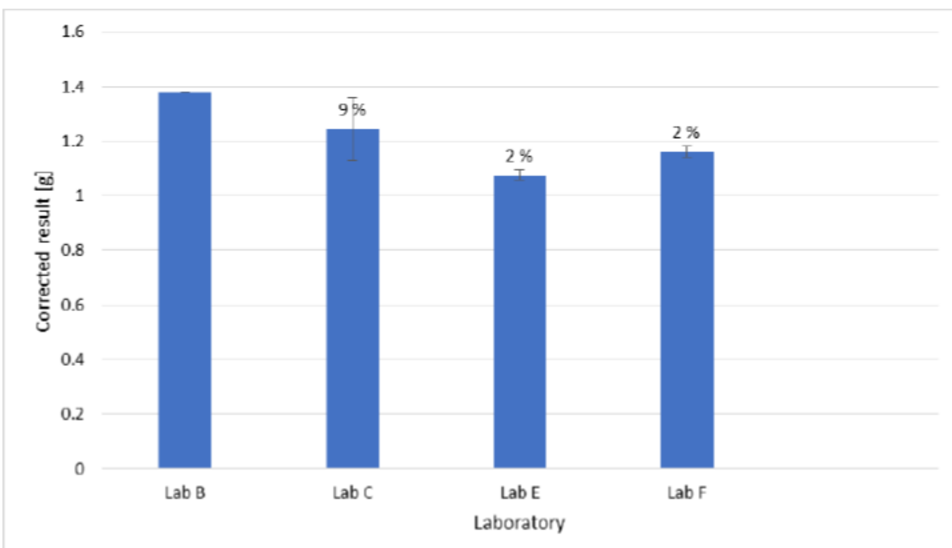
Data parameters: Tire A, Test Stone: K0058, Year 2017, Stone height 0mm, Test Speed 100km/h, Track temperature ALL, Stud protrusion change ALL.



Data parameters: Tire A, Test Stone: K0058, Year 2017, Stone height 0mm, Test Speed 100km/h, Track temperature ≤25°C, Stud protrusion change ±25%.



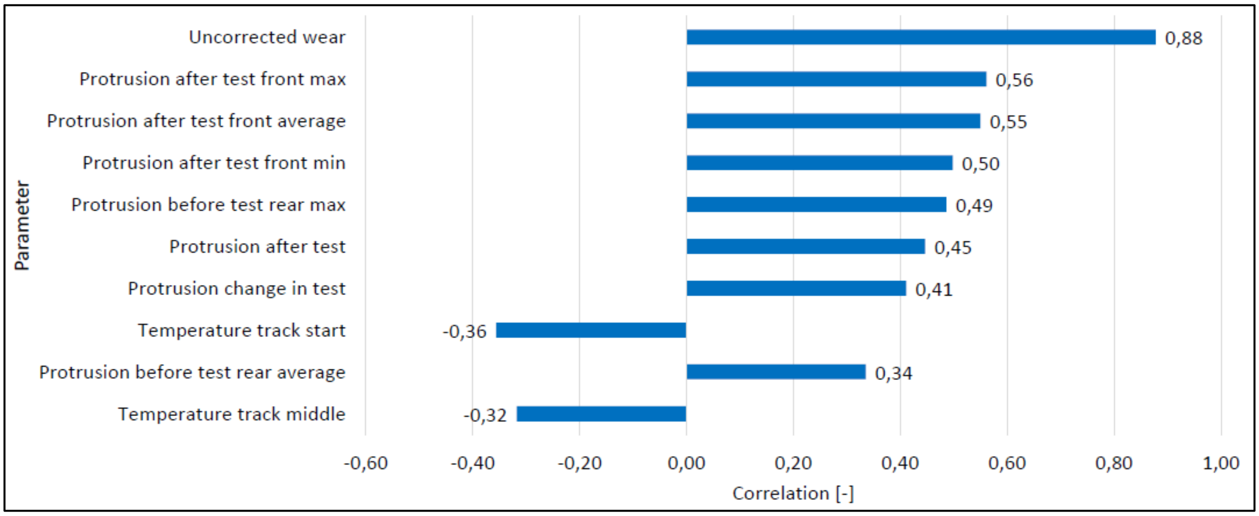
Data parameters: Tire B, Test Stone: K0058, Year 2017, Stone height 0mm, Test Speed 100km/h, Track temperature ALL, Stud protrusion change ALL



Data parameters: Tire B, Test Stone: K0058, Year 2017, Stone height 0mm, Test Speed 100km/h, Track temperature ≤25°C, Stud protrusion change ±25%. Laboratory A could not perform test for tire B with the parameters within the required criteria, therefore it was excluded from last diagram.

5. Outdoor: Top 10 correlations

All measurement parameters were examined to find undetected effects. The parameters' correlation to the corrected final result was calculated to rank their linear relationships. The highest absolute correlations have the strongest linear dependency. The inspection was constrained to Tire A with relative stone height of 0mm.

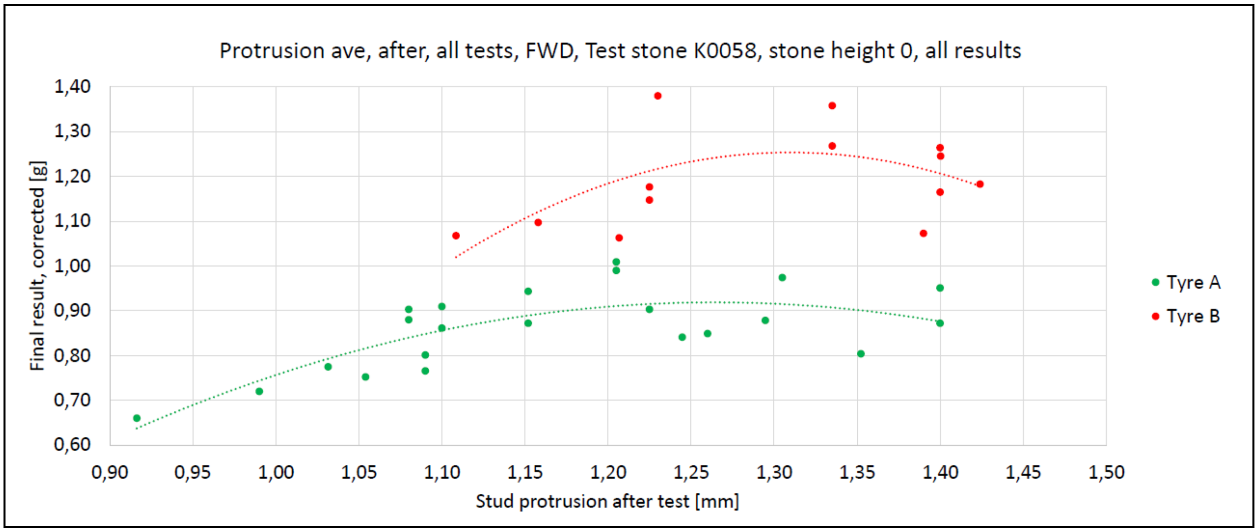


As expected, the highest absolute correlation was found with uncorrected result. Increasing the uncorrected final result increases the corrected final result. Well below this reference level were several parameters related to the stud protrusion. Increasing stud protrusion increases the corrected final result. The third largest effect were various measures for track temperature.

According to this inspection, either most of the variables are independent or they are non-linear. There were no unexpected parameters with exceedingly high absolute correlation.

6. Outdoor: Effect of stud protrusion

Stud protrusion was identified as one of the potential influencers of road wear and therefore also as potential cause of variation. In the overrun test method, stud protrusion is measured 2 times, before the test (new tire) and after the test. Trafi have defined a quality criteria for acceptable change of stud protrusion (±25%.) This was also clearly visible based on correlation analysis.



Based on the trendline for both, tire A and tire B, can be expected that average stud protrusion have correlation for road wear, but it is not linear influence. Higher protrusion increase road wear up to certain limit and then after that limit, higher protrusion decreases road wear.

Mechanism for this is dependent to tire-stud combination and will variate for each tire. It is likely that other parameters, such as temperature, track, driver, etc., have influence to this mechanism but it is difficult to analyze how strong the influence is.

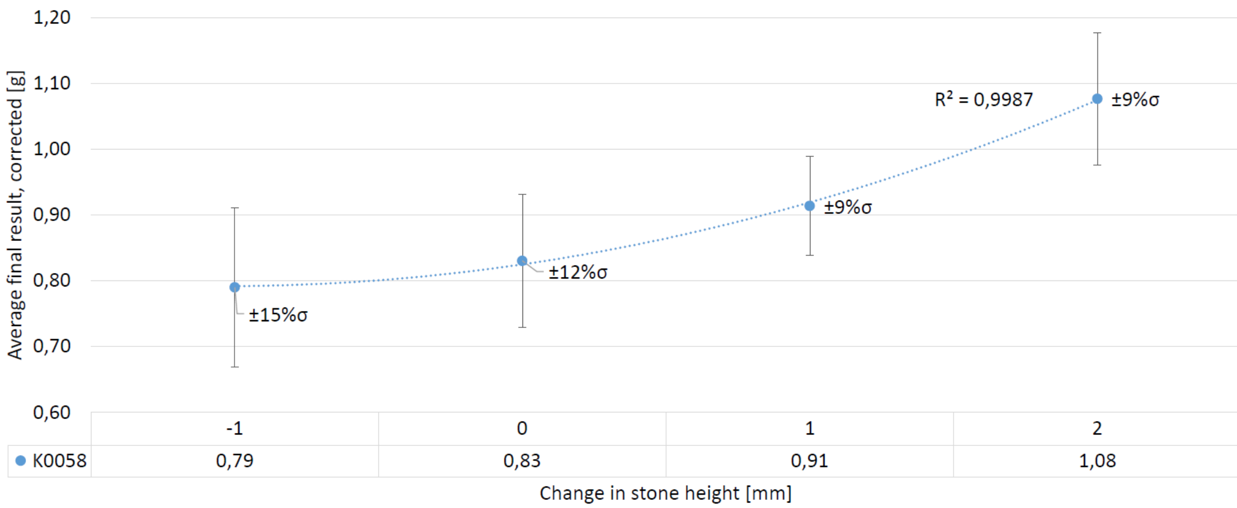
Based on correlation analysis, track temperature has inversely correlation to road wear. It is also studied that temperature have influence to stud force.

All these parameters can be expected as general function of studded tire, but as it is a combination of stud and tire design, it is different for individual design.

7. Outdoor: Corrected results for K0058, effect of the height of the stone

The level of the stones respect to the track was considered as a potential influencing parameter. This parameter was initially considered previously in the investigation of 2016 *"Influence of the height of the test stones"*. A round Robin test was carried out among the different laboratories with same stones, same tires and same type of vehicle. The frames were prepared with different configurations: The stones were raised adding sims of different thickness under the stones. Like this, the level of the stones was set at -1 mm, 0 mm, +1 mm and +2 mm respect to the frame level.

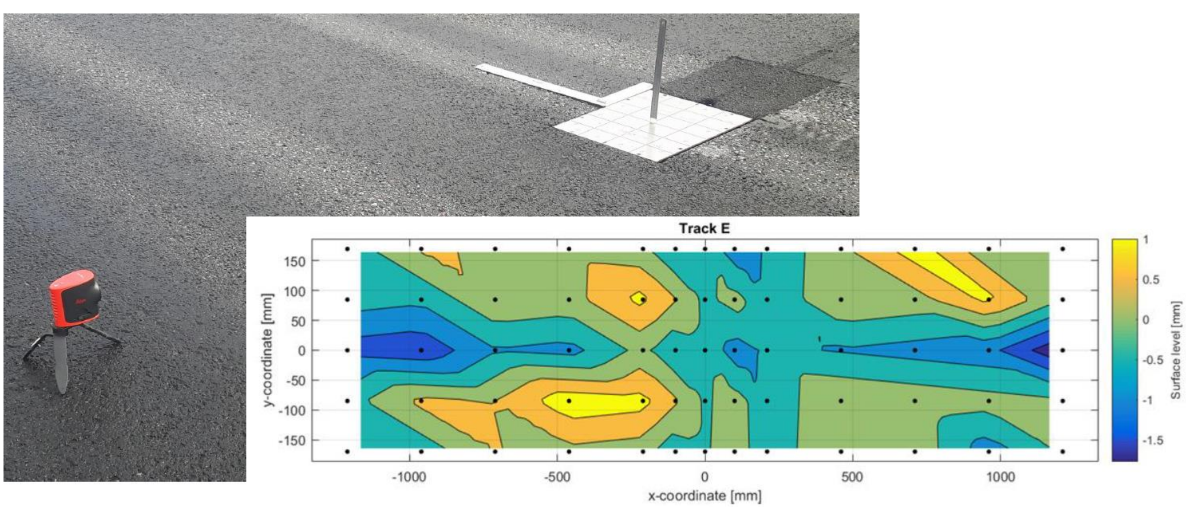
The laboratories performed several tests, and the average results are shown as follows:



The stones at higher level presented a higher result, so there is a relation between the level of the stones and the mass loss. Task Force suggested to develop a method to measure frame (and stone) position in relation to surrounding ground.

8. Outdoor: Track measurements

The track surface level was measured using a laser and a probe on 6 different tracks. The point heights were measured at specific locations on a grid. The measurement grid included points on the test stone frame and in front and back of the frame. The frame point measurements were used to fit a plane in space. Then the rest of the point measurements were compared to this ideal plane. These residual differences can be used to judge the level and grooving of the track close to the stone frame. The measured tracks were level within 10mm. If the level is not within satisfactory levels, the track should be repaired.



d. Standardization

In parallel to all the investigations, the group has been writing a standard of the test. Started in 2016, this allows to write a more detailed description of the test method to avoid different interpretations of the current description and to align all laboratories. It was written with Kemesta Association, standards writing body for Finish Standards Association SFS. The method is called "*Road wear test of studded tyres*" in the standard.

4. CONCLUSIONS

After all these investigations, the following ideas can be assumed:

- The groove depth and width of the samples influence the mass loss.
- During the Over-run test, the studs are causing wear most commonly at sample edges.
- Weighing operations seems to be consistent if details are aligned.
- Drying conditions influence mass loss measurements (ventilation, capacity).
- Reproducibility can be further improved through technical alignment and more specific description of test method.
- It is not clear if watering of the complete track has influence on test result.
- The propulsion system of the vehicle could influence the mass loss. For certain tire sizes, it is difficult to find certain propulsion type.
- Influence of sample sourcing seems to be minor.
- Lower test speed produces lower wear result.
- Element wear is impact of the stud at high speed and stud scratch at low speed.
- Tire pressure may influence in test results.
- Vehicle load has minor influence in wear result.
- Samples wear increases with high number of tire passes.
- Stone variability has a low impact on overall results.
- Individual tire variability exists even under laboratory conditions.
-The variation caused by individual tires (6.18%) is higher than the variation caused by stone samples (2.45%).
- Temperature (air and track) is indirectly influencing to one or more wear mechanisms.
- Stud protrusion and track temperature are the parameters most correlated with test result. And other variables could be non-linear.
- There is a relation between the level of the stones and the mass loss.
- Test variation has been reduced with the actions implemented by the members of Task Force group.

5. RECOMMENDATIONS

Focus on technical alignment between test laboratories regarding the test method and test conditions. The current test method's accuracy can be significantly improved by more specific description of test method and test conditions, and elimination of identified sources of variation.

The recommendations already implemented are:

- A standardized report and a template for the calculation of the correction format proposed by Trafi to prevent different interpretations are already used.

- All laboratories have the same retention system of the stones during the overrun passes (same frame).

- All laboratories keep stone geometry Labra-0058 from the same supplier as the test stone.

- All laboratories agreed to always use the full capacity of the drying ovens.

- All samples are positioned in the oven in a way that unites maximum ventilation and stable positioning.

- The process of method standardization is started.

Additionally, it is recommended to consider the following points:

- Once more influencing factors are detected, the test method description should be further elaborated to specify test conditions in an even more detailed manner.

- Continue open dialogue between Task Force members and Trafi. The Task Force is open for other administrations to join as observers.

- Harmonization of legislation related to stud type approval for all Nordic countries.

- The test method should be feasible and the description needs to allow a realistic practice of the method.

- Reference stone correction should be changed to use maximum 0.025% instead of failing the test if reference stone correction is exceeded.

- Acceleration limit should not be considered, as the stud protrusion rules limit the acceleration.

- The worst-case tire approach is recommended, as R117 for other approvals, instead of testing three tires for the categories of a tire family.

- In case there are significant changes in legislation or test method, the tire industry will need a sufficient lead time to implement the required changes.