Test Certificate

Determination of petrographic, mechanical and physical properties of natural stone

Company that required the tests:	Palin Granit Oy P.O. Box 55 FIN-20101 TURKU Finland
Stone tested:	Baltic Brown quarry 12
Tests performed by:	Geological Survey of Finland P.O.Box 1237 70211 Kuopio Finland

Hannu Luodes
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CONTENTS

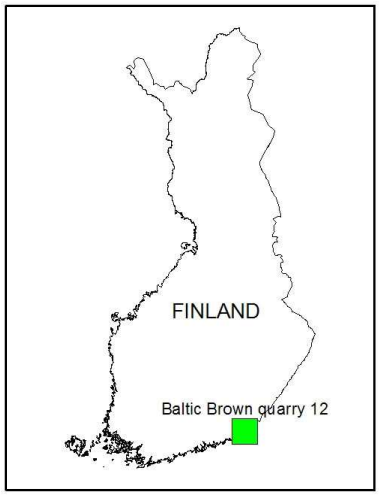
1. GENERAL INFORMATION

The tests performed enable CE marking of the products according to the following harmonized product standards:

EN 1341	Slabs of natural stones for external paving. Requirements and test methods.
EN 1342	Setts of natural stone for external paving. Requirements and test methods
EN 1343	Kerbs of natural stone for external paving. Requirements and test methods
EN 1469	Natural stone products. Slabs for cladding. Requirements
EN 12057	Natural stone products. Modular tiles. Requirements
EN 12058	Natural stone products. Slabs for floors and stairs. Requirements

2. LOCATION OF THE QUARRY

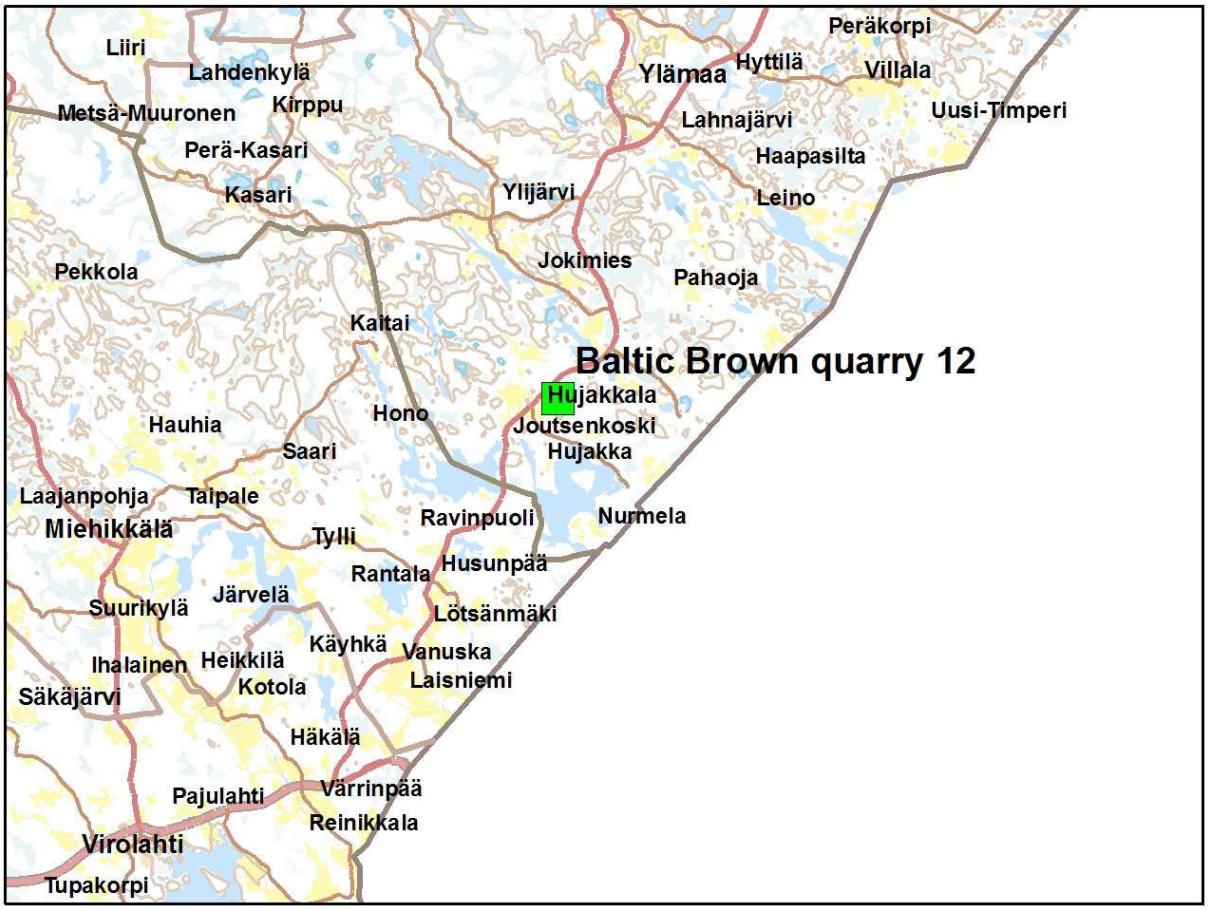
Company: Palin Granit Oy
P.O. Box 55
FIN-20101 TURKU
Finland



Stone: **Baltic Brown quarry 12**

The Baltic Brown quarry 12 is situated in Ylämaa,
in the town of Lappeenranta in south-eastern Finland.

The WGS84 coordinates of the quarry are:
N60.719023, E27.966415



Basemaps: © National Land Survey of Finland, licence no MML/VIR/TIPA/217/10 and Logica Suomi Oy.

3. MINERALOGY

3.1. SUMMARY OF THE RESULTS

Producer	Palin Granit Oy
Stone	Baltic Brown quarry 12
Mineral	Wt%
Plagioclase	36,9
K_feldspar	26,9
Quartz	23,1
Amphibole	7,3
Biotite	4,8
Others	1,0
Total	100,0

3.2. DESCRIPTION OF TEST

3.2.1. Petrographic description, EN 12407:2000

Company that required the test: Palin Granit Oy
P.O. Box 55
FIN-20101 TURKU
Finland

Specimen code: P 11
Baltic Brown quarry 12

Laboratory: Geological Survey of Finland / geologist Hannu Luodes
Research scientist Oleg Knauf

Address: Geological Survey of Finland
P.O.Box 1237
70211 KUOPIO
FINLAND

The date of preparation of the thin section: 25.9.2007
Dimension of the thin section: 35 x 25 mm

The date of the examination: 4.5.2010

Identification number: GTK P11

Sample: P 11

Macroscopic description

The colour of the fresh surface is brown.
The stone has a wiborgite structure, in which larger K-feldspar grains are surrounded by plagioclase rims. The space between these larger grains is composed of all the minerals of the rock with smaller grain size. The size of the larger K-feldspar-grains is usually several centimeters and the grain size of the smaller grain mineral mass under 10 mm. The texture of the rock is homogeneous and massive.

Microscopic description

Mineral	Wt % (1)	Dimension (mm)	Habit	Shape	Boundaries	Distribution	Orientation	Remarks
K-feldspar	29,1	2-18	Anhedral	Anisometric	Partly definable	Homogeneous	Isotropic	
Plagioclase	27,0	0,3-8	Subhedral	Anisometric	Partly straight and definable	Homogeneous	Isotropic	Somewhat altered to sericite
Quartz	26,3	Under 10	Anhedral	Anisometric	Partly definable	Homogeneous	Isotropic	
Amphibole	13,3	0,04-9	Anhedral	Anisometric	Partly definable	Homogeneous	Isotropic	Somewhat altered to ilmenite and magnetite
Biotite	2,3	Under 5	Anhedral	Anisometric	Partly definable	Homogeneous	Isotropic	Somewhat altered to ilmenite and magnetite
Others	1,9	Under 1,5	Partly subhedral	Anisometric	Partly definable	Homogeneous	Isotropic	

1) Mineral composition determined by MLA equipment with XMOD_std method. 19734 measurement points.

In the microscope the rock consists of larger K-feldspar grains and mineral mass of smaller grain size of all the minerals of the rock. The rock is massive. Plagioclase, amphibole and biotite are partly altered.

According to the thin section and sample the rock is **RAPAKIVI GRANITE**.

4. MECHANICAL AND PHYSICAL PROPERTIES

Laboratory: Stone Pole Laboratory, Juuka, Finland / Researcher Mrs Nike Luodes

4.1. SUMMARY OF THE RESULTS

	Producer **Stone**	Palin Granit Oy Baltic Brown quarry 12
Standard	**Test**	
EN 13755	Water absorption (%) mean value Standard deviation (%)	0,10 0,01
EN 1936	Apparent Density (kg/m3) mean value density from ... To ...(kg/m3) Standard deviation(kg/m3)	2680 2670 to 2700 10
EN 1936	Open porosity (%) mean value standard deviation (%)	0,28 0,02
EN 12372	Flexural strength (MPa) mean value Standard deviation(MPa) Min exp value(MPa)	9,1 1,3 6,6
EN 12371	Flexural strength after frost (MPa) mean value Change in mean flexural strength after 48 cycles (%) Standard deviation(MPa) Min exp value(MPa)	9,5 -4,4 1,2 6,9
EN 1926	Compression strength (MPa) mean value Standard deviation(MPa) Min exp value(MPa)	162 14,9 129
EN 12371	Compression strength after frost (MPa) mean value Standard deviation(MPa) Min exp value(MPa)	182 13,7 153
EN 1925	Water absorption by Capillarity C ($g/m^2s^{0,5}$) mean value Standard deviation($g/m^2s^{0,5}$)	0,301 0,023
EN 14231 and CE standards of reference	 Skid resistance - dry polished mean value Skid resistance - wet polished mean value Skid resistance - dry honed mean value Skid resistance - wet honed mean value	 48,9 11 54,2 30,4
EN 14157 and CE standards of reference	 Abrasion resistance (mm) mean value	 17
EN 13364	Resistance at the anchoring system Mean breaking Load(N) Min exp value (N) Standard deviation (N) d1(mm) bA(mm)	2400 1575 500 10 45,7
EN 14066	Resistance to Thermal shock visual changes max Mass change (%) max res. Freq. change (%)	 yes color 0,09 9,8
EN 1925	Water absorption by Capillarity C ($g/m^2s^{0,5}$) parallel mean value Standard deviation	no directions
EN 12524	water vapour resistance factor μ dry water vapour resistance factor μ wet	10000 10000

4.2. DESCRIPTION OF TESTS

4.2.1. Water absorption at atmospheric pressure, EN 13755:2002

The water absorption test has been performed following the standard SFS-EN 13755:2002*"Natural stone test methods. Determination of water absorption at atmospheric pressure"*

The specimens has been dried at constant mass, weighted, immersed gradually in water at atmospheric pressure and weighted in air when saturated.

The water absorption has been calculated as 100*(ms-md)/md
md: 2nd dry weigh (+24 h)
ms: saturated weigh
The mean value, the standard deviation and the coefficient of variation are given besides the uncertainty of the result.

Number and Dimensions (mm)- 6 specimens :50 mm x 50 mm x 50mm
Surface finish : saw

RESULTS:

Specimen codes:	P11/1	P11/2	P11/3	P11/4	P11/5	P11/6
m_d (g)	362,32	358,78	353,80	362,27	355,92	361,04
m_s (g)	362,68	359,11	354,17	362,62	356,25	361,37
Water absorption A_b (%)	0,1	0,1	0,1	0,1	0,1	0,1

Mean value m (%)	**0,10**	Standard dev. s (%)	0,01	Coef. of variation v	0,05

Uncertainty ΔA_b (%)	0,00

4.2.2. Determination of apparent density and open porosity, EN 1936:1999

The apparent density and open porosity test has been performed following the standard SFS-EN 1936:1999*"Natural stone test method. Determination of real density and apparent density, and of total and open porosity"*.

The specimens have been dried at constant mass, weighted (m_d), cooled down in a desiccator, put under vacuum for 1 day, introduced water under vacuum and let them there for 1 day, stop the vacuum and let them under water at atmospheric pressure for 1 day. Then the specimens have been weighted in water (m_h) and in air (m_s).
The apparent density has been calculated as: $\rho_{rh}*m_d/(m_s-m_h)$ in which ρ_{rh} is the density of water at 20ºC =998 kg/m^3. The results of the specimens have been approximated to the nearest 10kg/m^3 and also the average value has the same approximation.
The open porosity has been calculated as: $100*(m_s-m_d)/(m_s-m_h)$ and the results and the average value have been approximated to the nearest 0,1%.
The mean value, the standard deviation and the coefficient of variation are given besides the uncertainty of the result.

Number and Dimensions (mm)- 6 specimens :50 mm x 50 mm x 50mm
Surface finish : saw

Specimen codes:	P11/1	P11/2	P11/3	P11/4	P11/5	P11/6
m_d (g)	362,26	358,72	353,74	362,21	355,86	360,98
m_h(g)	227,51	225,47	222,42	228,61	223,38	227,13
m_s (g)	362,62	359,06	354,15	362,60	356,23	361,33
Apparent density r_b (kg/m^3)	2680	2680	2680	2700	2670	2680
Mean value m (kg/m^3)	2680	Stand. deviation s (kg/m^3)	10	Coefficient of variation v	0,00	
Open porosity p_o (%)	0,3	0,3	0,3	0,3	0,3	0,3
Mean value m (kg/m^3)	0,28	Stand. deviation s (kg/m^3)	0,02	Coefficient of variation v	0,08	

4.2.3. Freeze/thaw resistance, EN 12371: 2003

The frost resistance is performed in accordance with EN 12371: 2003 , with 48 cycles of frost in air and thaw in water. The temperature range is shown in the standard. At the end the specimens are dried at constant mass at 70ºC. The frost test is stopped if the specimen broke during the cycles.

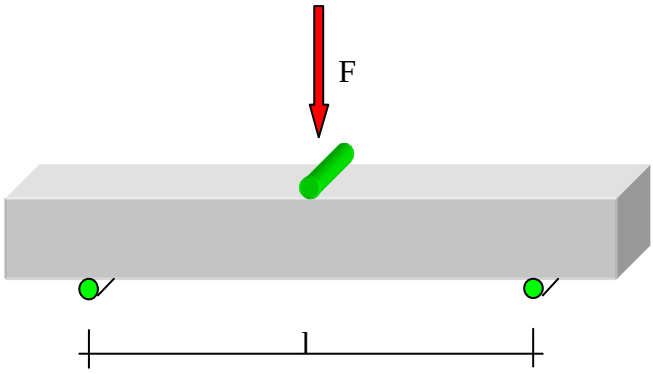
4.2.4. Flexural strength under concentrated load, EN 12372:1999

The flexural strength test has been performed according to the standard SFS-EN 12372:1999

The load has been applied at a uniform rate following the scheme as shown is figure. The specimen has been brought to rupture and the maximum load has been recorded to the nearest 10 N. The dimensions that have been measured are the following:

l is the distance between the supporting rollers

B is the width of the specimen adjacent to the plane of fracture recorded to the nearest 0,1 mm.

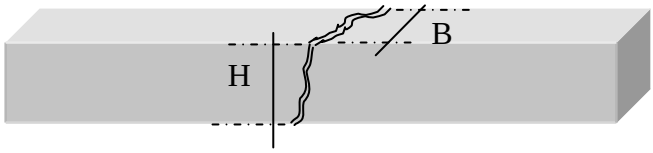


H is the thickness of the specimen adjacent to the plane of fracture recorded to the nearest 0,1 mm

The flexural strength has been calculated as: $3Fl/2BH^2$ and has been expressed to the nearest 0,1 MPa.

In the results are given the average, the standard deviation and the minimum expected value.

After the test:



FRESH MATERIAL
RESULTS OF FLEXURAL STRENGTH

Specimens: 10 prisms: 60x50x300 mm

Specimen codes:	P11/31	P11/32	P11/33	P11/34	P11/35	P11/36	P11/37	P11/38	P11/39	P11/40
Span l (mm)	250	250	250	250	250	250	250	250	250	250
Width B (mm)	60,98	60,50	60,63	61,08	61,11	60,87	60,39	60,71	61,05	60,58
Thickness H (mm)	51,58	51,94	51,58	51,49	51,68	51,78	51,54	51,47	51,75	52,12
Breaking load F (N)	4455	3457	4325	3474	4590	3609	4411	4288	3074	3531
Flex. strength R_{tf} (MPa)	10,3	7,9	10,1	8,0	10,5	8,3	10,3	10,0	7,0	8,0

Mean *m* (MPa)	**9,1**	Standard deviation *s* (MPa)	1,3	Coefficient of variation *v*	0,14

MATERIAL AFTER FROST CYCLES
RESULTS OF FLEXURAL STRENGTH:

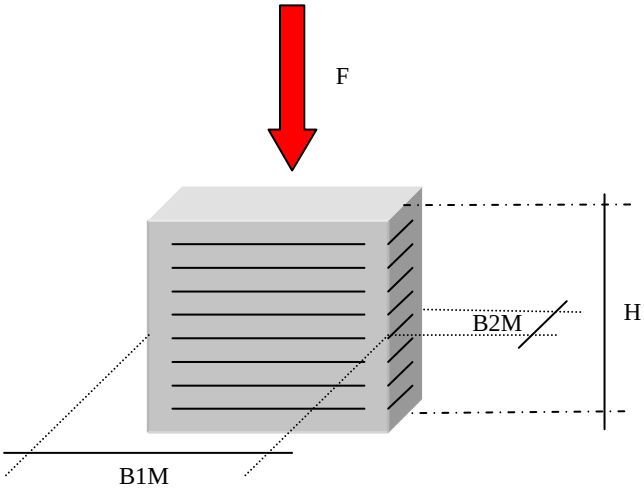
Specimens**:** 10 prisms: 60mm x 50mm x 300 mm, surface sawed

Specimen codes:	P11/41	P11/42	P11/43	P11/44	P11/45	P11/46	P11/47	P11/48	P11/49	P11/50
Span l (mm)	250	250	250	250	250	250	250	250	250	250
Width B (mm)	60,36	60,95	60,71	60,94	60,86	61,00	60,59	60,58	61,06	60,99
Thickness H (mm)	51,45	51,03	51,50	51,34	51,40	51,30	51,96	51,48	52,15	51,36
Breaking load F (N)	3521	4531	3947	3302	4691	5325	3972	4171	3659	3725
Flex. strength R_{tf} (MPa)	8,3	10,7	9,2	7,7	10,9	12,4	9,1	9,7	8,3	8,7

Mean *m* (MPa)	**9,5**	Standard deviation *s* (MPa)	1,5	Coefficient of variation *v*	0,15

4.2.5. Compressive strength, EN 1926:1999

The compressive strength test has been performed according to the standard SFS-EN 1926:1999



The specimens have been dried at constant mass.

Before to perform the test the dimensions of the specimens have been measured:

H is the height of the specimen

B1M and B2M are the cross sectional dimensions:
B1M is obtained by averaging 2 measures taken in the upper and lower face of the cube in one direction and is calculated to the nearest 0,1 mm
B2M is obtained by averaging 2 measures taken in the upper and lower face of the cube in the direction perpendicular to the previous one and is calculated to the nearest 0,1 mm
l_m is obtaining averaging B1M and B2M.

Then the load has been applied continuously at a constant stress rate until the brake happen, and the maximum load has been recorded (F), approximated to the nearest 1kN.
The uniaxial compressive strength (R) of the specimen is given by the ratio: $F/(l_m * l_m)$
The Average value, the standard deviation and the coefficient of variation are as well indicated.

FRESH MATERIAL
RESULTS OF COMPRESSIVE STRENGTH:

Specimens: 6 prisms: 70mm x 70mm x 70 mm, surface sawed

Specimen codes:	P11/11	P11/12b	P11/13	P11/14	P11/15	P11/16
Average length l_m (mm)	70,7	70,5	71,0	70,5	70,7	71,0
Breaking load F (kN)	809,4	680,8	903,4	843,2	771,9	857,7
Compressive strength R (MPa)	162	137	179	170	154	170

Mean *m* (MPa)	**162**	Standard deviation *s* (MPa)	14,9	Coefficient of variation *v*	0,092

RESULTS OF COMPRESSIVE STRENGTH AFTER FROST CYCLES:

Specimens: 6 prisms: 70mm x 70mm x 70 mm, surface sawed

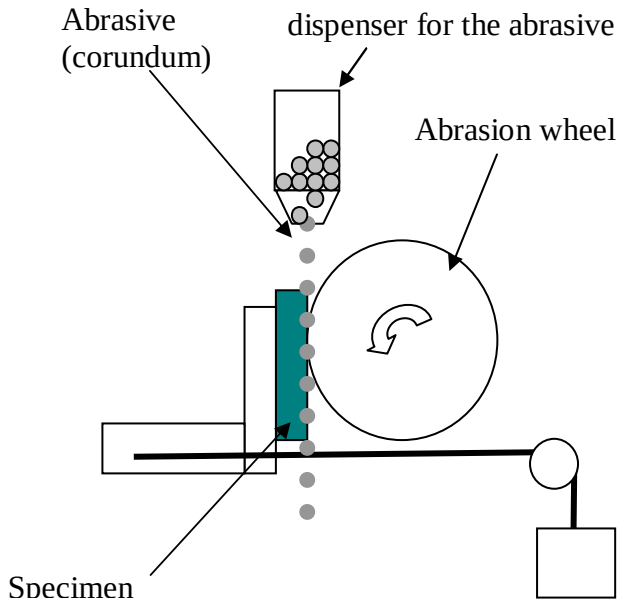
Specimen codes:	P11/21	P11/22	P11/23	P11/24	P11/25	P11/26
Average length l_m (mm)	70,6	70,5	70,5	70,7	70,4	71,4
Breaking load F (kN)	935,4	870,7	849,3	883,0	863,3	1058,4
Compressive strength R (MPa)	188	175	171	177	174	208

Mean *m* (MPa)	**182**	Standard deviation *s* (MPa)	13,7	Coefficient of variation *v*	0,075

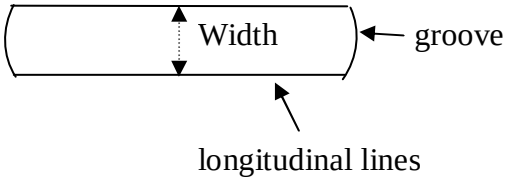
4.2.6. Abrasion resistance, EN 14157

Test performed following:EN 14157 Natural stone test methods - Determination of the abrasion resistance

Scheme of the apparatus:



The specimen is painted and is placed on the holding part, the dispenser is open and the abrasive starts to fall down, the wheel starts to turn. After 75 rotations it stops and the specimen is taken out. The print (groove) given by the wheel is measured.
The groove has a rectangle shape and the width is measured in the middle section after to have drawn the two longitudinal lines (The two external points of the groove are A and B).



Specimens: 6 specimens 110x160x30mm

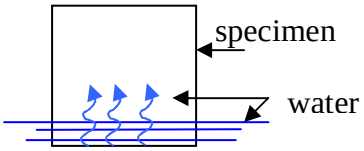
code specim.	P11/61	P11/62	P11/63	P11/64	P11/65	P11/66
Groove length AB (mm)	15,91	15,38	15,77	16,28	15,14	16,27
Abrasion resistance R_i (mm)	16	19	16	17	16	17

Mean value (m): 17 mm

4.2.7. Determination of water absorption coefficient by capillarity, EN 1925:1999

Test performed following the European standard SFS- EN 1925:1999

Description of the test:



The specimens have been dried at constant mass, measured the dimension of one base, weighed and immerse in (3±1)mm of water the base measured. Each specimen has been taken out of water, damped and weighted at determined time intervals.

The results are put on a graph in which it is shown the mass of water absorbed (g) divided by the area of the immersed base (m^2**)** in function of the time (s). For the point of the first part of the graph is controlled that the coefficient of correlation between the measures performed and the regression line is >0,90 or 0,95 depending on how many measures have been taken.

The coefficient of water absorption by capillarity is represented by the slope of the regression line and it can be calculated as: m_i-$m_d/At_i^{0,5}$, in which:
m_d mass of dried specimen
m_i successive masses of specimen during testing
A area of the immersed base of the specimen
t_i times from beginning of the test until the time in which the masses are measured

The average and the standard deviation are given as a result.

Specimens: 6 specimens 70x70x70mm

Specimen codes:	P11/11		P11/12	P11/13	P11/14		P11/15	P11/16
Surface A (mm^2)	5003,33		5001,13	5040,99	4977,99		4997,47	5050,92
C ($g/m^2s^{0,5}$)	0,3		0,3	0,3	0,3		0,3	0,3
C. correlation r	0,963		0,987	0,989	0,950		0,985	0,985

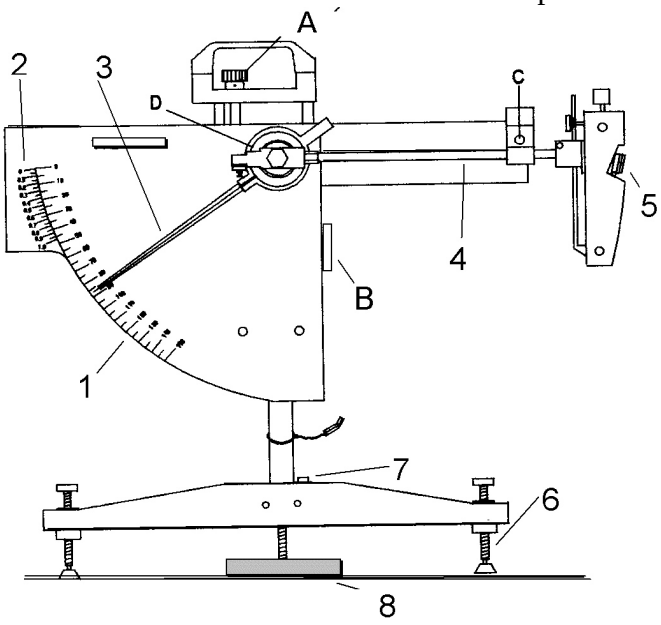
Average m ($g/m^2s^{0,5}$)	**0,301**	standard dev. ($g/m^2s^{0,5}$)	0,023	Coefficient of variation *v*	0,078

Water absorption by Capillarity C (g/m2s0,5) parallel: no directions

4.2.8. Measurement of the slip resistance value (SRV), EN 1342, EN 1341 and EN14231

Test as in EN 1342 and EN 1341 and as in EN14231 in wet and dry conditions:

In the Dry test the specimens are kept dry and the test is performed in dry conditions, in the Wet test the specimens are immersed in water at 20ºC for more than 2 hours and the test is performed in wet condition. The position of the pendulum tester is controlled adjusting the bubble level and the zero of the apparatus is calibrated. The specimen is placed and the height of the pendulum arm is controlled. In the dry test the pendulum is released and the value on the scale is red.
In the wet test the surface of the stone is spread of water as the surface of the rubber slider, then the pendulum is released and the value on the scale is read.
For each specimen are done 5 or 3 measurements in 2 opposite directions and written the means values on both the directions. The value of the specimen will be the mean value of the 2 values recorded.



1 scale (126 mm sliding length)
2 scale (76 mm sliding length)
3 Pointer
4 Pendulum
5 Rubber Slider
6 Levelling Screw
7 Spirit Level
8 Test Specimen Holder
9 Vertical Adjustment Screw

A Screw for the vertical adjustment
B Screw for block or release the vertical adjustment
C Button for release the pendulum
D Friction for calibrate the zero of the apparatus
The slider used has dimensions: 76 mm wide

RESULTS SLIP RESISTANCE TEST POLISHED SURFACE - DRY

Code of specimens:	P11/51	P11/52	P11/53	P11/54	P11/55	P11/56
Average in the direction a	45,60	45,00	46,60	50,00	52,00	53,00
Average in the direction b	46,60	45,00	48,00	51,20	50,00	53,80
Rounded average on the slab	46,1	45,0	47,3	50,6	51,0	53,4

Mean value: 48,9

RESULTS SLIP RESISTANCE TEST POLISHED SURFACE - WET

Code of specimens:	P11/51	P11/52	P11/53	P11/54	P11/55	P11/56
Average in the direction a	8,20	12,00	11,00	11,80	14,60	11,00
Average in the direction b	8,00	10,80	10,00	11,00	13,00	10,80
Rounded average on the slab	8,1	11,4	10,5	11,4	13,8	10,9

Mean value: 11,0

RESULTS SLIP RESISTANCE TEST HONED SURFACE - DRY

Code of specimens:	P11/81	P11/82	P11/83	P11/84	P11/85	P11/86
Average in the direction a	55,00	54,00	52,60	55,00	54,40	54,80
Average in the direction b	54,60	54,00	52,40	55,00	54,80	53,40
Rounded average on the slab	54,8	54,0	52,5	55,0	54,6	54,1

Mean value: 54,2

RESULTS SLIP RESISTANCE TEST HONED SURFACE - WET

Code of specimens:	P11/81	P11/82	P11/83	P11/84	P11/85	P11/86
Average in the direction a	29,20	29,20	31,40	33,80	30,00	28,00
Average in the direction b	30,00	30,00	30,20	33,40	30,80	29,20
Rounded average on the slab	29,6	29,6	30,8	33,6	30,4	28,6

Mean value: 30,4

4.2.9. Thermal shock, EN 14066:2003

Reference to standard SFS-EN 14066:2003 Natural stone test method- Determination of thermal shock

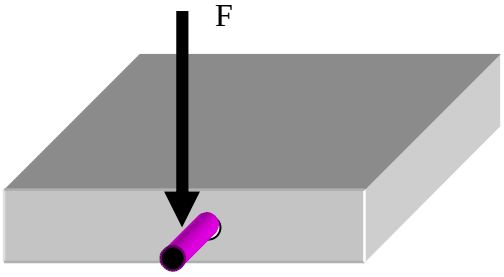
The stone is dried to constant mass and weighed (m0), the fundamental resonance frequency is measured according to EN 14146. Twenty cycles of heat at 105°C and immersion in water at 20ºC are performed and the tiles are visually inspected and reweighed (mf), the fundamental resonance frequency is measured again. A visual description of the tiles, the evaluation of change of mass (Δm) and of change of dynamic elastic modulus are performed.
$\Delta m\ (\%) = (m_f\text{-}m_0/m_0)*100$
$\Delta E_d\ (\%) = (Ed_0\text{-}Ed_f/Ed_0)*100$

VISUAL DESCRIPTION

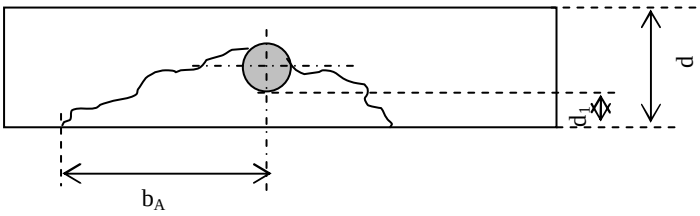
Visual changes	Yes, colour
Max Mass change (%)	0,09
Max res. Freq. change (%)	9,8

4.2.10. Breaking load at dowel hole, EN 13364:2001

Reference standard EN13364:2001 "Natural stone Test methods- Determination of the breaking load at dowel hole"



The specimen has dimension 200x200x30 mm. A hole of 10 mm is made on one side, and a dowel of 6mm diameter is placed with Cement I 52,5R.
A force is applied until the specimen brake.



At the end is recorder
- The breaking load (F) in (N) approximated to the nearest 50N
-the distance from the hole to the face in the direction of the force (d1) in (mm), approximate to 1,0 mm
- maximum distance of the centre of the hole to the fracture edges (b_A) in (mm), approximate to 1,0 mm
The mean load and the standard deviation are given as well in the results.

Code spec.	P11/71	P11/72	P11/73	P11/74	P11/75	P11/76	P11/77	P11/78	P11/79	P11/80
d_1 (mm)	10,15	10,03	10,32	9,54	9,63	10,39	10,00	10,50	9,70	9,70
b_A (mm)	55,16	45,49	52,79	43,00	36,87	48,72	45,90	36,01	38,29	54,49
F (N)	2428,75	1921,71	2674,39	2494,46	1939,92	3477,48	2112,88	2807,46	2184,49	1963,84
Breaking thickness d_1 (mm)	10,2	10,0	10,3	9,5	9,6	10,4	10,0	10,5	9,7	9,7
Max. fracture length b_A (mm)	55,2	45,5	52,8	43,0	36,9	48,7	45,9	36,0	38,3	54,5

Average max. fracture length b_A (mm)	45,7	Average breaking thickness d_1 (mm)	10,0

Breaking load F (N)	2450	1900	2650	2500	1950	3500	2100	2800	2200	1950

Mean *m* (N)	**2400**	Standard deviation *s* (N)	500	Coefficient of variation *v*	0,20

4.2.11. Water vapour permeability, EN 12524

From the tables of the EN 12524 and after have determined the apparent density of the material can be interpolated the vapour resistance factor in dry and wet conditions.

Classification:				Water vapour resistance factor μ	
STONE	density ρ, (kg/m3)	Design thermal conductivity (λ, W/(mK)	Specific heat capacity c_p J/(kgK)	DRY	WET
Natural crystalline rock	2800	3,5	1000	10000	10000
natural sedimentary rock	2600	2,3	1000	250	200
natural sedimentary rock light	1500	0,85	1000	30	20
natural, porous,eg lava	1600	0,55	1000	20	15
Basalt	2700 - 3000	3,5	1000	10000	10000
gneiss	2400 - 2700	3,5	1000	10000	10000
granite	2500 - 2700	2,8	1000	10000	10000
marble	2800	3,5	1000	10000	10000
slate	2000 - 2800	2,2	1000	1000	800
limestone, extra soft	1600	0,85	1000	30	20
limestone soft	1800	1,1	1000	40	25
limestone, semihard	2000	1,4	1000	50	40
limestone hard	2200	1,7	1000	200	150
limestone extra hard	2600	2,3	1000	250	200
snadstone (silica)	2600	2,3	1000	40	30
natural pomice	400	0,12	1000	8	6
artificial stone	1750	1,3	1000	50	40

Water vapour resistance factor is the important one to evaluate the water permeability of the material:

dry conditions	wet conditions
μ =10000	**μ =10000**

The water vapour resistance factor is independent from the barometric pressure, since the barometric pressure of the air and of the material are considered the same. It is therefore a parameter of reference for calculations related to buildings.

To find the water vapour permeability of the material can be referred to SFS EN ISO 12572 where:

$$\text{Water vapour permeability of material} = \frac{\text{Water vapour permeability of air}}{\mu}$$

The water vapour permeability of air can be evaluated from the following graphic (referred to 23° C).