Road and Transportation Research Association

Working Group on Aggregates, Unbound Pavements

FGSV

Technical testing regulations for aggregates in road construction

R 1

Part 6.6.3
Water susceptibility of fine aggregates – Shaking abrasion method

TP Gestein-StB

Edition 2018, Translation 2021

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Water susceptibility of fine aggregates – Shaking abrasion method

Edition: 2018

1 Purpose and field of application

The shaking abrasion method is used to determine the water susceptibility of fine aggregates or the proportion of fine aggregates in aggregate mixtures (including the respective filler contained therein) for bituminous mixtures. The method is based on the procedure pursuant to DIN EN 12274-7 "Slurry surfacing – Part 7: Shaking abrasion test".

Note: The method can also be applied to investigate the water susceptibility of fillers using standard bitumen and standard sand, or bitumen using standard sand and standard limestone powder.
In Annex B, a method for determining the water susceptibility of fillers is given as an alternative to the method pursuant to DIN EN 1744-4 "Tests for chemical properties of aggregates – Part 4: Determination of water susceptibility of fillers for bituminous mixtures".
Annex C describes a method for determining the water susceptibility of asphalt mixture fillers.
Annex D describes a method for determining the water susceptibility of bitumen for asphalt.

2 Short description of the method

The shaking abrasion test determines the water susceptibility of an asphalt mixture – prepared using fillers, fine aggregates or aggregate mixtures and a bitumen. The test measures the abrasion of standardised specimens that occurs when cylindrical specimens of a compacted asphalt mixture are placed in water-filled shaking cylinders, which in turn are rotated around an axis in a suitable device with overhead movement. In addition, the cylindrical specimens are tested for swelling as a result of being stored in water.

When testing fine aggregates or the proportion of fine aggregates in aggregate mixtures, two series of tests are performed. In the E series, the particle size classifications sieved out of the fine aggregate or aggregate mixture are applied. In the F series, the filler content (particle size classification 0/0.125 mm) is replaced by a standard limestone powder.

Three cylindrical specimens measuring 30 mm in diameter are tested in each series of tests. They are prepared from a standardised specimen mixture using a standard bitumen. The specimens are statically compacted.

3 Materials and testing equipment

Conical steel bowl, 18 cm in diameter

Porcelain crucible 1000 ml with porcelain handle

3x porcelain crucible 125 ml with porcelain handle

Porcelain pestle, 57 mm in diameter, 180 mm in length

Stirring thermometer up to 220 °C

Heater with air bath

Heating chamber with air circulation, temperature controlled, for maintaining a temperature of (110 ± 5) °C and (150 ± 5) °C

Test sieves with metal mesh pursuant to DIN ISO 3310- 1 with opening widths of 2.0 mm, 0.71 mm, 0.4 mm, 0.25 mm and 0.125 mm

Compaction moulds with base plates pursuant to DIN EN 12274-7 (at least 3 per series of tests)

Compaction pistons, one per compaction mould pursuant to DIN EN 12274-7

Filling funnel pursuant to DIN EN 12274-7

Thermostatic water bath (DIN EN 12697-12:2008-10, Section 5, Method A)

Vacuum system (DIN EN 12697-12:2008-10, Section 5, Method A)

Compression test machine with a suitable load range and a feed rate of (20 ± 3) mm/min

Shaking device equipped with at least 3 shaking cylinders (see Figure 1 and DIN EN 12274-7:2005-08, Figure 4)

Shaking cylinder with sealing cap (see DIN EN 12274-7:2005-08 Figures 4 and 5)

Chamois cloth

Hardboard, approx. 1 cm thick

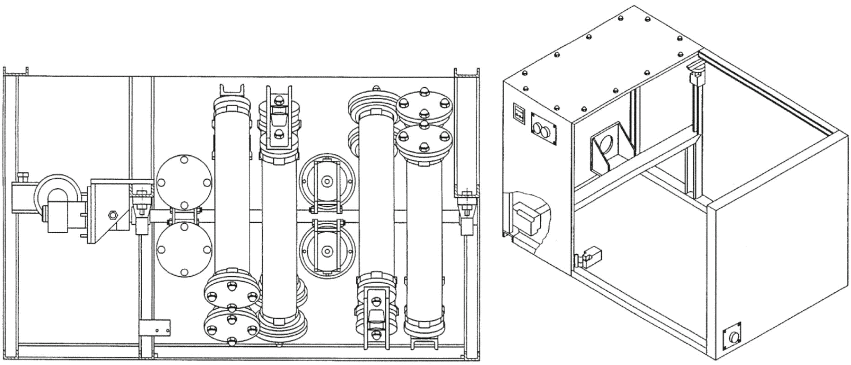

Figure 1: Shaking device

The binder used for these tests is a bitumen 70/100 pursuant to DIN EN 12591 "Bitumen and bituminous binders – Specifications for paving grade bitumens". The reference address for the applied bitumen can be found at www.fgsv.de/bezugsadressen.

For the F series, a standard limestone powder must be applied. The reference address for the applied standard limestone powder can be found at www.fgsv.de/bezugsadressen.

4 Preparing the test

4.1 Preparing the specimens (sand asphalt specimens)

4.1.1 Preparing the aggregate

The aggregates must be dried at (110 ± 5) °C inside the heating chamber.

Note: Drying aggregates with an open flame or an IR radiator is not permitted.

The unwashed aggregates are divided by dry sieving pursuant to DIN EN 933-1:2012-03, Section 7.2 into the particle size classifications 0/0.125; 0.125/0.25; 0.25/0.71 and 0.71/2 mm.

4.1.2 Composition of the specimen mixture

The specimen mixture must consist of 0/2 mm aggregate and standard bitumen. Two series of tests are performed. In the E series, the particle size classifications sieved out of the fine aggregate for testing are applied. In the F series, the filler content (particle size classification 0/0.125 mm) is replaced by a standard limestone powder.

For the actual test, the aggregate must have the following composition (Table 1):

Table 1: Proportion of particle size classifications applied in the specimen mixture when determining water susceptibility using the shaking abrasion method

Particle size classification [mm]	**Proportion** [% by mass]
0.71 – 2.0	20
0.25 – 0.71	35
0.125 – 0.25	20
0 – 0.125	25

The required mass of aggregate is composed for each series for the required three specimens according to Table 2.

Table 2: Specimen mixture composition for determining water susceptibility using the shaking abrasion method

Particle size classification [mm]	**Net weight of aggregate** [g]
0.71 – 2.0	48 ± 0.2
0.25 – 0.71	84 ± 0.2
0.125 – 0.25	48 ± 0.2
0 – 0.125	60 ± 0.2

The quantity of binder B (± 0.1 g) is determined as a function of the bulk density of the aggregate 0/2 as follows.

$$B = \frac{15.5 \cdot 2.700}{\rho_g} \text{ [g]}$$

Where

B = the quantity of binder, rounded to the nearest 0.1 g

ρ_g = the bulk density of the aggregate 0/2 mm with a composition according to Table 2 in g/cm³ and calculated according to Section 6.1.

The densities of the aggregates are to be determined as follows:

– Unwashed aggregate 0.125/2.0 with a composition according to Table 2 based on DIN EN 1097-6:2013-09, Annex A

– Series E filler pursuant to DIN EN 1097-7

– Series F filler (standard limestone powder) pursuant to DIN EN 1097-7.

Note: Additional test quantities need to be obtained according to Table 2 to determine the densities.

4.1.3 Preparing the specimen mixture

When heating the aggregate to the mixing temperature, the homogenised, weighed aggregate is placed in a steel bowl for (180 ± 10) minutes inside the heating chamber at a temperature of (150 ± 5) °C.

The respective portion of cold binder is weighed into a porcelain crucible and then covered and placed inside the same heating chamber for (18 ± 2) minutes before the end of the aggregate tempering period.

Note: Alternatively, the binder can be tempered in a hot air bath. The binder must not be heated more than once. Aluminium foil or a metal lid can be used to cover the binder.

The heated aggregates are then added to the binder in the porcelain crucible, pre-mixing at the same time with the stirring thermometer. Pre-mixing, including pouring, must be carried out for (30 ± 3) seconds.

Immediately afterwards, the porcelain crucible is placed on the hardboard to reduce heat loss and the asphalt mixture is kneaded (about one stirring rotation per second) with the heated porcelain pestle for (150 ± 10) seconds without the application of heat. The mixture, which has cooled slightly as a result of kneading, is then heated to (150 ± 5) °C over the heater with air bath, while stirring continuously with the stirring thermometer. Subsequently, the mixture is then kneaded for a second time on the hardboard with the porcelain pestle for (150 ± 10) seconds without the application of heat.

Once the specimen mixture has cooled down to below 50 °C, the quantities of mixture required for each specimen are weighed into individual porcelain crucibles (125 ml). The net weight is (40 ± 0.3) g.

4.1.4 Preparing the specimens

The specimens are prepared on the day of mixture preparation. The asphalt mixture specimens, which have cooled down to room temperature, are placed in the small porcelain crucibles inside the heating chamber tempered to (150 ± 5) °C. The compaction moulds and pistons with their base plates are also heated here. After a tempering period of (30 ± 2) minutes, only the first specimen is removed from the heating chamber. The remaining specimens and their moulds remain inside the heating chamber. The removed specimen is poured through the filling funnel into the heated compaction mould. Pre-compaction is achieved by lightly tapping the filled compaction mould on the hardboard. The compaction piston is then placed on the pre-compacted specimen, and the compaction mould with piston is placed in the compression test machine. Compaction takes place at a feed rate of (20 ± 3) mm/min until a force of (10 ± 0.5) kN is reached. After the aforesaid force has been reached, the specimen must be immediately relieved of the force.

The second and third specimens are prepared in the same way as the first specimen. This process must be carried out quickly to ensure compaction of the third specimen is completed no more than 10 minutes after the start of compaction of the first specimen.

After being air cooled to a temperature of 40 to 80 °C, the specimens are pushed downwards and demoulded, i.e. pushed out of the other end of the slightly conical mould cylinders.

Note: Demoulding can be done using, e.g., a light hand press or a vice.

The three specimens are stored in air for (24 ± 3) hours at (25 ± 2) °C after demoulding.

Before any further tests are carried out, protruding burrs must be removed from the upper and lower edges of the specimens. The sand asphalt specimens obtained in this way are designated P1 to P3 for each series.

Note: Fine sandpaper is suitable for deburring.

5 Test method

5.1 Determining water absorption and swelling

The dry mass (m_p) of the three specimens (P1, P2 and P3) must be determined to the nearest 0.01 g at the start of the test.

The specimens (P1, P2 and P3) are to be stored at (25 ± 2) °C in a water bath. After being stored in water for (90 ± 30) minutes, they are weighed under water (m_{WA}) and in air (m_{LA}) as specified in DIN EN 12697-6:2012-07, Method B, Steps d), e) and g) to the nearest 0.01 g. The difference between the determined masses ($m_{LA} - m_{WA}$) is equal to the numerical value of the initial volume of the specimen V_A in cm³.

Afterwards, the specimens P1, P2 and P3 are treated pursuant to DIN EN 12697-12:2008-10, Sections 6.1.2.2.1 to 6.1.2.2.4.

For this purpose, the specimens are stored on a tray with a perforated intermediate base in distilled water tempered to (20 ± 5) °C inside a vacuum chamber. The specimens must be covered at least 20 mm with distilled water.

The vacuum chamber must be evacuated to a residual pressure of (6.7 ± 0.3) kPa within (10 ± 1) minutes. This pressure is to be maintained for a period of (30 ± 5) minutes. After which, the atmospheric pressure should be allowed to build up again in the vacuum chamber.

The tray with the specimens is then removed from the vacuum system, transferred to the water bath and stored there for (90 ± 30) minutes at (25 ± 2) °C. After storage, the specimens are to be weighed under water (m_{WV}) and in air (m_{LV}) according to the aforesaid procedure. The difference between the determined masses ($m_{LV} - m_{WV}$) is equal to the numerical value of the volume after water absorption of the specimen V_V in cm³.

Subsequently, the specimens P1 to P3 are stored for (72 ± 6) hours in a water bath at (25 ± 2) °C.

After being stored in water, the specimens (P1, P2 and P3) are to be weighed again under water (m_{WQ}) and in air (m_{LQ}) as specified in DIN EN 12697-6:2012-07, Method B, Steps d), e) and g) to the nearest 0.01 g. The difference between the two weighing results is used to determine the volume after swelling V_Q, similar to the V_A calculation procedure.

Note: Drinking water can be applied if it has been demonstrated that its use produces the same results as distilled water.

5.2 Determining the shaking abrasion

The test shall be carried out immediately after determining the volume after swelling V_Q (section 5.1) on specimens P1, P2 and P3. Each specimen is to be placed in one of the shaking cylinders previously filled with (750 ± 5) ml of fresh drinking water at a temperature of (25 ± 2) °C. Afterwards, the shaking cylinders are fitted with the sealing caps and inserted into the shaking device. The shaking device is then operated at a speed of (20 ± 2) rpm at room temperature until completing a total of (3600 ± 10) rotations. The specimens are to be extracted from the cylinders and any loose components immediately removed under running water. After dabbing the specimens with the damp chamois leather, the mass is determined to the nearest 0.01 g after exposure to shaking abrasion (ms).

Note: There must be no residual solvent in the shaking cylinders during the test.

6 Evaluation

6.1 Bulk density of the composite aggregate 0/2 mm of a series

The bulk density of the composite aggregate 0/2 mm of a series is calculated using the following equation:

$$\rho_g = \frac{100}{\frac{P_{a1}}{\rho_{a1}} + \frac{P_{a2}}{\rho_{a2}}} \text{ [g/cm³]}$$

Where

ρ_g = the bulk density of the composite aggregate 0/2 mm of a series, rounded to the nearest 0.001 g/cm³

P_{a1} = the percentage of the aggregate 0.125/2.0 in the aggregate 0/2 mm(in % by mass) according to Table 1

ρ_{a1} = the bulk density of the aggregate 0.125/2.0, rounded to the nearest 0.001 g/cm³

P_{a2} = the percentage of the filler 0/0.125 (series E or F) in the aggregate 0/2 mm (in % by mass) according to Table 1

ρ_{a2} = the bulk density of the filler 0/0.125 (series E or F), rounded to the nearest 0.001 g/cm³.

6.2 Water absorption

The water absorption (W) is calculated pursuant to DIN EN 12274-7, Section 6.1.2 and is to be stated, rounded to the nearest 0.1 % by volume, as the arithmetic mean of three individual values (P1, P2 and P3).

$$W_V = \frac{m_{LV} - m_p}{m_{LA} - m_{WA}} \cdot 100 \text{ [\% by volume]} \quad \text{for } V_V \le V_A$$

$$W_V = \frac{(m_{WV} - m_p) + (m_{LA} - m_{WA})}{m_{LA} - m_{WA}} \cdot 100 \text{ [\% by volume]} \quad \text{for } V_V > V_A$$

Where

W_V = the water absorption, in % by volume

m_{LA} = the mass of the specimen in air before the application of vacuum, in g

m_{WA} = the mass of the specimen under water before the application of vacuum, in g

m_{LV} = the mass of the specimen in air after the application of vacuum, in g

m_{WV} = the mass of the specimen under water after the application of vacuum, in g

m_p = the mass of the specimen in air before the test, in g

V_A = corresponds approximately to $m_{LA} - m_{WA}$, in g – the volume of the specimen before water absorption, in cm³

V_V = corresponds approximately to $m_{LV} - m_{WV}$, in g – the volume of the specimen after water absorption, in cm³.

6.3 Swelling

The swelling (Q), rounded to nearest 0.1% by volume, is to be stated as the arithmetic mean of the three individual values (P1, P2 and P3).

$$Q = \frac{V_Q - V_A}{V_A} \cdot 100 \text{ [\% by volume]}$$

Where

Q = the swelling, in % by volume

V_Q = the volume of the specimen after swelling, in cm³

V_A = the initial volume of the specimen, in cm³.

6.4 Shaking abrasion

The shaking abrasion (S_A), rounded to the nearest 0.1% by mass, is to be stated as the arithmetic mean of the three individual values (P1, P2 and P3).

$$S_A = \frac{m_{LQ} - m_s}{m_{LQ}} \cdot 100 \text{ [\% by mass]}$$

Where

S_A = the shaking abrasion of the specimen, rounded to the nearest 0.1% by mass

m_{LQ} = the mass of the specimen in air after storage in water, rounded to the nearest 0.01 g

m_s = the mass of the specimen after exposure to shaking-abrasion, rounded to the nearest 0.01 g.

7 Test report

The following must be stated in the test report:

- Information on sampling and origin of the material
- Type of aggregate
- Designation of the particle size fraction/particle size group from which the test particle was obtained
- Water absorption (W)
- Swelling (Q)
- Shaking abrasion (S_A).

The results of the two series of tests (E and F) are recorded in tabular form.

Table 3: Example of tabular representation

Test feature	Result series E	Result series F	
Water absorption (W)			% by volume
Swelling (Q)			% by volume
Shaking abrasion (S_A)			% by mass

8 Precision of the method

The precision of the method is unknown.

Annex A

Literature references

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Annex B

Water susceptibility of fillers using the shaking abrasion method

Changes to the procedure of the main part

Regarding Section 4.1.2 Composition of the specimen mixture

When determining the water susceptibility of fillers using the shaking abrasion method, only one series of tests is investigated using a bitumen 70/100 pursuant to DIN EN 12591 “Bitumen and bituminous binders – Specifications for paving grade bitumens” and the standard sands (“FH31” and “F36”). The reference addresses for the applied bitumen and the applied standard sands can be found at www.fgsv.de/bezugsadressen.

For the test, the aggregate must have the following composition:

Table 1: Proportion of particle size classifications applied in the specimen mixture when determining water susceptibility using the shaking abrasion method

Particle size classification [mm]	**Proportion** [% by mass]
0.25 – 0.4	25
0.125 – 0.25	50
0 – 0.125	25

The particle size classification 0/0.125 mm consists exclusively of the filler being tested, the particle size range > 0.125 mm consists exclusively of the standard sand.

Table 2: Specimen mixture composition for determining water susceptibility using the shaking abrasion method

Particle size classification [mm]	**Net weight of aggregate** [g]
0.25 – 0.4	60 ± 0.2
0.125 – 0.25	120 ± 0.2
0 – 0.125	60 ± 0.2

The quantity of binder B (± 0.1 g) is determined as a function of the bulk density of the filler as follows.

$$B = \frac{12.0 \cdot 2.700}{\rho_g} \text{ [g]}$$

Where

B = the quantity of binder, rounded to the nearest 0.1 g

ρ_g = the bulk density of the aggregate with a composition according to Table 2 in g/cm³ and calculated according to Section 6.1.

The required mass of aggregate and standard bitumen is composed for the required three specimens.

Regarding Section 5.1 Determining water absorption and swelling

The specimens P1 to P3 are stored in water for (144 ± 6) hours.

Regarding Section 7 Test report

The results are recorded in tabular form.

Table 3: Example of tabular representation

Test feature	Result	
Water absorption (W)		% by volume
Swelling (Q)		% by volume
Shaking abrasion (S_A)		% by mass

Annex C

Water susceptibility of mixed fillers using the shaking abrasion method

Changes to the procedure of the main part

In the case of mixed fillers, the binder requirement is higher for the shaking abrasion method than in the case of fillers due to their special properties. Further, the binder content cannot be determined uniformly, as it depends on the quantity of hydrated lime contained. Therefore, it is necessary to determine the binder content during a preliminary test.

Regarding Section 4.1.2 Composition of the specimen mixture

When determining the water susceptibility of mixed fillers using the shaking abrasion method, only one series of tests is investigated using a bitumen 70/100 pursuant to DIN EN 12591 “Bitumen and bituminous binders – Specifications for paving grade bitumens” and the standard sands (“FH31” and “F36”). The reference addresses for the applied bitumen and the applied standard sands can be found at www.fgsv.de/bezugsadressen.

For the test, the aggregate must have the following composition:

Table 1: Proportion of particle size classifications applied in the specimen mixture when determining water susceptibility using the shaking abrasion method

Particle size classification [mm]	**Proportion** [% by mass]
0.25 – 0.4	25
0.125 – 0.25	50
0 – 0.125	25

The particle size classification 0/0.125 mm consists exclusively of the mixed filler to be tested, the particle size range > 0.125 mm consists exclusively of the standard sand.

The binder content in the dry matter must be determined in a preliminary test. Preparation of the specimen mixture for the preliminary test:

Table 2: Composition of the aggregate mixture when determining the binder content (preliminary test)

Particle size classification [mm]	**Net weight of aggregate** [g]
0.25 – 0.4	60 ± 0.2
0.125 – 0.25	120 ± 0.2
0 – 0.125	60 ± 0.2

The aggregate mixture must be weighed to the nearest 0.1 g in a porcelain crucible (1000 ml) and recorded as M_1. The aggregate mixture is then to be heated to the mixture temperature in the porcelain crucible for (180 ± 10) minutes inside a heating chamber at (150 ± 5) °C.

Approximately 50 g of cold standard bitumen is weighed into another porcelain crucible and then placed inside the same heating chamber for (25 ± 5) minutes before the end of the aggregate mixture tempering period.

Note: Alternatively, the binder can be heated with a hot air bath. The tempering period must be adjusted accordingly.

The tempered aggregate mixture must now be tared on a heat-proof scale to control the addition of binder. Some of the tempered binder is then added to the heated aggregate in the porcelain crucible, pre-mixing at the same time with the stirring thermometer. Immediately afterwards, the porcelain crucible is placed on the hardboard to reduce heat loss and the asphalt mixture is kneaded with the heated porcelain pestle for (150 ± 10) seconds without the application of heat.

The asphalt mixture must now be assessed visually.

The optimum binder content (BM_{opt}) is achieved when the asphalt mixture is crumbly, any lumps that have formed break up easily and the asphalt mixture is matt.

Note: The consistency of the asphalt mixture with the optimum binder content (BM_{opt}) is similar to the plastic limit of fines in soil mechanics.

If the asphalt mixture is powdery, increase the binder content. To do so, the asphalt mixture, which has cooled down during kneading, is reheated over a heater with air bath to (150 ± 5) °C, while stirring continuously with the stirring thermometer. After the further addition of binder, the asphalt mixture is kneaded again on the hardboard with the porcelain pestle for (150 ± 10) seconds without the application of heat.

Repeat this procedure until the optimum binder content (BM_{opt}) has been reached.

After the asphalt mixture has cooled down, it has to be weighed again to the nearest 0.1 g and recorded as M_2.

The difference between M_2 and M_1 is the binder requirement (M_3) in g, which is necessary for the preparation of three specimens according to TP Gestein-StB, Part 6.6.3, Annex B.

The specimen mixture of the preliminary test must not be applied for the preparation of specimens!

The optimum binder content (BM_{opt}) is calculated according to the following equation:

$$BM_{opt} = \frac{M_2 - M_1}{240} \cdot 100\ \%$$

It must be stated in the test report rounded to the nearest 0.1%.

The required mass of aggregate and standard bitumen is composed for the required three specimens according to Table 3.

Table 3: Specimen mixture composition for determining water susceptibility using the shaking abrasion method (mixed filler)

Particle size classification [mm]	**Net weight of aggregate** [g]
0.25 – 0.4	60 ± 0.2
0.125 – 0.25	120 ± 0.2
0 – 0.125	60 ± 0.2
	Net weight of bitumen [g]
	M_3 ± 0.1

Regarding Section 5.1 Determining water absorption and swelling

The specimens P1 to P3 are stored in water for (144 ± 6) hours.

Regarding Section 7 Test report

The results are recorded in tabular form.

Table 4: Example of tabular representation

Test feature	**Result**	
Optimum binder content (BM_{opt})		% by mass
Water absorption (W)		% by volume
Swelling (Q)		% by volume
Shaking abrasion (S_A)		% by mass

Annex D

Water susceptibility of bitumen using the shaking abrasion method

Changes to the procedure of the main part

Regarding Section 4.1.2 Composition of the specimen mixture

When determining the water susceptibility of bitumen using the shaking abrasion method, only one series of tests is investigated using standard limestone powder and the standard sands ("FH31" and "F36"). The reference addresses for the applied standard limestone and the applied standard sands can be found at www.fgsv.de/bezugsadressen.

For the test, the aggregate must have the following composition:

Table 1: Proportion of particle size classifications applied in the specimen mixture when determining water susceptibility using the shaking abrasion method

Particle size classification [mm]	**Proportion** [% by mass]
0.25 – 0.4	25
0.125 – 0.25	50
0 – 0.125	25

The particle size classification 0/0.125 mm consists exclusively of the standard limestone powder, the particle size range > 0.125 mm consists exclusively of the standard sand. The binder content in the dry matter is uniformly 5.0% by mass.

The required mass of aggregate and the bitumen being tested is composed for the required three specimens.

A binder content of 5.0% by mass results in the following net weights:

Table 2: Specimen mixture composition for determining water susceptibility using the shaking abrasion method

Particle size classification [mm]	**Net weight of aggregate** [g]
0.25 – 0.4	60 ± 0.2
0.125 – 0.25	120 ± 0.2
0 – 0.125	60 ± 0.2
	Net weight of bitumen [g]
	12 ± 0.1

Regarding Section 5.1 Determining water absorption and swelling

The specimens P1 to P3 are stored in water for (144 ± 6) hours.

Regarding Section 7 Test report

The results are recorded in tabular form.

Table 3: Example of tabular representation

Test feature	Result	
Water absorption (W)		% by volume
Swelling (Q)		% by volume
Shaking abrasion (S_A)		% by mass

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These publications either specify the technical design or realization (R1) or give recommendations on the technical design or realization (R2).

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