REPEATABILITY AND REPRODUCIBILITY OF WHEEL-TRACKING TESTS

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ABSTRACT
All the European standards on asphalt products specify the requirement of resistance to permanent deformation. This parameter has to be determined by using the equipment and applying the methods identified in standard EN 12697-22:2003+A1:2008 entitled "Rutting". The Hungarian requirements on asphalt products derived from the European standards on asphalt products also specify resistance to permanent deformation. In Hungary, the test is carried out with a small-wheel equipment, method B at 60 °C air according to EN 12697-22:2003+A1:2008. Unfortunately, the European test standard fails to provide accuracy figures for this test procedure.
In order to conform to the requirement values and interpret the test results, it was important to determine the repeatability and reproducibility of the results obtained with the equipment we use in Hungary. 15 laboratories in Hungary have small-wheel equipment. In order to determine the repeatability of the results, all the involved laboratories used their own compacting equipment to prepare laboratory samples of AC 22, AC 11 and SMA 11 type asphalt mixes produced with regular and modified bitumen. The laboratories repeated the tests on the same asphalt mixes at least 21 times. The tests were also performed on laboratory samples to determine the reproducibility of the results. On one occasion, one of the laboratories produced the specimens required for all the tests and delivered them to the other laboratories. On another occasion, all the laboratories made specimens from the same asphalt mix, which in turn were tested at one of the laboratories.
The presentation elaborates on the test results obtained through the various methods applied, the assessment of the test results and the conclusions drawn.

Keywords: mechanical properties, wheel-tracking test, testing

1. INTRODUCTION

Hungarian road specifications on asphalt mixes [1, 2, 3] are based on the European asphalt product standards [4, 5, 6]. Permanent deformation is a specification in European asphalt product standards, therefore, the same requirement is also representative of Hungarian road specifications. Hungarian specifications provide requirements for the PRD_{AIR} parameter with respect to type tests. Type tests usually begin by laboratory validation [7]. Clients' laboratories frequently check the properties determined in type tests, therefore, permanent deformation as well. Clients also frequently demand wheel-tracking tests to be carried out on asphalt mixes produced in mixing plants or the samples taken from built asphalt layers. In such cases test results may not always fulfil the requirements. In Hungary, the test is carried out with a small-wheel equipment, method B at 60 °C air according to EN 12697-22:2003+A1:2008. Unfortunately, the European test standard fails to provide accuracy figures for this test procedure. At the same time, the disputes with clients over inadequate results often raise the question of the reliability of the test procedure applied, namely what extent does the inaccuracy of the test method influences the deviation in the test results and to what extent can we attribute the test results to the actual quality defect of the material or the structure constructed. In order to answer this question under Hungarian conditions, ÚTLAB Association involving Hungarian road construction laboratories organised a wheel-tracking round robin test. The test results of the round robin tests are summarised below.

2. ORGANIZATION OF ROUND ROBIN TEST

There are 11 laboratories in Hungary that have small wheel-tracking equipment, which are made in Germany or in England. The wheel-tracking test is carried out with a small-wheel equipment, method B at 60 °C air according to EN 12697-22:2003+A1:2008. The test specimen are compacted by a roller compactor in compliance with the specifications in Chapter 7.2.4.2 of EN 12697-33:2003 +A1:2008 [9]. The compacting equipment available were manufactured in Hungary, Germany or England.

We organised the round robin tests in order to ascertain the reliability of the wheel-tracking tests performed in Hungarian laboratories. In the first series of round robin tests, one laboratory produced all the test specimens from an asphalt mix manufactured at the mixing plant, then distributed them among the 11 laboratories for testing. We examined the reliability of the wheel-tracking equipment with this test series. In the second series of round robin tests, there were 8 laboratories that ventured to produce 4-4 test specimens from the same asphalt mix manufactured at a mixing plant. After that, two laboratories tested all the test specimens independently from each other. We examined the reliability of the test specimen production equipment with this test series.

We performed the third round robin test to verify the reliability of laboratories for repeatability. The laboratories participating in the round robin tests performed at least 20 tests on each of the three types of asphalt mixes manufactured at a mixing plant.

3. TEST RESULTS

In the first round robin test, one laboratory used a roller compactor to prepare test specimens according to Chapter 7.2.4.2 of EN 12697—33:2003 +A1:2008 from AC 11 wearing (F) 50/70 and SMA 11 wearing (mF) 25/55-65 asphalt mixes manufactured in a mixing plant. The test specimen slabs were 4 cm thick, and the thickness deviation of all manufactured samples were within 1 mm for both asphalt mixes. The bulk density of all test specimens measured by method B of EN 12697-6:2003+A1:2008 [10] showed a deviation of 0.7 % for the AC 11 wearing (F) 50/70 mix and that of 0.8 % for the SMA 11 wearing (mF) 25/55-65 mix. The laboratories participating in the round robin test received 2 pieces of each specimen with possibly identical bulk densities, or a bulk density deviation of maximum 0.1 %.

Figure 1 presents the test results of round robin test. The PDR_{AIR} values in the diagram represent the mean of two tests for each laboratory.

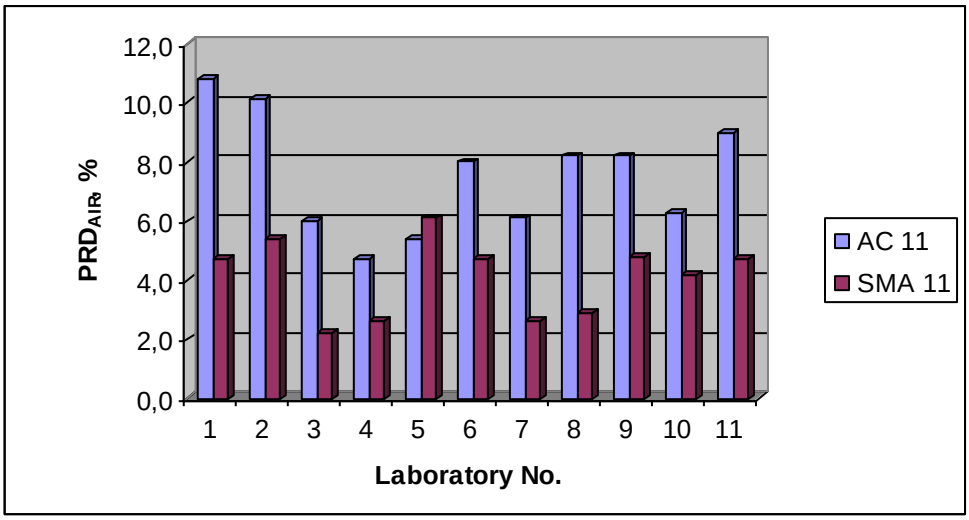

Figure 1: Wheel-tracking results of the tested asphalt mixes

Figure 1 shows that laboratory No. 1 had the highest result and laboratory No. 4 had the lowest result for the AC 11 mix, while laboratory No. 5 had the highest result and laboratory No. 3 had the lowest result for the SMA 11 mix. Table 1 summarises the means and the deviation of the test results. Table 1 shows that deviation expressed in % of mean of PRD_{AIR} is quite high for both asphalt types, so for that reason we omitted the results of the laboratories with extreme results and recalculated the means and deviation. The results are also indicated in Table 1 below. The results were somewhat favourable after the recalculation.

Table 1: Mean and deviation of PRD_{AIR} values

Type of mix	PRD_{AIR} mean value,%	Standard deviation, %	Deviation % in mean of PRD_{AIR}	PRD_{AIR} minimum, %	PRD_{AIR} maximum, %
AC 11	7,5	2,0	27	4,7	10,8
SMA 11	4,1	1,3	32	2,2	6,1
Omitting extreme values					
AC 11	7,5	1,6	21	5,4	10,1
SMA 11	4,1	1,1	27	2,6	5,4

In the second series of round robin test, 8 laboratories tested an AC 11 wearing (F) 50/70 type asphalt mix after using their own compacting equipment to prepare 4-4 slabs. The samples were compacted by a roller compactor in compliance with the specifications in Chapter 7.2.4.2 of EN 12697-33:2003 +A1:2008. Laboratory No. 5 tested two and laboratory No. 6 tested the other two of the 4-4 samples. Both laboratories use a wheel track equipment of the same product. The samples tested were 4 cm thick with a deviation of thickness below 1 mm. The bulk density of the tested samples was within 1 %. Figure 2 presents the test results. The PDR_{AIR} values in Figure 2 represent the mean of two tests for each laboratory. It is clear from the diagram that no trend exists between the test results of the two laboratories. Table 2 presents the means and the deviations of the test results. The table clearly indicates that the means of both laboratories' results are identical, however, deviations are diverse. The results of laboratory No. 6 show greater deviations than those of laboratory No. 5.

The results of the two round robin tests reveal that if we minimise the two factors that influence the results of the wheel-tracking test, that is the uncertainty of preparing the test specimens and that of the test itself, then the mean of the deviation of the test results in percentage is around 30 %.

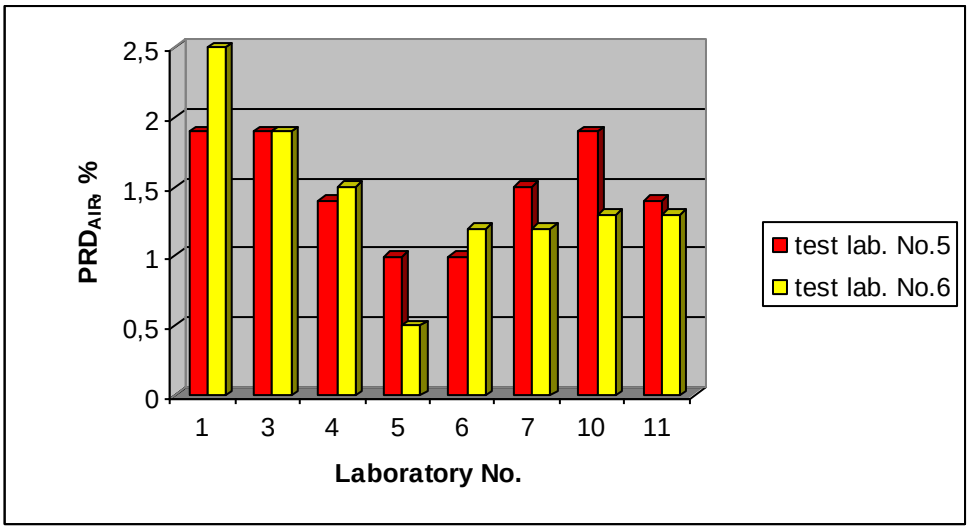

Figure 2: Wheel-tracking results of the AC 11 type mix

Table 2: Mean and deviation of the PRD_{AIR} values for AC 11 type mix

Test lab.	PRD_{AIR} mean value,%	Standard deviation, %	Deviation % in mean of PRD_{AIR}	PRD_{AIR} minimum, %	PRD_{AIR} maximum, %
No. 5	1,3	0,4	29	1,0	1,9
No. 6	1,3	0,6	44	0,5	2,5

Table 3: Test results of the third round robin test

Test lab.	No. I. AC 11 wearing (mF)25-55/65	No. II. AC 22 binder (mF)25/55-65	No. III. SMA 11 wearing (mF)25/55-65
	PRD_{AIR} mean value,%		
No.1	4,1	2,5	3,9
No.2	4,2	2,9	3,1
No.3	4,1	2,4	3,8
No.4	4,5	2,4	5,3
No.5	4,1	2,0	2,6
No.6	4,3	1,8	3,4
	Standard deviation, %		
No.1	0,37	0,32	0,45
No.2	0,68	0,45	0,32
No.3	0,51	0,23	0,61
No.4	0,43	0,24	0,53
No.5	0,39	0,25	0,20
No.6	0,54	0,41	0,53
	No. of tests		
No.1	20	20	20
No.2	68	54	60
No.3	20	20	16
No.4	20	62	60
No.5	20	20	20
No.6	20	20	20

The goal of the third round robin test, in addition to establish reproducibility between the various laboratories, was to gain information on the repeatability of the tests. Six laboratories were involved in the round robin test. Each laboratory performed 20 tests on three different asphalt mixes (AC 11 wearing (mF) 25-55/65, AC 22 binder (mF) 25/55-65, SMA 11 wearing (mF) 25/55-65) from mixing plants after preparing the slab specimens using their own compacting equipment in compliance with Chapter 7.2.4.2 of EN 12697-33:2003 +A1:2008, and performing the wheel-tracking test with its own small wheel equipment applying method B at 60 °C air according to EN 12697-22:2003+A1:2008. The deviation of the bulk density of the samples the laboratories tested was less than 1 %. The AC 22 test specimens were 8 cm, while the AC 11 and SMA 11 test specimens were 4 cm in thickness. The deviation between the thickness of the individual samples was less than 2 %.

Themeans and deviation of the round robin test results as well as the number of samples each laboratory tested are indicated in Table 3.
We used JCGM 104:2009 [11] to determine the deviation in the repeatability and reproducibility of the round robin test results. Table 4 summarises some mathematical statistical characteristics of the round robin tests without the intermediate calculations.

Table 4: Mathematical statistical characteristics

	No. I.	No. II.	No. III.	Mean
Mean value of round robin tests	4,2	2,3	3,7	3,4
Deviation of repeatability	0,56	0,34	0,45	0,45
Deviation of reproducibility	1,07	1,21	1,33	1,20
Deviation of repeatability in % of the mean	13	15	12	13
Deviation of reproducibility in % of the mean	25	53	36	35

Table 4 shows that the percentage value of the deviation in repeatability is the lowest for the SMA 11 mix and the highest for the AC 22 mix. The percentage value of the deviation in reproducibility is the lowest for the AC 11 mix, and the highest for the AC 22 mix. We note that all the tested mixes were made with modified bitumen and fulfilled the requirements on asphalt mix production tolerance under standard EN 13108-21:2006 [12]. Our experience shows that the test results of AC 11 mixes produced with regular 50/70 type bitumen show a higher repeatability deviation than those of mixes made with modified bitumen.

4. SUMMARY, CONCLUSIONS

We looked at the repeatability and reproducibility of the permanent deformation test under Hungarian conditions using method B at 60 °C air according to EN 12697-22:2003+A1:2008. There are 11 wheel-tracking units in operation in Hungary. The slab specimens required for the test are compacted by a roller compactor in compliance with the specifications in Chapter 7.2.4.2 of EN 12697-33:2003 +A1:2008. We organised three round robin tests to establish the reliability parameters of the test. In the course of the first round robin test, one laboratory produced all the samples and every participating laboratory tested 2 of each sample. The participating laboratories in the second round robin test produced 4 samples of each mix and two laboratories tested the two samples of each mix in tandem. The third round robin test ran in a manner that the involved laboratories carried out at least 20 tests on three types of asphalt mixes.
We used the results of the third round robin test to calculate the repeatability and reproducibility deviation of the tests. We can establish that both deviation values are subject to the type of the asphalt mix tested. We consider the reproducibility deviation values (12-15 %) obtained through analysing the test results realistic since we had sufficient data available to determine this parameter (altogether 560 tests). Nevertheless, reproducibility deviation values should be considered only for information purposes, because the number of involved laboratories and round robin tests was not sufficient to gather reliable values. We note, however, that the deviation of the first two round robin tests – minimising the inaccuracies of the wheel-tracking test and of producing the samples as far as possible – and reproducibility deviation values are relatively close to each other. The results obtained are very important for us so that we can estimate the fluctuation caused by testing inaccuracies when performing control tests that produce different results. In addition, we hope that our test results can also provide information for the upcoming revision of the EN standard on wheel-tracking testing.

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