Notitie

Oude Waalsdorperweg 63
2597 AK Den Haag
P.O. Box 96864
2509 JG The Hague
The Netherlands

www.tno.nl

T +31 88 866 10 00
F +31 70 328 09 61

To
Cyrus Infra Engineering

From
G.B. Derksen

Subject
Round Robin Test FAP 2013

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Our reference
TNO-060-DHW-2014-00335

E-mail
giljam.derksen@tno.nl

Direct dialling
+31 88 866 63 49

Introduction

This memorandum contains the evaluation of the **Friction After Polishing (FAP) Round Robin Test of 2013.**In this study, 9 laboratories received 6 asphalt cores in order to determine the friction coefficient. These coefficients were calculated after 90, 135, 180, 225 and 270 thousand polishing passes. The cores were taken from two types of porous asphalt (PA), three from PA 16 and three from PA 8. Descriptions of how this FAP test was carried out and how the measurements were converted into FAP values can be found in [1]. In general, the calculation boils down to the following, see Section 8 "Calculation and expression of the results" of [1]

> *The mean value of the friction coefficient of the fitted graphs at 60 km/h shall be taken as the measuring result* μ_m
> *The measuring results obtained from the control plate before and after the friction measurement shall be averaged* μ_{km}
> *The laboratory skid resistance* μ_{PWS} *for the sample, corresponding to a control surface with a grip value of* μ_{ref}*, results in the following*
> $$\mu_{PWS}=\mu_m-\mu_{km}+\mu_{ref}$$
> *The test result PWS is the average calculated from at least two individual measurements. If the difference between two individual results is greater than 0.03 the test is invalid and an additional sample shall be tested. This additional result shall be averaged with the closer initial result. The result PWS is given to an accuracy of two digits after the comma.*

The input for the evaluation of the Round Robin Test is comprised of the μ_m(FAP[…]) values and the measurements on the control plates (μ_{km}), see appendix 1[1)].

This evaluation will examine the calculation of test values and the determination of method reproducibility depended on road surface type and number of polishing passes. A manner in which the references plates may be further used as a quality parameter will also be indicated.

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1) Different laboratories reported the data using varying numbers of decimal places, prevalently 3 or 4 decimals.

Control plate (μ_{km})

A part of the procedure involved a control plate, which was measured twice; once prior and once subsequent to the various FAP determinations of a core. The purpose was to correct any temporary distortion.
Figure 1 lists the average FAP values for each core in relation to the average values from the control plates. Assuming that the material is "identical", a relationship must exist between these variables. Measurement of a high or low FAP value may be explained by a correspondingly high or low control measurement. This methodology enables correction of systematic differences. The figure reveals that no clear relationship exists between the FAP values and the control plates.

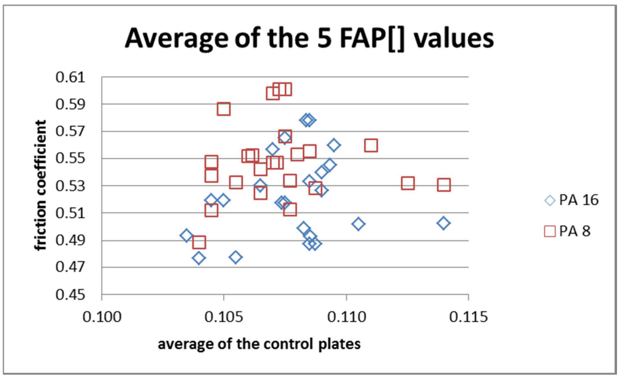

Figure 1: Average FAP[ ] values and the control plates for each core taken from road surfaces types ZOAB 0/16 and ZOAB 4/8

The averages of the FAP values, the reference values and the corrected FAP values are calculated for each laboratory. The results are presented in table 1, which lists the laboratories in the order of the relevant measurement. The included tables reveal that differences among the labs with regard to the control plate is small in relation to the differences in FAP values. In other words, the corrective effect of the control plates is minimal.

Lab	average of all FAP values	Lab	average of the plates	Lab	corrected
7	0.4973	7	0.1047	7	0.3926
4	0.5165	2	0.1048	4	0.4038
3	0.5186	8	0.1069	3	0.4102
2	0.5234	9	0.1075	2	0.4187
1	0.5452	6	0.1075	1	0.4359
6	0.5472	5	0.1076	6	0.4397
9	0.5472	3	0.1084	9	0.4397
8	0.5488	1	0.1094	8	0.4419
5	0.5658	4	0.1128	5	0.4582

Table 1: Average FAP values of bore cores, control plates and corrected values in relation to the laboratory number

Conclusion

The effect of the control plate is negligible.

Points for consideration
It may be that the use of control plates is counter-productive, requiring additional measurements while no relationship exists between the plates and the FAP values. These additional measurements introduce additional noise.

Use of the control plate as quality parameter

Normally, the control plate is only used as a corrective term. It can, however, also be used to investigate if

1) something has gone wrong during testing of a core at any of the laboratories participating in the Round Robin Test
2) the circumstances with regard to the situation changes during the study. Such changes can be further differentiated on the basis of:
   a. one control measurement and, more precisely, the one performed prior to determination of the FAP values
   b. two measurements, the average of the control measurements before and after the determination of FAP values.

The procedures for these 3 tests are based on the standard deviation of an individual measurement of the control plate.
Since 8 to 12 measurements of control plates are made in each laboratory, an analysis of variance makes it possible to estimate the standard deviation of the control plate measurements. Such an analysis yields a residual variance of $2.3*10^{-6}$ (85 degrees of freedom), which means that the sigma value of a single control plate measurement equals $1.5*10^{-3}$, resulting in a reproducibility (R) of $4.2*10^{-3}$.
The procedures for the 3 tests are consequently as follows:

1) Problems during performance of the test.
   Calculating the difference between the control plate measurements before and after the FAP test. If the absolute value of this difference is larger than reproducibility of 0.004, it is then demonstrated with 95% confidence that the difference in not 0. For 99% confidence, this value is 0.006.
2) Differences with regard to the situation during the Round Robin Test.
   a. Calculate the difference between the measurement of the control plate prior to the FAP test and the average from the relevant lab during the Round Robin Test (see table 1). If the absolute value of this difference is larger than 0.003, it is then demonstrated with 95% confidence that the difference in not 0. For 99%confidence, this value is 0.005.
   b. Calculate the difference from the average control plate measurement before and after the FAP test and the average from the relevant lab during the Round Robin Test (see table 1). If the absolute value of this difference is larger than 0.002, it is then demonstrated with 95% confidence that the difference in not 0. For 99%confidence, this value is 0.003.

Use of the reference value (μ_{ref})

According to the procedure, a second correction must occur (uniformly applicable to all labs) after the correction for the control plates by means of a reference value $\mu_{ref.}$ Given that this value is the same for each laboratory, it is, from a theoretical perspective, not relevant in the context of a Round Robin Test. After all, a Round Robin Test examines differences between the laboratories.

Points for consideration

In practice, the use of the reference value μ_{ref} may have an impact on reproducibility as a result of the above-mentioned rounding procedure.
μ_{ref} is certainly of importance if the aim is to use an absolute FAP value. The question is what this reference value must be. It seems reasonable that μ_{ref} must lay in the order of magnitude of the control plates so that the corrected value does not deviate too much from the measurements.

Determining reproducibility

The final result of an FAP measurement is the average of 2 cores. In this Round Robin Test, each laboratory investigated 2 or 3[2)] cores from both PA 16 and PA 8. According to the definition of an FAP result, each laboratory provided only 1 measurement for each type of PA. The variation between labs is then the variation between labs including measurement error. Under this study design, it is not possible to obtain an estimate of the pure measurement error. This would have been possible if each laboratory had received 6 cores of each PA type, but would have also required a doubling in the number of required cores and measurement effort.
The variance S2 between the lab averages constitutes the basis for estimating reproducibility (R). The results for the 2 asphalt compounds are presented in table 2. These variables were calculated with and without taking the control plates into account. In these calculations,

- there is no correction by means of μ_{ref} because
    - an accepted reference value μ_{ref} is missing.
    - μ_{ref} is not really necessary for calculation of reproducibility.
- All provided measurements are first rounded to 2 decimals.

Conclusion

Reproducibility is lower (but not significantly) for uncorrected control plates than for corrected ones.
Reproducibility for the 2 types of road surface are not significant different
Reproducibility for the 2 the various FAP levels are not significant different
Average reproducibility R is 0.070

[2)] It appears that some of the laboratories normally test 3 cores, regardless of the fact that the testing of just 2 cores would have been sufficient.

	including plates				without plates			
	PA 16		PA 8		PA 16		PA 8	
	S^2	R	S^2	R	S^2	R	S^2	R
FAP[90]	0.00080	0.080	0.00053	0.065	0.00049	0.062	0.00064	0.072
FAP[135]	0.00064	0.071	0.00071	0.075	0.00060	0.069	0.00035	0.053
FAP[180]	0.00088	0.084	0.00074	0.077	0.00070	0.075	0.00060	0.069
FAP[225]	0.00065	0.072	0.00055	0.067	0.00056	0.067	0.00064	0.071
FAP[270]	0.00070	0.075	0.00049	0.062	0.00062	0.070	0.00048	0.062
avg	0.00073	0.077	0.00060	0.069	0.00059	0.069	0.00054	0.066

Table 2 Variances (S^2) among laboratories and reproducibility (R) for the Friction after Polishing test as a function of road surface type, number of polishing passes and the use of control plates.

References

[1] CEN/TC 227 (2011-3), prEN 12697-49:2011. Bituminous mixtures – Test methods for hot mix asphalt- Part49: Determination of Friction After Polishing

[2] ISO 3534-1; 1993. Statistics -Vocabulary and symbols- Part 1: Probability and general terms.

Appendix 1: data round robin test FAP 2013

laboratory number	Type of asphalt	core	controle plate before	FAP[90]	FAP[135]	FAP[180]	FAP[225]	FAP[270]	controle plate after
1	PA 16	1	0.1090	0.5630	0.5410	0.5390	0.5290	0.5260	0.1090
1	PA 16	2	0.1100	0.5410	0.5350	0.5230	0.5190	0.5150	0.1080
1	PA 8	1	0.1090	0.5650	0.5600	0.5570	0.5500	0.5450	0.1080
1	PA 8	2	0.1100	0.5670	0.5660	0.5600	0.5560	0.5480	0.1120
2	PA 16	1	0.1040	0.5400	0.5270	0.5180	0.5060	0.5040	0.1060
2	PA 16	2	0.1050	0.5220	0.5260	0.4980	0.5290	0.5200	0.1040
2	PA 16	3	0.1030	0.4950	0.4940	0.4980	0.4890	0.4920	0.1040
2	PA 8	1	0.1030	0.5400	0.5410	0.5390	0.5350	0.5310	0.1060
2	PA 8	2	0.1040	0.5490	0.5580	0.5480	0.5420	0.5400	0.1050
2	PA 8	3	0.1060	0.5370	0.5190	0.5270	0.5200	0.5190	0.1070
3	PA 16	1	0.1105	0.5725	0.5496	0.5413	0.5357	0.5277	0.1082
3	PA 16	2	0.1096	0.5102	0.4998	0.4917	0.4843	0.4775	0.1074
3	PA 16	3	0.1100	0.5105	0.5075	0.4982	0.4915	0.4850	0.1065
3	PA 8	1	0.1067	0.5446	0.5419	0.5347	0.5277	0.5202	0.1088
3	PA 8	2	0.1096	0.5413	0.5351	0.5279	0.5219	0.5153	0.1079
3	PA 8	3	0.1089	0.5275	0.5189	0.5107	0.5065	0.5007	0.1065
4	PA 16	1	0.1150	0.5020	0.5160	0.4980	0.4970	0.4980	0.1130
4	PA 16	2	0.1090	0.5050	0.5190	0.4940	0.4980	0.4930	0.1120
4	PA 8	1	0.1120	0.5380	0.5360	0.5340	0.5220	0.5290	0.1130
4	PA 8	2	0.1130	0.5380	0.5360	0.5310	0.5220	0.5250	0.1150
5	PA 16	1	0.1070	0.5520	0.5370	0.5290	0.5270	0.5210	0.1100
5	PA 16	2	0.1080	0.5840	0.5760	0.5670	0.5530	0.5440	0.1070
5	PA 16	3	0.1100	0.5850	0.5720	0.5550	0.5490	0.5360	0.1090
5	PA 8	1	0.1100	0.5920	0.5530	0.5430	0.5410	0.5350	0.1060
5	PA 8	2	0.1050	0.6170	0.5990	0.5970	0.5930	0.5840	0.1090
5	PA 8	3	0.1040	0.6160	0.6030	0.5800	0.5720	0.5610	0.1060
6	PA 16	1	0.1079	0.5937	0.5857	0.5726	0.5740	0.5651	0.1088
6	PA 16	2	0.1104	0.5244	0.4979	0.4782	0.4694	0.4672	0.1071
6	PA 16	3	0.1067	0.5313	0.5234	0.5157	0.5114	0.5067	0.1080
6	PA 8	1	0.1084	0.5480	0.5546	0.5519	0.5429	0.5370	0.1059
6	PA 8	2	0.1063	0.5789	0.5623	0.5545	0.5382	0.5267	0.1060
6	PA 8	3	0.1055	0.5956	0.6083	0.6065	0.6025	0.5922	0.1090
7	PA 16	1	0.1040	0.4990	0.4910	0.4690	0.4660	0.4580	0.1040
7	PA 16	2	0.1060	0.4970	0.4890	0.4770	0.4750	0.4480	0.1050
7	PA 8	1	0.1070	0.5600	0.5410	0.5350	0.5150	0.5110	0.1040
7	PA 8	2	0.1060	0.5010	0.5010	0.4860	0.4810	0.4740	0.1020
7	PA 8	3	0.1060	0.5330	0.5270	0.4960	0.5030	0.5000	0.1030
8	PA 16	1	0.1070	0.5470	0.5400	0.5300	0.5200	0.5130	0.1060
8	PA 16	2	0.1070	0.5780	0.5680	0.5570	0.5450	0.5350	0.1070
8	PA 8	1	0.1060	0.5600	0.5470	0.5380	0.5360	0.5290	0.1070
8	PA 8	2	0.1090	0.5800	0.5790	0.5710	0.5560	0.5460	0.1060
9	PA 16	1	0.1080	0.5940	0.5860	0.5730	0.5740	0.5650	0.1090
9	PA 16	2	0.1100	0.5240	0.4980	0.4780	0.4690	0.4670	0.1070
9	PA 16	3	0.1070	0.5310	0.5230	0.5160	0.5110	0.5070	0.1080
9	PA 8	1	0.1080	0.5480	0.5550	0.5520	0.5430	0.5370	0.1060
9	PA 8	2	0.1060	0.5790	0.5620	0.5540	0.5380	0.5270	0.1060
9	PA 8	3	0.1060	0.5960	0.6080	0.6070	0.6030	0.5920	0.1090