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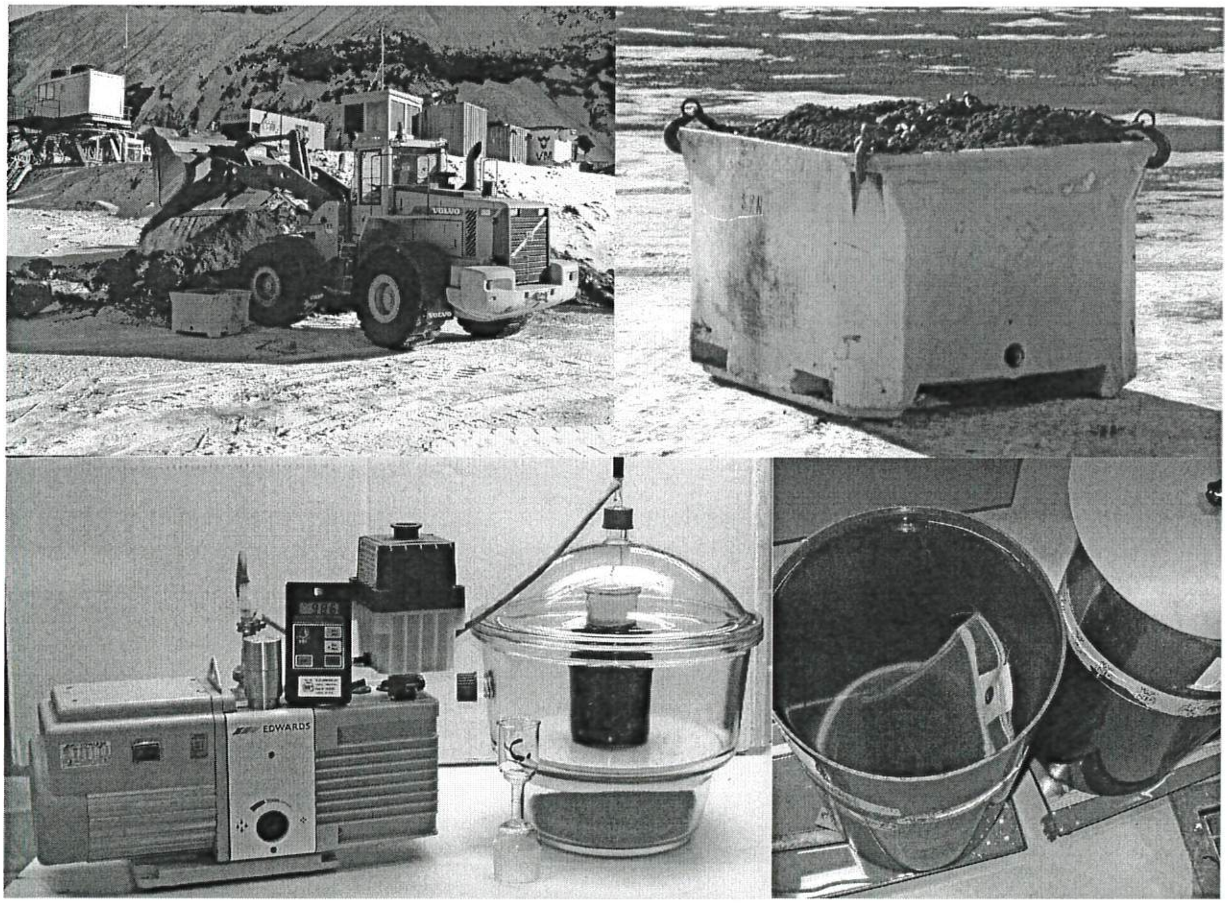
Test methods adapted for alternative and recycled, porous aggregate materials
Part 3 – Water absorption

NORDTEST Project No. 1531-01



SP Swedish National Testing and Research Institute
Building Technology
SP REPORT 2003:24

Abstract

This report presents the results of Nordtest project No. 1580-02. It is the third report in a series of projects dealing with test methods for mainly alternative and recycled aggregates (1292-96 and 1393-97). This study focuses on the problem of water absorption of porous aggregates in atmospheric pressure in accordance with EN 1097-6 *Determination of particle density and water absorption,* and the implication on durability aspects.

The water absorption has been measured on incinerator bottom ash, crushed concrete, porous basalt and lightweight aggregate (expanded clay). The test procedure followed EN 1097-6 for atmospheric pressure. In addition a long term test of 300 days water soaking was performed. Boiling and vacuum were also used in order to see whether a quick method could be developed.

The results clearly show that water absorption for 24 hours in atmospheric pressure and conditioning is not suitable for these very porous materials. They also show that there is a significant difference when pre-drying the materials before testing compared to soaking the materials in a natural state, "as delivered". The four tested materials performed quite differently during long term saturation in relation to the quick tests, which indicates that it may be difficult to find one unique quick test method valid for all of them.

The long time to water saturate the materials also has implications for other tests, e.g. durability, when the materials shall be conditioned and/or tested in a wet condition. One such example is compaction before tri-axial dynamic testing which is usually performed in a wet condition. Also when assessing the frost resistance, the materials shall be saturated before the freeze-thaw cycles. If this is done for only 24 hours the results could be unreliable.

It has not been possible to develop one unique, quick test methods valid for all materials. Until such a method is developed, one has to let the materials absorb water until steady state is reached or develop an indirect method validated for each type of material!

Key words: Aggregates, Recycled materials, test methods, water absorption.

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Preface

Various national regulations in most European countries are introduced in order to facilitate the use of recycled aggregates, aggregates from secondary sources and others that can be termed as alternative aggregates compared to natural gravel and crushed rocks.

The European standardisation of Aggregates CEN TC 154 has focused its work on the standardised test methods suitable for natural aggregates. In order to have a fair competition between natural aggregates and alternative aggregates and, equally important, to get relevant data when testing alternative aggregates, SP has focused several projects on validation of test methods for such materials. This Nordtest project no. 1580-02, two other Nordtest projects (no. 1292-96 and 1393-97) and one national project co-financed by the Swedish Road Authority and SP have therefore been carried out in an attempt to give guidelines to the standardisation organisation.

The project has been carried out in collaboration with Petur Petursson from the Icelandic Building Research Institute (IBRI) and Joralf Aurstad from SINTEF, Norway.

The financial support from Nordtest is greatly appreciated.

Björn Schouenborg

Borås, November 2003

1 Introduction

A major trend, not only for aggregates, is the ever increasing awareness of our nature's sensitivity and demands. Some countries have been forced to act due to the simple fact that there is an actual shortage in natural aggregate resources. In other cases, the demands from society require a change towards a more sustainable production and consumption. Significantly increased deposition taxes work in the same way; "everything shall be used and re-used". Alternative aggregate materials and a more "efficient" use of existing deposits may be part of the solution.

In 1999, the Swedish Parliament adopted 15 environmental quality objectives, describing what state of the Swedish environment is sustainable in the long term. Also, about 70 interim targets have been adopted by Parliament. One of them, "a good built environment" stipulates that the amount of waste directed to landfill should be decreased by 50% from 1994 to 2005. This environmental objective also includes a goal saying that recycled aggregates should reach a level of 15% of all ballast by the year 2010. Also, landfill will become increasingly expensive due to the stricter demands on landfill sites stipulated by the Council Directive 1999/31/EC of 26 April 1999.

This has attracted a lot of interest from the producers of waste materials which might be suitable as aggregates. For example, Värmeforsk (Thermal Engineering Research Institute) in Sweden has launched a research and development program focused on recycling of ash for a variety of purposes, such as road construction material or concrete. To ensure a satisfying function, the materials have to be tested and compared to the demands appropriate for different applications. Currently, SP runs a project for assessment of quality criteria for ash for road construction and civil engineering purposes. Certification rules are being developed for blast furnace slag and steel slag. The use of adequate methods is crucial in this work.

An ad hoc group was formed under TC 154 to deal with Recycled Aggregates. The outcome was a technical report giving guidance on the most suitable properties to verify on such materials [1]. However, it only makes reference to standardised test methods. The properties and performance of recycled aggregates and aggregates from secondary sources have traditionally been assessed by use of standardised test methods for natural aggregates. However, it has repeatedly been demonstrated that most standardised test methods are not suitable for other materials [2, 3, 4 & 5].

The present study has focused on how to test the water absorption of highly porous aggregates, natural and alternative. It has been anticipated that such material will continue to soak water for a very long time, in some cases more than one year! The present European standard EN 1097-6 [6] is therefore not suitable for production control.

2 Test methods, equipment and scheme

2.1 European standard

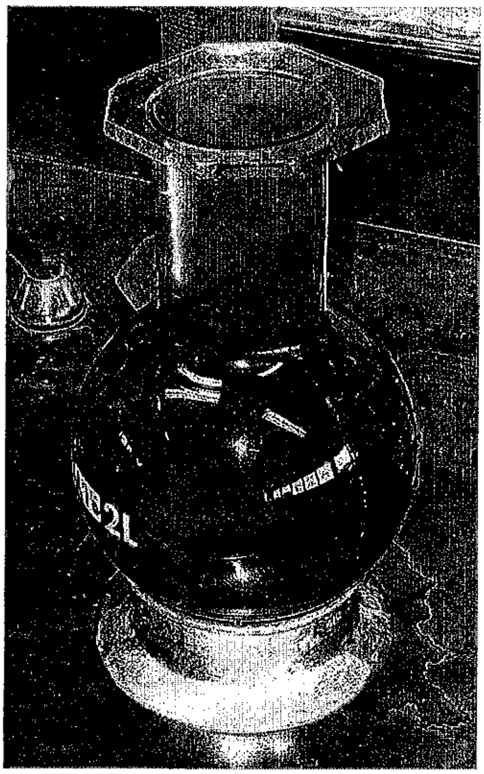
EN 1097-6 *Determination of particle density and water absorption* is divided into the following different parts:

- Pyknometer method for aggregate particles between 0,063 and 4 mm
- Pyknometer method for aggregate particles between 4 and 31,5 mm
- Wire-basket method for aggregate particles between 31,5 and 63 mm

This project has focused on materials with particles between 4 and 31,5 mm. Both the pyknometer and the wire basket procedure have been executed. The wire basket procedure has been used for the long-term water absorption.

2.2 Standard water absorption test by use of Pyknometer

According to the standard method (in short), the material shall be immersed in water in a pyknometer for 24 hours at a temperature of 22 °C. The material is then surface-dried, and water absorption and particle density can be calculated following the described procedure.



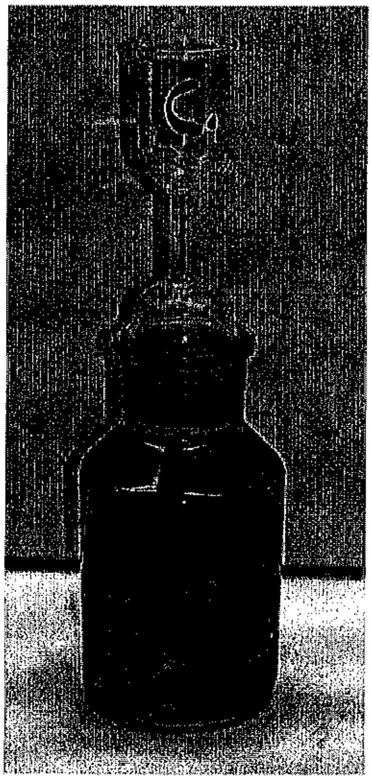


Figure 2.1. Examples of glass pyknometers used in the project.

2.3 Vacuum treatment

In order to see whether it was possible to develop a quick method, the materials were allowed to absorb water in different vacuum; 30, 50 and 75 mbar.

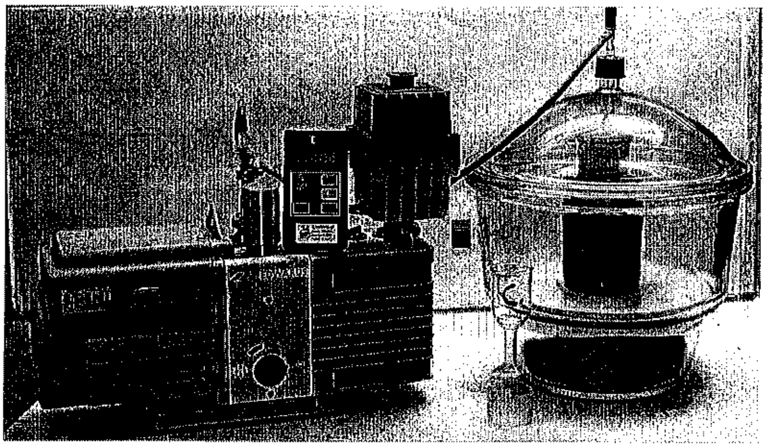


Figure 2.2. Photo of the vacuum enhanced water absorption equipment used at SP.

2.4 Boiling

Looking for another "quick procedure", boiling of the materials was also tried out. Perforated metal baskets and a big electronic boiling pot (figure 2.3) were used for boiling the materials for 1, 8 and 24 hours respectively.

Boiling was only performed on the crushed concrete and the porous basalt. The procedure revealed some problems; the surface dried measurements were rather difficult (the hot samples dried off very quickly) and some disintegration of the materials could be observed.

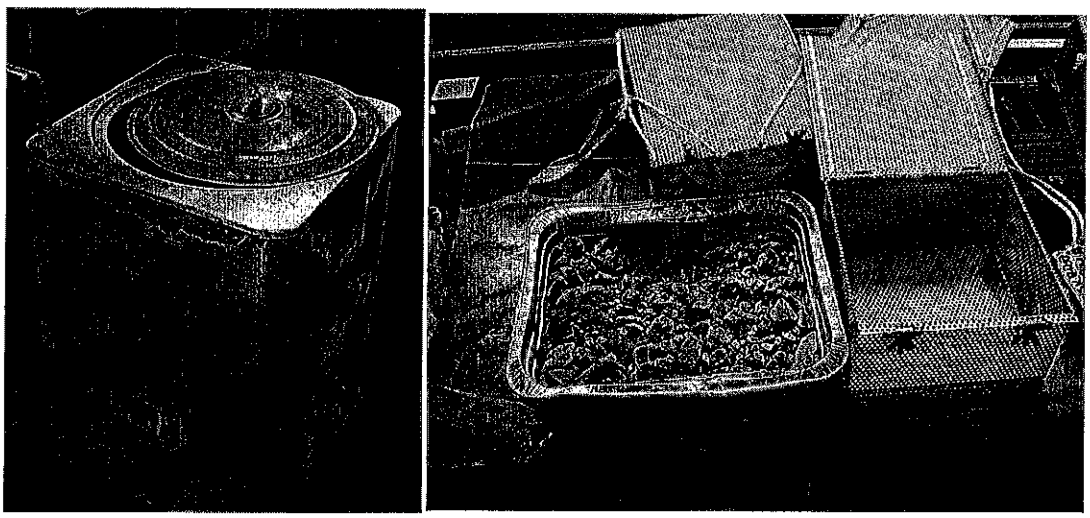


Figure 2.3. The old boiler at the IBRI to the left and the prepared sample to the right.

2.5 Long term saturation

In order to study the long term water absorption, the wire basket procedure was used (figure 2.4). Here the materials were kept in the containers, hanging in the semi-permeable bags, and the weight increase was monitored for a period of 300 days.

The densities and absorptions obtained after this period are likely to be comparable to the "real" material properties under field conditions.

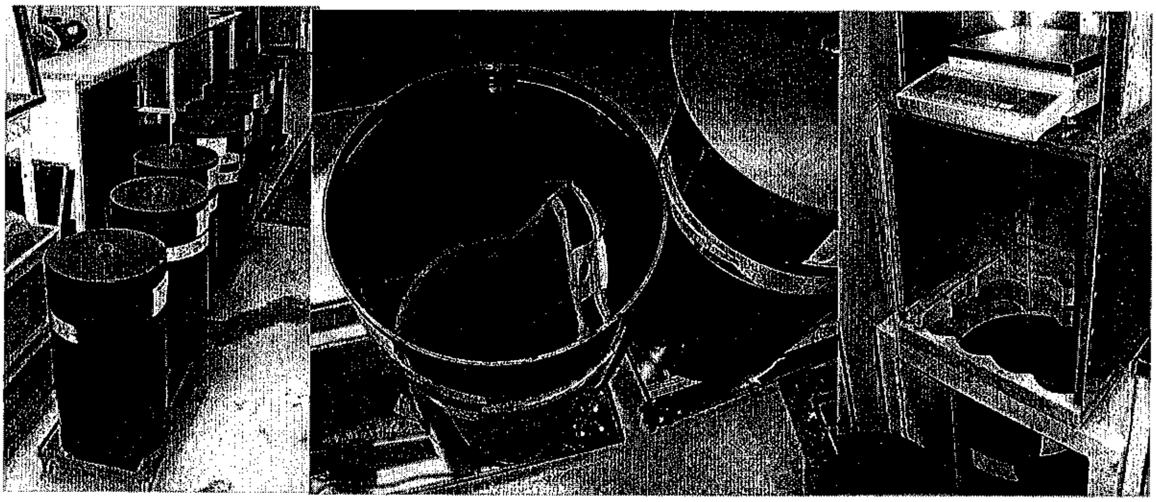


Figure 2.4. Photos of the containers for long term water absorption, the semi-permeable bags containing the test materials and the weighing in water.

2.6 Test scheme

A number of pre-tests were performed in order to determine the best test procedure for the parallel testing. SP therefore evaluated tests performed under different vacuum (75, 50 and 30 mbar) and time (1, 5 and 24 hours) for the absorption.

IBRI evaluated the influence of pre-drying compared to having the materials absorb water in a "natural" moist condition as they were received at the laboratories. IBRI also evaluated whether boiling could be a suitable quick method.

When the best test procedure had been determined all three laboratories performed tests on concrete, ash and basalt according to the same modified test procedure as a small inter-comparison test.

SP was responsible for the long-term water absorption which was performed to have a more realistic estimate of the maximum possible absorption that can take place in a construction.

SP also performed additional tests on lightweight aggregates for comparison reasons and SINTEF performed additional tests on crushed bricks.

3 Sampling, materials and sample preparation

3.1 Sampling and sample preparation

The materials chosen for this project have been studied in other projects for other properties. They represent the most commonly used highly porous natural, "artificial" and alternative aggregates. Previous research projects have shown that highly porous materials may need special attention when testing.

Only coarse aggregates were used in this study. Particles smaller than 4 mm were discarded by sieving. Fine material is treated with a different procedure in the standard.

All materials were shipped to SP for homogenization and sample splitting by use of rotary divider (see figure 3.1).

The particle size distribution was determined in accordance with the guidance in Nordtest project no. 1292-96 [2]. The curves are displayed in Appendix 1.

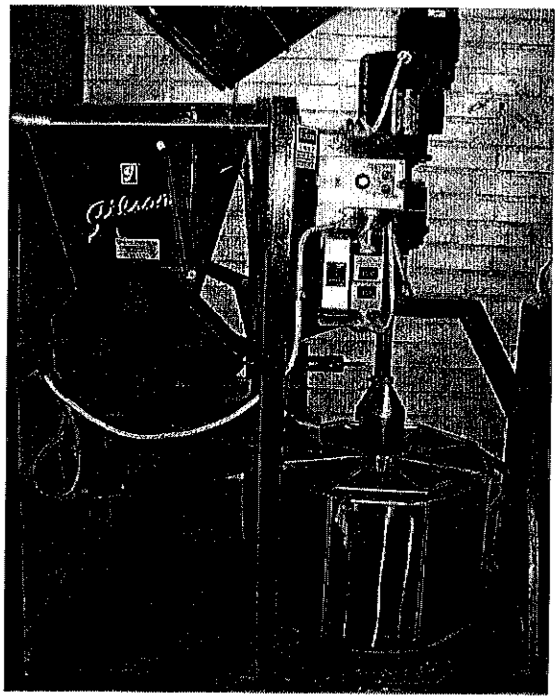


Figure 3.1. Sample splitting in a rotary sample divider

3.2 Crushed concrete

The Icelandic crushed concrete was sampled from a single building site, where a concrete house was being demolished and removed. Further information about the material can be obtained from the published report [7].

Crushed concrete is one of the few recycled materials that are commonly used for construction and civil engineering purposes. Swedish regulations have e.g. been developed for the use of crushed concrete when making new concrete [8].

3.3 Incinerator bottom ash

Incinerator bottom ash from coal combustion was sampled at Sydkraft Öst, Händelöverket in Norrköping.

Ash of this type has been used for several construction purposes during the 1990s in the area around Norrköping [9]. The most important project was the construction of subbases for a highway around Norrköping. In this case the material was used as a replacement for lightweight aggregates, which saved both natural resources and landfill space. During the first 10 years of the construction, there have been no indications that the material does not fulfil its function.

3.4 Porous basalt

The porous basalt is a fresh pillow lava formation and was sampled by IBRI in Iceland, see figure 3.2. The material is generally used for unbound basecourse and as aggregate for concrete purposes. It has been used in many previous projects for the Icelandic Aggregate Committee in the years 1985 to 1994 [10] and for the BUSL co-operation in the years 1995 to 2000 [11].

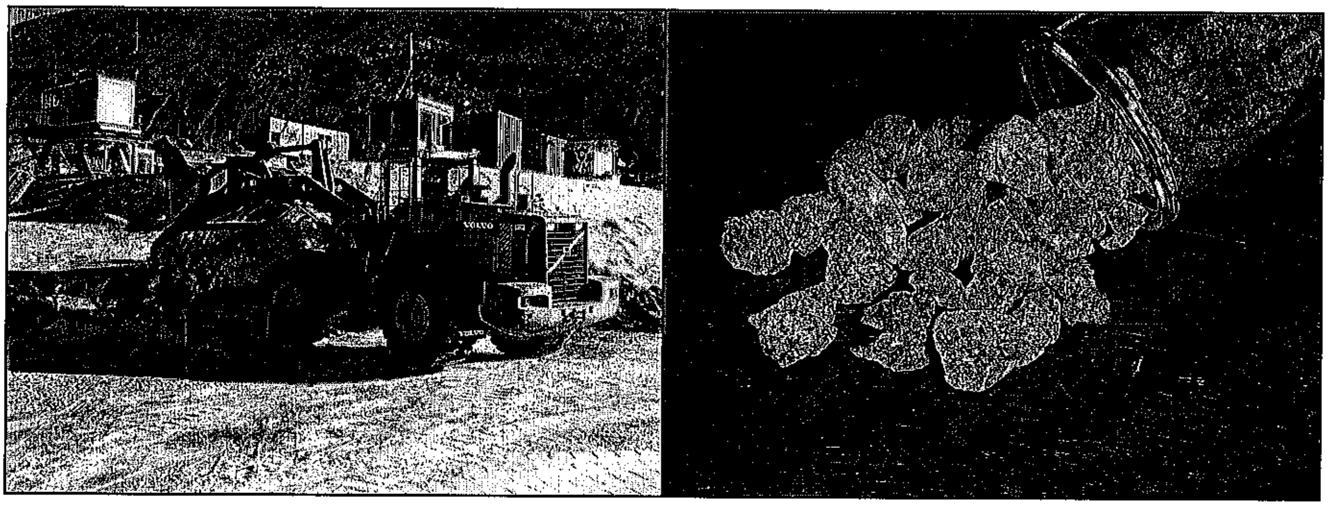


Figure 3.2. Sampling of the porous basalt (left). Prepared and dried basalt sample (right).

3.4 Lightweight aggregate

Lightweight aggregate came from LECA and was sampled in combination with the yearly 3rd party inspection connected with the factory production control.

The reason for choosing this lightweight material is because it has many properties in common with porous recycled aggregates. However, it is manufactured in short gradings that can't be directly compared with the long gradings of ash and crushed concrete.

The grading chosen for this project was 12-20 mm. One of the more common applications as a load compensating material in civil engineering works on unstable grounds.

4 Test results and discussions

4.1 Results from the vacuum tests

The vacuum tests were performed on crushed concrete, basalt and bottom ash. Three different pressures (75, 50 and 30 mbar) were used. The pyknometers were also left in the vacuum device for a different period of time (1, 5 and 24 hours).

Table 4.1. The results from testing at 3 different pressures.

(Wt-%)	75 mbar		50 mbar		30 mbar	
Water absorption bottom ash (31,5-4mm)	**Mean**	**Std dev.**	**Mean**	**Std dev.**	**Mean**	**Std dev.**
Water absorption (0h)	25,1	1,00	36,1	1,24	35,41	0,65
Water absorption (1h)	36,7	1,22	37,4	0,94	36,58	0,57
Water absorption (5h)	**37,0**	**1,18**	**37,5**	**0,99**	**36,58**	**0,65**
Water absorption (24h)	37,2	1,26	37,5	0,70	36,44	0,82
Water absorption Conrete (25-4mm)						
Water absorption (0h)	8,32	0,18	8,41	0,25	8,44	0,14
Water absorption (1h)	8,74	0,25	8,41	0,28	8,43	0,17
Water absorption (5h)	**8,67**	**0,23**	**8,38**	**0,25**	**8,45**	**0,15**
Water absorption (24h)	8,61	0,23	8,59	0,13	8,43	1,10
Water absorption Basalt (31,5-4mm)						
Water absorption (0h)	2,53	0,06	5,27	0,09	5,87	0,14
Water absorption (1h)	4,65	0,31	5,68	0,05	6,14	0,25
Water absorption (5h)	**4,65**	**0,31**	**5,68**	**0,05**	**6,14**	**0,25**
Water absorption (24h)	5,57	0,06	6,27	0,04	6,41	0,17

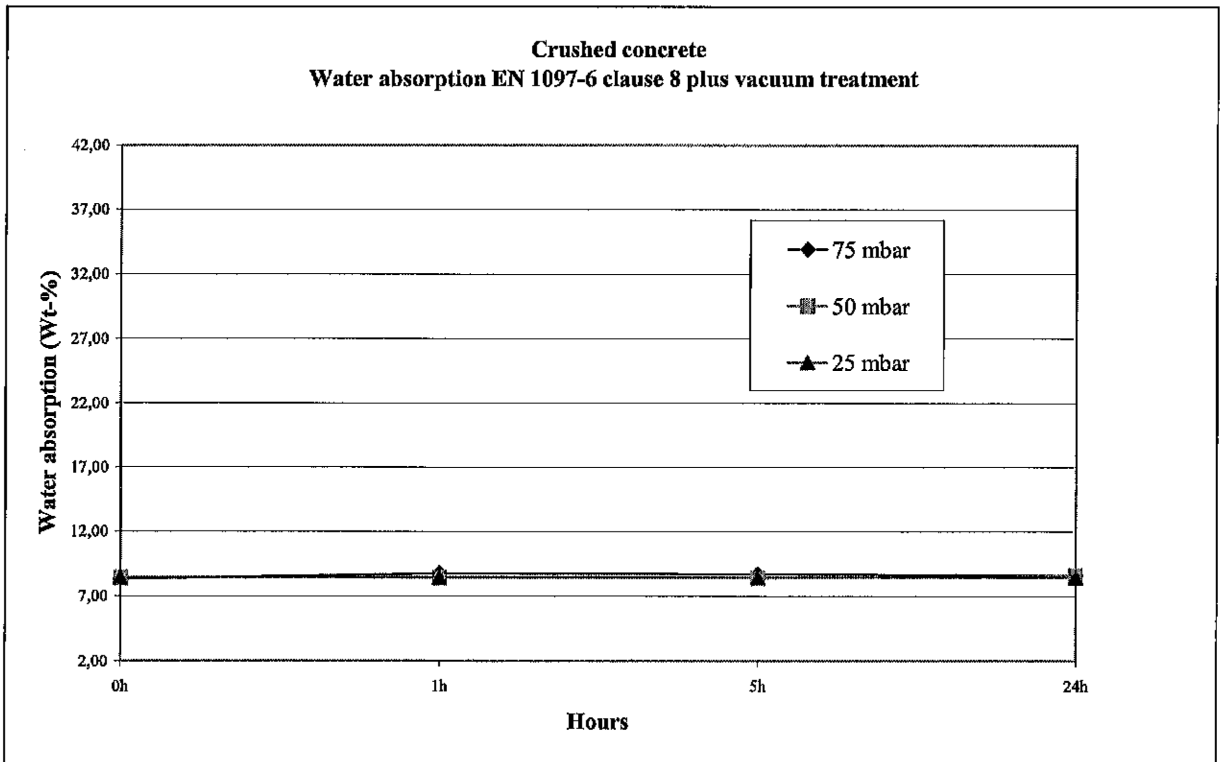


Figure 4.1. Water absorption of crushed concrete in vacuum

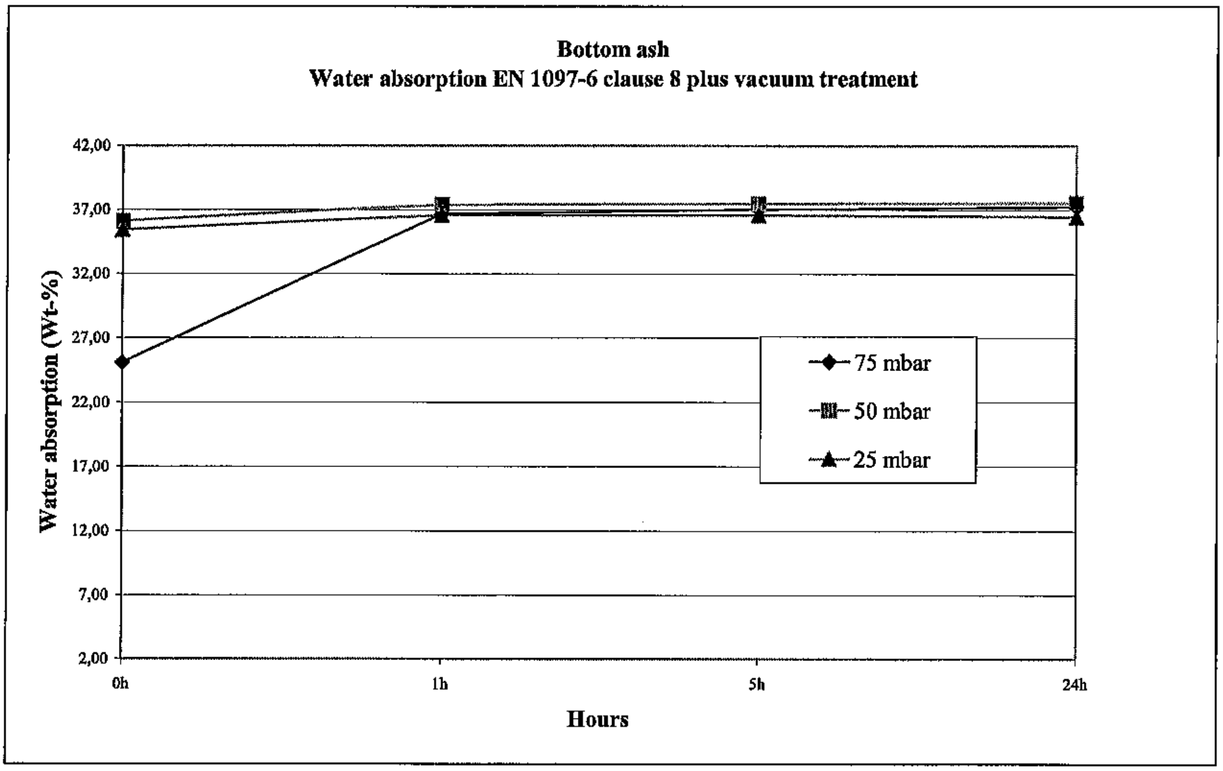


Figure 4.2. Water absorption of bottom ash in vacuum

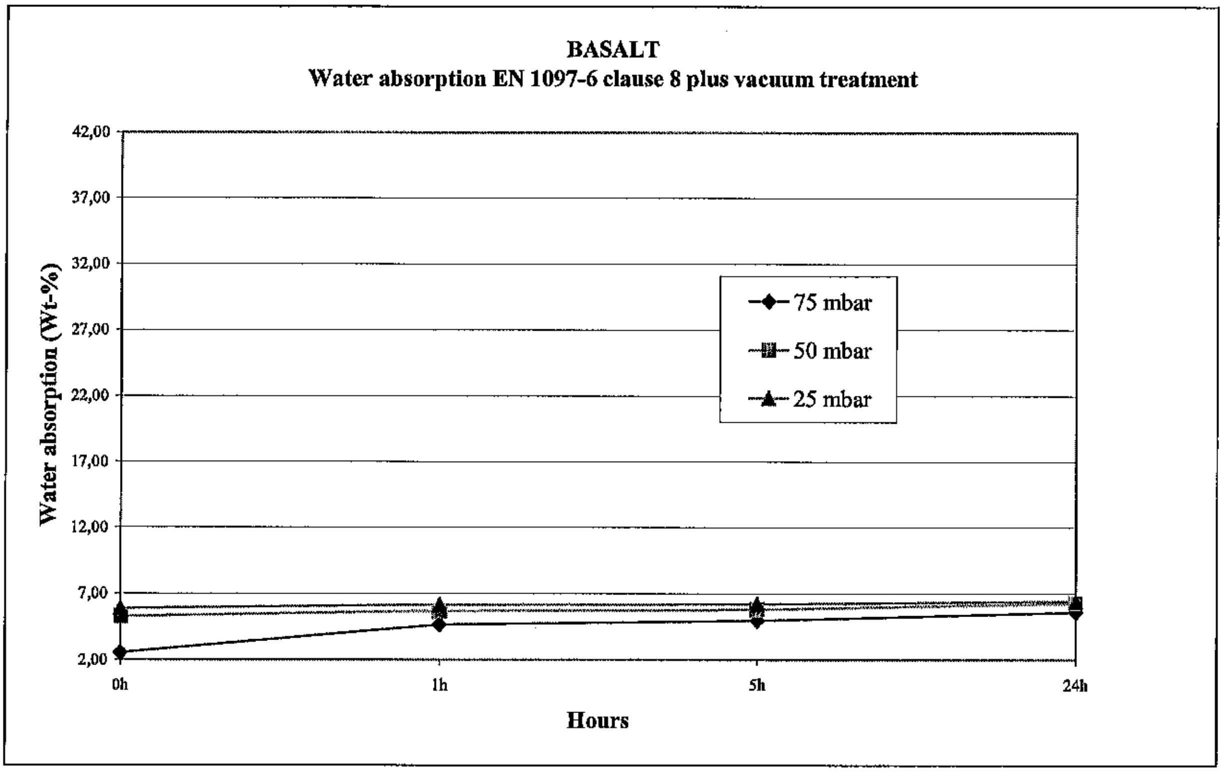


Figure 4.3. Water absorption of porous basalt in vacuum

4.2 Results from parallel testing of water saturation in atmospheric pressure

After the evaluation of the pre-test at SP concerning the vacuum procedure it was decided to use 50 mbar for 5 hours. The parallel testing was performed on Basalt, Incinerator ash and Crushed concrete. The results are displayed in the tables below.

Table 4.2. Results from parallel testing at the three laboratories – Crushed concrete

Concrete (4mm - 31,5 mm)					
		Particle density (Mg/m3)			**Water absorption**
Lab.	Number of samples	Apparent	On an oven dried basis	On a saturated and surface-dried basis	Water abs. (weight-%)
SP	1	2,902	2,398	2,572	7,24
	2	2,886	2,354	2,539	7,82
	3	2,891	2,366	2,547	7,68
	Mean (within)	**2,89**	**2,37**	**2,55**	**7,6**
	Stdav.(within)	**0,008**	**0,023**	**0,017**	**0,30**
SINTEF	1	2,880	2,351	2,535	7,82
	2	2,900	2,365	2,549	7,80
	Mean (within)	**2,89**	**2,36**	**2,54**	**7,8**
	Stdav.(within)	**0,014**	**0,010**	**0,010**	**0,01**
IS	1	2,923	2,403	2,581	7,40
	2	3,958	2,994	3,237	8,14
	Mean (within)	**3,44**	**2,70**	**2,91**	**7,8**
	Stdav.(within)	**0,732**	**0,418**	**0,464**	**0,52**
	Mean (between)	**3,07**	**2,48**	**2,67**	**7,7**
	Pooled std dev	**0,423**	**0,242**	**0,268**	**0,349**

Table 4.3. Results from parallel testing at the three laboratories – Bottom ash.

		Bottom ash (4mm - 31,5 mm)			
		Particle density (Mg/m3)			**Water absorption**
Lab.	Number of samples	Apparent	On an oven dried basis	On a saturated and surface-dried basis	Water abs.
SP	1	1,843	1,135	1,519	33,86
	2	1,884	1,171	1,550	32,32
	3	1,858	1,135	1,524	34,30
	Mean (within)	**1,86**	**1,15**	**1,53**	**33,5**
	Stdav.(within)	**0,021**	**0,021**	**0,017**	**1,04**
SINTEF	B.ash 11 1	1,880	1,130	1,529	35,33
	B.ash 11 2	1,922	1,143	1,548	35,42
	Mean (within)	**1,90**	**1,14**	**1,54**	**35,4**
	Stdav.(within)	**0,030**	**0,010**	**0,014**	**0,06**
IS	5/9 2003 1	1,862	1,141	1,528	33,91
	5/9 2003 2	1,858	1,153	1,532	32,91
	Mean (within)	**1,86**	**1,15**	**1,53**	**33,4**
	Stdav.(within)	**0,003**	**0,008**	**0,003**	**0,71**
	Mean (between)	**1,87**	**1,14**	**1,53**	**34,09**
	Pooled std dev	**0,021**	**0,014**	**0,013**	**0,727**

Table 4.4. Results from parallel testing at the three laboratories – Porous basalt.

		BASALT (4mm - 31,5 mm)			
		Particle density (Mg/m3)			**Water absorption**
Lab.	Number of samples	Apparent	On an oven dried basis	On a saturated and surface-dried basis	Water abs. (weight-%)
SP	1	2,713	2,390	2,509	4,98
	2	2,700	2,381	2,500	4,96
	3	2,706	2,359	2,487	5,43
	Mean (within)	**2,71**	**2,38**	**2,50**	**5,1**
	Stdav.(within)	**0,007**	**0,016**	**0,011**	**0,27**
SINTEF	1	2,721	2,434	2,540	4,32
	2	2,717	2,438	2,541	4,22
	Mean (within)	**2,72**	**2,44**	**2,54**	**4,3**
	Stdav.(within)	**0,003**	**0,003**	**0,001**	**0,07**
IS	1	2,737	2,412	2,531	4,93
	2	2,604	2,320	2,429	4,70
	Mean (within)	**2,67**	**2,37**	**2,48**	**4,8**
	Stdav.(within)	**0,094**	**0,065**	**0,072**	**0,16**
Total	**Mean (between)**	**2,70**	**2,39**	**2,51**	**4,7**
	Pooled std dev	**0,054**	**0,039**	**0,042**	**0,185**

4.3 Results from boiling and comparison of conditioning procedures by pre-drying

Testing on materials after pre-drying or in an "as received" state is often argued. Table 4.7 shows results from RB, where samples were tested oven dried at 105 °C on the one hand and not oven dried, but conditioned at 40°C for 120 hours, on the other hand. The table clearly displays that there is a considerable difference in the results obtained from these two procedures. In all cases, the oven dried samples do not reach the same water absorption as the samples that were not oven dried.

Table 4.5 Difference in water absorption of oven dried and not oven dried samples.

		BOILING					
	Oven dry	1 hour, g	%	8 hour	%	24 hours	%
Porous basalt							
Oven dried	1957,8	2031,2	**3,75**	2037,1	**4,05**	2050,4	**4,73**
Not oven dried	1913,3	1996,1	**4,33**	2005,2	**4,80**	2018,5	**5,50**
Crushed concrete							
Oven dried	1721,2	1843,3	**7,09**	1847,9	**7,36**	1849,9	**7,48**
Not oven dried	1739,0	1865,4	**7,27**	1871,5	**7,62**	1872,3	**7,67**
Bottom ash							
Oven dried	1090	1401,9	**28,61**	1454,5	**33,44**	1456,8	**33,65**
Not oven dried	1340,7	1781,4	**32,87**	1808	**34,85**	1796,2	**33,97**

4.4 Results of long-term water absorption

The materials were weighed at regular intervals, more frequently at the beginning of the test period. All results are displayed in Appendix xx. Table 4.6 displays a summary of the time for the materials to be completely saturated, except for the lightweight aggregate.
A comparison between long-term test and vacuum treatment is displayed in section 4.5.

Table 4.6. Accumulated, relative wt % of the maximum water absorption (set to 100 %) after a defined period of time.

	Basalt		Light weight aggregate		Bottom ash		Concrete	
Days	W %	Accumulative	W %	Accumulative	W %	Accumulative	W %	Accumulative
0	1,4	17,9	0	2,1	6,9	19,9	3,63	40,8
0,003	1,7	21,6	0,003	3,72	10,0	28,6	4,53	50,9
0,083	2,1	26,2	0,083	8,06	14,5	41,6	6,40	71,9
1	2,5	31,3	1	12,7	18,5	53,1	7,13	80,1
7	3,4	42,9	7	22,0	24,3	69,8	7,61	85,5
14	4,3	53,4	14	30,5	27,8	79,9	7,88	88,6
30	5,4	67,0	30	40,1	30,8	88,4	8,18	91,9
60	6,2	78,1	60	47,9	32,7	94,1	8,40	94,4
90	6,8	85,5	90	56,9	33,6	96,4	8,55	96,1
120	7,2	89,8	120	61,5	34,0	97,6	8,64	97,1
150	7,4	92,4	150	64,7	34,2	98,2	8,68	97,6
180	7,6	94,4	180	65,2	34,4	98,8	8,74	98,2
210	7,7	96,8	210	68,5	34,5	99,2	8,78	98,7
300	8,0	100,0	300	77,4	34,8	100,0	8,90	100,0

4.5 Comparison of different test procedures

In order to try to find a quick test usable for production control, both boiling and vacuum were used. The results from these tests are compared with the long-term absorption in the diagrams below (figures 4.4 - 4.7).

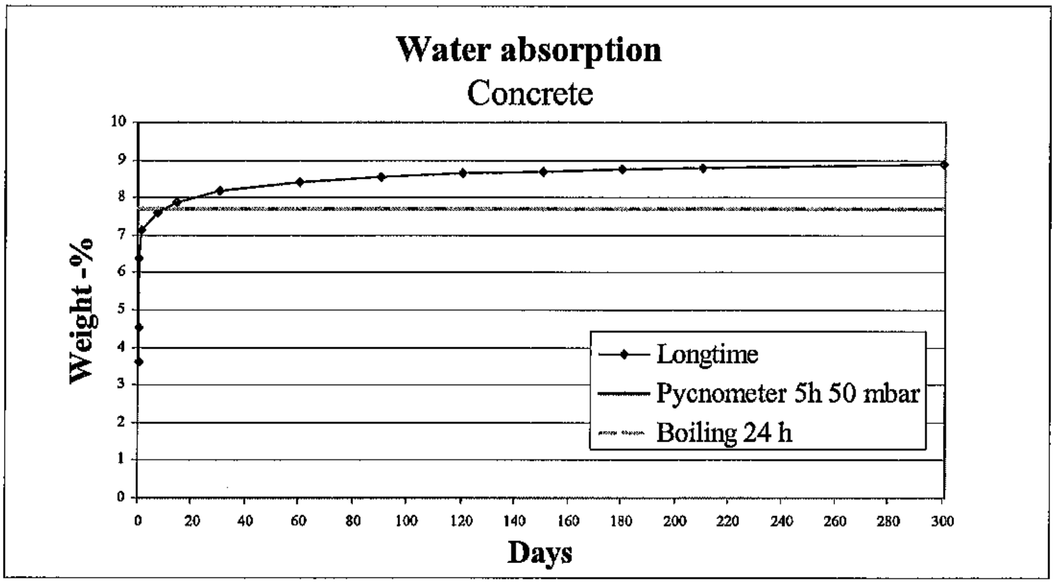


Figure 4.4. Comparison between long-term water absorption and quick tests by vacuum and boiling – Crushed concrete

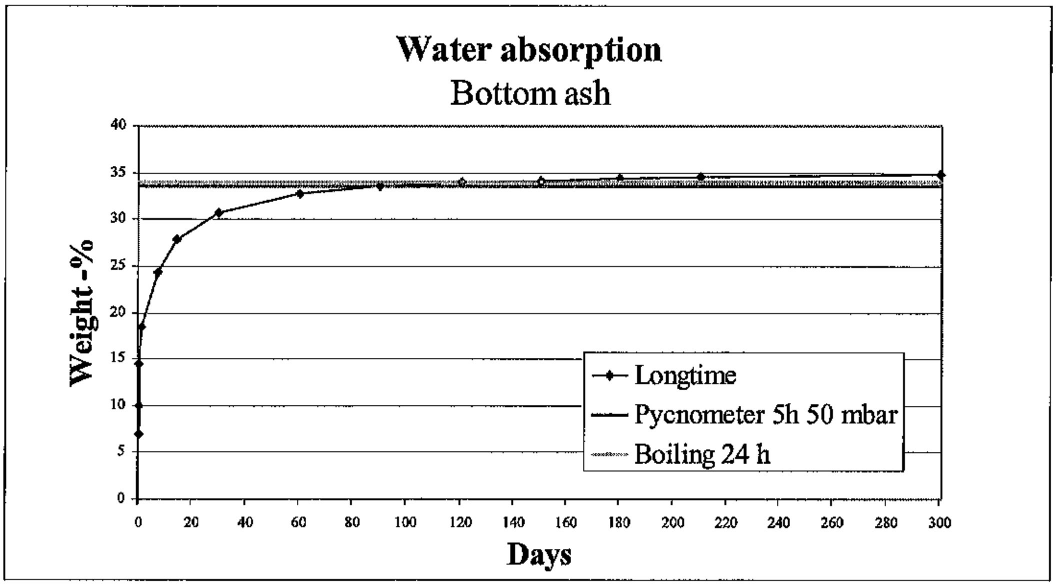


Figure 4.5. Comparison between long-term water absorption and quick tests by vacuum and boiling – Bottom ash.

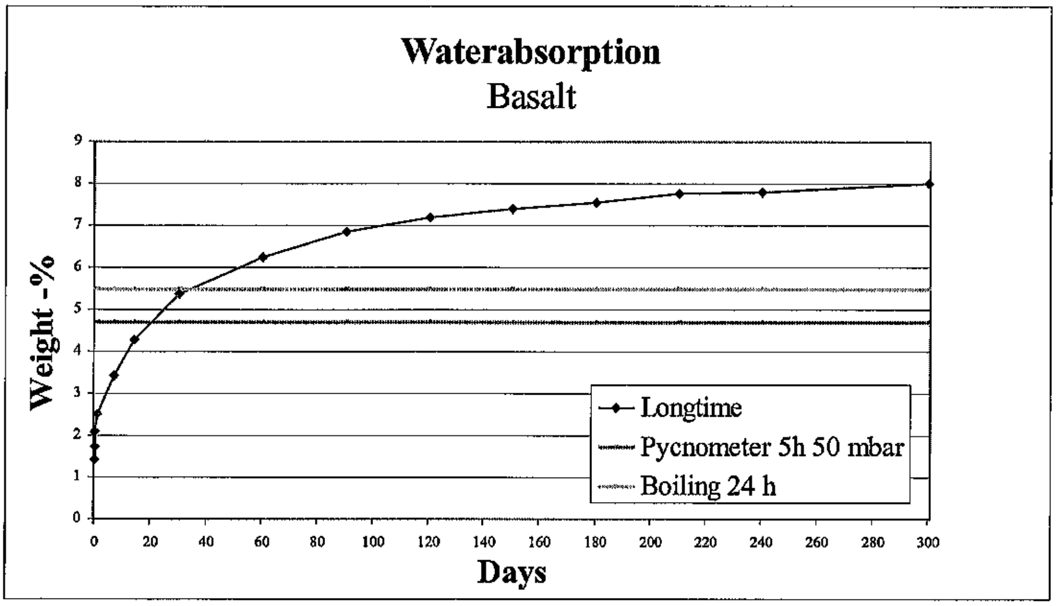


Figure 4.6. Comparison between long-term water absorption and quick tests by vacuum and boiling – Porous basalt

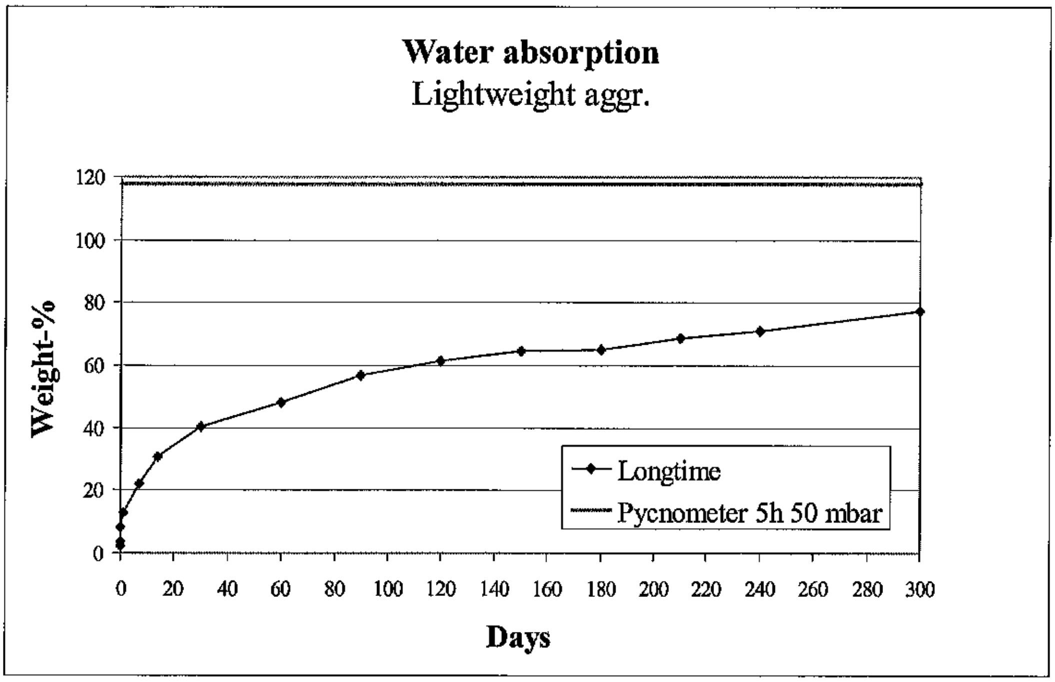


Figure 4.7. Comparison between long-term water absorption and quick tests by vacuum and boiling – Lightweight aggregate.

4.6 Complementary test results from other materials

Table 4.7 below displays a compilation of results from water saturation in 50 mbar vacuum of the "project" materials and other materials for comparison.

Table 4.7. Water absorption of the project materials and other common RAC and one reference gravel

GRANITE	**Test portion**	**Test portion**	**Test portion**	**Average**
Particle density and water absorption	**a**	**b**	**c**	
Water absorption.(weight-%)	1,24	1,12	1,20	**1,19**
Particle density on an oven dried basis . (Mg/m3)	2,57	2,58	2,58	**2,58**
Particle density on a saturated and surface-dried basis . (Mg/m3)	2,60	2,61	2,61	**2,61**
POROUS BASALT				
Particle density and water absorption				
Water absorption.(weight-%)	4,98	4,96	5,43	**5,12**
Particle density on an oven dried basis . (Mg/m3)	2,39	2,38	2,36	**2,39**
Particle density on a saturated and surface-dried basis . (Mg/m3)	2,51	2,50	2,49	**2,50**
BLAST FURNACE SLAG				
Particle density and water absorption				
Water absorption.(weight-%)	4,93	4,94	5,62	**5,16**
Particle density on an oven dried basis . (Mg/m3)	2,42	2,42	2,38	**2,42**
Particle density on a saturated and surface-dried basis . (Mg/m3)	2,53	2,54	2,51	**2,53**
LIGHT WEIGHT AGGREGATE				
Particle density and water absorption				
Water absorption.(weight-%)	120	115	117	**117**
Particle density on an oven dried basis . (Mg/m3)	0,42	0,42	0,41	**0,42**
Particle density on a saturated and surface-dried basis . (Mg/m3)	0,93	0,91	0,89	**0,91**
CRUSHED CONCRETE				
Particle density and water absorption				
Water absorption.(weight-%)	7,24	7,82	7,68	**7,58**
Particle density on an oven dried basis . (Mg/m3)	2,40	2,35	2,37	**2,38**
Particle density on a saturated and surface-dried basis . (Mg/m3)	2,57	2,54	2,55	**2,55**
BOTTOM ASH				
Particle density and water absorption				
Water absorption.(weight-%)	33,9	32,3	34,3	**33,5**
Particle density on an oven dried basis . (Mg/m3)	1,13	1,17	1,13	**1,15**
Particle density on a saturated and surface-dried basis . (Mg/m3)	1,52	1,55	1,52	**1,53**
CRUSHED BRICKS				
Particle density and water absorption				
Water absorption.(weight-%)	21,5	22,6		**22,0**
Particle density on an oven dried basis . (Mg/m3)	1,70	1,66		**1,68**
Particle density on a saturated and surface-dried basis . (Mg/m3)	2,07	2,04		**2,05**

4.7 Modelling of long-term water absorption in a construction

The Swedish National Road Administration (SNRA) is currently using a mathematical model for prediction of the long-term water absorption and unit weight of lightweight aggregates [12].

The model also considers whether the material is used above or below the ground water level and the unit weight can be calculated for both cases.

The obtained relative moisture content after 300 days totally submerged in water in the laboratory was approximately 117 %. According to the model, this content corresponds to 14 years in the construction (see figure 4.8).

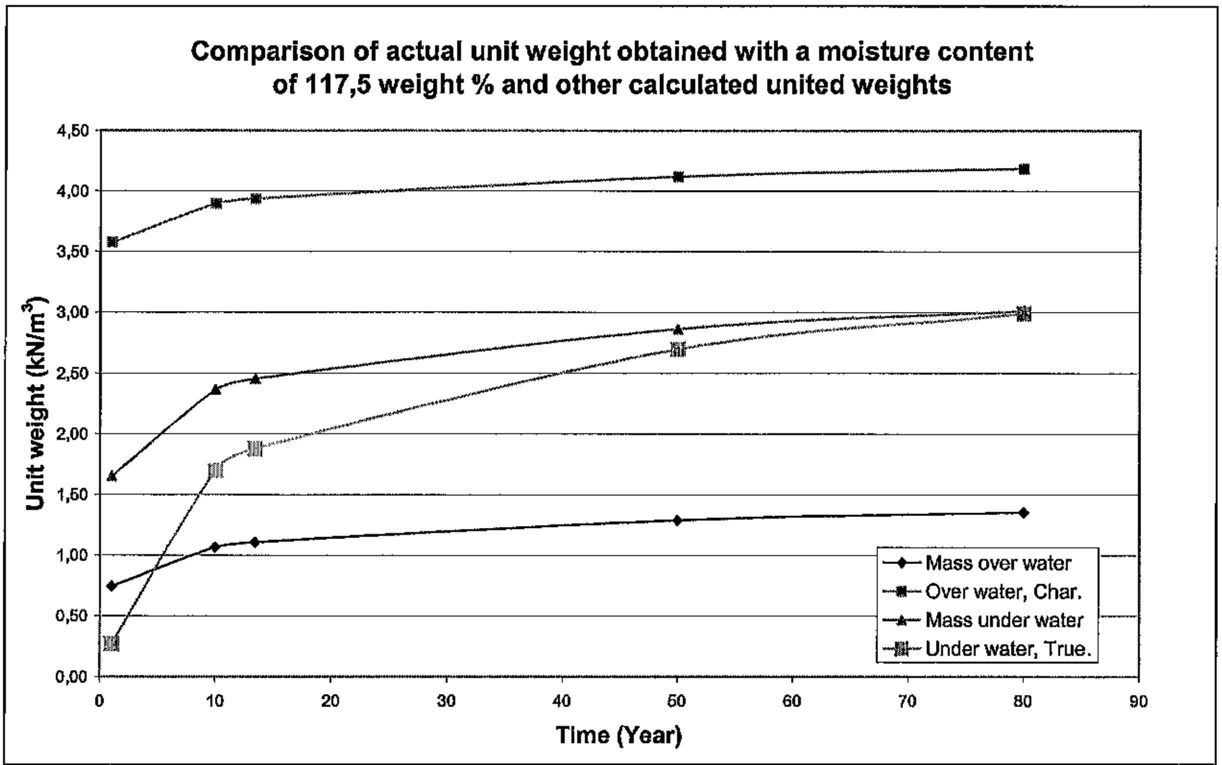


Figure 4.8. The test results obtained after 300 days have been used to calculate the unit weight after a certain period of time in a construction above and below the ground water level.

Table 4.7 shows the data obtained from the long term water absorption of lightweight aggregate. The grey coloured data are omitted in figure 4.9 since they destroy the possibility to extrapolate the water absorption over the years. The yellow coloured data is the extrapolated water absorption up to 40 years which is the service life of a road according to SNRA.

Table 4.7. Long term water absorption and calculated after one year (ca. 300 days).

Days	0	0,00	0,08	1	7	14	30	60	90	120	150	180	210	240	300	1000	2000	3000	4745	5000	10000	14600
W-abs	2,1	3,72	8,06	12,68	22,02	30,50	40,13	47,94	56,90	61,46	64,67	65,22	68,54	70,84	77,40	92	103	109	116	116	127	132

The point in making these calculations and showing the diagrams (4.9 and 4.10) is to find out Whether the pattern observed for the other materials is repeated also for lightweight aggregates and also to evaluate whether the mathematical model of SNRA gives relevant results.

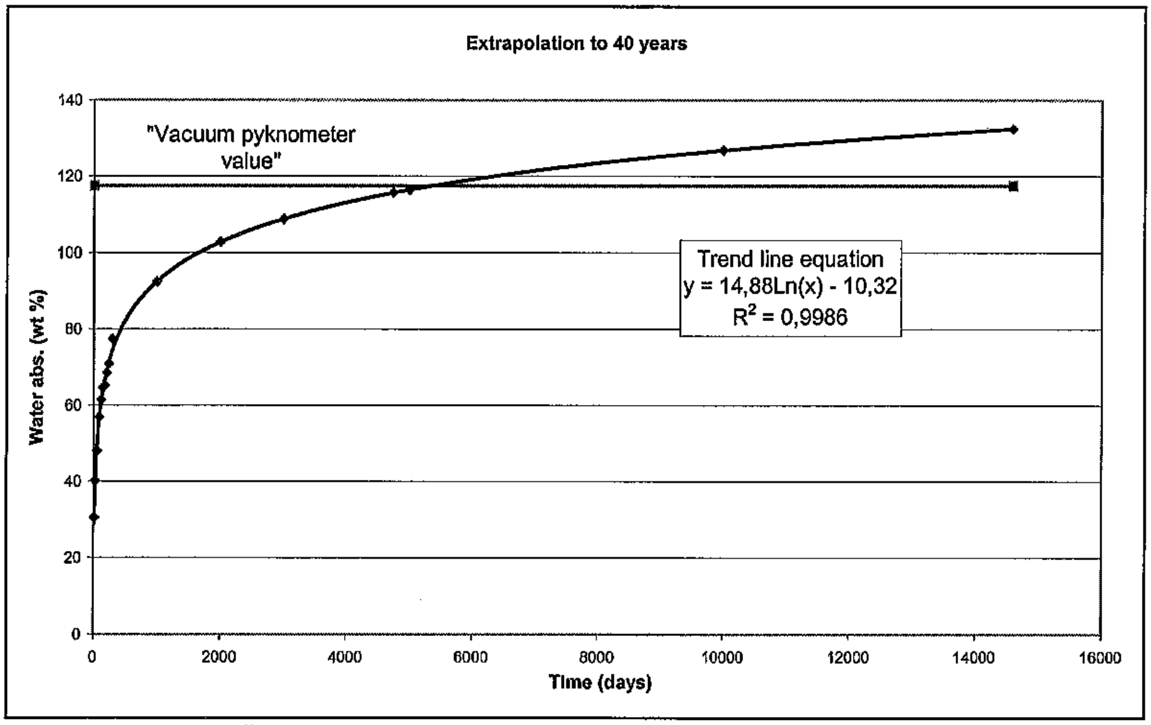


Figure 4.9. Best fit curve for the data between 14 days and 300 days is used for extrapolating up to 40 years.

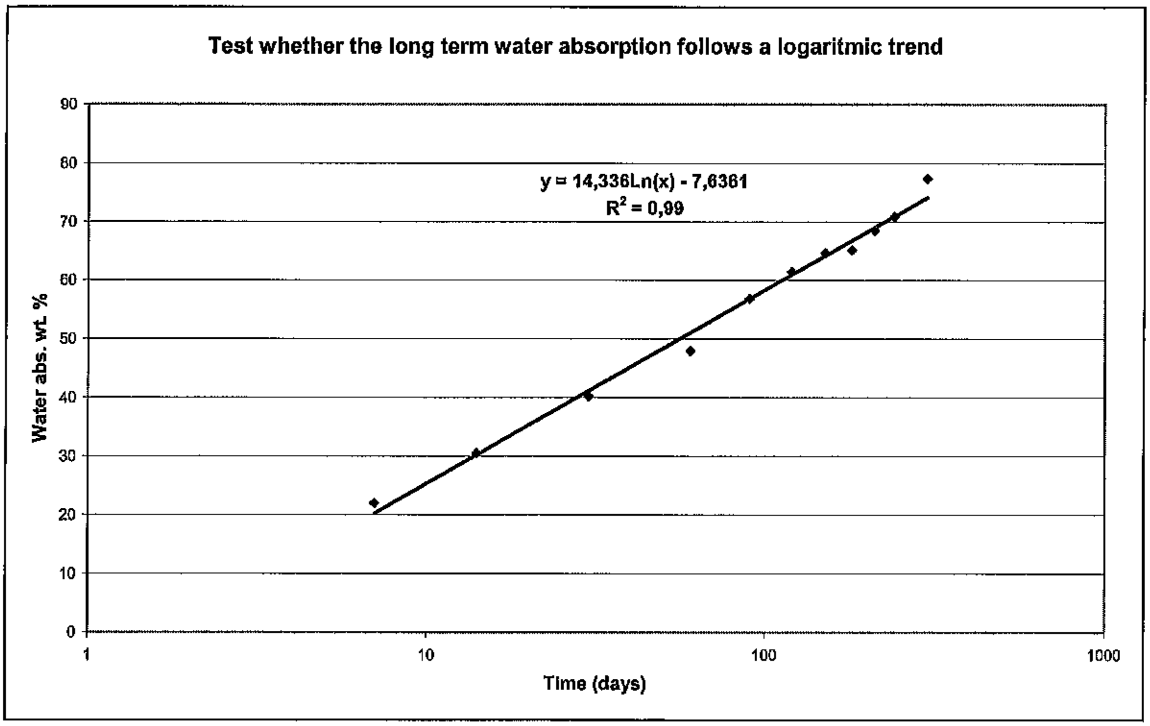


Figure 4.10. Evaluation, whether the water absorption data follows a logaritmic development.

5 Discussion

The pre tests were performed in order to determine the most relevant and efficient tests and material to continue with in the project. The pre-test included testing the water absorption by use of a vacuum method with different pressure and different period of time. The conclusion was that a vacuum of 50 mbar for 5 hours is sufficient. After this time, the change was very small compared to the final absorption. The subsequent parallel testing was carried out in accordance with these recommendations.

The coefficient of variation, between laboratories, when the overall mean is compared with the pooled standard deviation, is between 2,1 and 4,5 %. This is considered to be very good, especially with materials as heterogeneous as these. The repeatability can be expressed in terms of coefficient of variation within the laboratories. This value is between 0,01 and 6,7 %. The prerequisite for obtaining such a good precision is the use of an efficient sample division, good test instructions and careful operation by the laboratory personnel. By use of a rotary sample divider it has been possible to produce tests samples that are very alike.

Pre-testing of boiling pre-dried versus non-conditioned samples was also undertaken. The results from the pre-drying procedure clearly indicate that the water absorption is lowered if the material is pre-dried. In other words, it is more difficult to fill all available pores with water once the material has been completely dried out. Since the test procedure is slowed down due to the pre-drying it's relevance can be questioned.

During the boiling procedure some material was disintegrated. It was also rather difficult to measure the saturated surface dry samples as the samples dried very quickly due to their high temperature. Both these problems led to the conclusion not to continue with either pre-drying or boiling and that the boiling procedure was too laborious and contained too many uncertainties to be recommended.

It has been shown that most of the porous materials absorb water for a very long time. It was therefore decided to develop and use a long-term test method as reference for the quick methods. SP has successfully used the same type of semi-permeable bags/baskets for this kind of test in a previous project [5]. The project materials and light-weight aggregate (LECA) were included in this test. There was no problem encountered during the test period of 300 days. The bags work very well and can probably be used for particle sizes down to about 1 or 2 mm. It is important to lightly shake the bags before weighing them since air bubbles tend to stick to the bags and also some of the aggregate particles. The only drawback is that the bags and their containers take up a lot of space.

In commission work SP has also tried to use the same type of pyknometer as were used in this project. In resent CEN enquiry concerning the lightweight test procedure SP has proposed to use the glass pyknometer also for the long-term test. One argument in favour of this equipment is that they don't require the same amount of space as the bags and containers. Another strong argument is the very good precision obtained in this Nordtest project.

EN 1097-6 Annex C (normative): "Determination of water absorption and density of light-weight aggregates", includes NOTE no. 2, stating that "The operation can also be carried out at other times (2 h and 7 days are examples to suit the end users for the aggregate)". NOTE 3 states that 24 hours is sufficient for most tests. The project results clearly show that all tested materials need at least 3 months to be close to a steady-state. Steady-state, in this case, can be interpreted as the best estimate of the maximum obtainable water absorption in a construction.

All materials except lightweight aggregate absorbed water to a steady state. The lightweight aggregate still had an "absorbing trend" after 300 days. The mathematical model by the SNRA indicates that the results obtained by the vacuum method correspond to approximately 13 years in the construction. To test whether an extrapolation based on the water absorption data coincides with the SNRA model a best fit logarithmic curve was used. The expected water absorption from this extrapolation indicated that the same water absorption is reached after 14 years which may be considered as a rather good correspondence.

The unit weight can be calculated and expressed either as the weight above or below the ground water level. It is possible to compare the total pore volume with the water absorption by vacuum and see whether the pores have been totally or partially filled with water. To be able to do this it is necessary first to determine the apparent volume of the particles and then pulverise them and determine the true volume of the material (volume of the solid part). However, this is outside the scope of the project.

The results for bottom ash were those that corresponded best with the vacuum and boiling measurements. The long-term water absorption of the crushed concrete was approximately 1 % (absolute) higher compared to boiling and vacuum. The long-term absorption of the porous basalt was similarly higher than the absorption by boiling and vacuum. The difference is even bigger in the latter case. Finally, the long-term water absorption of the lightweight aggregate was substantially lower than the vacuum absorption. However, the data modelling performed in accordance with SNRA regulations indicates that also lightweight aggregates have a lower absorption by vacuum than the extrapolated long-term absorption.

The differences in behaviour clearly indicate the problem of developing one unique test method applicable for all alternative aggregates. The differences are most likely due to a different permeability and pore structure of the materials.

The difference in results between water absorption for 24 hours in atmospheric pressure compared to the long-term absorption indicate that the prescribed conditioning of test samples for other tests such as frost resistance and compaction before tri-axial dynamic strength testing is insufficient and should be changed. This may have a strong influence on the relevance of the results from such tests due to the fact that the open pore volume may be only partially filled.

A possible continuation would be to focus on each material separately and evaluate if the vacuum method can be used for several different types of incinerator ashes and if there is a similar relation between most crushed concrete materials as this one. One must remember that the variation in aggregates from secondary sources is very large and that test results obtained in this project apply only to the tested material and it has not been proven that the tested material is fully representative of all varieties.

6 Conclusion

The major aim of the project was to evaluate whether the existing European standard for determination of water absorption of aggregate is suitable for testing porous alternative aggregates. Another aim was to try to develop an alternative quick test.

It has clearly been demonstrated that EN 1097-6 is unsuitable for such materials and that a different test method has to be developed if relevant test results shall be achieved.

It has also been demonstrated that pre-drying of the test materials is unnecessarily laborious and does not give reliable results. The importance of the difference between results obtained by pre-drying and testing the materials "as received" has to be assessed on a case-by-case basis.

Absorption by use of boiling may be a possible alternative quick method for some materials that will not disintegrate during the test. However, the method presents some other problems and can therefore not be recommended as a general test method suitable for all materials.

The results of the long-term water absorption demonstrate that Annex C of the standard substantially underestimates the time needed to reach a steady-state and achieve relevant data for the water absorption of lightweight aggregates and alternative aggregates. Bottom ash and crushed concrete need approximately three months to reach steady-state. Lightweight aggregate and porous basalt need more than one year! The SNRA mathematical model provides a relevant extrapolation that may be possible to use also for other alternative materials.

The chosen quick test by vacuum enhanced absorption has proven to give repeatable and reproducible results for each material. The best correspondence between the vacuum method and the long-term method was obtained on crushed concrete and bottom ash. However, the vacuum method can not be recommended as a general method for all materials without additional research.

Vacuum enhanced absorption may also be possible to use for conditioning of samples for other tests where the materials are tested in a wet condition.

Future research should therefore focus on validation of the vacuum procedure by testing several types of e.g. incinerator ashes, crushed concrete etc. In addition, the pore structure and permeability should be determined to be able to find the mechanism by which the pores are filled with water. One should also perform direct frost resistance tests and tests of other properties where the conditioning included water absorption and compare the results from vacuum enhanced absorption with the results on samples conditioned for 24 h hours in water.

7 References

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8 APPENDIX - list

1 (5) Particle size distribution of the tested materials

2 (1) Excerpt of EN 1097-6

The scope from the standard

EN 1097-6 Annex C (normative)
Determination of water absorption and density of light- weight aggregates

3 (16) Pre-testing

SP Vacuum test, 75, 50, 30 mbar and 1, 5 and 24 hours
IBRI atmospheric pressure, pre-drying and boiling

4 (9) Parallel testing

SP, IBRI, SINTEF:
50 mbar and 5 hours (concrete, ash and basalt)

5 (5) Additional tests

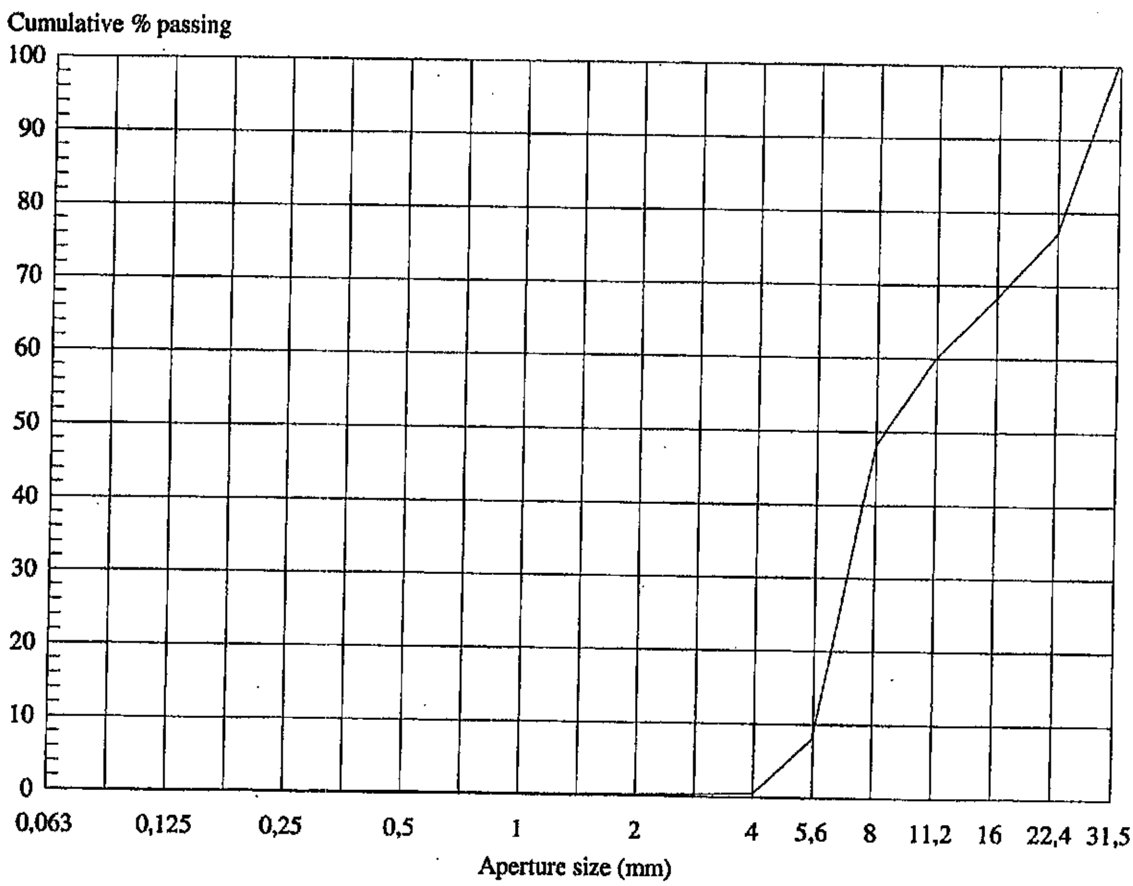
Long term water absorption
Other materials for comparison (lightweight aggregates, granite, blast furnace slag and crushed bricks)

6 (1) Modelling of final water absorption and unit weight of lightweight aggregates according to the Swedish National Road Administration

Reference: Appendix 1.1
Sample marking: Granite

Particle size distribution

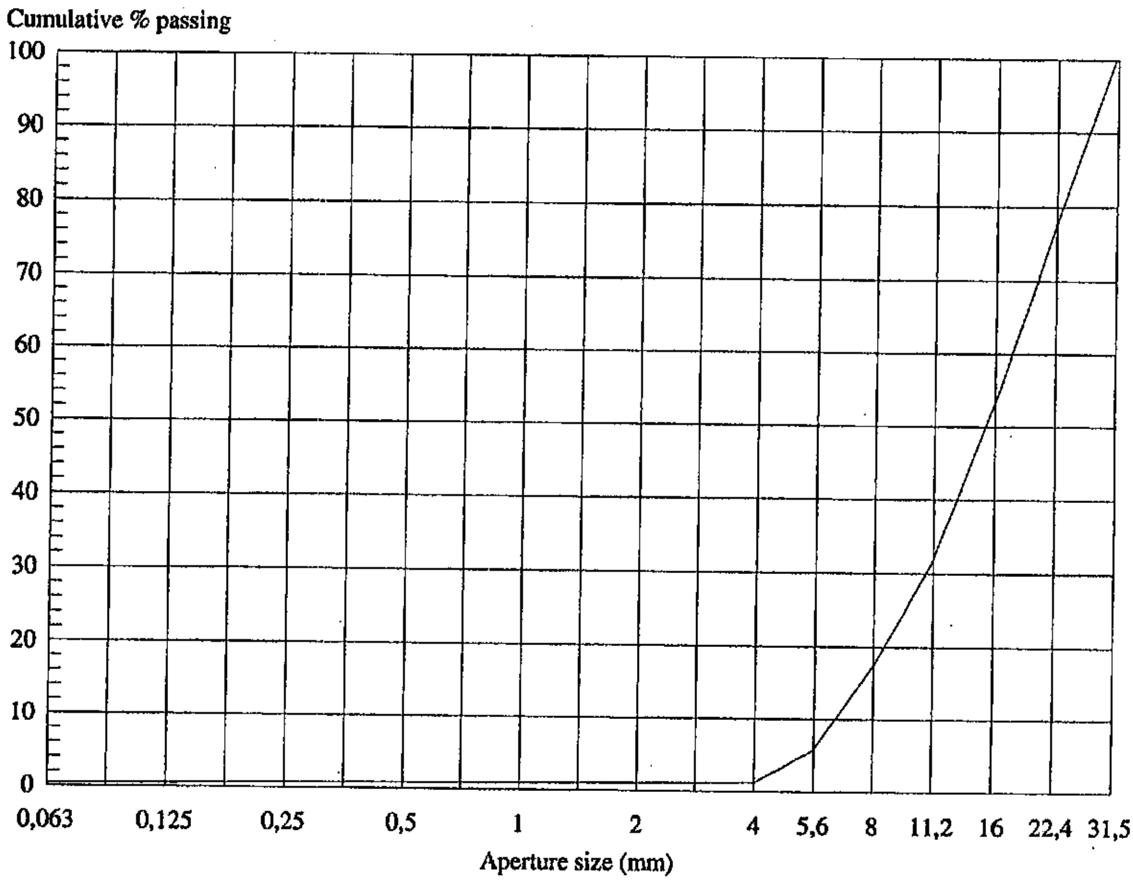
Aperture size (mm)	Mass (g) Testspecimen 1	Mass (g) Testspecimen 2	Mass (%) Testspecimen 1	Mass (%) Testspecimen 2	Cumulative % passing Testspecimen 1	Cumulative % passing Testspecimen 2	Average
31,5	0,00		0,00		100,00		100,0
22,4	501,70		22,97		77,03		77,0
16	187,90		8,60		68,43		68,4
11,2	184,70		8,45		59,98		60,0
8	254,80		11,66		48,32		48,3
5,6	883,60		40,45		7,87		7,9
4	161,20		7,38		0,49		0,5
2	5,80		0,27		0,22		0,2
1	0,60		0,03		0,20		0,2
0,5	0,60		0,03		0,17		0,2
0,25	0,60		0,03		0,14		0,1
0,125	0,70		0,03		0,11		0,1
0,063	0,70		0,03		0,08		0,1
Pan	1,70		0,08				
Sum:	2184,60		100,00				
Tot dry mass:	2184,50						
Loss:	-0,10						



Reference: Appendix 1.2
Sample marking: Crushed concrete

Particle size distribution

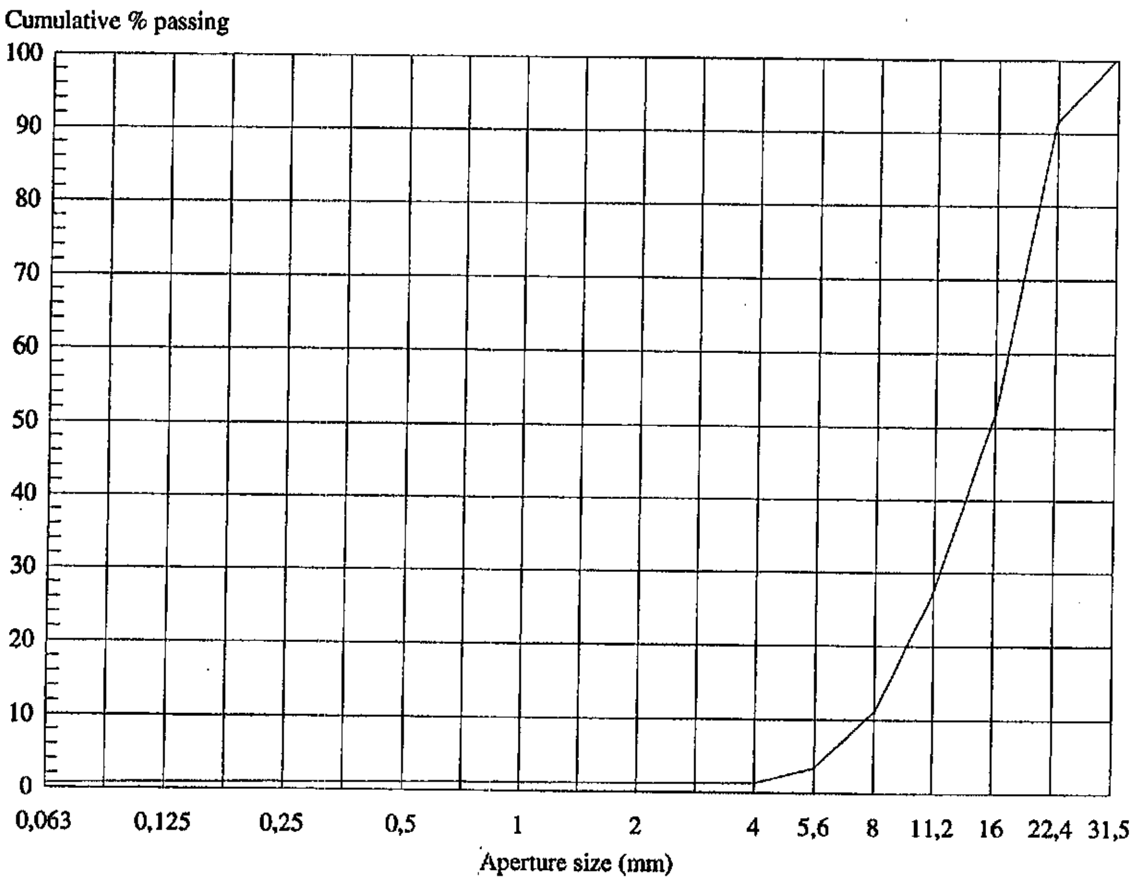
Aperture size (mm)	Mass (g) Testspecimen 1	Mass (g) Testspecimen 2	Mass (%) Testspecimen 1	Mass (%) Testspecimen 2	Cumulative % passing Testspecimen 1	Cumulative % passing Testspecimen 2	Average
31,5	0,00		0,00		100,00		100,0
22,4	561,00		22,64		77,36		77,4
16	591,20		23,86		53,50		53,5
11,2	543,20		21,92		31,58		31,6
8	348,60		14,07		17,51		17,5
5,6	296,40		11,96		5,55		5,6
4	108,30		4,37		1,18		1,2
2	3,30		0,13		1,05		1,0
1	2,40		0,10		0,95		0,9
0,5	2,60		0,10		0,84		0,8
0,25	3,20		0,13		0,71		0,7
0,125	4,40		0,18		0,54		0,5
0,063	4,30		0,17		0,36		0,4
Pan	9,00		0,36				
Sum:	2477,90		100,00				
Tot dry mass:	2479,00						
Loss:	1,10						



Reference: Appendix 1.3
Sample marking: Basalt

Particle size distribution

Aperture size (mm)	Mass (g) Testspecimen 1	Mass (g) Testspecimen 2	Mass (%) Testspecimen 1	Mass (%) Testspecimen 2	Cumulative % passing Testspecimen 1	Cumulative % passing Testspecimen 2	Average
31,5	0,00		0,00		100,00		100,0
22,4	223,50		8,52		91,48		91,5
16	1036,50		39,53		51,95		52,0
11,2	654,90		24,98		26,97		27,0
8	412,40		15,73		11,24		11,2
5,6	207,70		7,92		3,32		3,3
4	53,80		2,05		1,27		1,3
2	1,40		0,05		1,21		1,2
1	0,60		0,02		1,19		1,2
0,5	1,10		0,04		1,15		1,1
0,25	2,50		0,10		1,05		1,0
0,125	4,00		0,15		0,90		0,9
0,063	5,40		0,21		0,69		0,7
Pan	18,20		0,69				
Sum:	2622,00		100,00				
Tot dry mass:	2624,10						
Loss:	2,10						

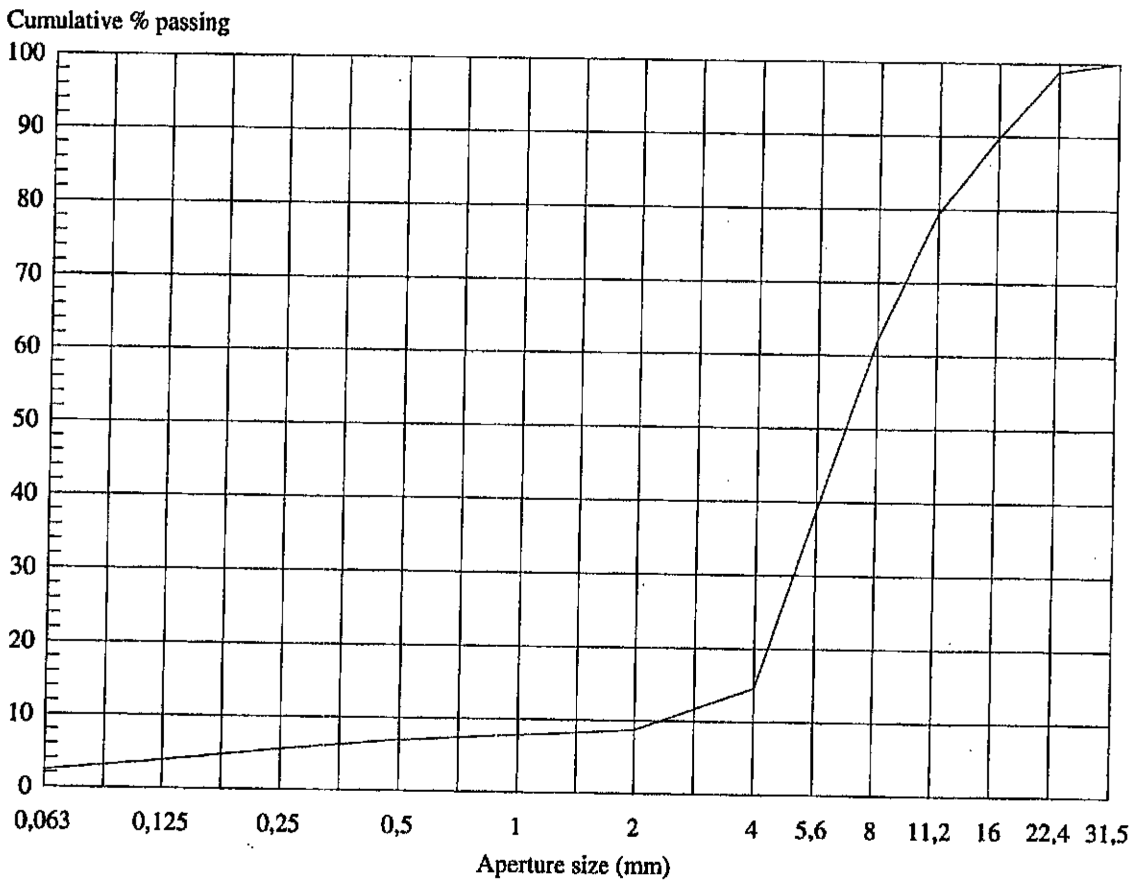


SP 511

Reference: Appendix 1.4
Sample marking: Bottom ash

Particle size distribution

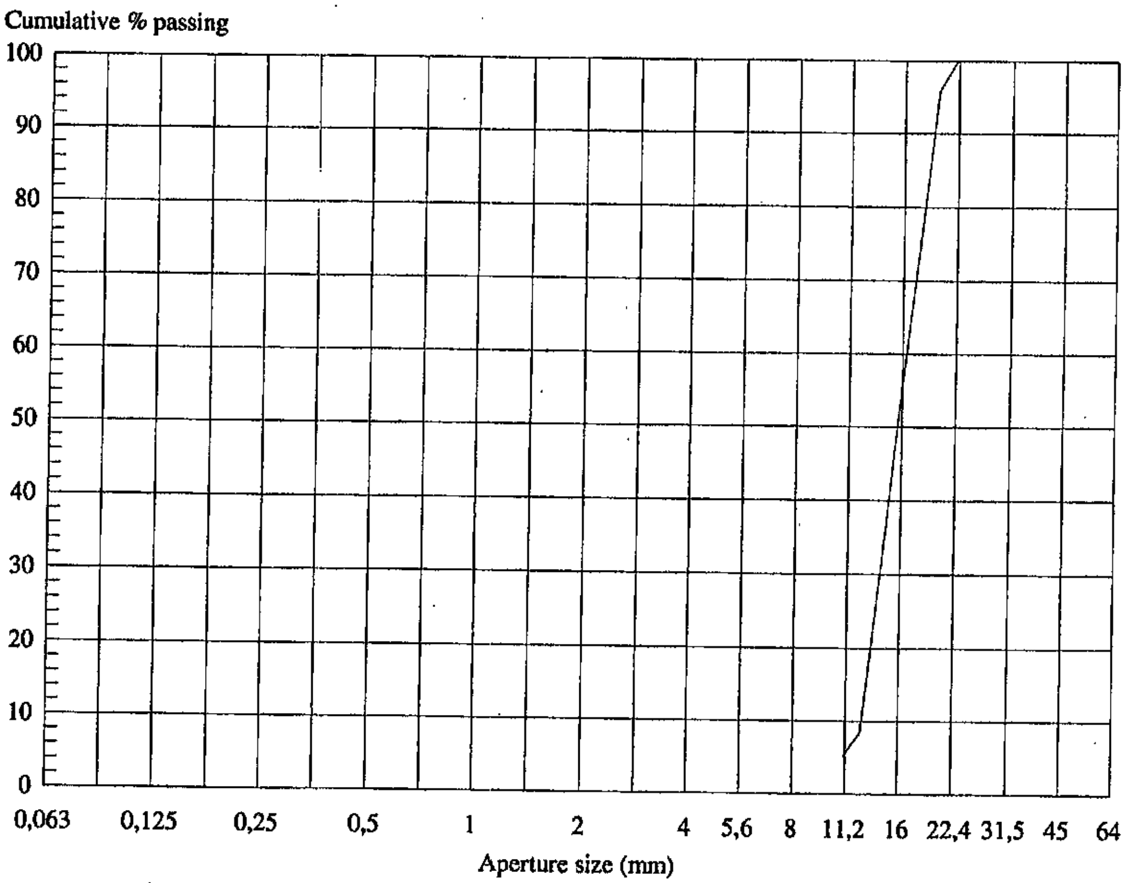
Aperture size (mm)	Mass (g) Testspecimen 1	Mass (g) Testspecimen 2	Mass (%) Testspecimen 1	Mass (%) Testspecimen 2	Cumulative % passing Testspecimen 1	Cumulative % passing Testspecimen 2	Cumulative % passing Average
31,5	0,00		0,00		100,00		100,0
22,4	13,80		1,21		98,79		98,8
16	103,20		9,04		89,75		89,8
11,2	120,70		10,57		79,17		79,2
8	193,20		16,93		62,25		62,3
5,6	275,10		24,10		38,15		38,2
4	268,20		23,50		14,65		14,6
2	67,90		5,95		8,70		8,7
1	10,60		0,93		7,77		7,8
0,5	9,90		0,87		6,90		6,9
0,25	15,90		1,39		5,51		5,5
0,125	19,50		1,71		3,80		3,8
0,063	16,20		1,42		2,38		2,4
Pan	27,20		2,38				
Sum:	1141,40		100,00				
Tot dry mass:	1146,00						
Loss:	4,60						



Reference: Appendix 1.5
Sample marking: Light weight aggregate

Particle size distribution

Aperture size (mm)	Mass (g) Testspecimen 1	Mass (g) Testspecimen 2	Mass (%) Testspecimen 1	Mass (%) Testspecimen 2	Cumulative % passing Testspecimen 1	Cumulative % passing Testspecimen 2	Cumulative % passing Average
22,4	0,00	0,00	0,00	0,00	100,00	100,00	100,0
20	17,90	14,60	4,64	3,74	95,36	96,26	95,8
16	151,60	164,90	39,29	42,21	56,07	54,06	55,1
12,5	188,90	173,60	48,96	44,43	7,10	9,62	8,4
11,2	10,40	15,20	2,70	3,89	4,41	5,73	5,1
Pan	17,00	22,40	4,41	5,73			
Sum:	385,80	390,70	100,00	100,00			
Tot dry mass:	385,40	391,00					
Loss:	-0,40	0,30					



Excerpt of EN 1097-6

Scope

This European Standard specifies methods for the determination of the particle density and water absorption of aggregates. The first five methods are applicable to normal aggregates with a sixth method for lightweight aggregates.

The principal methods specified are:

a) a wire basket method for aggregates passing a 63 mm sieve but retained on a 31.5 mm sieve:

b) pyknometer methods for aggregates passing a 31.5 mm sieve but retained on a 0.063 mm sieve.

NOTE 1 The wire basket method may be used as an alternative to the pyknometer method for aggregates between 4 mm and 31.5 mm. In case of dispute, the pyknometer method described in clause 8 should be used as the reference method.

NOTE 2 The wire basket method can also be used for single aggregate particles retained on a 63 mm sieve.

A method for the determination of pre-dried particle density of dense aggregates is specified in annex A.

NOTE 3 As the absorption of dense aggregates is low, pre-dried particle density can be determined directly in water. This method is different to the determination of particle density on an oven dried basis.

A modified version of the wire-basket method suitable for determining the particle density and water absorption of coarse aggregates saturated to constant mass is specified in annex B.

For lightweight aggregates, a modified version of the pyknometer test specified in annex A is specified in annex C.

EN 1097-6 Annex C (normative)
Determination of water absorption and density of light- weight aggregates

NOTE 2 The operation can also be carried out at other times (2 h and 7 days are examples to suit the end users for the aggregate).

NOTE 3 For most tests *Mw* will be determined after 24 h.

Expanded clay lightweight aggregate 12-20 mm **APPENDIX 6**

Unit weight in short and long time according to BVH 585.11 och ATB publication 2003:1

Test sample		**mm**	**Density**	**kg/m^3**	**kN/m^3**	**Unit weight**	**(kN/m^3)**
Grain size min		12	ρ_{comp}	2650	26,5	W_Y	0,30
Grain size max		20	$\rho_{bulk\ (loose)}$	230	2,3	$W_{A,char}$	4,19
Mean value		16	ρ_{grain}	455	4,55	$\gamma_{true\ (dry)}$	-3,03

Waterabsorption				**Unit weight**				
				Over water			**Under water**	
time			Moisture content weight (%)	Mass $W_{A,t}$ (kN/m^3)	Mass $W_{A,char,t}$ (kN/m^3)	Characteri $\gamma_{char,t}$ (kN/m^3)	Mass $W_{B,char,t}$ (kN/m^3)	True γ_{true} (kN/m^3)
(min)	(days)	(Year)						
5	0	0,00	3,72	-	-	-	-	-
120	0	0,00	8,06	-	-	-	-	-
	1	0,00	12,68	-	-	-	-	-
	30	**0,08**	40,13	**0,9**	**0,39**	**3,22**	**0,87**	**-1,28**
	90	0,25	56,90	*1,3*	*0,55*	3,38	1,22	-0,60
	150	0,41	64,67	*1,4*	*0,62*	3,45	1,37	-0,28
	180	0,49	65,22	*1,5*	*0,64*	3,47	1,43	-0,17
	210	0,58	68,54	*1,5*	*0,67*	3,50	1,48	-0,07
	240	0,66	70,84	*1,6*	*0,68*	3,51	1,52	0,01
	300	**0,82**	77,40	**1,7**	**0,72**	**3,55**	**1,59**	**0,15**
	365	1	-	-	*0,74*	*3,57*	*1,65*	*0,27*
	3650	10	-	-	*1,06*	*3,89*	*2,36*	*1,70*
1)	***4886***	***13***	**117,50**	*2,7*	***1,10***	***3,93***	***2,45***	***1,88***
	18250	50	-	-	*1,29*	*4,12*	*2,86*	*2,70*
	29200	80	-	-	*1,35*	*4,18*	*3,01*	*2,99*

1) Moisture 117,5 weight % obtained after test in pycnometer at 50 mbar

Remark: Text in italics are extrapolerated results

Excerpt of EN 1097-6

Scope

This European Standard specifies methods for the determination of the particle density and water absorption of aggregates. The first five methods are applicable to normal aggregates with a sixth method for lightweight aggregates.

The principal methods specified are:

a) a wire basket method for aggregates passing a 63 mm sieve but retained on a 31.5 mm sieve:

b) pyknometer methods for aggregates passing a 31.5 mm sieve but retained on a 0.063 mm sieve.

NOTE 1 The wire basket method may be used as an alternative to the pyknometer method for aggregates between 4 mm and 31.5 mm. In case of dispute, the pyknometer method described in clause 8 should be used as the reference method.

NOTE 2 The wire basket method can also be used for single aggregate particles retained on a 63 mm sieve.

A method for the determination of pre-dried particle density of dense aggregates is specified in annex A.

NOTE 3 As the absorption of dense aggregates is low, pre-dried particle density can be determined directly in water. This method is different to the determination of particle density on an oven dried basis.

A modified version of the wire-basket method suitable for determining the particle density and water absorption of coarse aggregates saturated to constant mass is specified in annex B.

For lightweight aggregates, a modified version of the pyknometer test specified in annex A is specified in annex C.

EN 1097-6 Annex C (normative)
Determination of water absorption and density of light- weight aggregates

NOTE 2 The operation can also be carried out at other times (2 h and 7 days are examples to suit the end users for the aggregate).

NOTE 3 For most tests *Mw* will be determined after 24 h.

Ash (31,5 mm - 4mm)
Absolute pressure 30 mbar

(g)	A	B
Pyknometer (empty)	1223,57	1225,23
Pyknometer + surface dried sample (0h)	2125,30	2093,95
Pyknometer + sample + water (0h)	3086,49	3069,53
Pyknometer + sample + water (1h) $M2_1$	3094,61	3076,61
Moister ratio after 1h	1,22	1,11
Increase of absorbed water amount (g) between 0h och 1h	8,12	7,08
Pyknometer + surface dried sample (1h) 1h	2133,42	2101,03
Pyknometer + sample + water (1h+ 4h) $M2_5$	3094,47	3077,24
Moister ratio after 5h	1,19	1,21
Increase of absorbed water amount (g) between 0h och 5h	7,98	7,71
Pyknometer + surface dried sample (1h+ 4h) 5h	2133,28	2101,66
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3096,35	3078,37
Moister ratio after 24h	1,48	1,38
Increase of absorbed water amount (g) between 0h och 24h	9,86	8,84
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2131,36	2101,3
Increase of surface dried sample mellan 24h och 0h	6,06	7,35
Pyknometer + water M3	2767,40	2759,20
Lost of sample, including error i measurment 0-reading	3,80	1,49

(g)	A	B
$M1_0$ (0h)	901,73	868,72
$M1_1$ (1h)	909,85	875,8
$M1_5$ (5h)	909,71	876,43
$M1_{24}$ (24h)	907,79	876,07

DENSITY (Mg/m^3)

		A	B	Average	Stdev.
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	1,562	1,568	1,565	0,0048
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	1,561	1,570	1,565	0,0058
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	1,568	1,573	1,571	0,0034

WATERABS. (%)

			A	B	Average	Stdev.
waterabs. (0h)	WA0	100 x ($M1_0$ - M4)/M4	34,96	35,87	35,41	0,646
waterabs. (1h)	WA1	100 x ($M1_1$ - M4)/M4	36,17	36,98	36,58	0,570
waterabs. (5h)	WA5	100 x ($M1_5$ - M4)/M4	36,15	37,08	36,61	0,654
waterabs. (24h)	WA24	100 x ($M1_{24}$ - M4)/M4	35,86	37,02	36,44	0,818

Dried at 110 °C to constant mass (g)

	A	B
Dried sample M4	668,16	639,37
Tara	202,57	181,8
Tara + surface dried sample	1109,31	1057,13
Surface dried sample	906,74	875,33
Tara + dried sample at roomtemperature	870,73	821,17

DENSITY (Mg/m^3)

		A	B	Average	Stdev.
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	1,154	1,148	1,151	0,0044
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	1,147	1,145	1,146	0,0012

Ash (31,5 mm - 4mm)
Absolute pressure 50 mbar

(g)	B	C
Pyknometer (empty)	1223,57	1225,23
Pyknometer + surface dried sample (0h)	2127,19	2101,12
Pyknometer + sample + water (0h)	3082,05	3067,85
Pyknometer + sample + water (1h) $M2_1$	3092,17	3074,79
Moister ratio after 1h	1,51	1,09
Increase of absorbed water amount (g) between 0h och 1h	10,12	6,94
Pyknometer + surface dried sample (1h) 1h	2137,31	2108,06
Pyknometer + sample + water (1h+ 4h) $M2_5$	3092,30	3075,4
Moister ratio after 5h	1,53	1,18
Increase of absorbed water amount (g) between 0h och 5h	10,25	7,55
Pyknometer + surface dried sample (1h+ 4h) 5h	2137,44	2108,67
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3094,35	3077,13
Moister ratio after 24h	1,84	1,45
Increase of absorbed water amount (g) between 0h och 24h	12,30	9,28
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2139,23	2107,77
Increase of surface dried sample mellan 24h och 0h	12,04	6,65
Pyknometer + water M3	2767,40	2759,20
Lost of sample, including error i measurment 0-reading	0,26	2,63

(g)	B	C
$M1_0$ (0h)	903,62	875,89
$M1_1$ (1h)	913,74	882,83
$M1_5$ (5h)	913,87	883,44
$M1_{24}$ (24h)	915,66	882,54

DENSITY		B	C	Average	Stdev. (Mg/m³)
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	1,551	1,556	1,554	0,0035
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	1,552	1,557	1,555	0,0041
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	1,555	1,563	1,559	0,0055

DENSITY				Average	Stdev. (Mg/m³)
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	1,135	1,132	1,134	0,0018
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	1,134	1,127	1,131	0,0052

WATERABS.			B	C	Average	Stdev. (%)
Vattenabs. (0h)	W_{A0}	$100 \times (M1_0 - M4)/M4$	35,24	36,99	36,12	1,239
Vattenabs. (1h)	W_{A1}	$100 \times (M1_1 - M4)/M4$	36,75	38,08	37,42	0,936
Vattenabs. (5h)	W_{A5}	$100 \times (M1_5 - M4)/M4$	36,77	38,17	37,47	0,990
Vattenabs. (24h)	W_{A24}	$100 \times (M1_{24} - M4)/M4$	37,04	38,03	37,54	0,701

Dried at 110 °C to constant mass (g)	B	C
Dried sample M4	668,16	639,37
Tara	202,57	181,8
Tara + surface dried sample	1109,31	1057,13
Surface dried sample	906,74	875,33
Tara + dried sample at roomtemperature	870,73	821,17

Ash (31,5 mm - 4mm)
Absolute pressure 75 mbar

	B (g)	C (g)
Pyknometer (empty)	1223,57	1225,23
Pyknometer + surface dried sample (0h)	2054,54	2029,43
Pyknometer + sample + water (0h)	3007,82	2993,09
Pyknometer + sample + water (1h) $M2_1$	3084,3	3068,31
Moister ratio after 1h	11,45	11,76
Increase of absorbed water amount (g) between 0h och 1h	76,48	75,22
Pyknometer + surface dried sample (1h) 1h	2131,02	2104,65
Pyknometer + sample + water (1h+ 4h) $M2_5$	3086,85	3070,35
Moister ratio after 5h	11,83	12,08
Increase of absorbed water amount (g) between 0h och 5h	79,03	77,26
Pyknometer + surface dried sample (1h+ 4h) 5h	2133,57	2106,69
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3091,96	3075,24
Moister ratio after 24h	12,59	12,85
Increase of absorbed water amount (g) between 0h och 24h	84,14	82,15
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2134,55	2108,33
Increase of surface dried sample mellan 24h och 0h	80,01	78,90
Pyknometer + water M3	2767,86	2758,97
Lost of sample, including error i measurment 0-reading	4,13	3,25

(g)

$M1_0$ (0h)	830,97	804,20
$M1_1$ (1h)	907,45	879,42
$M1_5$ (5h)	910,00	881,46
$M1_{24}$ (24h)	910,98	883,1

DENSITY (Mg/m³)

		A	B	Average	Stdev.
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	1,535	1,543	1,539	0,0051
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	1,540	1,546	1,543	0,0046
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	1,552	1,558	1,555	0,0040

DENSITY (Mg/m³)

		A	B	Average	Stdev.
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	1,138	1,128	1,133	0,0074
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	1,131	1,122	1,126	0,0064

WATERABS. (%)

			A	B	Average	Stdev.
Vattenabs. (0h)	W_{A0}	$100 \times (M1_0 - M4)/M4$	24,37	25,78	25,07	0,999
Vattenabs. (1h)	W_{A1}	$100 \times (M1_1 - M4)/M4$	35,81	37,54	36,68	1,224
Vattenabs. (5h)	W_{A5}	$100 \times (M1_5 - M4)/M4$	36,19	37,86	37,03	1,180
Vattenabs. (24h)	W_{A24}	$100 \times (M1_{24} - M4)/M4$	36,34	38,12	37,23	1,258

(g)

Dried at 110 °C to constant mass	A	B
Dried sample M4	668,16	639,37
Tara	202,57	181,8
Tara + surface dried sample	1109,31	1057,13
Surface dried sample	906,74	875,33
Tara + dried sample at roomtemperature	870,73	821,17

Basalt (31,5 mm - 4mm)
Absolute pressure 30 mbar

(g)

	A	B
Pyknometer (empty)	1169,28	1225,23
Pyknometer + surface dried sample (0h)	2664,71	2810,94
Pyknometer + sample + water (0h)	3569,04	3718,47
Pyknometer + sample + water (1h) $M2_1$	3571,74	3723,74
Moister ratio after 1h	0,19	0,30
Increase of absorbed water amount (g) between 0h och 1h	2,70	5,27
Pyknometer + surface dried sample (1h) 1h	2667,41	2816,21
Pyknometer + sample + water (1h+ 4h) $M2_5$	3571,76	3724,74
Moister ratio after 5h	0,19	0,36
Increase of absorbed water amount (g) between 0h och 5h	2,72	6,27
Pyknometer + surface dried sample (1h+ 4h) 5h	2667,43	2817,21
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3576,53	3727,02
Moister ratio after 24h	0,53	0,49
Increase of absorbed water amount (g) between 0h och 24h	7,49	8,55
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2672	2819,33
Increase of surface dried sample mellan 24h och 0h	7,29	8,39
Pyknometer + water M3	2664,58	2759,06
Lost of sample, including error i measurment 0-reading	0,20	0,16

(g)

	A	B
$M1_0$ (0h)	1495,43	1585,71
$M1_1$ (1h)	1498,13	1590,98
$M1_5$ (5h)	1498,15	1591,98
$M1_{24}$ (24h)	1502,72	1594,1

(Mg/m³)

DENSITY

		A	B	Average	Stdev.
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	2,535	2,540	2,538	0,0037
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	2,535	2,542	2,538	0,0048
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	2,544	2,546	2,545	0,0016

(%)

WATERABS.

			A	B	Average	Stdev.
Vattenabs. (0h)	W_{A0}	$100 \times (M1_0 - M4)/M4$	5,77	5,97	5,87	0,139
Vattenabs. (1h)	W_{A1}	$100 \times (M1_1 - M4)/M4$	5,96	6,32	6,14	0,253
Vattenabs. (5h)	W_{A5}	$100 \times (M1_5 - M4)/M4$	5,97	6,39	6,18	0,299
Vattenabs. (24h)	W_{A24}	$100 \times (M1_{24} - M4)/M4$	6,29	6,53	6,41	0,170

(g)

Dried at 110 °C to constant mass

	A	B
Dried sample M4	1413,81	1496,39
Tara	179,08	149,07
Tara + surface dried sample	1680,21	1742,02
Surface dried sample	1501,13	1592,95
Tara + dried sample at roomtemperature	1592,89	1645,46

(Mg/m³)

DENSITY

		A	B	Average	Stdev.
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	2,393	2,390	2,392	0,0023
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	2,392	2,389	2,391	0,0022

Basalt (31,5 mm - 4mm)
Absolute pressure 50 mbar

	A	B
		(g)
Pyknometer (empty)	1169,28	1225,23
Pyknometer + surface dried sample (0h)	2658,40	2799,51
Pyknometer + sample + water (0h)	3560,58	3709,51
Pyknometer + sample + water (1h) $M2_1$	3566,05	3716,10
Moister ratio after 1h	0,39	0,44
Increase of absorbed water amount (g) between 0h och 1h	5,47	6,59
Pyknometer + surface dried sample (1h) 1h	2663,87	2806,1
Pyknometer + sample + water (1h+ 4h) $M2_5$	3567,4	3717,87
Moister ratio after 5h	0,48	0,51
Increase of absorbed water amount (g) between 0h och 5h	6,82	8,36
Pyknometer + surface dried sample (1h+ 4h) 5h	2665,22	2807,87
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3570,64	3722,5
Moister ratio after 24h	0,71	0,87
Increase of absorbed water amount (g) between 0h och 24h	10,06	12,99
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2672,14	2815,12
Increase of surface dried sample mellan 24h och 0h	13,74	15,61
Pyknometer + water M3	2664,58	2759,15
Lost of sample, including error i measurment 0-reading	-3,68	-2,62

	A	B
		(g)
$M1_0$ (0h)	1489,12	1574,28
$M1_1$ (1h)	1494,59	1580,87
$M1_5$ (5h)	1495,94	1582,64
$M1_{24}$ (24h)	1502,86	1589,89

DENSITY		A	B	Average	Stdev. (Mg/m³)
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	2,520	2,534	2,527	0,0098
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	2,522	2,537	2,529	0,0102
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	2,518	2,538	2,528	0,0137

WATERABS.			A	B	Average	Stdev. (%)
Vattenabs. (0h)	W_{A0}	$100 \times (M1_0 - M4)/M4$	5,33	5,21	5,27	0,086
Vattenabs. (1h)	W_{A1}	$100 \times (M1_1 - M4)/M4$	5,71	5,65	5,68	0,048
Vattenabs. (5h)	W_{A5}	$100 \times (M1_5 - M4)/M4$	5,81	5,76	5,79	0,032
Vattenabs. (24h)	W_{A24}	$100 \times (M1_{24} - M4)/M4$	6,30	6,25	6,27	0,036

Dried at 110 °C to constant mass	A	B (g)
Dried sample M4	1413,81	1496,39
Tara	179,08	149,07
Tara + surface dried sample	1680,21	1742,02
Surface dried sample	1501,13	1592,95
Tara + dried sample at roomtemperature	1592,89	1645,46

DENSITY		A	B	Average	Stdev. (Mg/m³)
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	2,369	2,388	2,379	0,0137
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	2,384	2,398	2,391	0,0104

Basalt (31,5 mm - 4mm)
Absolute pressure 75 mbar

	A	B
		(g)
Pyknometer (empty)	1169,28	1225,23
Pyknometer + surface dried sample (0h)	2618,23	2760,14
Pyknometer + sample + water (0h)	3521,41	3697,06
Pyknometer + sample + water (1h) $M2_1$	3548,99	3716,10
Moister ratio after 1h	1,95	1,27
Increase of absorbed water amount (g) between 0h och 1h	27,58	19,04
Pyknometer + surface dried sample (1h) 1h	2645,81	2794,46
Pyknometer + sample + water (1h+ 4h) $M2_5$	3553,1	3701,94
Moister ratio after 5h	2,24	0,33
Increase of absorbed water amount (g) between 0h och 5h	31,69	4,88
Pyknometer + surface dried sample (1h+ 4h) 5h	2649,92	2798,96
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3564,53	3712,49
Moister ratio after 24h	3,05	1,03
Increase of absorbed water amount (g) between 0h och 24h	43,12	15,43
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2661,2	2805,57
Increase of surface dried sample mellan 24h och 0h	42,97	45,43
Pyknometer + water M3	2664,08	2759,23
Lost of sample, including error i measurment 0-reading	0,15	-30,00

	A	B
		(g)
$M1_0$ (0h)	1448,95	1534,91
$M1_1$ (1h)	1476,53	1569,23
$M1_5$ (5h)	1480,64	1573,73
$M1_{24}$ (24h)	1491,92	1580,34

DENSITY		**A**	**B**	**Average**	**Stdev.** (Mg/m^3)
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	2,496	2,563	2,529	0,0473
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	2,503	2,494	2,498	0,0062
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	2,522	2,520	2,521	0,0016

WATERABS.			**A**	**B**	**Average**	**Stdev.** (%)
Vattenabs. (0h)	W_{A0}	100 x ($M1_0$ - M4)/M4	2,49	2,57	2,53	0,063
Vattenabs. (1h)	W_{A1}	100 x ($M1_1$ - M4)/M4	4,44	4,87	4,65	0,305
Vattenabs. (5h)	W_{A5}	100 x ($M1_5$ - M4)/M4	4,73	5,17	4,95	0,312
Vattenabs. (24h)	W_{A24}	100 x ($M1_{24}$ - M4)/M4	5,52	5,61	5,57	0,060

Dried at 110 °C to constant mass	A	B (g)
Dried sample M4	1413,81	1496,39
Tara	179,08	149,07
Tara + surface dried sample	1680,21	1742,02
Surface dried sample	1501,13	1592,95
Tara + dried sample at roomtemperature	1592,89	1645,46

DENSITY		**A**	**B**	**Average**	**Stdev.** (Mg/m^3)
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	2,390	2,386	2,388	0,0029
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	2,390	2,371	2,381	0,0130

Concrete (25 mm - 4mm)
Absolute pressure 30 mbar

	A	B
		(g)
Pyknometer (empty)	1169,27	1223,60
Pyknometer + surface dried sample (0h)	2741,32	2718,79
Pyknometer + sample + water (0h)	3620,05	3672,77
Pyknometer + sample + water (1h) $M2_1$	3619,57	3672,99
Moister ratio after 1h	-0,03	0,01
Increase of absorbed water amount (g) between 0h och 1h	-0,48	0,22
Pyknometer + surface dried sample (1h) 1h	2740,84	2719,01
Pyknometer + sample + water (1h+ 4h) $M2_5$	3620,09	3673,07
Moister ratio after 5h	0,00	0,02
Increase of absorbed water amount (g) between 0h och 5h	0,04	0,30
Pyknometer + surface dried sample (1h+ 4h) 5h	2741,36	2719,09
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3620,10	3672,91
Moister ratio after 24h	0,00	0,01
Increase of absorbed water amount (g) between 0h och 24h	0,05	0,14
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2741,44	2718,53
Increase of surface dried sample mellan 24h och 0h	0,12	-0,26
Pyknometer + water M3	2664,22	2767,48
Lost of sample, including error i measurment 0-reading	-0,07	0,40

	A	B
$M1_0$ (0h)	1572,05	1495,19
$M1_1$ (1h)	1571,57	1495,41
$M1_5$ (5h)	1572,09	1495,49
$M1_{24}$ (24h)	1572,17	1494,93

(Mg/m³)

DENSITY		A	B	Average	Stdev.
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	2,550	2,535	2,543	0,0108
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	2,551	2,535	2,543	0,0113
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	2,551	2,536	2,543	0,0107

(%)

WATERABS.			A	B	Average	Stdev.
Vattenabs. (0h)	W_{A0}	$100 \times (M1_0 - M4)/M4$	8,34	8,54	8,44	0,138
Vattenabs. (1h)	W_{A1}	$100 \times (M1_1 - M4)/M4$	8,31	8,55	8,43	0,172
Vattenabs. (5h)	W_{A5}	$100 \times (M1_5 - M4)/M4$	8,34	8,56	8,45	0,151
Vattenabs. (24h)	W_{A24}	$100 \times (M1_{24} - M4)/M4$	8,35	8,52	8,43	0,119

Dried at 110 °C to constant mass	A	B
Dried sample M4	1451,01	1377,59
Tara	148,08	150,47
Tara + surface dried sample	1718,07	1644,11
Surface dried sample	1569,99	1493,64
Tara + dried sample at roomtemperature	1599,09	1528,06

(Mg/m³)

DENSITY		A	B	Average	Stdev.
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	2,354	2,337	2,346	0,0124
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	2,355	2,335	2,345	0,0137

Concrete (25 mm - 4mm)
Absolute pressure 30 mbar

(g)

	A	B
Pyknometer (empty)	1169,27	1223,60
Pyknometer + surface dried sample (0h)	2739,79	2719,57
Pyknometer + sample + water (0h)	3619,57	3672,61
Pyknometer + sample + water (1h) $M2_1$	3618,93	3672,48
Moister ratio after 1h	-0,04	-0,01
Increase of absorbed water amount (g) between 0h och 1h	-0,64	-0,13
Pyknometer + surface dried sample (1h) 1h	2739,15	2719,44
Pyknometer + sample + water (1h+ 4h) $M2_5$	3619,08	3672,19
Moister ratio after 5h	-0,03	-0,03
Increase of absorbed water amount (g) between 0h och 5h	-0,49	-0,42
Pyknometer + surface dried sample (1h+ 4h) 5h	2739,3	2719,15
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3620,13	3673,04
Moister ratio after 24h	0,04	0,03
Increase of absorbed water amount (g) between 0h och 24h	0,56	0,43
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2743,63	2720,78
Increase of surface dried sample mellan 24h och 0h	3,84	1,21
Pyknometer + water M3	2663,99	2767,19
Lost of sample, including error i measurment 0-reading	-3,28	-0,78

	A	B
$M1_0$ (0h)	1570,52	1495,97
$M1_1$ (1h)	1569,88	1495,84
$M1_5$ (5h)	1570,03	1495,55
$M1_{24}$ (24h)	1574,36	1497,18

(Mg/m^3)

DENSITY		A	B	Average	Stdev.
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	2,553	2,533	2,543	0,0141
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	2,553	2,532	2,543	0,0146
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	2,547	2,532	2,539	0,0104

(%)

WATERABS.			A	B	Average	Stdev.
Vattenabs. (0h)	W_{A0}	$100 \times (M1_0 - M4)/M4$	8,24	8,59	8,41	0,252
Vattenabs. (1h)	W_{A1}	$100 \times (M1_1 - M4)/M4$	8,19	8,58	8,39	0,277
Vattenabs. (5h)	W_{A5}	$100 \times (M1_5 - M4)/M4$	8,20	8,56	8,38	0,255
Vattenabs. (24h)	W_{A24}	$100 \times (M1_{24} - M4)/M4$	8,50	8,68	8,59	0,127

(g)

Dried at 110 °C to constant mass	A	B
Dried sample M4	1451,01	1377,59
Tara	148,08	150,47
Tara + surface dried sample	1718,07	1644,11
Surface dried sample	1569,99	1493,64
Tara + dried sample at roomtemperature	1599,09	1528,06

(Mg/m^3)

DENSITY		A	B	Average	Stdev.
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	2,347	2,330	2,338	0,0123
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	2,360	2,333	2,346	0,0190

Concrete (25 mm - 4mm)
Absolute pressure 75 mbar

	A (g)	B (g)
Pyknometer (empty)	1211,67	1223,60
Pyknometer + surface dried sample (0h)	2781,61	2717,56
Pyknometer + sample + water (1h) $M2_1$	3694,40	3671,74
Pyknometer + surface dried sample (1h) 1h	2786,95	2724,11
Pyknometer + sample + water (1h+ 4h) $M2_5$	3694,24	3671,00
Pyknometer + surface dried sample (1h+ 4h) 5h	2786,23	2722,90
Pyknometer + sample + water (1h+ 4h + 19h) $M2_{24}$	3694,78	3672,43
Pyknometer + surface dried sample (1h+ 4h + 19h) 24h	2785,17	2722,03
Pyknometer + water M3	2740,56	2767,40

	A (g)	B (g)
$M1_0$ (0h)	1569,94	1493,96
$M1_1$ (1h)	1575,28	1500,51
$M1_5$ (5h)	1574,56	1499,30
$M1_{24}$ (24h)	1573,50	1498,43

DENSITY (Mg/m³)

		A	B	Average	Stdev.
ρ_{ssd} (1h)	$M1_1/(M1_1-(M2_1-M3))$	2,535	2,517	2,526	0,0127
ρ_{ssd} (5h)	$M1_5/(M1_5-(M2_5-M3))$	2,536	2,517	2,526	0,0135
ρ_{ssd} (24h)	$M1_{24}/(M1_{24}-(M2_{24}-M3))$	2,541	2,525	2,533	0,0111

VATTENABS. (%)

			A	B	Medelv.	Stdav.
Vattenabs. (0h)	W_{A0}	$100 \times (M1_0 - M4)/M4$	8,20	8,45	8,32	0,177
Vattenabs. (1h)	W_{A1}	$100 \times (M1_1 - M4)/M4$	8,56	8,92	8,74	0,253
Vattenabs. (5h)	W_{A5}	$100 \times (M1_5 - M4)/M4$	8,51	8,83	8,67	0,226
Vattenabs. (24h)	W_{A24}	$100 \times (M1_{24} - M4)/M4$	8,44	8,77	8,61	0,233

Dried at 110 °C to constant mass	A (g)	B (g)
Dried sample M4	1451,01	1377,59
Tara	148,08	150,47
Tara + surface dried sample	1718,07	1644,11
Surface dried sample	1569,99	1493,64
Tara + dried sample at roomtemperature	1599,09	1528,06

DENSITY

		A	B	Average	Stdev.
ρrd (24h)	$M4/(M1_{24}-(M2_{24}-M3))$	2,343	2,322	2,332	0,0152
ρrd (5h)	$M4/(M1_5-(M2_5-M3))$	2,337	2,313	2,325	0,0173

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Determination of particle density and water absorption

Sample: Bottom ash   Date: 31/5 2002
Grading: 4-25 mm   Name: Birgir Vilhelmsson
Conditioning: **Oven dried, 24 hour soaking**

Pyknometer no.			10	5	
Dry sample+pyknometer	m_2	g			
Pyknometer	m_1	g			
Dry sample*	m_2-m_1= m_{ds}	g	960,5	888,4	0
Pyknometer+water+sample (25°C)	m_3	g	3465,1	3456,1	
Waterfilled pyknometer (25°C)	m_4	g	3140,4	3165,1	
Volume of sample	V_s= m_4+m_{ds}-m_3	cm^3	635,8	597,4	0
Apparent particle density	Q_a= m_{ds}/V_s	g/cm^3	1,51	1,49	
Mean				**1,50**	
Sample saturated, surface dry	m_5	g	1175,1	1070,9	
Water absorption	$100x(m_5-m_{ds})/m_{ds}$	%	22,34	20,54	
Mean				**21,44**	

Particle density on a ssd basis	Q_{ssd}= $m_5/(m_5-(m_3-m_4)$	1,38	1,37	
Mean			**1,38**	
Part. dens. on an oven dried basis	Q_{odb}= $m_{ds}/m_5-(m_3-m_4)$	1,13	1,14	
Mean			**1,13**	

*In all cases, the oven dry value after the completion of the test shall be recorded and used.

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Determination of particle density and water absorption

Sample: Bottom ash Date: 31/5 2002
Grading: 4-25 mm Name: Birgir Vilhelmsson
Conditioning: **Not oven dried, 24 hours soaking**

Pyknometer no.			8	8	
Dry sample+pyknometer	m_2	g			
Pyknometer	m_1	g			
Dry sample*	m_2-m_1= $\mathbf{m_{ds}}$	g	928,9	934,6	0
Pyknometer+water+sample (25°C)	m_3	g	3512,6	3503,8	
Waterfilled pyknometer (25°C)	m_4	g	3165,1	3140,4	
Volume of sample	$\mathbf{V_s}$= m_4+m_{ds}-m_3	cm^3	581,4	571,2	0
Apparent particle density	$\mathbf{Q_a}$= $\mathbf{m_{ds}/V_s}$	g/cm^3	1,60	1,64	
Mean				**1,62**	
Sample saturated, surface dry	$\mathbf{m_5}$	g	1191,7	1184,1	
Water absorption	100x(m_5-m_{ds})/m_{ds}	%	28,29	26,70	
Mean				**27,49**	

Particle density on a ssd basis	$\mathbf{Q_{ssd}= m_5/(m_5-(m_3-m_4)}$	1,41	1,44	
Mean			**1,43**	
Part. dens. on an oven dried basis	$\mathbf{Q_{odb}= m_{ds}/m_5-(m_3-m_4)}$	1,10	1,14	
Mean			**1,12**	

*In all cases, the oven dry value after the completion of the test shall be recorded and used.

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Determination of particle density and water absorption

Sample: Porous basalt
Grading: 4-25 mm
Conditioning: **Oven dried, 24 hours soaking**
Date:
Name: Pétur Pétursson

Pyknometer no.			A-10	A-8	A-4
Dry sample+pyknometer	m_2	g			
Pyknometer	m_1	g			
Dry sample*	m_2-m_1= $\mathbf{m_{ds}}$	g	1623,0	1811,7	1989,9
Pyknometer+water+sample (25°C)	m_3	g	4130,4	4231,8	4353,1
Waterfilled pyknometer (25°C)	m_4	g	3141,1	3128,5	3140,2
Volume of sample	$V_s = m_4 + m_{ds} - m_3$	cm^3	633,7	708,4	777
Apparent particle density	$\mathbf{Q_a = m_{ds}/V_s}$	g/cm^3	2,56	2,56	2,56
Mean				**2,56**	
Sample saturated, surface dry	$\mathbf{m_5}$	g	1663,7	1862,1	2043,9
Water absorption	$100x(m_5-m_{ds})/m_{ds}$	%	2,51	2,78	2,71
Mean				**2,67**	
	(Oven dried before testing):		*1626,3*	*1816,5*	*1994,5*

Particle density on a ssd basis	$\mathbf{Q_{ssd} = m_5/(m_5-(m_3-m_4))}$	2,47	2,45	2,46
Mean			**2,46**	
Part. dens. on an oven dried basis	$\mathbf{Q_{odb} = m_{ds}/m_5-(m_3-m_4)}$	2,41	2,39	2,39
Mean			**2,40**	

*In all cases, the oven dry value after the completion of the test shall be recorded and used.

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Determination of particle density and water absorption

Sample: Porous basalt
Grading: 4-25 mm
Conditioning: **Not oven dried, 24 hours soaking**
Date: 23/3 2002
Name: Pétur Pétursson

Pyknometer no.			A-10	A-8	A-4
Dry sample+pyknometer	m_2	g			
Pyknometer	m_1	g			
Dry sample*	m_2-m_1= m_{ds}	g	1804,2	1872,3	1940,2
Pyknometer+water+sample (25°C)	m_3	g	4278,3	4313,9	4365,5
Waterfilled pyknometer (25°C)	m_4	g	3141,1	3128,5	3140,2
Volume of sample	$V_s = m_4+m_{ds}-m_3$	cm^3	667	686,9	714,9
Apparent particle density	$Q_a = m_{ds}/V_s$	g/cm^3	2,70	2,73	2,71
Mean				**2,71**	
Sample saturated, surface dry	m_5	g	1898,5	1965,4	2037,3
Water absorption	$100x(m_5-m_{ds})/m_{ds}$	%	5,23	4,97	5,00
Mean				**5,07**	

Particle density on a ssd basis	$Q_{ssd} = m_5/(m_5-(m_3-m_4)$	2,49	2,52	2,51
Mean			**2,51**	
Part. dens. on an oven dried basis	$Q_{odb} = m_{ds}/m_5-(m_3-m_4)$	2,37	2,40	2,39
Mean			**2,39**	

*In all cases, the oven dry value after the completion of the test shall be recorded and used.

	Pre-testing	Appendix 3 (14)
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Determination of particle density and water absorption

Sample: Crushed concrete
Grading: 4-25 mm
Conditioning: **Oven dried, 24 hour soaking**

Date: 10/5 2002
Name: Birgir Vilhelmsson

Pyknometer no.			6	6	
Dry sample+pyknometer	m_2	g			
Pyknometer	m_1	g			
Dry sample*	m_2-m_1= m_{ds}	g	1911,3	1864	0
Pyknometer+water+sample (25°C)	m_3	g	4375,4	4345,2	
Waterfilled pyknometer (25°C)	m_4	g	3137,2	3137,2	
Volume of sample	V_s= m_4+m_{ds}-m_3	cm^3	673,1	656	0
Apparent particle density	Q_a= m_{ds}/V_s	g/cm^3	2,84	2,84	
Mean				**2,84**	
Sample saturated, surface dry	m_5	g	2045,5	1997,2	
Water absorption	100x(m_5-m_{ds})/m_{ds}	%	7,02	7,15	
Mean				**7,08**	

Particle density on a ssd basis	Q_{ssd}= m_5/(m_5-(m_3-m_4))	2,53	2,53	#########
Mean			**2,53**	
Part. dens. on an oven dried basis	Q_{odb}= m_{ds}/m_5-(m_3-m_4))	2,37	2,36	#########
Mean			**2,36**	

*In all cases, the oven dry value after the completion of the test shall be recorded and used.

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Determination of particle density and water absorption

Sample: Crushed concrete Date: 10/5 2002
Grading: 4-25 mm Name: Birgir Vilhelmsson
Conditioning: **Not oven dried, 24 hours soaking**

Pyknometer no.			8	8	
Dry sample+pyknometer	m_2	g			
Pyknometer	m_1	g			
Dry sample*	m_2-m_1= $\mathbf{m_{ds}}$	g	1743,8	1914,9	0
Pyknometer+water+sample (25°C)	m_3	g	4270,0	4385,2	
Waterfilled pyknometer (25°C)	m_4	g	3127,8	3127,8	
Volume of sample	V_s= m_4+m_{ds}-m_3	cm^3	601,6	657,5	0
Apparent particle density	Q_a= m_{ds}/V_s	g/cm^3	2,90	2,91	
Mean				**2,91**	
Sample saturated, surface dry	m_5	g	1880,2	2064,2	
Water absorption	100x(m_5-m_{ds})/m_{ds}	%	7,82	7,80	
Mean				**7,81**	

Particle density on a ssd basis	Q_{ssd}= m_5/(m_5-(m_3-m_4))	2,55	2,56	#########
Mean			**2,55**	
Part. dens. on an oven dried basis	Q_{odb}= m_{ds}/m_5-(m_3-m_4)	2,36	2,37	#########
Mean			**2,37**	

*In all cases, the oven dry value after the completion of the test shall be recorded and used.

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Rev.

Determination of water absorption after boiling

Sample: Porous basalt/Crushed concrete/Bottom ash
Grading: 4-25 mm
Date: 10/5 2002
Name: Birgir Vilhelmsson

		BOILING					
	Oven dry	1 hour, g	%	8 hour	%	24 hours	%
Porous basalt							
Oven dried	1957,8	2031,2	**3,75**	2037,1	**4,05**	2050,4	**4,73**
Not oven dried	1913,3	1996,1	**4,33**	2005,2	**4,80**	2018,5	**5,50**
Crushed concrete							
Oven dried	1721,2	1843,3	**7,09**	1847,9	**7,36**	1849,9	**7,48**
Not oven dried	1739,0	1865,4	**7,27**	1871,5	**7,62**	1872,3	**7,67**
Bottom ash							
Oven dried	1090	1401,9	**28,61**	1454,5	**33,44**	1456,8	**33,65**
Not oven dried	1340,7	1781,4	**32,87**	1808	**34,85**	1796,2	**33,97**

Parallel test

SP
Sample: Ash
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Test portion c	Average
Pyknometer (empty). (g) + grid	M_0	718,85	738,30	714,96	
Pyknometer + dry washed sample. (g) + grid	M_5	1253,39	1312,37	1275,09	
Dry washed sample (g)	M	534,54	574,07	560,13	556,25
Pyknometer + saturated sample in water. (g) + grid	M_2	2235,01	2261,96	2240,42	
Pyknometer + water. (g) + grid	M_3	1992,28	1996,53	1983,99	
Saturated and surface dried sample in air. (g)	M_1	710,45	748,42	745,94	734,94
Oven-dried sample in air M_4. (g)	M_4	530,73	565,60	555,42	550,58
Water absorption.(weight-%)	W	33,86	32,32	34,30	33,50
Apparent particle density. (Mg/m^3)	ρ_a	1,843	1,884	1,858	1,86
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	1,135	1,171	1,135	1,15
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	1,519	1,550	1,524	1,53

Table 2

Moisture content at start,
third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	450,14
Weight after drying to constant weight in 110^{0}C. (g)	M_7	445,32
Weight water content M_6 -M_7. (g)	M_w	4,82
Moister ratio. (weight-%)	MR	1,08

Parallel test

SP
Sample: Concrete
Testing conditions: Absolute pressure 50 mbar for 5 hours

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Test portion c	Average
Pyknometer (empty). (g)	M_0	714,99	734,72	711,45	
Pyknometer + dry washed sample. (g)	M_5	1931,70	2029,96	1982,77	
Dry washed sample (g)	M	1216,71	1295,24	1271,32	1261,09
Pyknometer + saturated sample in water. (g)	M_2	2779,32	2829,98	2803,81	
Pyknometer + water. (g)	M_3	1989,67	1993,89	1981,55	
Saturated and surface dried sample in air. (g)	M_1	1291,98	1379,46	1353,64	1341,69
Oven-dried sample in air M_4. (g)	M_4	1204,73	1279,36	1257,15	1247,08
Water absorption.(weight-%)	W	7,242	7,824	7,675	7,58
Apparent particle density. (Mg/m^3)	ρ_a	2,902	2,886	2,891	2,89
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	2,398	2,354	2,366	2,38
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,572	2,539	2,547	2,55

Table 2

Moisture content at start, third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	1286,06
Weight after drying to constant weight in 110^{0}C. (g)	M_7	1269,42
Weight water content M_6 -M_7. (g)	M_w	16,64
Moister ratio. (weight-%)	MR	1,31

Parallel test

SP
Sample: Basalt
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Test portion c	Average
Pyknometer (empty). (g)	M_0	714,96	734,68	711,41	
Pyknometer + dry washed sample. (g)	M_5	1871,97	1962,14	1926,88	
Dry washed sample (g)	M	1157,01	1227,46	1215,47	1199,98
Pyknometer + saturated sample in water. (g)	M_2	2719,08	2765,52	2746,59	
Pyknometer + water. (g)	M_3	1989,67	1993,89	1981,55	
Saturated and surface dried sample in air. (g)	M_1	1212,76	1286,20	1279,43	1259,46
Oven-dried sample in air M_4. (g)	M_4	1155,21	1225,40	1213,53	1198,05
Water absorption.(weight-%)	W	4,98	4,96	5,43	5,12
Apparent particle density. (Mg/m^3)	ρ_a	2,713	2,700	2,706	2,71
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	2,390	2,381	2,359	2,39
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,509	2,500	2,487	2,50

Table 2

Moisture content at start, third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	1371,36
Weight after drying to constant weight in 110^{0}C. (g)	M_7	1370,02
Weight water content M_6 -M_7. (g)	M_w	1,34
Moister ratio. (weight-%)	MR	0,10

IBRI
Sample: Ash
Testing conditions: Absolute pressure 50 mbar for 5 hours

Table 1
Particle density and water absorption

		Sample 2 Test portion a	Sample 16 Test portion b	Average
Pycnometer (empty). (g)	M_0	524,16	578,59	
Pycnometer + oven-dried sample (40 ^{0}C). (g)	M_5	1412,21	1511,29	
Oven-dried sample (40 ^{0}C). (g)	M	888,05	932,70	**910,38**
Pycnometer + saturated sample in water. (g)	M_2	3517,19	3561,90	
Pycnometer + water. (g)	M_3	3109,60	3135,60	
Saturated and surface dried sample in air. (g)	M_1	1179,08	1227,11	**1203,10**
Oven-dried (110^{0}C) sample in air. (g)	M_4	880,45	923,25	**901,85**
Water absorption.(weight-%)	W_{a5}	33,918	32,912	**33,41**
Apparent particle density. (Mg/m^3)	ρ_a	1,862	1,858	**1,86**
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	1,141	1,153	**1,15**
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	1,528	1,532	**1,53**

Table 2
Moisture content at start, third test portion (Chapter 8.2)

		Sample 6 Test portion c
Mass of sample after ? 120 h (40 ^{0}C). (g)	M_6	861,5
Mass of oven-dried sample (110^{0}C). (g)	M_7	856,76
Mass of water content M_6 -M_7. (g)	M_w	4,74
Moister content. (weight-%)	MC	0,55

IBRI
Sample: Concrete
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1
Particle density and water absorption

		Test port. no. 6	Test port. no. 22	Average
Pyknometer (empty). (g)	M_0	524,16	578,59	
Pyknometer + dry washed sample. (g)	M_5	2981,80	2881,96	
Dry washed sample (g)	M	2457,64	2303,37	
Pyknometer + saturated sample in water. (g)	M_2	4703,40	4832,40	
Pyknometer + water. (g)	M_3	3109,60	3135,60	
Saturated and surface dried sample in air. (g)	M_1	2601,79	2455,20	
Oven-dried sample in air M_4. (g)	M_4	2422,58	2270,42	
Water absorption.(weight-%)	W	7,40	8,14	**7,77**
Apparent particle density. (Mg/m^3)	ρ_a	2,923	3,958	**3,44**
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	2,403	2,994	**2,70**
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,581	3,237	**2,91**

Table 2
Moisture content at start,
third test portion (Chapter 8.2)

		Test portion no. 19
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	2507,70
Weight after drying to constant weight in 110^{0}C. (g)	M_7	2475,59
Weight water content M_6 -M_7. (g)	M_W	32,11
Moister ratio. (weight-%)	MR	1,30

Parallel test

IBRI
Sample: Basalt
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1
Particle density and water absorption

		Test port. no. 9	Test port. no. 19	Average
Pyknometer (empty). (g)	M_0	578,6	545,87	
Pyknometer + dry washed sample. (g)	M_5	2896,78	2977,03	
Dry washed sample (g)	M	2318,18	2431,16	
Pyknometer + saturated sample in water. (g)	M_2	4603,60	4661,00	
Pyknometer + water. (g)	M_3	3135,60	3166,70	
Saturated and surface dried sample in air. (g)	M_1	2427,16	2539,72	
Oven-dried sample in air M_4. (g)	M_4	2313,03	2425,63	
Water absorption.(weight-%)	W	4,93	4,70	**4,82**
Apparent particle density. (Mg/m^3)	ρ_a	2,737	2,604	**2,67**
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	2,412	2,320	**2,37**
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,531	2,429	**2,48**

Table 2
Moisture content at start,
third test portion (Chapter 8.2)

		Test portion no. 6
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	2551,64
Weight after drying to constant weight in 110^{0}C. (g)	M_7	2548,76
Weight water content M_6 -M_7. (g)	M_w	2,88
Moister ratio. (weight-%)	MR	0,11

SINTEF
Sample: Ash
Testing conditions: Absolute pressure 50 mbar for 5 hours

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Average
Pyknometer (empty). (g)	M_0	525,2	524,60	
Pyknometer + dry washed sample. (g)	M_5	1458,50	1484,70	
Dry washed sample (g)	M	933,30	960,10	946,70
Pyknometer + saturated sample in water. (g)	M_2	3085,30	3103,50	
Pyknometer + water. (g)	M_3	2692,80	2701,30	
Saturated and surface dried sample in air. (g)	M_1	1134,50	1135,50	1135,00
Oven-dried sample in air M_4. (g)	M_4	838,30	838,50	838,40
Water absorption.(weight-%)	W	35,333	35,420	35,38
Apparent particle density. (Mg/m^3)	ρ_a	1,880	1,922	1,90
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	1,130	1,143	1,14
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	1,529	1,548	1,54

Table 2

Moisture content at start, third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	896,1
Weight after drying to constant weight in 110^{0}C. (g)	M_7	890,8
Weight water content M_6 -M_7. (g)	M_w	5,3
Moister ratio. (weight-%)	MR	0,59

SINTEF
Sample: Cocrete
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Average
Pyknometer (empty). (g)	M_0	617,7	617,00	
Pyknometer + dry washed sample. (g)	M_5	2691,30	2675,20	
Dry washed sample (g)	M	2073,60	2058,20	2065,90
Pyknometer + saturated sample in water. (g)	M_2	4204,00	4189,00	
Pyknometer + water. (g)	M_3	2879,00	2879,90	
Saturated and surface dried sample in air. (g)	M_1	2188,30	2154,00	2171,15
Oven-dried sample in air M_4. (g)	M_4	2029,60	1998,10	2013,85
Water absorption.(weight-%)	W	7,819	7,802	7,81
Apparent particle density. (Mg/m^3)	ρ_a	2,880	2,900	2,89
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	2,351	2,365	2,36
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,535	2,549	2,54

Table 2

Moisture content at start, third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	2516,5
Weight after drying to constant weight in 110^{0}C. (g)	M_7	2478,7
Weight water content M_6 -M_7. (g)	M_w	37,8
Moister ratio. (weight-%)	MR	1,52

SINTEF
Sample: Basalt
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Average
Pyknometer (empty). (g)	M_0	523,5	522,40	
Pyknometer + dry washed sample. (g)	M_5	2593,80	2540,40	
Dry washed sample (g)	M	2070,30	2018,00	2044,15
Pyknometer + saturated sample in water. (g)	M_2	3998,50	3952,50	
Pyknometer + water. (g)	M_3	2691,60	2679,10	
Saturated and surface dried sample in air. (g)	M_1	2155,80	2099,90	2127,85
Oven-dried sample in air M_4. (g)	M_4	2066,50	2014,90	2040,70
Water absorption.(weight-%)	W	4,321	4,219	4,27
Apparent particle density. (Mg/m^3)	ρ_a	2,721	2,717	2,72
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	2,434	2,438	2,44
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,540	2,541	2,54

Table 2

Moisture content at start, third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	2652,8
Weight after drying to constant weight in 110^{0}C. (g)	M_7	2650,7
Weight water content M_6 -M_7. (g)	M_w	2,1
Moister ratio. (weight-%)	MR	0,08

Additional test

SP
Sample: Granite
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1
Particle density and water absorption

		Test portion a	Test portion b	Test portion c	Average
Pyknometer (empty). (g)	M_0	714,94	734,68	711,4	
Pyknometer + dry washed sample. (g)	M_5	2064,31	2127,06	2059,21	
Dry washed sample (g)	M	1349,37	1392,38	1347,81	1363,19
Pyknometer + saturated sample in water. (g)	M_2	2829,18	2861,35	2820,60	
Pyknometer + water. (g)	M_3	1989,67	1993,89	1981,55	
Saturated and surface dried sample in air. (g)	M_1	1363,65	1405,57	1361,19	1376,80
Oven-dried sample in air M_4. (g)	M_4	1346,90	1390,00	1345,10	1360,67
Water absorption.(weight-%)	W	1,24	1,12	1,20	1,19
Apparent particle density. (Mg/m^3)	ρ_a	2,65	2,66	2,66	2,66
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	2,57	2,58	2,58	2,58
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,60	2,61	2,61	2,61

Table 2
Moisture content at start, third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	1063,23
Weight after drying to constant weight in 110^{0}C. (g)	M_7	1061,54
Weight water content M_6 -M_7. (g)	M_w	1,69
Moister ratio. (weight-%)	MR	0,16

Additional test

SP
Sample: Blast furnace slag
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1
Particle density and water absorption

		Test portion a	Test portion b	Test portion c	Average
Pyknometer (empty). (g)	M_0	714,93	734,67	711,39	
Pyknometer + dry washed sample. (g)	M_5	1991,00	2056,50	2004,92	
Dry washed sample (g)	M	1276,07	1321,83	1293,53	1297,14
Pyknometer + saturated sample in water. (g)	M_2	2795,92	2829,79	2799,42	
Pyknometer + water. (g)	M_3	1988,86	1993,05	1980,81	
Saturated and surface dried sample in air. (g)	M_1	1333,13	1381,42	1360,74	1358,43
Oven-dried sample in air M_4. (g)	M_4	1270,51	1316,40	1288,28	1291,73
Water absorption.(weight-%)	W	4,93	4,94	5,62	5,16
Apparent particle density. (Mg/m^3)	ρ_a	2,74	2,74	2,74	2,74
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	2,42	2,42	2,38	2,42
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,53	2,54	2,51	2,53

Table 2
Moisture content at start,
third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	1265,16
Weight after drying to constant weight in 110^{0}C. (g)	M_7	1260,92
Weight water content M_6 -M_7. (g)	M_w	4,24
Moister ratio. (weight-%)	MR	0,34

Additional test

SP
Sample: Light weigt aggregates
Testing conditions: Absolute pressure
50 mbar for 5 hours

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Test portion c	Average
Pyknometer (empty). (g) + grid	M_0	718,85	738,30	714,96	
Pyknometer + dry washed sample. (g) + grid	M_5	959,63	971,80	955,85	
Dry washed sample (g)	M	240,78	233,50	240,89	238,39
Pyknometer + saturated sample in water (g) + grid	M_2	1953,64	1941,61	1924,47	
Pyknometer + water. (g) + grid	M_3	1992,28	1994,08	1987,76	
Saturated and surface dried sample in air. (g)	M_1	530,79	520,64	508,11	519,85
Oven-dried sample in air M_4. (g)	M_4	241,30	241,66	234,13	239,03
Water absorption.(weight-%)	W	119,97	115,44	117,02	117,48
Apparent particle density. (Mg/m^3)	ρ_a	0,86	0,82	0,79	0,82
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	0,42	0,42	0,41	0,42
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	0,93	0,91	0,89	0,91

Table 2

Moisture content at start, third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	288,61
Weight after drying to constant weight in 110^{0}C. (g)	M_7	288,52
Weight water content M_6 -M_7. (g)	M_w	0,09
Moister ratio. (weight-%)	MR	0,03

Additional test

SINTEF

Sample: Crushed bricks (modified, 5 h vakuum)

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Average
Pyknometer (empty). (g)	M_0	617,7	617,00	
Pyknometer + dry washed sample. (g)	M_5	1955,70	1925,10	
Dry washed sample (g)	M	1338,00	1308,10	1323,05
Pyknometer + saturated sample in water. (g)	M_2	3730,30	3712,70	
Pyknometer + water. (g)	M_3	2879,00	2879,90	
Saturated and surface dried sample in air. (g)	M_1	1653,10	1615,00	1634,05
Oven-dried sample in air M_4. (g)	M_4	1334,90	1305,90	1320,40
Water absorption.(weight-%)	W	23,837	23,669	23,75
Apparent particle density. (Mg/m^3)	ρ_a	2,760	2,760	2,76
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	1,665	1,670	1,67
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,062	2,065	2,06

Table 2

Moisture content at start, third test portion (Chapter 8.2)

		Test portion c
Weight after ? 5 days drying in 40 ^{0}C. (g)	M_6	1335,7
Weight after drying to constant weight in 110^{0}C. (g)	M_7	1333,9
Weight water content M_6 -M_7. (g)	M_w	1,8
Moister ratio. (weight-%)	MR	0,13

Additional test

SINTEF

Sample: Crushed bricks (24h in water)

Table 1

Particle density and water absorption

		Test portion a	Test portion b	Average
Pyknometer (empty). (g)	M_0			
Pyknometer + dry washed sample. (g)	M_5			
Dry washed sample (g)	M			0,00
Pyknometer + saturated sample in water. (g)	M_2	3542,30	3480,20	
Pyknometer + water. (g)	M_3	2691,60	2679,10	
Saturated and surface dried sample in air. (g)	M_1	1648,50	1573,60	1611,05
Oven-dried sample in air M_4. (g)	M_4	1357,30	1284,00	1320,65
Water absorption.(weight-%)	W	21,454	22,555	22,00
Apparent particle density. (Mg/m^3)	ρ_a	2,679	2,659	2,67
Particle density on an oven dried basis . (Mg/m3)	ρ_{rd}	1,701	1,662	1,68
Particle density on a saturated and surface-dried basis . (Mg/m3)	ρ_{ssd}	2,066	2,037	2,05

Expanded clay lightweight aggregate 12-20 mm

APPENDIX 6

Unit weight in short and long time according to BVH 585.11 och ATB publication 2003:1

Test sample	**mm**	**Density**	**kg/m^3**	**kN/m^3**	**Unit weight**	**(kN/m^3)**
Grain size min	12	ρ_{comp}	2650	26,5	W_Y	0,30
Grain size max	20	$\rho_{bulk\ (loose)}$	230	2,3	$W_{A,char}$	4,19
Mean value	16	ρ_{grain}	455	4,55	$\gamma_{true\ (dry)}$	-3,03

Waterabsorption				**Unit weight**				
				Over water			**Under water**	
time			Moisture	Mass	Mass	Characteri	Mass	True
(min)	(days)	(Year)	content	$W_{A,t}$	$W_{A,char,t}$	$\gamma_{char,t}$	$W_{B,char,t}$	γ_{true}
			weight (%)	(kN/m^3)	(kN/m^3)	(kN/m^3)	(kN/m^3)	(kN/m^3)
5	0	0,00	3,72	-	-	-	-	-
120	0	0,00	8,06	-	-	-	-	-
	1	0,00	12,68	-	-	-	-	-
	30	**0,08**	40,13	**0,9**	**0,39**	**3,22**	**0,87**	**-1,28**
	90	0,25	56,90	*1,3*	*0,55*	3,38	1,22	-0,60
	150	0,41	64,67	*1,4*	*0,62*	3,45	1,37	-0,28
	180	0,49	65,22	*1,5*	*0,64*	3,47	1,43	-0,17
	210	0,58	68,54	*1,5*	*0,67*	3,50	1,48	-0,07
	240	0,66	70,84	*1,6*	*0,68*	3,51	1,52	0,01
	300	**0,82**	77,40	**1,7**	**0,72**	**3,55**	**1,59**	**0,15**
	365	1	-	-	*0,74*	*3,57*	*1,65*	*0,27*
	3650	10	-	-	*1,06*	*3,89*	*2,36*	*1,70*
1)	***4886***	***13***	**117,50**	*2,7*	***1,10***	***3,93***	***2,45***	***1,88***
	18250	50	-	-	*1,29*	*4,12*	*2,86*	*2,70*
	29200	80	-	-	*1,35*	*4,18*	*3,01*	*2,99*

1) Moisture 117,5 weight % obtained after test in pycnometer at 50 mbar

Remark: Text in italics are extrapolerated results

APPENDIX - list

1(5) **Particle size distribution**

2 (1) **Excerpt of EN 1097-6**

The scope from the standard

3 (16) **Pre-testing**

SP Vacuum test, 75, 50, 30 mbar and 1, 5 and 24 hours
IBRI atmospheric pressure, pre-drying and boiling

4 (9) **Parallel testing**

SP, IBRI, SINTEF:
50 mbar and 5 hours (concrete, ash and basalt)

5 (+5) **Additional tests**

Long term water absorption
Other materials for comparison (granite, blast furnace slag and crushed bricks)

6 () Modelling of final water absorption of light weight aggregates according to the Swedish Road Authority

Enhetsvis

Enhet/Sektion	Prefix	Nr	Rubrik	Underrubrik
ELe ELe 8300	SS	629	UTRUSTNING FÖR ARBETE UNDER SPÄNNING	BEST 96-08-26
ELe ELe 8300	SS	643	KOPPLINGSAPPARATER, KOPPLINGSUTRUSTNING,	BEST 96-08-26
ELe ELe 8300	SS	649	ELEKTRISKA HUSHÅLLSAPPARATER	BEST 96-08-26
ELe ELe 8300	SS	664	ELEKTRISK MÄTUTRUSTNING OCH INDUSTRIELL PROCESSTYRNING	BEST 96-08-26
ELe ELe 8300	SS	676	ELEKTROMEDICINSK UTRUSTNING FÖR MEDICINSKT BRUK	BEST 96-08-26
ELe ELe 8300	SS	679	ELEKTRONISK UTRUSTNING FÖR HEM- OCH KONTORSBRUK	BEST 96-08-26