Conférence Européenne des Directeurs des Routes

Conference of European Directors of Roads

DRaT – Development of the Ravelling Test

Factual report on test results

Deliverable 7

May 2017

Project Coordinator: TRL Limited, United Kingdom

Project Partners: The Netherlands Organisation for Applied Scientific Research
Belgian Road Research Centre, Belgium
BAM Infra Asfalt, Netherlands
Heijmans Integrale Projecten, Netherlands
IFSTTAR, France
Technische Universität Darmstadt, Germany
RWTH Aachen University, Germany

Call 2014: Asset Management and Maintenance

Development of the Ravelling Test

Deliverable 7 –Factual report on test results

Due date of deliverable: 31/03/17

Actual submission date: 31/05/17

Start date of project: 01/09/2015 End date of project: 31/08/2017

Author(s) this deliverable:

Joëlle De Visscher, BRRC, Belgium

Project coordinator: Matthew Wayman, TRL

PEB Project Managers: Arash Khojinian (HE) and Franz Bommert (BASt)

Version: 1

Executive summary

This report describes the work done within the scope of WP3 ‘Test program’ of the DRaT project. The objectives of WP3 were:

1. To provide detailed instructions for testing and reporting to the test labs.
2. To undertake the scuffing test on a range of asphalt mixtures using different devices.
3. To collect the test results and deliver the factual report.

The test program considered three variants of three asphalt mixture designs that are tested using six scuffing machines (two of two of the options and one each for the other two options) with four replicates of each combination of mixture, variant and test machine. All testing was undertaken on laboratory prepared samples, manufactured by BAM as part of WP2.

This report contains all data collected in WP3. After a short summary of the work done in WP 2, the instructions for testing and reporting test conditions and results are described. The instructions aimed at obtaining comparable results in a common format, to facilitate comparison and further processing of the data. All Excel test sheets, as filled out by the six participating labs, are added in annex 3.

The test conditions are checked for their compliance with the test specifications and suspicious test results are highlighted. It is concluded that the instructions were followed correctly and the test conditions mostly complied, except for a few cases where the test temperature was above the maximum limit. This may lead to systematically higher material loss, but such a systematic impact was not observed in the test data. In a few cases, the time between manufacturing and testing (10 weeks +/- 1 week) was exceeded. Since the specimens were all stored correctly at a temperature below 20 °C, it is not expected that there could have been any significant ageing in that period that would have an impact on the resistance to ravelling.

This report also contains graphs showing the evolution of material loss during testing. This shows different trends: in some cases, the rate of material loss seems to be more or less constant, while in other cases, the rate either increases or decreases.

The data are processed further, to identify any possible correlations between scuffing test results and other measured data, such as bulk density and surface texture of the samples. The data plots show no correlations, although it is known that less compacted samples and samples with an open textured surface are more susceptible to ravelling. The fact that this is not observed in the DRaT test data is explained by the extremely narrow range of density and texture depth within each series of samples. This confirms the high quality and repeatability of the manufacturing process used to prepare the samples in WP2.

The report does not include any interpretation or statistical data analysis, which is one of the aims of WP4.

Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

List of Tables

List of Figures

Table of content

1 Introduction

The transnational research programme "**Call 2014: Asset Management and Maintenance**" was launched by the Conference of European Directors of Roads (CEDR). CEDR is an organisation which brings together the road directors of 25 European countries. The aim of CEDR is to contribute to the development of road engineering as part of an integrated transport system under the social, economic and environmental aspects of sustainability and to promote co-operation between the National Road Administrations (NRA).

The participating NRAs in this Call are Belgium-Flanders, Finland, Germany, Ireland, Norway, the Netherlands, Sweden, United Kingdom and Austria. As in previous collaborative research programmes, the participating members have established a Programme Executive Board (PEB) made up of experts in the topics to be covered. The research budget is jointly provided by the NRAs who provide participants to the PEB as listed above.

Ravelling is a common mode of early failure for many types of asphalt pavement. Recently several simulative laboratory tests have been developed to give an indication of the ravelling potential of an asphalt mixture. These tests use scuffing machines that repeatedly apply a scuffing action to slab samples to replicate in service loading. The test methods for four such scuffing machines have been written up as a draft technical specification by Comité Européen de Normalisation (CEN) as prCEN/TS 12697-50, Resistance to scuffing. However, these methods need to be culled or combined so that there is only one (harmonised) test method for this one property before the technical specification can be converted into a test standard.

The CEDR-DRaT project looks at the methods of test and the results produced for the four scuffing machines in order to identify:

- The extent to which sample preparation needs to be standardised, such as compaction level, evenness, storage conditions and age when tested.
- The most effective method of measurement in terms of extent of differentiation, validity as a measure of ravelling and practicality.
- Whether the results from one or more scuffing machines can be validated from experience on site.
- Whether the results from different scuffing machines can be converted to a common measure.
- Estimates of the precision of the results with each scuffing machine or, if the results can be converted to a common measure, of the common measure.
- Whether the results from either pair of similar machines are comparable and their results are reproducible.
- A procedure to identify if other scuffing machines can be used for the standard test.

These findings may be the same for all asphalt mixture types or different for different types.

The evaluations will be made based on three variants of three asphalt mixture designs that are tested using six scuffing machines (two of two of the options and one each for the other two options) with four replicates of each combination of mixture, variant and test machine. All testing will be undertaken on laboratory prepared samples. The validation of the test methods will be sought by identifying how mixtures with each tested mix design have performed on site or in trials.

The overall objective is to provide advice on how to refine prCEN/TS 12697-50 to be an acceptable standard with a draft incorporating that advice.

The CEDR-DRaT project is organized in 5 Work Packages (see fig. 1). The test slabs are prepared by one single laboratory in WP2 ‘Sample preparation’ and sent to the different labs for testing in WP3 ‘Test program’. The output of WP3 is the collection of test results from the individual labs, to be used as input to WP4 ‘Analysis’.

This report describes the execution of WP3 ‘Test program’.

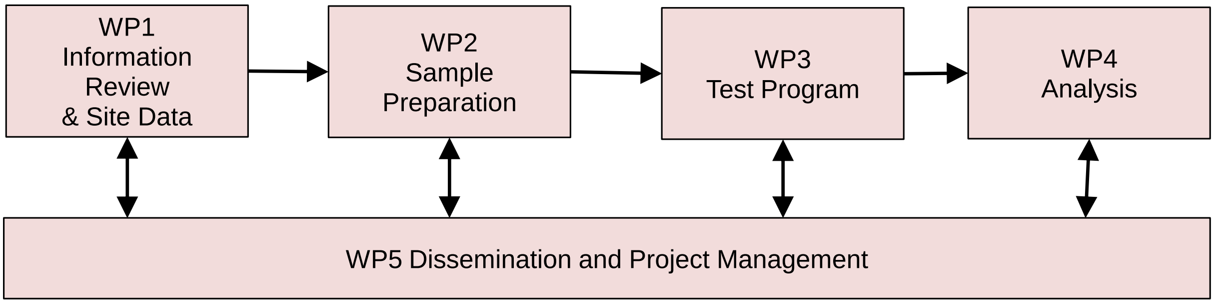


Figure 1 Project organization

2 Objectives of WP3

The objectives of WP3 ‘Test program’ are:

1. To provide detailed instructions for testing and reporting to the test labs.
2. To undertake the scuffing test on a range of asphalt mixtures using different devices.
3. To collect the test results and write the factual report.

Three subtasks were defined to reach these objectives, as described below.

2.1 Provide detailed instructions to the test labs

The detailed instructions are intended to accurately describe the test preparation, the test procedure, the reporting format and the timing, to make sure that every laboratory proceeds in the same way and obtain comparable results.

The test preparation includes identification upon reception, storage conditions before testing, measurement of the dimensions and mass and photographing before testing.

The test procedure describes the test conditions (temperature, load, number of cycles, measuring intervals, etc.) and the procedure for measuring scuffing and other related parameters, such as the surface temperature. The procedure is based on the outcome of WP1, where prCEN/TS 12697 50 has been reviewed, but it is more precise on some points (e.g. the test temperature) in order to obtain results that can be compared.

The instructions also specify the reporting format. This ensures the completeness of the reported data and facilitates further data processing. A report template was prepared and sent to the test labs for filling in their test results.

In addition to the test results, the labs are also asked to provide additional data related to the test method. For example, the surface loaded during the test is needed to determine the material loss per unit of surface area. Such requirements are also included in the instructions, to ensure that every laboratory determines these additional data in the same comparable way.

The timing of the test program is very important since all samples shall be tested at the same age. The testing of each sample was therefore scheduled on the basis of the date of manufacturing of the slab, depending on WP2.

2.2 Perform scuffing tests on different scuffing machines

This task consists of performing the tests exactly as described in the instructions provided. The test data and results are reported in the report template. Any deviations which may occur due to unforeseen situations, such as a technical problem, are reported, so that the impact on comparability, reproducibility, timing, etc. can be evaluated.

2.3 Report the test results

This report collects all the reported data and represents it in an orderly way. Any deviations or other important information that may have an impact or relevance for the interpretation are reported. The report will not include any interpretation or statistical data analysis, which is one of the aims of WP4.

3 Summary of work done in WP2

Three types of mixtures are considered in the test program:

- M1 : PA (Porous asphalt)
- M2 : BBTM (Béton bitumineux très mince)
- M3 : SMA (Stone mastic asphalt)

For each mixture type, three variants were considered (see Table 1). Variants 2 and 3 were intended to increase the susceptibility to ravelling, compared to the reference.

More details on the mix design are given in the report of WP2.

Table 1 Mix variants

Mix type	**Binder**	**Aggregate grading**	**1 - Reference**	**2 – lower compaction temperature**	**3 – lower binder content**
PA	B70/100	0/16 mm	Compaction at 150°C 5.2 % binder	Compaction at 110°C	4.2 % binder
BBTM	B50/70	0/6 mm	Compaction at 160°C 5.6 % binder; 12-19 % air voids	Compaction at 110°C	4.6 % binder
SMA	PMB with 3 % SBS polymer	0/11 mm	Compaction at 160°C 6.8 % binder; 3 % voids; fibres	Compaction at 110°C	5.5 % binder

Compaction of the slabs, verification of the quality and distribution of the samples to the different labs were all done by BAM in WP2. For details on the procedures, one is also referred to the WP2 report.

Manufacturing started in January and ended in May 2016. In this period, a total of 177 slabs were compacted to provide the necessary number of samples.

It was decided that each laboratory shall test four samples per mix variant. Three labs need a whole slab per test sample, the other three labs only need a quarter slab. To ensure that the variance between the four samples of each variant is identical for all, the three labs using quarter slabs received four quarters coming from four different slabs. BRRC used the spare quarters to perform tests at two different temperatures (20 °C and 40 °C).

BAM distributed the test slabs among the different labs using a random distribution scheme, as proposed by TNO. Each sample was clearly labelled by BAM before packaging the batch of samples (one mix per batch). Every time a batch was ready, BAM provided BRRC with a list of the samples, their manufacturing date and the lab that will receive each slab. BRRC completed these lists with the target dates of testing and forwarded the lists to the different labs together with the instructions for testing and reporting. The lists with the data of the individual slabs are added in Annex 1.

4 Instructions for testing and reporting

There are 6 participating laboratories taking part in the test program, using 4 devices, as shown in Table 2.

Table 2 Participating labs and devices

Laboratory	Device	Annex in prCEN/TS 12697-50
TU Aachen	ARTe	Annex A
BAM	ARTe	Annex A
TU Darmstadt	DSD	Annex B
BRRC	DSD	Annex B
Heijmans	RSAT	Annex C
IFSTTAR	TRD	Annex D

4.1 Instructions based on prCEN/TS 12697/50

In WP1, task 1.2, prCEN/TS 12697-50 (version of 03/2014) has been reviewed and a list was made of the requirements common to all methods (Table 3), as well as the requirements which are different from method to method (Table 4).

The aim was to harmonize the methods to a maximum extent for the purpose of the DRaT test program.

Table 3 Requirements common to all methods (according to prCEN/TS 12697-50)

Attribute	Requirements
No. of samples	2 slabs or 2 (sets of) cores
Slab dimensions	(500 ± 20) mm by (500 ± 20) mm or (500 ± 20) mm by (320 ± 20) mm
Core dimensions	Diameter of (150 ± 2) mm
Sample thickness	Between 30 mm and 80 mm
Storage	Below 20 °C for between 14 days and 42 days from time of manufacture
Test results	Visual inspection and/or pictures before and after the test Material loss (or increase in texture) per covered area

Table 4 Requirements depending on the method (according to prCEN/TS 12697-50)

Attribute	**Annex A ARTe**	**Annex B DSD**	**Annex C RSAT**	**Annex D TRD**
Slab dimensions		(260 ± 5) mm by (260 ± 5) mm	Octagonal, c. 50 cm by 50 cm and thickness between 30 mm and 60 mm	Parallelepiped 185 mm by 247 mm from 40 cm x 60 cm slab
Core dimensions			Diameter of (150 ± 1) mm and height between 30 mm and 60 mm – 3 cores per test	300 mm in diameter
Conditioning	(20 ± 2) °C for at least 4 h	for 2.5 h at (40 ± 1) °C	test temperature for 14 h to 18 h. Preloaded with ≥ 20 kg for ≥ 1 h	(20 ± 2) °C for 2 h to 3 h
Initial measurements	Dimensions and mass Photograph or 3 dimensional texture	Mass and photograph		Surface flatness Macro-texture Photograph Dimensions and mass
Initial preparation			Removal of loose material	Removal of loose material
Cleaning during test		Vacuuming of lose grains and wiping off as required	Removal of all loose material by vacuum cleaner	Removal of all loose material by vacuum cleaner
Test load	(250 ± 5) kg	(1000 ± 10) N for pressure of 0,25 N/mm²	(35.0 ± 0.1) kg for pressure of (0.60 ± 0.01) N/mm²	Average 1500 N with an amplitude of 500 N for apparent pressure of 1.33 N/mm²
Test temperature	18 °C to 25 °C	(40 ± 1) °C	(-10 ± 1) °C to (25 ± 1) °C with standard (20 ± 1) °C	(20 ± 2) °C
Final measurements	Visual, photograph and 3-dimensional texture (if available)	Photograph Residue and lose grains from the asphalt specimen and the tyre	Aggregate loss after removal of rubber lost from tyre	Aggregate loss Number of cycles to reach specified degree of degradation

For the requirements common to all test methods (Table 3**), the DRaT test program deviated from prCEN/TS 12697 50 on the following attributes:**

Number of samples: For a more accurate statistical analysis, 4 samples were tested per mix variant, while prCEN/TS 12697-50 prescribes only 2 samples.

Storage / age of the samples: The age of the samples is the time elapsed between the date of compaction of the slab and the testing date. In the DRaT test programme, which is very extensive and where all test slabs were prepared by one single lab and subsequently shipped to all other labs, it was logistically impossible to fix the age of the specimens at the time of testing below 42 days (7 weeks). Since a few weeks extra in age is not expected to have a significant impact, and the essential point is that all labs test at the same age, it was decided to schedule the tests at the age of 10 weeks (+/- 1 week).

For the requirements not common to all test methods (Table 4**), further harmonization was endeavoured where possible:**

Sample dimensions: No further harmonization is possible, since the type (slabs/cores) and dimensions depend on the test device.

Conditioning: This was further harmonized as follows:

- All devices except DSD: (20 ± 2) °C for at least 4 h
- DSD: (40 ± 2) °C for at least 4 h

Note that the tolerance on the conditioning temperature is harmonized to ± 2 °C, while in the present version of prCEN/TS 12697-50, the tolerance was only ± 1 °C for DSD (see Table 4).

Initial measurements: At least the following initial measurements are required:

- Dimensions and mass
- Photographs (top view and 45 ° angle view)

Initial preparation: Removal of all loose material by vacuum cleaner

Cleaning during test: Removal of all loose material by vacuum cleaner

Test load: No further harmonization is possible, the load shall be appropriate for each type of device

Test temperature: 20 °C is a temperature in the standard range of all devices, except the DSD, which is used in Germany at a standard temperature of 40 °C. Therefore, it was decided to select the following test temperatures:

- All devices except DSD: (20 ± 2) ° C
- DSD: (40 ± 2) ° C

To allow for a better comparison between the DSD and the other devices, BRRC proposed to do tests on the DSD not only at 40 °C, but also at 20 °C.

Note that the tolerance on the test temperature is harmonized to ± 2 °C, while in the present version of prCEN/TS 12697-50, the tolerance was only ± 1 °C for DSD and RSAT (see Table 4).

Final measurements: At least the following initial measurements are required:

- Dimensions and mass
- Photographs (top view and 45 ° angle view)
- Mass of aggregate lost during test

4.2 Further instructions in the framework of the DRaT test program

Every lab cuts its own specimens to the right geometry and size depending on the test device. It was asked to do this as soon as possible upon reception of the slabs, to allow more time for the water to evaporate during further storage.

Texture measurements can be made on voluntary basis, before or at different intervals of the measurement (if the device permits this). In case of using the sand patch method, it is essential to ensure removal of all beads, since remaining beads, as any debris on the surface of an asphalt pavement, may have an impact on the subsequent ravelling behaviour.

As explained in part 3 of this report, the method of distribution of the quarter slabs between three labs implies that there was one spare quarter left from each mix variant. BRRC used these for additional tests on the DSD at 20 °C.

It was decided to perform the data analysis in WP4 not only on the final results, but also on intermediate results. Therefore, it was agreed that test labs shall also measure mass loss in at least three intermediate stages (after one quarter of the total number of cycles, half way, and after three quarters).

BRRC prepared a document describing the instructions for testing (Annex 2). This was sent to the labs together with the Excel reporting templates. These reporting templates were prepared by BRRC in liaison with TNO, with some information already filled in (testing lab, sample identification, date of compaction and target date of testing).

5 Test results

The Excel sheets containing the test results are added in annex 3 (9 sheets per lab ⇨ 54 sheets)

5.1 Test conditions

The data sheets were checked to verify if the test conditions complied with the test specifications. In this section, observed deviations from the test conditions are listed.

TU Aachen

- Room or enclosure temperature:
    - 23 °C (> 22 °C) for tests on SMA
- Sample surface temperature at start of the measurement:
    - not always within range 18 °C - 22 °C
    - for tests on M3, the maximum temperature at start went up to 35 °C

      Note: For this set of test results, no systematic relation is observed between mass loss in a test interval and the temperature at the start of the test interval. Therefore, there is no strong reason to reject the measurements made outside the specified temperature range for the further statistical analysis.

BAM

- All test conditions were as specified

BRRC

Tests at 40 °C

- Sample surface temperature at start of the measurement: always within 40 °C ± 2 °C, as specified in the DRaT test instructions

  Note: prCEN/TS 12697-50, version 03/2014, specifies a tolerance of only ± 1 °C. This is more strict than for some other devices (ARTe and TRD) and difficult to comply with. A tolerance of ± 2 °C for all devices in the norm will contribute to a better harmonization.

Tests at 20 °C

- Test load
    - Using a test load of 1000 N, there was no loss of material for any of the variants, except for 2 specimens of the series M1-3 (PA with lower binder content), from which a few small stones were detached after 16 cycles (4 and 6 g respectively).
    - The test load was therefore increased to 2000 N and the number of load cycles to 50.
- Room or enclosure temperature:
    - between 20 and 24 °C (> 22 °C) in the period of testing
- Sample surface temperature at start of the measurement:

  - not always within range 18 °C - 22 °C
  - for a few specimens, the maximum temperature at start was 23 °C (difficult to lower the temperature, since the room had no air conditioning system)
- Time of measurement:
  - delay of approximately 12 months for PA, 11 months for BBTM and 9 months for SMA

TU Darmstadt

- Sample surface temperature at start of the measurement: some (few) measurements are above 42 °C (maximum reported is 43.0 °C)

Heijmans

- Conditioning temperature: different for different mixes:
  - 20 °C for PA
  - 5 °C for SMA and BBTM

  Note: this is not a deviation from the specified conditions (according to prCEN/TS 12697-50, the conditioning temperature shall be not more than 20 °C), but it is reported here because it is different from the other labs.
- Time of measurement:
  - delay of approximately 1 month for PA, due to technical problem with test device (broken shaft)
  - delay of approximately 2 months for BBTM and SMA

IFSTTAR

- Time of measurement:
  - delay of approximately 1 month for BBTM
  - delay of approximately 2 months for SMA
- Room or enclosure temperature:
  - 24 °C (> 22 °C) for sample M2-2-11 (BBTM)
  - 24 °C (> 22 °C) for all tests on SMA
- Sample surface temperature at start of the measurement: not measured (room temperature is reported instead)

General conclusion:

The instructions were followed fairly well and the test conditions mostly complied, except in a few cases where the test temperature was above the maximum limit. This may lead to systematically higher material loss, but such a systematic impact is not observed in the test data.

Maintaining the test temperature within the specified range seems to be the most difficult test condition to satisfy, since there is significant heating of the plate surface due to friction.

Waiting until the sample has cooled before resuming the test leads to longer testing times. However, given the strong temperature sensitivity of the ravelling phenomenon, it is important to take all possible measures to control the temperature and keep it within the specified tolerance.

In a few cases, the time between manufacturing and testing (10 weeks +/- 1 week) was exceeded by one to two months. Since the specimens were all stored correctly at a temperature below 20 °C, it is not expected that there could have been any significant ageing in that period which would have an impact on the resistance to ravelling.

The additional tests made by BRRC at 20 °C were made with a delay of 9 to 12 months. Before testing, the specimens were stored at a temperature below 20 °C.

As expected, changing the test temperature from 40 °C to 20 °C has a huge effect on the ravelling resistance. The tests of BRRC show that at 20 °C, the test load has to be doubled and the number of load cycles tripled, in order to measure a sufficiently high amount of material loss. However, even with these heavier test conditions, the material loss at 20 °C is still lower than with the normal test conditions at 40 °C.

5.2 Density and thickness

According to prCEN/TS 12697-50 (§5.5): “the bulk density of the slab or core shall be determined according to EN 12697-6 using the bulk density by dimensions procedure”.

This was done by BAM for each slab, before sending the slabs to the other labs. Following the test instructions, some labs repeated the bulk density measurements on the test samples, after cutting to the right dimensions and drying.

The individual measurements of sample dimensions and initial mass, as reported by the testing labs, are in annex 3. In this section, these data are summarized in tables, showing for each lab the results of the mean bulk density, the standard deviation and the maximum difference in density of each series of 4 samples.

When comparing the bulk density determined by BAM on the large slabs to the bulk density of the samples determined by the individual labs, differences may occur due to:

- reproducibility of the measurements: measurements carried out with different equipment by different technicians;
- sample cutting: for example, if the edges are less compacted than the centre, there will be a difference in density after cutting the edges from the slabs;
- some labs use only a quarter of the slabs to prepare their test samples.

According to the present version of prCEN/TS 12697-50, bulk densities shall be measured, but there is no requirement on the maximum difference. Knowing that the degree of compaction has a significant impact on the resistance to ravelling, it is recommended to specify a limit on the difference in density between samples. The feasibility of a maximum allowable difference of 0.050 g/cm³ can be evaluated from these tables.

prCEN/TS 12697-50 contains a requirement on the maximum difference in thickness within each sample, as measured in 8 equally spaced points: this difference shall remain below 2.5 mm. The tables therefore also show the maximum thickness difference measured within one sample.

TU Aachen

Table 5 Density and thickness of TU Aachen samples

		Density, measured by BAM (on large slabs of 60*60 cm²)			Density, measured by TU Aachen (on cut samples of 54*32 cm²)			Maximum difference in thickness within one sample
		mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	max-min (mm)
PA	M1-1	1.974	0.007	0.017	2.011	0.015	0.034	0.9
	M1-2	1.974	0.003	0.006	1.994	0.026	0.061	1.2
	M1-3	1.973	0.004	0.009	1.989	0.021	0.047	0.5
BBTM	M2-1	1.990	0.001	0.003	/	/	/	2.3
	M2-2	1.993	0.003	0.006	/	/	/	0.4
	M2-3	1.992	0.003	0.007	/	/	/	0.5
SMA	M3-1	2.361	0.001	0.002	/	/	/	/
	M3-2	2.358	0.002	0.005	/	/	/	/
	M3-3	2.360	0.001	0.002	/	/	/	/

/: not reported

Observations:

- There is more variation on TU Aachen measurements than on BAM measurements.
- Thickness variations within samples are below 2.5 mm ⇨ OK according to prCEN/TS 12697-50.
- The maximum difference in density between samples, as measured by TU Aachen, is in one case above 0.050 g/cm³.

BAM

Table 6 Density and thickness of BAM samples

		Density, measured by BAM (on large slabs of 60*60 cm²)			Density, measured by BAM (on cut samples of 50*50cm²)			Maximum difference in thickness within one sample
		mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	max-min (mm)
PA	M1-1	1.978	0.008	0.017	1.985	0.009	0.019	0.2
	M1-2	1.977	0.006	0.013	1.980	0.013	0.032	2.5
	M1-3	1.974	0.002	0.005	1.962	0.013	0.027	2.2
BBTM	M2-1	1.987	0.003	0.006	/	/	/	1.2
	M2-2	1.993	0.003	0.006	/	/	/	1.8
	M2-3	1.989	0.003	0.008	1.995	0.022	0.031	1.5
SMA	M3-1	2.360	0.002	0.004	/	/	/	1.5
	M3-2	2.362	0.004	0.009	/	/	/	1.7
	M3-3	2.360	0.003	0.006	/	/	/	1.8

/: not reported

Note: For BBTM and SMA, the mass measurements of the cut plates included the wooden bottom plates. Hence, the density by geometry was not determined on the samples after cutting. However, given the conclusion from the comparison for PA (see below) and the fact that only a very small part of the slabs is cut from the edges, the density values in the first column can be accepted as accurate values for the bulk densities of the test plates.

Observations:

- For PA (M1), there is no systematic difference between the density measured on the large slabs and the density after cutting the edges, but there is more variation on the density measurements after cutting
- Thickness variations within samples are below 2.5 mm ⇨ OK according to prCEN/TS 12697-50.
- The maximum difference in density between samples is below 0.050 g/cm³.

BRRC

Table 7 Density and thickness of BRRC samples (series tested at 40 °C)

		Density, measured by BAM (on large slabs of 60*60 cm²)			Density, measured by BRRC (on cut samples of 26*26 cm²)			Maximum difference in thickness within one sample
		mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	max-min (mm)
PA	M1-1	1.974	0.004	0.010	2.020	0.008	0.019	1.1
	M1-2	1.975	0.002	0.004	2.016	0.007	0.014	1
	M1-3	1.973	0.003	0.007	2.003	0.016	0.037	1
BBTM	M2-1	1.988	0.004	0.009	2.026	0.017	0.035	1.2
	M2-2	1.993	0.003	0.006	2.032	0.006	0.013	0.9
	M2-3	1.990	0.002	0.005	1.992	0.020	0.044	0.9
SMA	M3-1	2.358	0.007	0.015	2.313	0.030	0.069	0.7
	M3-2	2.362	0.001	0.003	2.327	0.021	0.048	1.2
	M3-3	2.360	0.004	0.008	2.320	0.003	0.006	1.7

Table 8 Density and thickness of BRRC samples (series tested at 20 °C)

		Density, measured by BAM (on large slabs of 60*60 cm²)			Density, measured by BRRC (on cut samples of 26*26 cm²)			Maximum difference in thickness within one sample
		mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	max-min (mm)
PA	M1-1	1.974	0.004	0.010	2.014	0.010	0.024	0.9
	M1-2	1.975	0.002	0.004	1.990	0.018	0.035	0.7
	M1-3	1.973	0.003	0.007	1.983	0.016	0.035	1.1
BBTM	M2-1	1.988	0.004	0.009	2.015	0.022	0.048	0.9
	M2-2	1.993	0.003	0.006	2.027	0.013	0.028	0.8
	M2-3	1.990	0.002	0.005	2.015	0.009	0.021	0.6
SMA	M3-1	2.358	0.007	0.015	2.301	0.030	0.071	0.7
	M3-2	2.362	0.001	0.003	2.321	0.008	0.017	0.9
	M3-3	2.360	0.004	0.008	2.306	0.025	0.057	0.9

Observations:

- Samples M3-1-12(c) (tested at 40 °C) and M3-1-12(d) (tested at 20 °C) had a relatively low density, when compared to the other samples of M3-1. This is reflected in a low mean value and a high standard deviation for M3-1. The low density of M3-1-12 is confirmed by the density measurements made by BAM on M3-1-12 and the density measurements of TU Darmstadt on M3-1-12(a).
- More variation on BRRC measurements than on BAM measurements (possible explanations: operator, method, smaller samples more sensitive to material heterogeneity).
- Lower compaction temperature has no impact on density, as expected, since compacted to same target density.
- Lower binder content leads to lower density for BRRC measurements. The difference is not significant, but observed for the 3 mixtures.
- Thickness variations within samples are below 2.5 mm ⇨ OK according to prCEN/TS 12697-50.
- The maximum difference in density between samples is below 0.050 g/cm³, except for M3-1, due to the low value for M3-1-12.

TUD

Table 9 Density and thickness of TUD samples

		Density, measured by BAM (on large slabs of 60*60 cm²)			Density, measured by TUD (on cut samples of 26*26 cm²)			Maximum difference in thickness within one sample
		mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	max-min (mm)
PA	M1-1	1.974	0.004	0.010	1.951 (1.981)*	0.063 (0.021)*	0.146 (0.039)*	2.1
	M1-2	1.975	0.002	0.004	1.979	0.017	0.039	0.8
	M1-3	1.973	0.003	0.007	1.975	0.014	0.034	1.5
BBTM	M2-1	1.988	0.004	0.009	2.011	0.015	0.010	0.8
	M2-2	1.994	0.002	0.004	2.005	0.008	0.015	0.9
	M2-3	1.990	0.002	0.005	1.989	0.021	0.043	0.7
SMA	M3-1	2.358	0.007	0.015	2.290	0.012	0.025	1.1
	M3-2	2.362	0.001	0.003	2.308	0.009	0.021	1.1
	M3-3	2.360	0.004	0.008	2.283	0.013	0.031	1.5

*: values obtained when suspiciously low density of sample M1-1-5(d) is rejected

Observations:

- Sample M1-1-5(d) has a suspect density (too low) in TUD measurements but not in BAM measurements. The measurements have been verified by TUD, but the same result was obtained.
- More variation on TUD measurements than on BAM measurements (possible explanations: operator, method, smaller samples more sensitive to material heterogeneity).
- Lower compaction temperature has no impact on density, as expected, since compacted to same target density.
- Lower binder content leads to lower density for TUD measurements. The difference is not significant, but observed for the 3 mixtures.
- Thickness variations within samples are below 2.5 mm ⇨ OK according to prCEN/TS 12697-50.
- The maximum difference in density between samples is below 0.050 g/cm³ (if suspect value of sample M1-1-5(d) is rejected).

Heijmans

Table 10 Density and thickness of Heijmans samples

		Density, measured by BAM (on large slabs of 60*60 cm²)			Density, measured by Heijmans (on cut samples)			Maximum difference in thickness within one sample
		mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	max-min (mm)
PA	M1-1	1.972	0.005	0.012	/	/	/	0.69
	M1-2	1.972	0.005	0.010	/	/	/	0.84
	M1-3	1.973	0.002	0.003	/	/	/	0.71
BBTM	M2-1	1.990	0.007	0.017	/	/	/	0.43
	M2-2	1.992	0.001	0.003	/	/	/	0.52
	M2-3	1.991	0.001	0.002	/	/	/	0.59
SMA	M3-1	2.360	0.002	0.004	/	/	/	0.65
	M3-2	2.360	0.003	0.006	/	/	/	0.53
	M3-3	2.363	0.001	0.003	/	/	/	0.68

/: not measured

Note: Due to the special geometry (octagonal samples), Heijmans did not measure the density by geometry.

Observations:

- Thickness variations within samples are below 2.5 mm ⇨ OK according to prCEN/TS 12697-50.
- The maximum difference in density between samples is below 0.050 g/cm³ (as measured by BAM).

IFSTTAR

Table 11 Density and thickness of IFSTTAR samples

		Density, measured by BAM (on large slabs of 60*60 cm²)			Density, measured by IFSTTAR (on cut samples of 25*17cm²)			Maximum difference in thickness within one sample
		mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	mean (g/cm³)	st.dev (g/cm³)	max-min (g/cm³)	max-min (mm)
PA	M1-1	1.974	0.004	0.010	/	/	/	/
	M1-2	1.975	0.002	0.004	/	/	/	/
	M1-3	1.973	0.003	0.007	/	/	/	/
BBTM	M2-1	1.988	0.004	0.009	1.938	0.051	0.125	1.4
	M2-2	1.993	0.003	0.006	1.989	0.036	0.075	1.3
	M2-3	1.990	0.002	0.005	1.950	0.027	0.059	1.6
SMA	M3-1	2.358	0.007	0.015	2.254	0.018	0.044	0.7
	M3-2	2.362	0.001	0.003	2.256	0.012	0.028	0.7
	M3-3	2.360	0.004	0.008	2.273	0.019	0.044	0.6

/: dimensions not reported ⇨ no bulk density by dimensions

Observations:

- Thickness variations within samples are below 2.5 mm ⇨ OK according to prCEN/TS 12697-50
- Huge density variations, as measured by IFSTTAR. For BBTM, the maximum difference in density between samples is always above 0.050 g/cm³

General conclusions:

The reported data on density and thickness of the specimens reflect the quality and repeatability of the slab manufacturing and compaction.

Variations in density within each series of samples are small. It seems feasible to produce series of samples with less than 0.050 g/cm³ difference in density.

Variations in thickness between the 8 measurement points within each slab, as an indication of flatness, are small. A maximum thickness variation of 2.5 mm within each sample seems feasible.

There are differences between densities as measured by BAM on the large slabs and densities measured by the individual labs on cut samples. This may be due to reproducibility of the geometric density measurements, the sample cutting or the fact that some labs only used a quarter of the slabs.

Lower compaction temperature has no impact on density. This could be expected, since the slabs were compacted to the same target density.

Lower binder content tends to result in a lower density. The difference is not significant, but measured for all 3 mixtures by both BRRC and TU Darmstadt.<

5.3 Material loss evolution

In this section, graphs of the evolution of the measured material loss as function of the number of loading cycles are presented.

TU Aachen

Mechanical loading conditions

- Covered area: 54*32 cm^2 = 1728 cm^2
- Pneumatic tyre pressure: 200 kPa
- Force : 2500 N (250 kg mass)
- Double tyre
- 1 cycle corresponds to a forwards and backwards translation of the plate under rotating tyres

Method of measuring material loss

The material loss is measured every 150 cycles, up to 600 cycles. At a rate of 6 cycles/minute, the total loading time is 100 minutes. Including the time of measuring the mass every 150 cycles, the test takes approximately half a day.

Material loss data

For one sample (M2-2-18), the operator reports material loss at the edge of the plate. This is clearly seen in the graph of M2 (BBTM). Therefore, there is a physical justification to reject this result (or possibly to correct, if the operator had weighed the material detached from the edge).

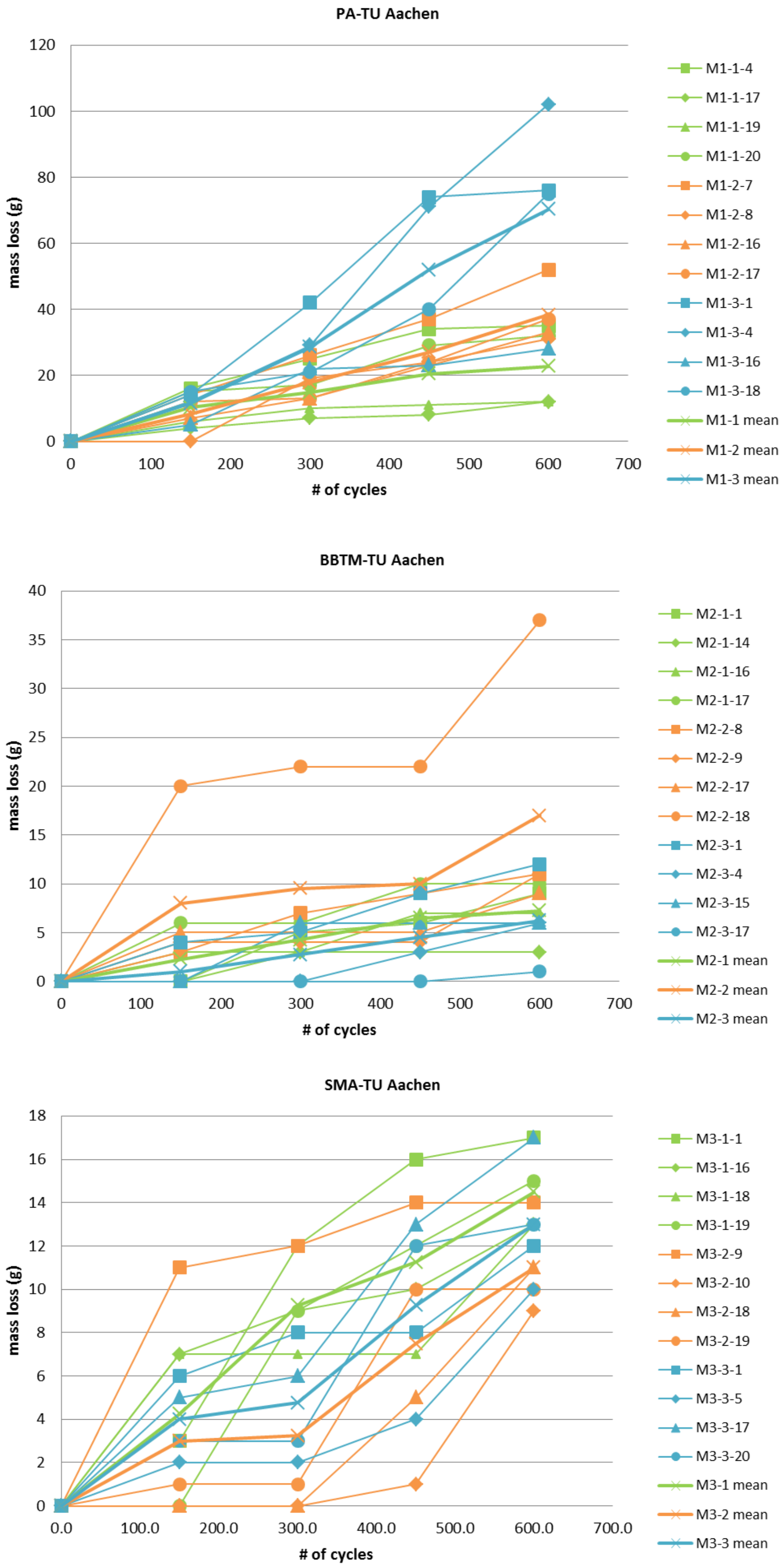


Figure 2 Graphical representation of material loss (TU Aachen)

BAM

Mechanical loading conditions

- Covered area: 50*50 cm² = 2500 cm²
- Pneumatic tyre pressure: 200 kPa
- Force : 2500 N (250 kg mass)
- Double tyre
- 1 cycle corresponds to a forwards and backwards translation of the plate under rotating tyres

Method of measuring material loss

2 methods are used:

- weighing cumulated material released from the plate
- weighing the plates (including supporting plates) and calculating the difference (M_0 – M_{end})

Test data show that (M_0 – M_{end}) is larger than the cumulated material loss, but the differences are small.

The results from the first method are further used.

The material loss is measured every 150 cycles, up to 600 cycles. At a rate of 6 cycles/minute, the total loading time is 100 minutes. Including the time of measuring the mass every 150 cycles, the test takes approximately half a day.

Material loss data

No suspect values were detected in the reported data.

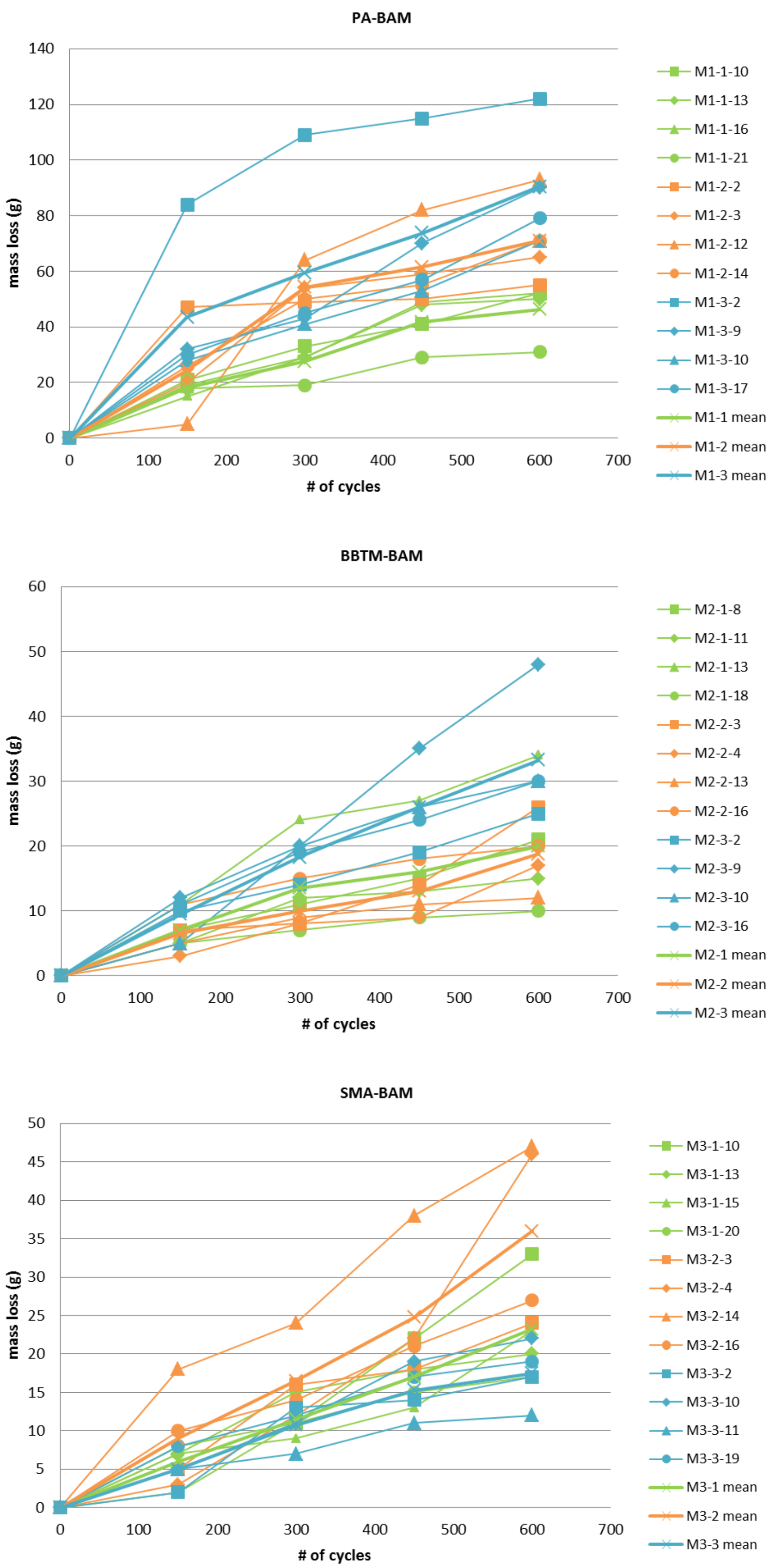


Figure 3 Graphical representation of material loss (BAM)

BRRC

Mechanical loading conditions

- Covered area: circular ∅ 22.5 cm ⇨ 397.6 cm²
- Pneumatic tyre pressure: 300 kPa
- Force :
    - 1000 N for tests at 40 °C
    - 2000 N for tests at 20 °C
- Single tyre
- 1 cycle is a combination of 5 translations (2-way) and 1 rotation over 180° (also 2-way)

Method of measuring material loss

2 methods are used:

- weighing cumulated material released from the plate
- weighing the plates before and after testing and calculating the difference (M_0 – M_{end})

Test data show that (M_0 – M_{end}) is larger than the cumulated material loss, but the differences are small.

The results from the first method are further used.

The material loss is measured every 4 cycles, up to 16 cycles. At a rate of approximately 1 cycles per 20 seconds, the total loading time is less than 6 minutes. Including the time of measuring the mass every 4 cycles, the test takes approximately half a day.

Material loss data

No suspect values were detected in the reported data.

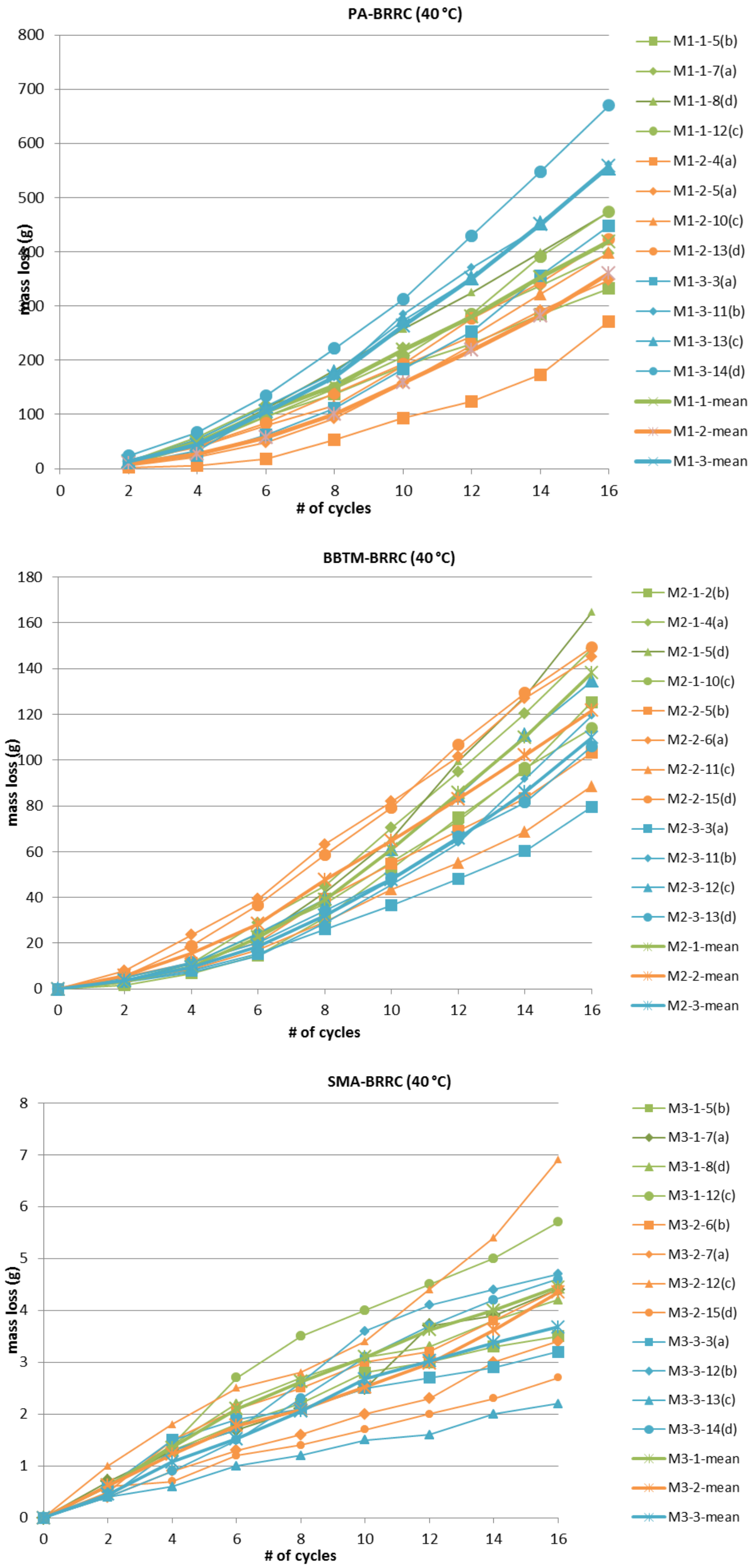


Figure 4 Graphical representation of material loss (BRRC, 40 °C)

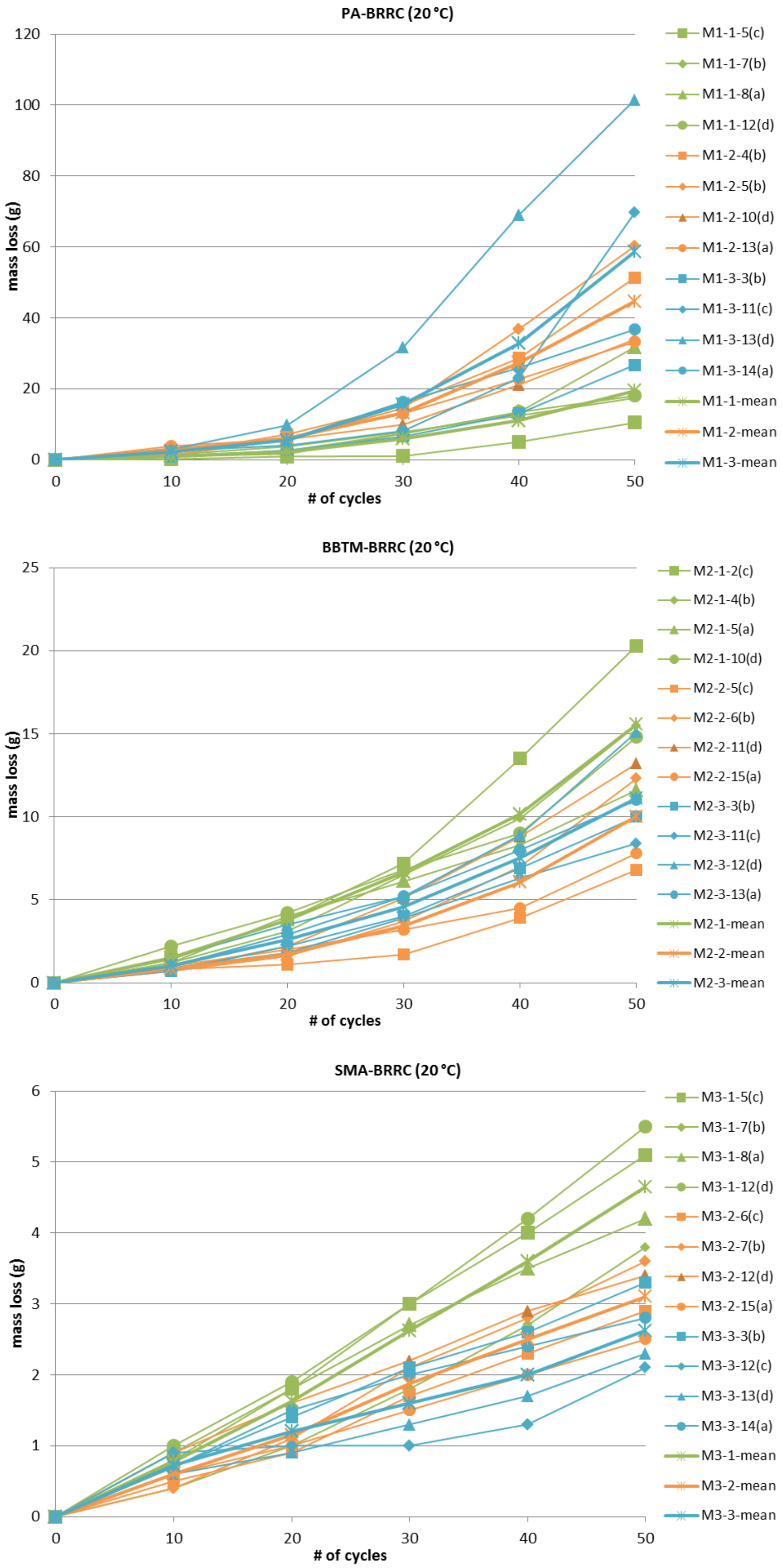


Figure 5 Graphical representation of material loss (BRRC, 20 °C)

TU Darmstadt

Mechanical loading conditions

- Covered area: circular ∅ 22.5 cm ⇨ 397.6 cm²
- Pneumatic tyre pressure: 300 kPa
- Force : 1000 N
- Single tyre
- 1 cycle is a combination of 5 translations (2-way) and 1 rotation over 180° (also 2-way)

Method of measuring material loss

2 methods are used:

- weighing cumulated material released from the plate
- weighing the plates before and after testing and calculating the difference (M_0 – M_{end})

Test data show that (M_0 – M_{end}) is larger than the cumulated material loss, but the differences are small.

The results from the first method are further used.

The material loss is measured every 4 cycles, up to 16 cycles. At a rate of approximately 1 cycles per 20 seconds, the total loading time is less than 6 minutes. Including the time of measuring the mass every 4 cycles, the test takes approximately half a day.

Material loss data

No suspect values were detected in the reported data.

Sample M1-3-11(d) was broken during testing (after cycle 8), so there is no result available at 16 cycles.

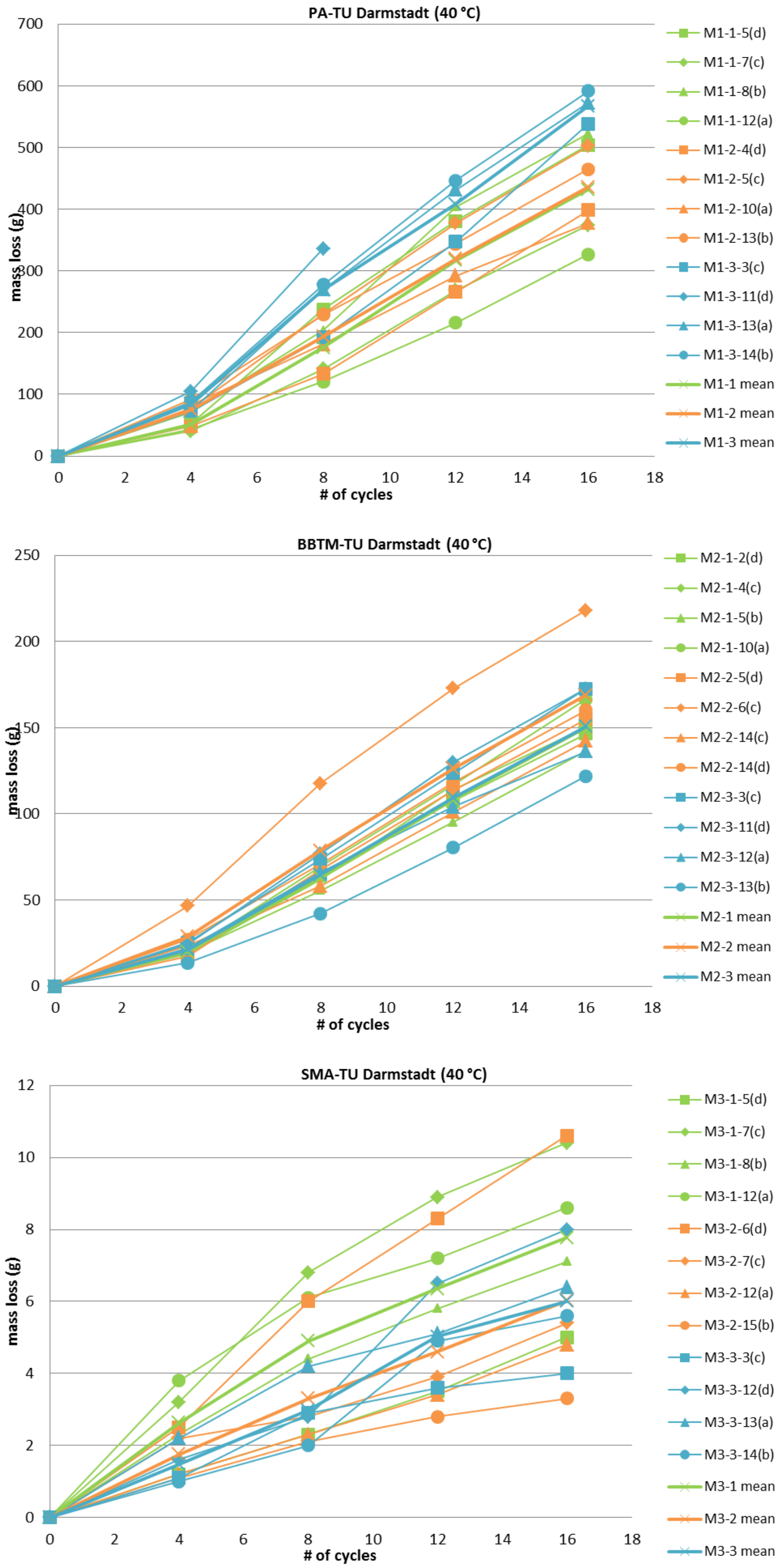


Figure 6 Graphical representation of material loss (TU Darmstadt, 40 °C)

Heijmans

Mechanical loading conditions

- Covered area: 1400 cm²
- Total cycles: 86.400, duration 24 hour
- 1 cycle: forwards and backwards movement with a rubber tyre at 33,7^{o} slip angle.
- solid rubber tyre with hardness number of 80 IHRD - ISO 7619
  (shore A hardness 67- ISO 48)
- Force : 350 N (35 kg mass)
- Wheel contact pressure: 600 kPa

Method of measuring material loss

Two methods are used:

- weighing of cumulated mass of the fraction larger than 2 mm (“stones”), separated from the released material
- $M_0 – M_{end}$, which is much larger than the mass of the cumulated stone fraction

The results from the first method are further used, since according to Heijmans, only these data represent the true ravelling.

The stone loss is measured continuously up to 24 hr total loading time.

Material loss data

One sample M1-1-9 shall be rejected, because the shaft of the device was broken during testing.

No suspect values were detected in the other reported data.

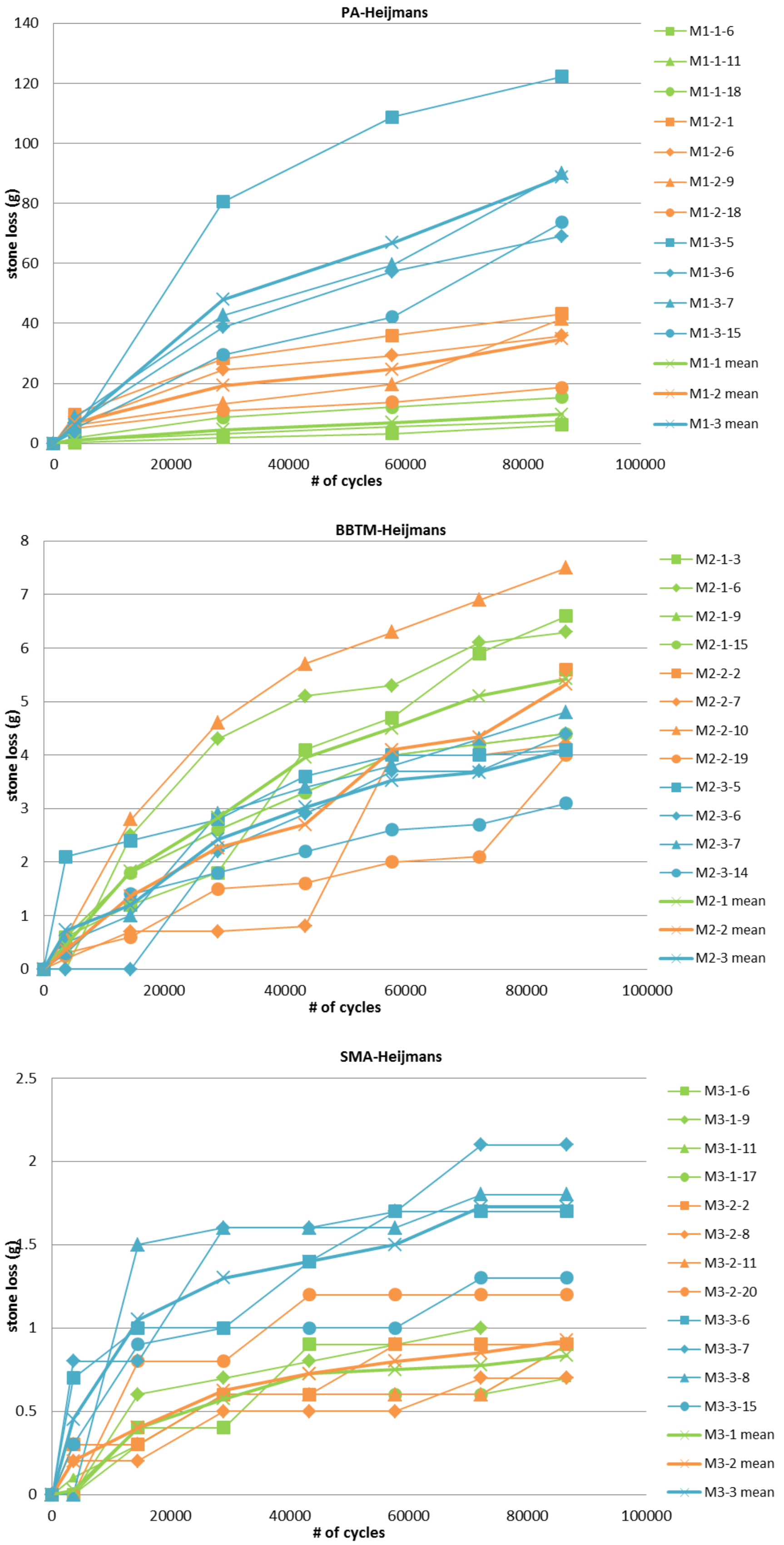


Figure 7 Graphical representation of material loss (Heijmans)

IFSTTAR

Mechanical loading conditions:

- The logarithmic pad is coated by an 8-mm thick rubber layer (shore A hardness 67- ISO 48). Its resistance to abrasion and wear must not exceed 90 mm^3, in accordance with Standard DIN 53516.
- Contact area between the logarithmic pad and surface specimen : rectangular 14 x 0.8 = 11.2 cm^2

The test protocol comprises three phases, one of which concerns removing debris potentially produced during the loading steps:

A - Pre-loading phase

The logarithmic pad is placed into contact with the material surface by applying an imposed displacement and then driving the force higher in order to continue loading on the sample, until reaching the required average vertical force. The necessary attachment time still averages 20 seconds. Attachment conditions are correlated with the state of the material surface, as well as with contact material stiffness and test temperature.

B - Cyclic loading phase

Once the required force (=1500 N) has been reached, a sinusoidal loading is imposed with an amplitude set at 1/3 of the average force (=500 N), so as to ensure that the pad is well attached, i.e. at a stable sliding speed and with as much friction as possible. The average vertical load is set at 1500 N to reproduce an apparent contact pressure (1330 kPa). 2000 cycles are performed with a loading frequency equal to 1 Hz.

C - Pad rising phase

The logarithmic pad is returned to the upper position, which serves to free space roughly 15 mm underneath the pad for the purpose of removing any stripped aggregates eventually present, using a compressed air-based ejection system placed at the same level as the specimen surface and projecting air parallel to the specimen surface; this phase lasts approximately 10 seconds.

Once the surface has been cleaned, the slab is weighed and the three phases are repeated with the same cyclic contact force. This procedure is then repeated the number of times necessary to obtain a specified degree of degradation. For 10000 cycles, the total duration of the test takes 4 hours, including the periods of measuring the material loss.

Method of measuring material loss

Material loss was determined by weighing the slab (after cleaning in phase C).

A series of sequences was programmed to reach 10000 cumulative cycles (or 5 mass measurements). The maximum number of cycles was variable (and less than 10000), depending on the degree of degradation.

⇨ only test data at a common number of cycles (6000 cycles) are used for comparison.

Material loss data

Sample M2-2-11 has a very high value for material loss, when compared to the other 3 samples of M2-2. A too high room temperature (24 °C) is reported in the test result sheet, which may be an explanation for this suspicious result.

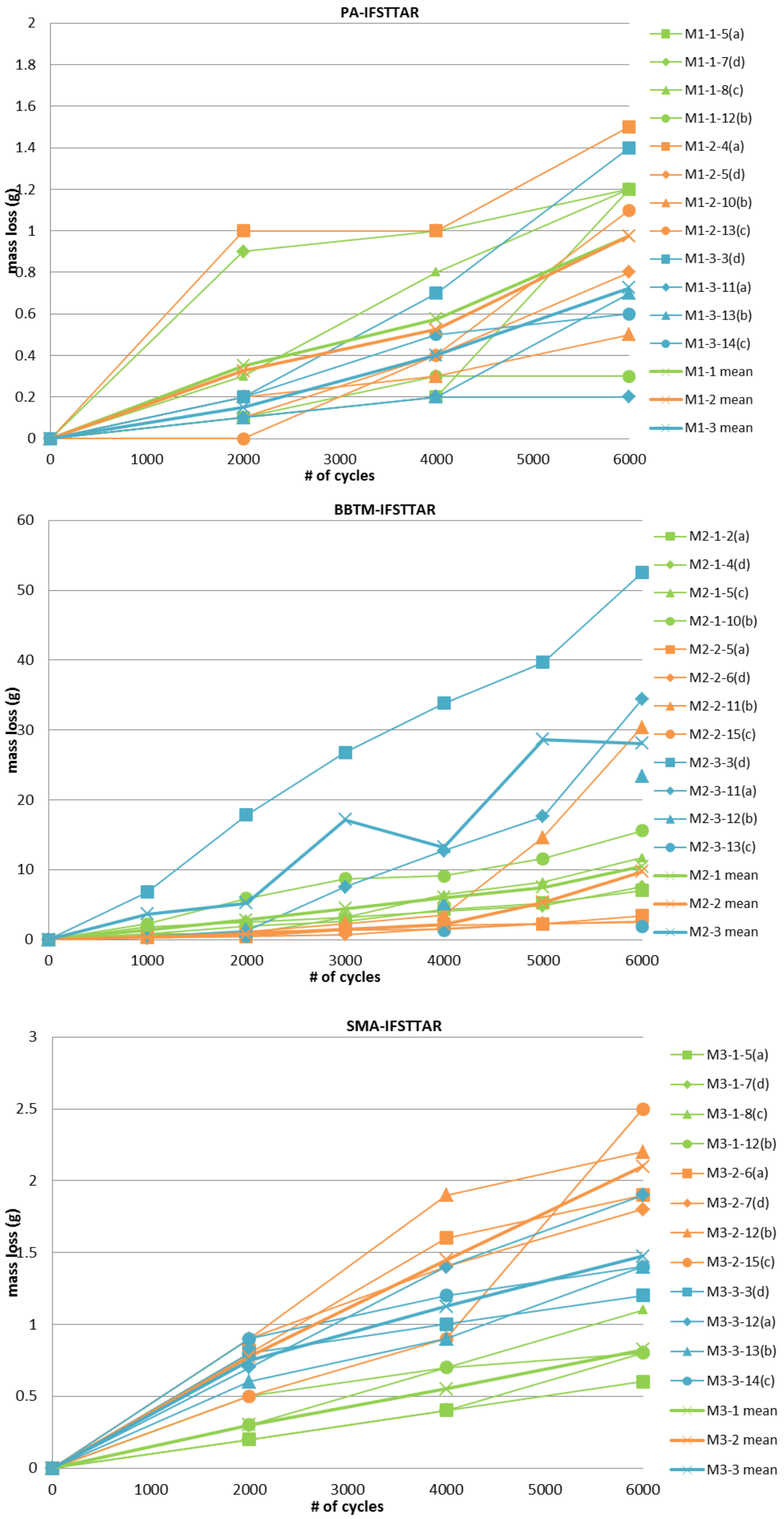


Figure 8 Graphical representation of material loss (IFSTTAR)

General observations:

The rate of material loss (slope of the curves) behaves differently depending on the test device. The DSD shows an increasing rate, especially for the PA and BBTM mixtures, while RSAT shows a decreasing rate. For the other devices, the rate is more or less constant.

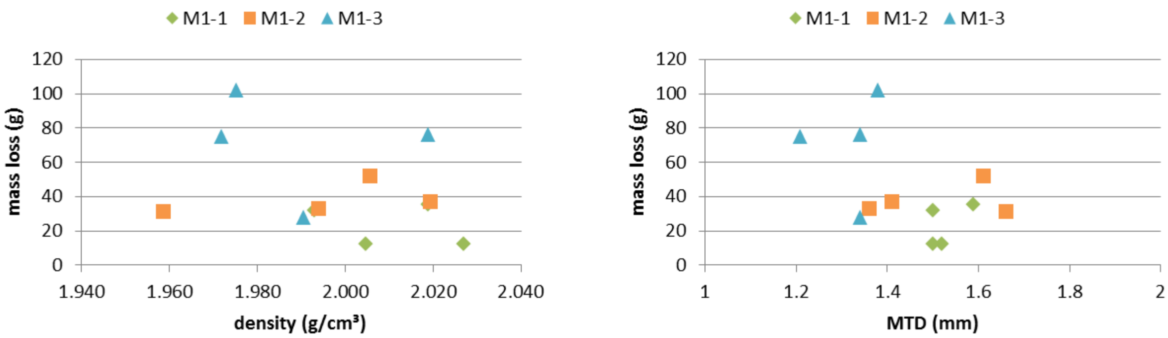
5.4 *Material loss versus density and texture*

Density and texture are two important parameters with a potential impact on ravelling resistance. A variation in density or texture between samples may lead to a variation in mass loss and hence to a poor repeatability of scuffing tests. In this section, plots are shown of the material loss (mass of released material) against these two parameters.

TU Aachen

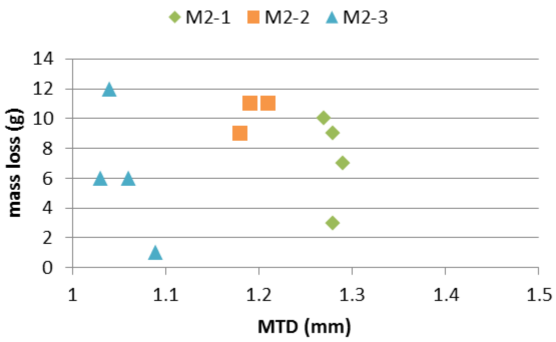
The cumulated mass loss at 600 cycles is shown in figure 9.

PA



BBTM

Density was not reported



SMA

Density was not reported

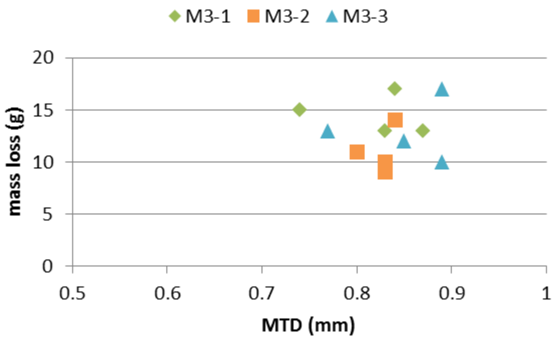


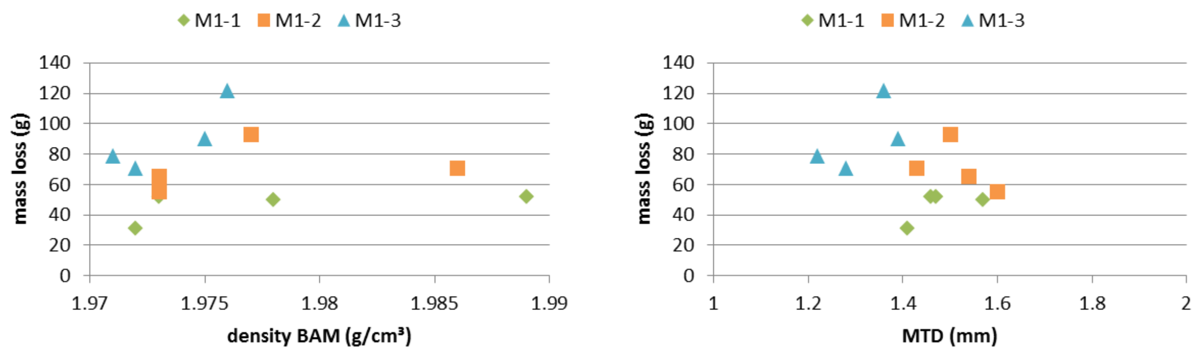
Figure 9 Mass loss versus density (left) and texture (right) (TU Aachen)

BAM

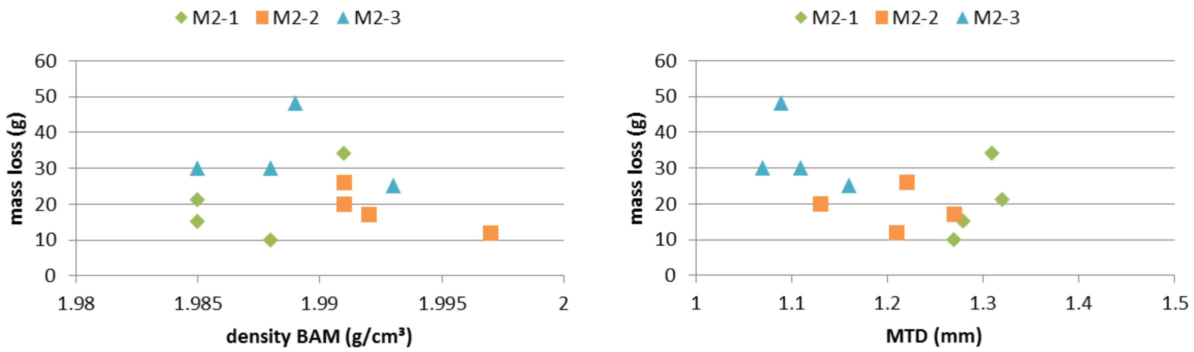
The cumulated mass loss at 600 cycles is shown in figure 10.

The density is the bulk density measured on the slabs of 60*60 cm², before cutting to the sample dimensions of 50*50 cm².

PA



BBTM



SMA

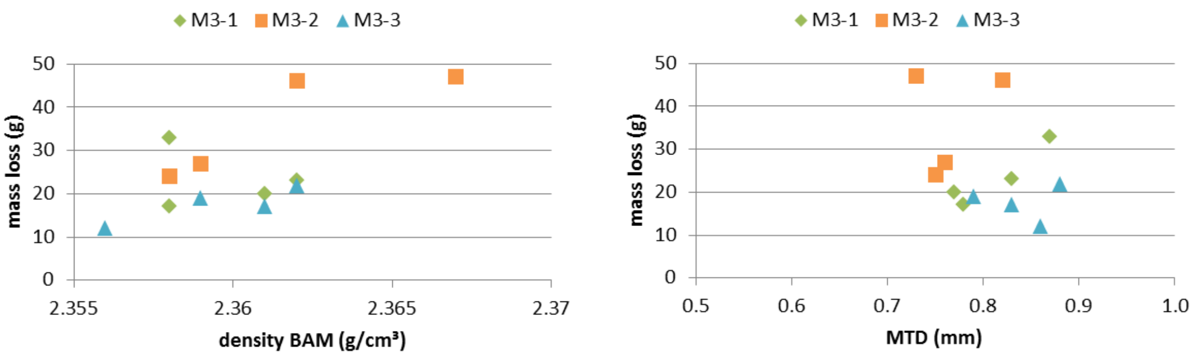
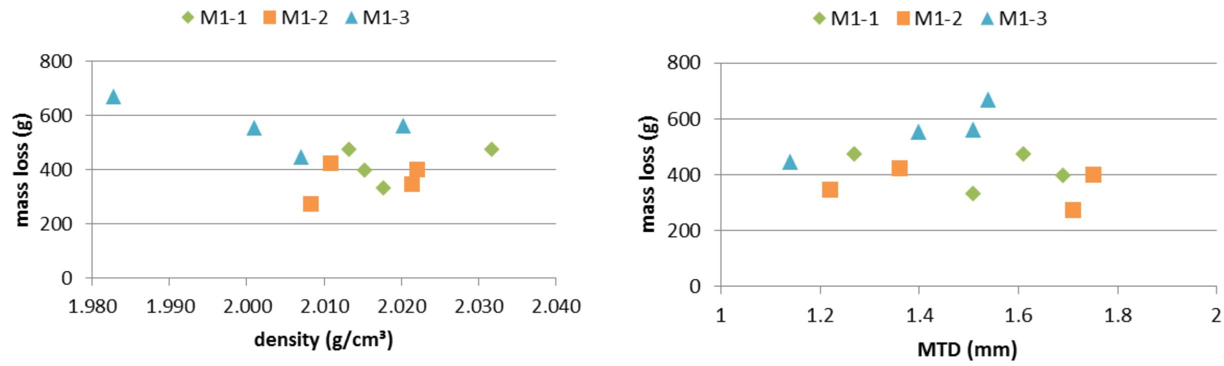


Figure 10 Mass loss versus density (left) and texture (right) (BAM)

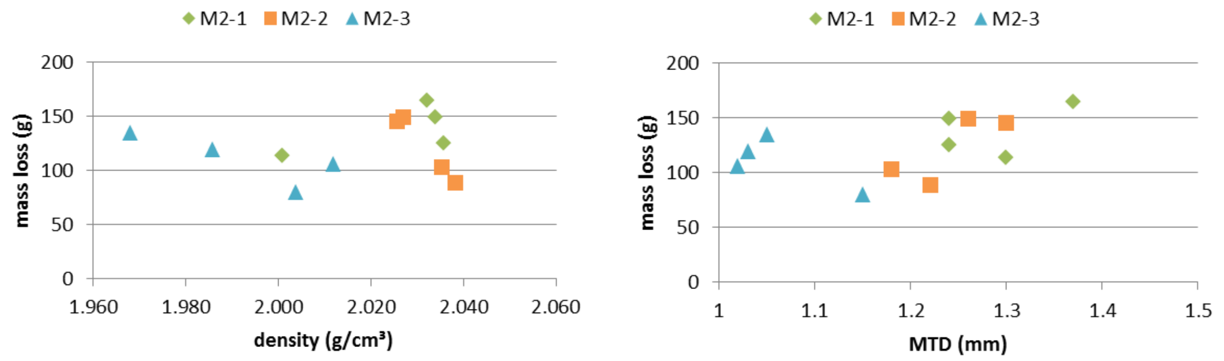
BRRC

For the tests at 40 °C, the cumulated mass loss at 16 loading cycles is shown in figure 11.

PA



BBTM



SMA

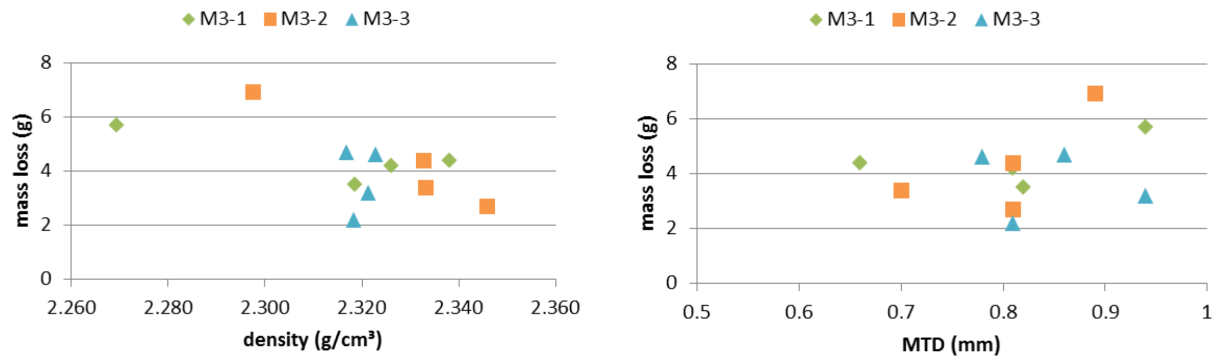
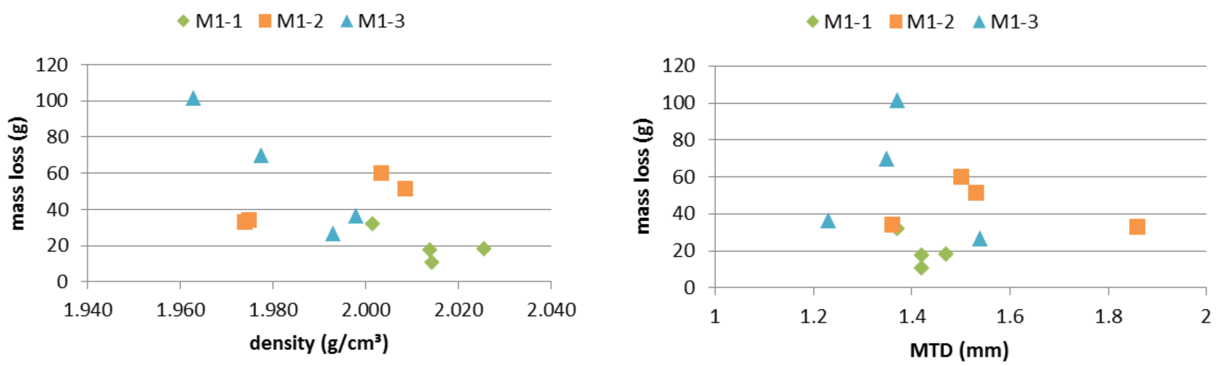


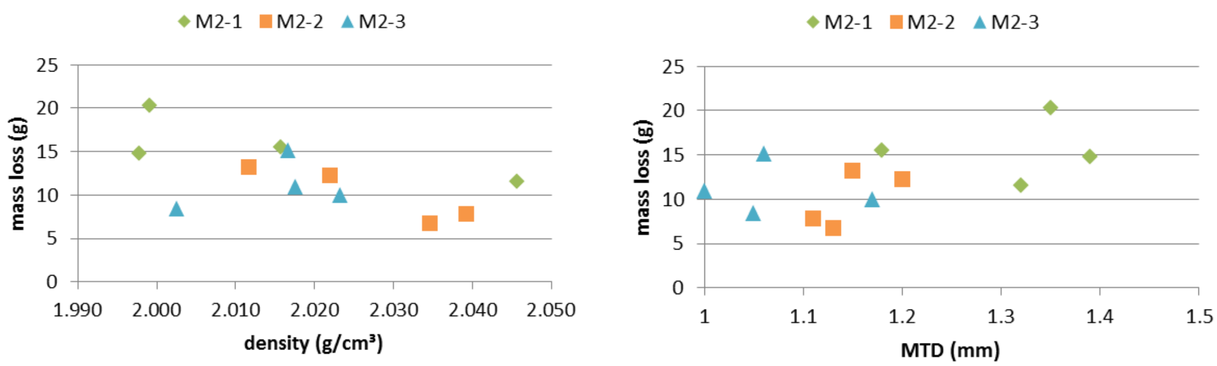
Figure 11 Mass loss versus density (left) and texture (right) (BRRC, tests at 40 °C)

For the tests at 20 °C, the cumulated mass loss at 50 loading cycles is shown in figure 12.

PA



BBTM



SMA

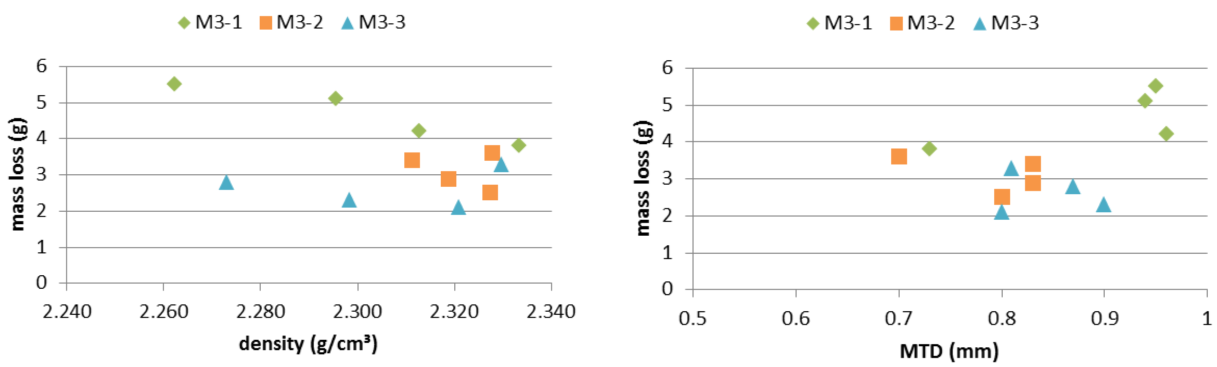
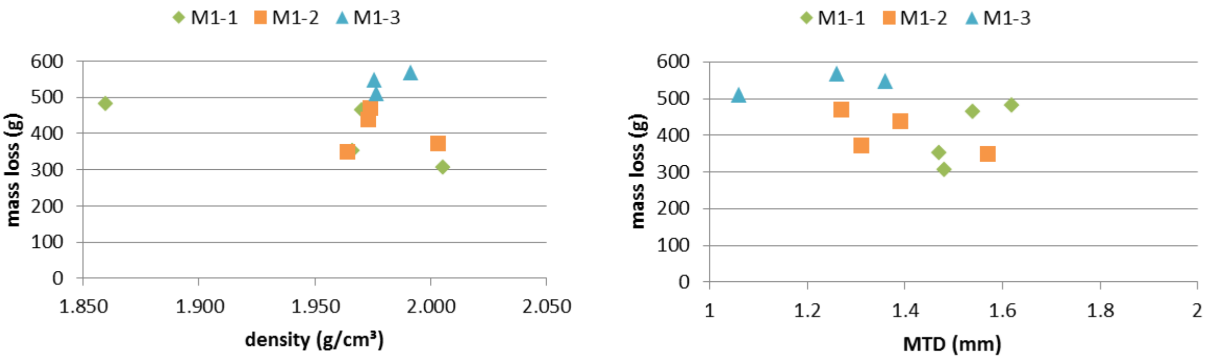


Figure 12 Mass loss versus density (left) and texture (right) (BRRC, tests at 20 °C)

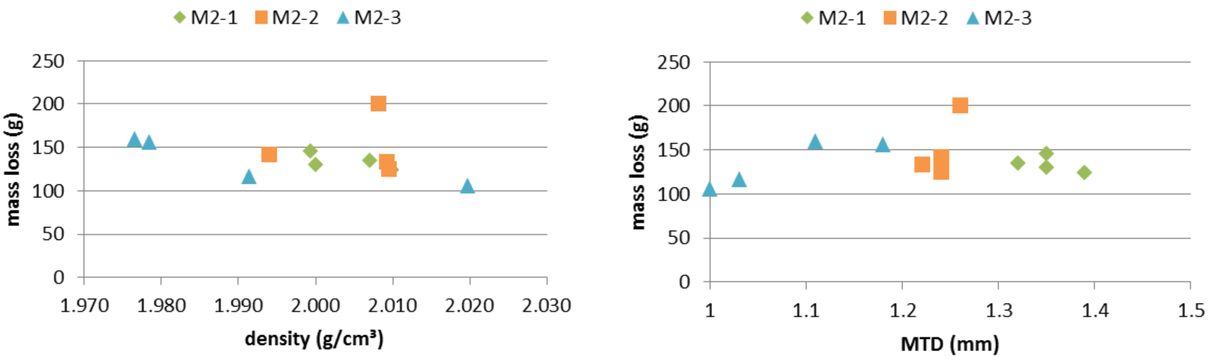
TU Darmstadt

The cumulated mass loss at 16 loading cycles is shown.

PA



BBTM



SMA

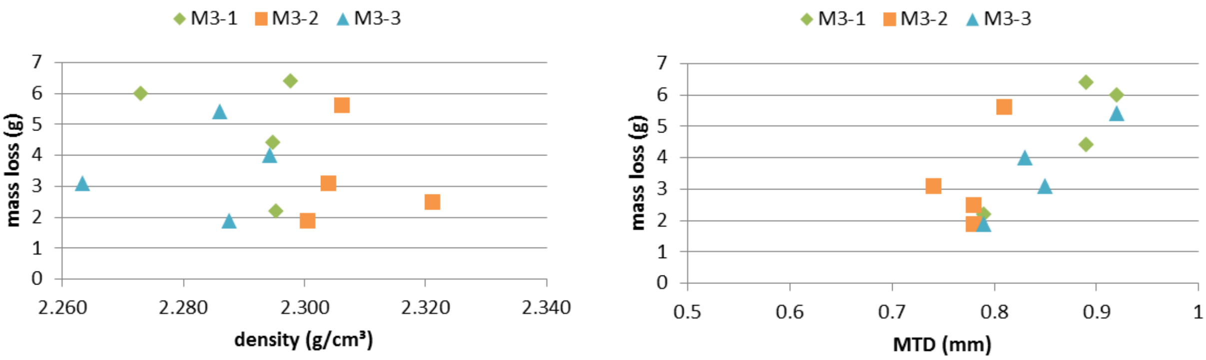


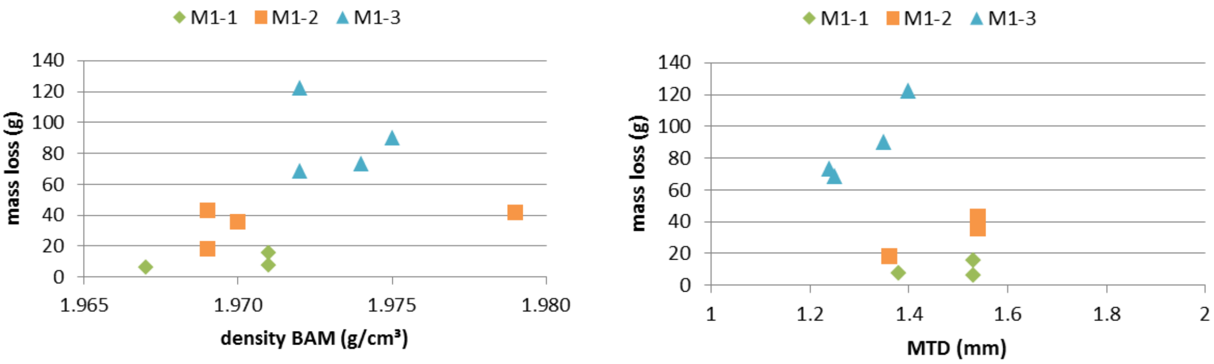
Figure 13 Mass loss versus density (left) and texture (right) (TUD, tests at 40 °C)

Heijmans

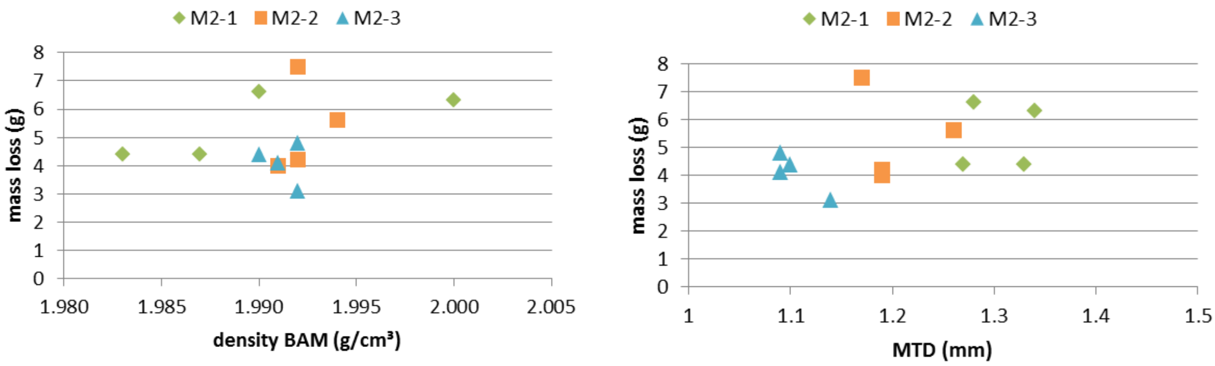
The mass of the released stones at 86600 cycles is shown.

The density is the bulk density measured by BAM on the slabs of 60*60 cm².

PA



BBTM



SMA

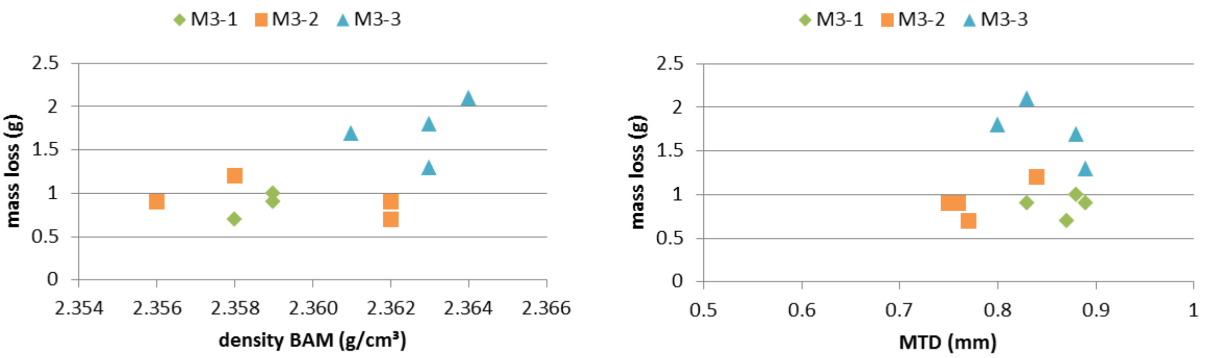
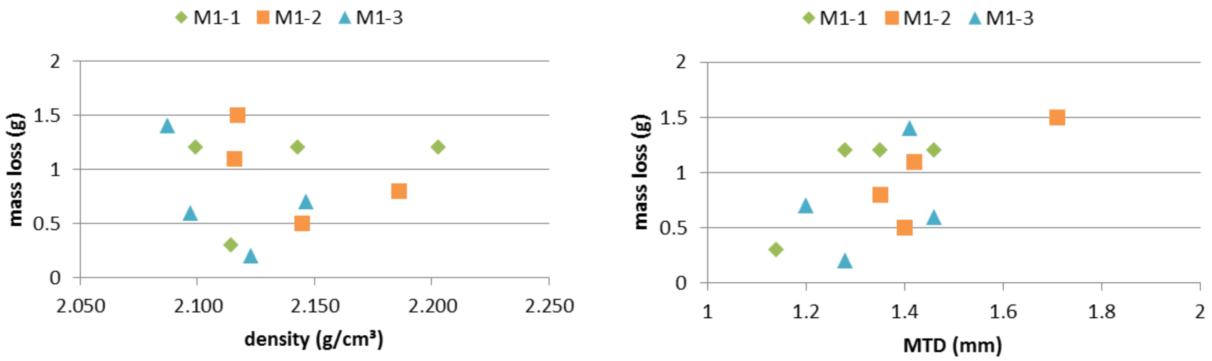


Figure 14 Mass loss versus density (left) and texture (right) (Heijmans)

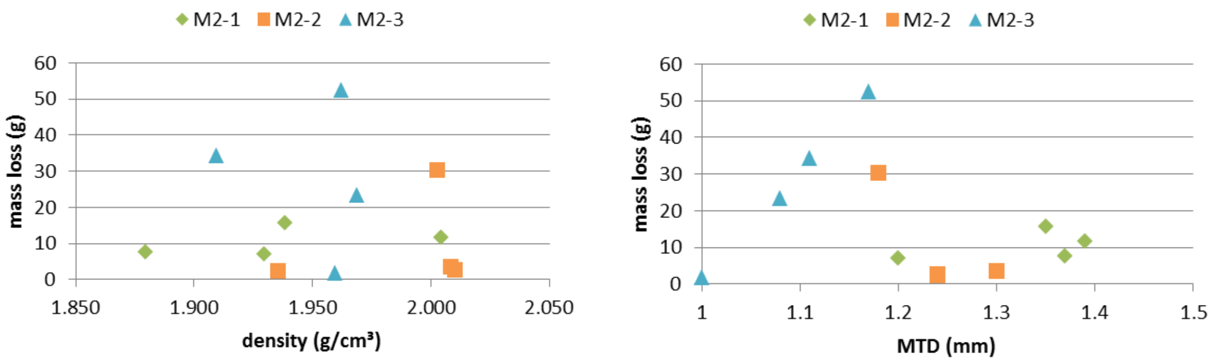
IFSTTAR

The cumulated mass loss at 6000 cycles is shown.

PA



BBTM



SMA

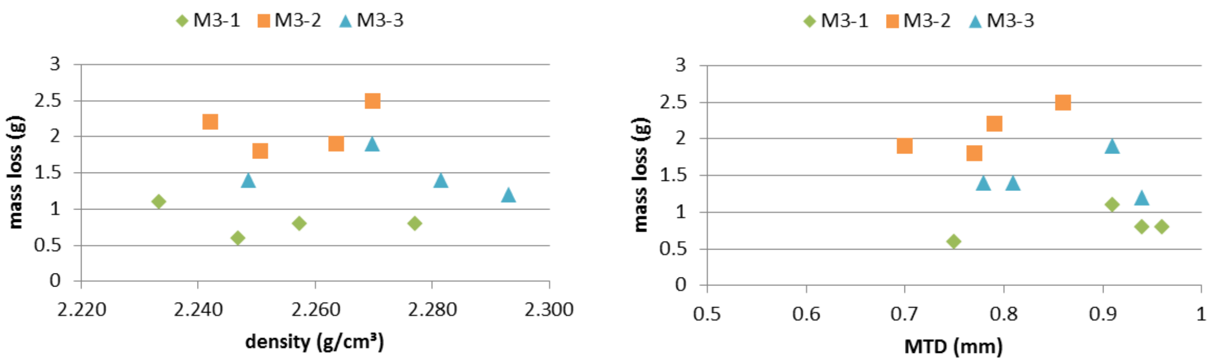


Figure 15 Mass loss versus density (left) and texture (right) (IFSTTAR)

General conclusion:

The plots show no correlations between mass loss and either density or texture. This is not surprising, as the variations in density and MTD within each series of samples of the same mix are very small. The conclusion is that the repeatability of the sample manufacturing for this test program was very good and that the mass loss measurements were not biased by differences in density and texture variations.

5.5 Visual inspection of the loaded area after testing

Pictures were taken from the test specimens before and after testing. It is very difficult to evaluate the damage from pictures, since the resolution, lighting and angle vary.

Inspection of the pictures did not reveal anything special. Only a few general observations are summarized hereafter.

PA

The pictures of the test specimens from the DSD show the most heavily damaged surface. This is as expected, since the stone loss (in grams) per unit of covered area is the highest (when comparing all test results at 20 °C). The DSD is also the test that shows the most naked stone surface. It is difficult to see if this is due to stripping, or stone fracture. Stripping is part of the explanation, since the form of many of the stripped stones looks the same before and after the test.

The pictures of the TRD specimens show no damage, as confirmed by the measured values of material loss (almost no material loss measured).

BBTM

The pictures show a comparable type of damage as for the PA, except for the fact that the aggregate size is smaller.

As for the PA, there is again some degree of stripping with the DSD, which is less visible on the pictures from the other devices.

Only for this mix, the pictures from the TRD show some raveling/abrasion in the middle of the specimen, again confirmed by the measured data.

SMA

On this mix, it is more difficult to see stone loss, since the texture of the surface is more closed. A change of texture before and after the test is seen, since the mastic is smeared out. This is especially seen on the pictures taken after the tests at 40 °C.

6 Conclusions

In this report, the test data are presented with some additional processing of the results, but without any statistical treatment or interpretation.

The following observations were made:

- The instructions were followed fairly well and the test conditions mostly complied, except in a few cases where the test temperature was above the maximum limit. This may lead to systematically higher material loss, but such a systematic correlation is not observed in the test data.
- The reported data on density and thickness of the specimens reflect the high quality and repeatability of the slab manufacturing and compaction:
    - Variations in density within each series of samples are small. It seems feasible to produce series of samples with less than 0.050 g/cm³ difference in density.
    - Variations in thickness between the 8 measurement points within each slab, as an indication of flatness, are small. A maximum thickness variation of 2.5 mm within each sample seems feasible.
- The rate of material loss (slope of the curves) behaves differently, depending on the test device. The DSD shows an increasing rate, especially for the PA and BBTM mixtures, while RSAT shows a decreasing rate. For the other devices, the rate is more or less constant.
- The plots show no correlations between mass loss and either density or texture. This is not surprising, as the variations in density and MTD (Mean Texture Depth) within each series of samples of the same mix are very small. The conclusion is that the repeatability of the sample manufacturing for this test program was very good and that the mass loss measurements were not biased by differences in density and texture variations.
- Visual inspection of the pictures taken from the test specimens before and after the tests did not reveal anything special, although it is very difficult to evaluate the damage from a picture. An exact protocol for taking pictures before and after the test (same resolution, lighting, distance, angle, …) may improve the comparability of pictures .

Except for a few specimens, for which the testing laboratory reported a problem with testing (e.g. due to a problem with the equipment), there are no test specimens of which the results should be rejected before performing the statistical analysis.

Annex 1: Numbering of slabs prepared by BAM

MIX 1-1: PA (reference)

Slab code	Date of compaction	Target date of testing	Random number	Transport to lab
M1-1-4	12 jan 2016	22 mar 2016	4	TU Aachen
M1-1-5	12 jan 2016	22 mar 2016	15	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-1-6	14 jan 2016	24 mar 2016	8	Heijmans
M1-1-7	14 jan 2016	24 mar 2016	14	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-1-8	14 jan 2016	24 mar 2016	17	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-1-9	14 jan 2016	24 mar 2016	7	Heijmans
M1-1-10	14 jan 2016	24 mar 2016	11	BAM
M1-1-11	19 jan 2016	29 mar 2016	6	Heijmans
M1-1-12	19 jan 2016	29 mar 2016	16	BRRC+I~~F~~FSTTAR+TU Darmstadt
M1-1-13	19 jan 2016	29 mar 2016	12	BAM
M1-1-15	19 jan 2016	29 mar 2016	13	IF~~F~~STTAR
M1-1-16	9 febr 2016	19 apr 2016	9	BAM
M1-1-17	9 febr 2016	19 apr 2016	3	TU Aachen
M1-1-18	9 febr 2016	19 apr 2016	5	Heijmans
M1-1-19	9 febr 2016	19 apr 2016	1	TU Aachen
M1-1-20	15 febr 2016	25 apr 2016	2	TU Aachen
M1-1-21	15 febr 2016	25 apr 2016	10	BAM

MIX 1-2: PA (lower compaction temperature)

Slab code	Date of compaction	Target date of testing	Random number	Transport to lab
M1-2-1	21 jan 2016	31 mar 2016	8	Heijmans
M1-2-2	21 jan 2016	31 mar 2016	9	BAM
M1-2-3	21 jan 2016	31 mar 2016	11	BAM
M1-2-4	21 jan 2016	31 mar 2016	15	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-2-5	21 jan 2016	31 mar 2016	14	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-2-6	26 jan 2016	5 apr 2016	5	Heijmans
M1-2-7	26 jan 2016	5 apr 2016	1	TU Aachen
M1-2-8	26 jan 2016	5 apr 2016	4	TU Aachen
M1-2-9	26 jan 2016	5 apr 2016	6	Heijmans
M1-2-10	26 jan 2016	5 apr 2016	16	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-2-11	28 jan 2016	7 apr 2016	13	IF~~F~~STTAR
M1-2-12	28 jan 2016	7 apr 2016	12	BAM
M1-2-13	28 jan 2016	7 apr 2016	17	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-2-14	28 jan 2016	7 apr 2016	10	BAM
M1-2-16	10 febr 2016	20 apr 2016	3	TU Aachen
M1-2-17	15 febr 2016	25 apr 2016	2	TU Aachen
M1-2-18	15 febr 2016	25 apr 2016	7	Heijmans

MIX 1-3: PA (lower binder content)

Slab code	Date of compaction	Target date of testing	Random	Transport to lab
M1-3-1	1 febr 2016	11 apr 2016	2	TU Aachen
M1-3-2	1 febr 2016	11 apr 2016	10	BAM
M1-3-3	1 febr 2016	11 apr 2016	14	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-3-4	1 febr 2016	11 apr 2016	1	TU Aachen
M1-3-5	1 febr 2016	11 apr 2016	5	Heijmans
M1-3-6	3 febr 2016	13 apr 2016	8	Heijmans
M1-3-7	3 febr 2016	13 apr 2016	6	Heijmans
M1-3-8	3 febr 2016	13 apr 2016	13	IF~~F~~STTAR
M1-3-9	3 febr 2016	13 apr 2016	11	BAM
M1-3-10	3 febr 2016	13 apr 2016	9	BAM
M1-3-11	5 febr 2016	15 apr 2016	15	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-3-13	5 febr 2016	15 apr 2016	16	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-3-14	5 febr 2016	15 apr 2016	17	BRRC+IF~~F~~STTAR+TU Darmstadt
M1-3-15	5 febr 2016	15 apr 2016	7	Heijmans
M1-3-16	10 febr 2016	20 apr 2016	4	TU Aachen
M1-3-17	15 febr 2016	25 apr 2016	12	BAM
M1-3-18	15 febr 2016	25 apr 2016	3	TU Aachen

MIX 2-1: BBTM (reference)

Slab code	Date of compaction	Target date of testing	Random	Transport to lab
M2-1-1	23/02/16	03/05/16	4	TU Aachen
M2-1-2	23/02/16	03/05/16	15	BRRC+IFSTTAR+TU Darmstadt
M2-1-3	23/02/16	03/05/16	8	Heijmans
M2-1-4	23/02/16	03/05/16	14	BRRC+IFSTTAR+TU Darmstadt
M2-1-5	23/02/16	03/05/16	17	BRRC+IFSTTAR+TU Darmstadt
M2-1-6	23/02/16	03/05/16	7	Heijmans
M2-1-8	26/02/16	06/05/16	11	BAM
M2-1-9	26/02/16	06/05/16	6	Heijmans
M2-1-10	26/02/16	06/05/16	16	BRRC+IFSTTAR+TU Darmstadt
M2-1-11	26/02/16	06/05/16	12	BAM
M2-1-12	26/02/16	06/05/16	13	IF~~F~~STTAR
M2-1-13	01/03/16	10/05/16	9	BAM
M2-1-14	01/03/16	10/05/16	3	TU Aachen
M2-1-15	01/03/16	10/05/16	5	Heijmans
M2-1-16	01/03/16	10/05/16	1	TU Aachen
M2-1-17	01/03/16	10/05/16	2	TU Aachen
M2-1-18	01/03/16	10/05/16	10	BAM

MIX 2-2: BBTM (lower compaction temperature)

Slabcode	Date of compaction	Target date of testing	Random	Transport to lab
M2-2-2	03/03/2016	12/05/16	8	Heijmans
M2-2-3	03/03/2016	12/05/16	9	BAM
M2-2-4	03/03/2016	12/05/16	11	BAM
M2-2-5	03/03/2016	12/05/16	15	BRRC+IFSTTAR+TU Darmstadt
M2-2-6	03/03/2016	12/05/16	14	BRRC+IFSTTAR+TU Darmstadt
M2-2-7	08/03/2016	17/05/16	5	Heijmans
M2-2-8	08/03/2016	17/05/16	1	TU Aachen
M2-2-9	08/03/2016	17/05/16	4	TU Aachen
M2-2-10	08/03/2016	17/05/16	6	Heijmans
M2-2-11	08/03/2016	17/05/16	16	BRRC+IFSTTAR+TU Darmstadt
M2-2-12	08/03/2016	17/05/16	13	IF~~F~~STTAR
M2-2-13	10/03/2016	19/05/16	12	BAM
M2-2-15	10/03/2016	19/05/16	17	BRRC+IFSTTAR+TU Darmstadt
M2-2-16	10/03/2016	19/05/16	10	BAM
M2-2-17	10/03/2016	19/05/16	3	TU Aachen
M2-2-18	10/03/2016	19/05/16	2	TU Aachen
M2-2-19	24/03/2016	02/06/16	7	Heijmans

MIX 2-3: BBTM (lower binder content)

Slab code	Date of compaction	Target date of testing	Random	Transport to lab
M2-3-1	15/03/2016	24/05/16	2	TU Aachen
M2-3-2	15/03/2016	24/05/16	10	BAM
M2-3-3	15/03/2016	24/05/16	14	BRRC+IFSTTAR+TU Darmstadt
M2-3-4	15/03/2016	24/05/16	1	TU Aachen
M2-3-5	15/03/2016	24/05/16	5	Heijmans
M2-3-6	15/03/2016	24/05/16	8	Heijmans
M2-3-7	17/03/2016	26/05/16	6	Heijmans
M2-3-8	17/03/2016	26/05/16	13	IFSTTAR
M2-3-9	17/03/2016	26/05/16	11	BAM
M2-3-10	17/03/2016	26/05/16	9	BAM
M2-3-11	17/03/2016	26/05/16	15	BRRC+IFSTTAR+TU Darmstadt
M2-3-12	17/03/2016	26/05/16	16	BRRC+IFSTTAR+TU Darmstadt
M2-3-13	22/03/2016	31/05/16	17	BRRC+IFSTTAR+TU Darmstadt
M2-3-14	22/03/2016	31/05/16	7	Heijmans
M2-3-15	22/03/2016	31/05/16	4	TU Aachen
M2-3-16	22/03/2016	31/05/16	12	BAM
M2-3-17	22/03/2016	31/05/16	3	TU Aachen

MIX 3-1: SMA (reference)

Slab code	Date of compaction	Target date of testing	Random	Transport to lab
M3-1-1	April 20, 2016	June 29	4	TU Aachen
M3-1-5	April 20, 2016	June 29	15	BRRC+IFSTTAR+TU Darmstadt
M3-1-6	April 20, 2016	June 29	8	Heijmans
M3-1-7	April 22, 2016	July 1	14	BRRC+IFSTTAR+TU Darmstadt
M3-1-8	April 22, 2016	July 1	17	BRRC+IFSTTAR+TU Darmstadt
M3-1-9	April 22, 2016	July 1	7	Heijmans
M3-1-10	April 22, 2016	July 1	11	BAM
M3-1-11	April 22, 2016	July 1	6	Heijmans
M3-1-12	April 22, 2016	July 1	16	BRRC+IFSTTAR+TU Darmstadt
M3-1-13	April 26, 2016	July 5	12	BAM
M3-1-14	April 26, 2016	July 5	13	IFSTTAR
M3-1-15	April 26, 2016	July 5	9	BAM
M3-1-16	April 26, 2016	July 5	3	TU Aachen
M3-1-17	April 26, 2016	July 5	5	Heijmans
M3-1-18	April 26, 2016	July 5	1	TU Aachen
M3-1-19	May 27, 2016	August 5	2	TU Aachen
M3-1-20	May 27, 2016	August 5	10	BAM

MIX 3-2: SMA (lower compaction temperature)

Slab code	Date of compaction	Target date of testing	Random	Transport to lab
M3-2-2	April 29, 2016	July 8	8	Heijmans
M3-2-3	April 29, 2016	July 8	9	BAM
M3-2-4	April 29, 2016	July 8	11	BAM
M3-2-6	April 29, 2016	July 8	15	BRRC+IFSTTAR+TU Darmstadt
M3-2-7	May 10, 2016	July 19	14	BRRC+IFSTTAR+TU Darmstadt
M3-2-8	May 10, 2016	July 19	5	Heijmans
M3-2-9	May 10, 2016	July 19	1	TU Aachen
M3-2-10	May 10, 2016	July 19	4	TU Aachen
M3-2-11	May 10, 2016	July 19	6	Heijmans
M3-2-12	May 10, 2016	July 19	16	BRRC+IFSTTAR+TU Darmstadt
M3-2-13	May 12, 2016	July 21	13	IFSTTAR
M3-2-14	May 12, 2016	July 21	12	BAM
M3-2-15	May 12, 2016	July 21	17	BRRC+IFSTTAR+TU Darmstadt
M3-2-16	May 12, 2016	July 21	10	BAM
M3-2-18	May 12, 2016	July 21	3	TU Aachen
M3-2-19	May 27, 2016	August 5	2	TU Aachen
M3-2-20	May 27, 2016	August 5	7	Heijmans

MIX 3-3: SMA (lower binder content)

Slab code	Date compaction	Date testing	Random	Transported to lab
M3-3-1	May 17, 2016	July 26	2	TU Aachen
M3-3-2	May 17, 2016	July 26	10	BAM
M3-3-3	May 17, 2016	July 26	14	BRRC+IFSTTAR+TU Darmstadt
M3-3-5	May 17, 2016	July 26	1	TU Aachen
M3-3-6	May 17, 2016	July 26	5	Heijmans
M3-3-7	May 19, 2016	July 28	8	Heijmans
M3-3-8	May 19, 2016	July 28	6	Heijmans
M3-3-9	May 19, 2016	July 28	13	IFSTTAR
M3-3-10	May 19, 2016	July 28	11	BAM
M3-3-11	May 19, 2016	July 28	9	BAM
M3-3-12	May 19, 2016	July 28	15	BRRC+IFSTTAR+TU Darmstadt
M3-3-13	May 25, 2016	August 3	16	BRRC+IFSTTAR+TU Darmstadt
M3-3-14	May 25, 2016	August 3	17	BRRC+IFSTTAR+TU Darmstadt
M3-3-15	May 25, 2016	August 3	7	Heijmans
M3-3-17	May 25, 2016	August 3	4	TU Aachen
M3-3-19	May 27, 2016	August 5	12	BAM
M3-3-20	May 27, 2016	August 5	3	TU Aachen

Annex 2: Instructions for testing and reporting

Measurements of dimensions and dry mass

(to be reported in the Excel worksheet “Dimensions-mass” of the Data template)

- Measure L (length) and W (width) at 4 positions, equally divided over the area (accuracy 0,1 mm).
- Measure T (thickness) in 8 points (at 4 corners and at 4 mid points of sides) (accuracy 0,1 mm).
- Measure M_0 (accuracy 0,1 g) of the dry specimens.

Notes:

- *A test specimen shall be considered “dry” after at least 8 h drying time and when two weighings performed minimum 4 h apart differ by less than 0,1 %.*
- *If a different procedure is used to measure the dimensions from prCEN/TS 12697-50 12697-50, please report.*

Photographs

(to be reported in the Excel worksheet “Photographs” of the Data template)

- Take photographs of the samples before and after testing (see examples below)

Top view

45 ° angle view

Texture measurements

(optional)

<u>Testing</u>

(to be reported in the Excel worksheets “M1-1”, “M1-2” and “M1-3” of the Data template)

- The test is subdivided in 4 steps:
  - End of step 2 corresponds to half the number of loading cycles;
  - End of step 4 corresponds to the total number (= end of testing);
  - Steps 1 and 3 are equally long intermediate steps.

This will lead to 5 data points for mass measurements: start, end of step 1, end of step 2 (= halfway the test), end of step 3 and end of step 4 (=end of test)

- Testing shall commence at the target date of testing (+/- 1 week).

- Measure the room temperature or the temperature of the enclosure in which the test is run.

- Condition the specimens to the test temperature for at least 4 h.

Only for RSAT: Run the test for 1 h without load.

- Measure the surface temperature at the start and at the end of each step (just before starting and immediately after stopping the machine).

Note: Other temperature measurement are optional (eg: tyre temperature, temperature of the enclosure, …).

- Measure the mass or the mass loss at the end of each step.

Use a vacuum cleaner to remove all loose material before weighing.

- If possible, rotate the plate by 180 ° halfway through the test, or by 90 ° after each step.

Note: Not relevant for RSAT, since test plate turns continuously.

- At the end of the test, measure M_{end} by weighing the tested specimen.

In addition to the completed Data template file, the following information shall be reported:

- Procedure for measuring the temperature(s)
- Procedure used to determine the covered area
- Procedure for measuring loss of mass (weighing plate or loose material or both)

- Whether rotation of the test plate during testing has been applied
- Texture measurement procedure and results (optional)
- Any deviation from the instructions
- Any anomaly observed during testing

Annex 3: Test data sheets

(see annex3.7z)