



# POLITECNICO DI TORINO

LABORATORIO MARMO

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## DETERMINATION OF PHYSICAL AND MECHANICAL PROPERTIES ON A SAMPLE OF A NATURAL STONE NAMED MIRONJA

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The Scientific Coordinator:  
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## DETERMINATION OF PHYSICAL AND MECHANICAL PROPERTIES ON A SAMPLE OF A NATURAL STONE NAMED MIRONJA

Requested by: KAMEN d.d. PAZIN, 52000 PAZIN, Trg Slobode 2  
HRVATSKA

Tested stone: (denomination in accordance with EN 12440):

Traditional name: MIRONJA

Petrographic name: limestone

Region of extraction: Slano (Dalmatia, Republic of Croatia)

The following tests have been requested, also according to EN 1341, 1342 and 1343, 1469, 12057, 12058, CE marking standards for slabs, kerbs and setts of natural stone for external paving and for slabs for cladding, modular tiles, slabs for floors and stairs:

- petrographic examination, according to EN 12407;
- apparent density and open porosity, according to EN 1936;
- water absorption, according to EN 13755;
- flexural strength under concentrated load according to EN 12372;
- freeze-thaw resistance, according to EN 12371 and EN 12372;
- compressive strength, according to EN 1926;
- freeze-thaw resistance, according to EN 12371 and EN 1926;
- abrasion resistance, according to EN 1341, Annex C and EN 1342, Annex B and to EN 14157;
- slip resistance, according to EN 1341 Annex D and EN 1342, Annex C and to to EN 14231 for the following surface finishes:
  - bush-hammered;
  - flamed;
- modulus of elasticity according to EN 14580;
- linear thermal expansion coefficient according to EN 14581;
- breaking load at dowel hole, according to EN 13364;
- resistance to salt crystallisation according to EN 12370.



## TEST RESULTS

### PETROGRAPHIC EXAMINATION

#### **Test method:**

The test has been performed according to EN 12407 – 2007 Natural stone test methods – Petrographic examination.

#### **Macroscopic description:**

The hand specimen appears fine grained and has an pale brownish colour with rare light spots and rare white calcitic veins. It is characterized by the presence of thin yellowish-reddish stylolites.

#### **Microscopic description:**

In thin section the rock appears almost completely made up by calcite.

The constituents are:

- micritic matrix (60 %);
- rounded grains (intraclasts) of sparitic calcite whose dimensions vary from 0.01 mm to 0.03 mm (35 %);
- fragments of not recognizable fossils (5 %), the dimensions of fragments vary from 0.05 mm to 0.5 mm;
- thin veins of sparitic calcite.

**The rock is a limestone (intramicrite).**



## APPARENT DENSITY AND OPEN POROSITY

**Test method:**

The apparent density and open porosity have been determined according to EN 1936- 2006 Natural stone test methods - Determination of real density and apparent density and of total and open porosity.

All the specimens are in natural conditions with sawn surface finish.

## APPARENT DENSITY AND OPEN POROSITY

Specimen identification number	Mass of the dry specimen (g)	Mass of the soaked specimen in water (g)	Mass of the soaked specimen in air (g)	Apparent density (kg/m <sup>3</sup> )		Open porosity (% by volume)	
				individual values	average value	individual values	average value
1	339.32	213.86	339.68	2690		0.3	
2	333.53	210.20	333.73	2690		0.2	
3	334.53	210.84	334.68	2700		0.1	
4	351.34	221.43	351.58	2690		0.2	
5	334.73	211.02	335.01	2690		0.2	
6	333.48	210.21	333.64	2700	2690	0.1	0.2



### WATER ABSORPTION

**Test method:**

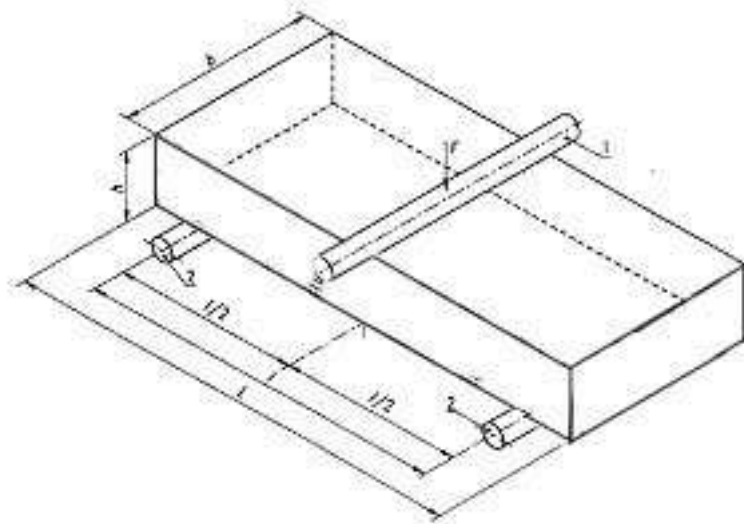
The water absorption has been determined according to EN 13755 - 2003 Natural stone test methods - Determination of water absorption at atmospheric pressure.

All the specimens are in natural conditions with sawn surface finish.

Specimens: 6 cubes having 50 mm edge.

Specimen identification number	Mass of the dry specimen (g)	Mass of the saturated specimen in water (g)	Water absorption (% by mass)	
			individual values	average value
1	341.21	341.40	0.06	
2	334.49	334.73	0.07	
3	341.22	341.40	0.05	
4	342.02	342.26	0.07	
5	349.03	349.33	0.09	
6	337.91	338.15	0.07	0.07

FLEXURAL STRENGTH UNDER CONCENTRATED LOAD ON SPECIMENS BOTH IN NATURAL CONDITIONS AND SUBJECTED TO FROST TEST



**Test method:**

The flexural strength has been determined according to EN 12372 - 2006 Natural stone test methods - Determination of flexural strength under concentrated load.

For the frost test ten specimens, previously saturated in water, have been submitted to 48 freezing and thawing cycles according to EN 12371 - 2001 Natural stone test methods - Determination of frost resistance.

All the specimens are in natural conditions with sawn surface finish.

**Specimens in natural conditions**

Specimen identification number	Length of span l (mm)	Height h (mm)	Width b (mm)	Total load at failure P (kN)	Flexural strength $\sigma$ (MPa)	
					individual values	average value
1	125	25.5	50.0	1.29	7.4	
2	125	25.2	50.3	4.69	27.5	
3	125	25.6	50.2	4.20	23.9	
4	125	25.3	50.1	3.91	22.9	
5	125	25.4	50.5	1.55	8.9	
6	125	25.4	50.2	3.51	20.3	
7	125	25.5	50.3	1.30	7.5	
8	125	25.5	50.3	3.41	19.5	
9	125	25.4	51.2	3.54	20.1	
10	125	25.1	50.7	2.52	14.8	17.3

**Specimens subjected to frost test**

Specimen identification number	Length of span l (mm)	Height h (mm)	Width b (mm)	Total load at failure P (kN)	Flexural strength $\sigma$ (MPa)	
					individual values	average value
11	125	25.3	50.0	2.08	12.2	
12	125	25.2	50.3	1.06	6.2	
13	125	25.3	51.0	0.90	5.2	
14	125	25.3	50.0	2.24	13.1	
15	125	25.0	50.2	1.40	8.4	
16	125	25.3	50.1	0.87	5.1	
17	125	25.4	50.5	1.98	11.4	
18	125	25.2	50.2	2.42	14.2	
19	125	25.0	51.2	1.77	10.4	9.6



COMPRESSION STRENGTH ON SPECIMENS BOTH IN NATURAL CONDITIONS AND SUBJECTED TO FROST TEST

Test method:

The compression strength has been determined according to EN 1926 – 2006 Natural stone test methods - Determination of compressive strength.

For the frost test: six specimens, previously saturated in water, have been submitted to 48 freezing and thawing cycles according to EN 12371 -2001 Natural stone test methods - Determination of frost resistance.

Specimens in natural conditions

Specimen identification number	Area of the bearing surface (mm <sup>2</sup> )	Total load at failure (kN)	Compressive strength	
			individual values (MPa)	average value (MPa)
1	4900	928	189	
2	4886	567	116	
3	4858	952	196	
4	4865	882	181	
5	4872	862	177	
6	4830	750	155	169

Specimens subjected to frost test

1	4879	1018	209	
2	4844	830	171	
3	4851	890	183	
4	4893	868	177	
5	4893	884	181	
6	4851	995	205	188





## DETERMINATION OF ABRASION RESISTANCE

### **Test method:**

The abrasion resistance has been determined according to EN 1341 -2001 Slabs of natural stone for external paving – Requirements and test methods - Annex C and EN 1342 - 2001 Setts of natural stone for external paving – Requirements and test methods - Annex B and to EN 14157 - 2004 Natural stone test methods - Determination of abrasion resistance.

All the specimens are in natural conditions with sawn surface finish.

Specimen identification number	Groove length (mm)	Mean groove length (mm)
1	17.5	
2	17.5	
3	18.5	
4	17.0	
5	17.5	
6	18.5	18.0



DETERMINATION OF SLIP RESISTANCE VALUE BY MEANS OF THE PENDULUM TESTER

**Test method:**

The slip resistance value (SRV) on dry specimens has been determined according to EN 14231- 2003 Natural stone test methods - Determination of the slip resistance by means of the pendulum tester.

The slip resistance value measured on wet specimens has been determined following EN 1341: 2001 “Slabs of natural stone for external paving – Requirements and test methods” Annex D, EN 1342: 2001 “Setts of natural stone for external paving – Requirements and test methods” Annex C and EN 14231- 2003 Natural stone test methods - Determination of the slip resistance by means of the pendulum tester.

For this reason for CE marking, concerning the specimens in wet conditions, the USRV (unpolished slip resistance value) requested by EN 1341 and 1342 is the same value of the SRV requested by EN 12057 and 12058.

**Specimen surface: BUSH HAMMERED**

Specimen identification number	SRV specimens in dry conditions	Mean SRV dry conditions	SRV - USRV specimens in wet conditions	Mean USRV wet conditions
1	84		58	
2	88		56	
3	84		52	
4	85		51	
5	87		50	
6	85	86	57	54

**Specimen surface: FLAMED**

Specimen identification number	SRV specimens in dry conditions	Mean SRV dry conditions	SRV - USRV specimens in wet conditions	Mean USRV wet conditions
1	59		55	
2	56		56	
3	54		53	
4	54		57	
5	53		55	
6	48	54	57	56



## MODULUS OF ELASTICITY

### **Test method:**

The modulus of elasticity has been determined according to EN 14580 - 2005 Natural stone test methods - Determination of static elastic modulus.

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Specimen identification number	Static elastic modulus (MPa)	Mean value (MPa)
1	77857	
2	76509	
3	76533	
4	68992	
5	66751	
6	69639	72714

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DETERMINATION OF LINEAR THERMAL EXPANSION COEFFICIENT

**Test method**

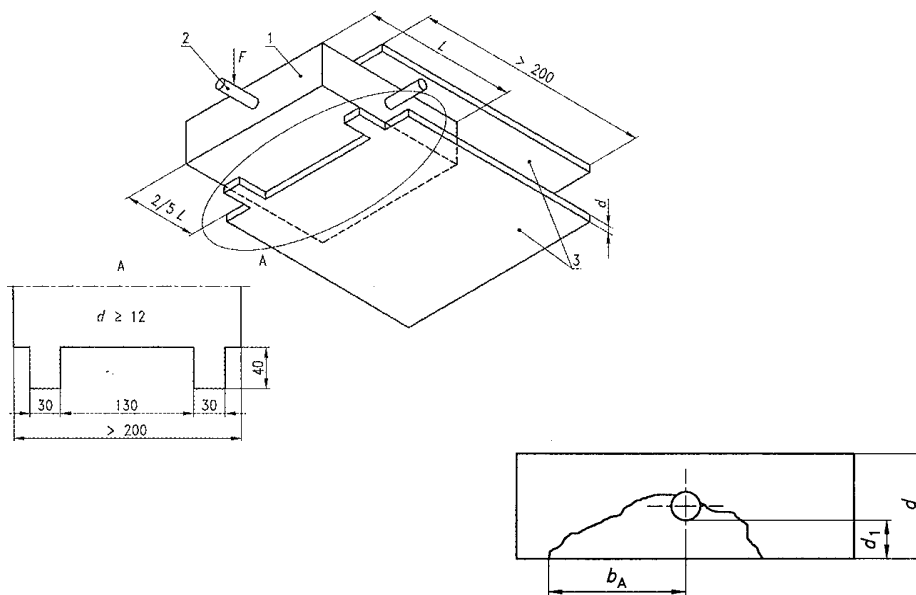
The test has been performed according to EN 14581 – 2004 Natural stone test methods - Determination of linear thermal expansion coefficient

Specimen identification number	Linear expansion coefficient ( $10^{-6} \cdot ^\circ\text{C}^{-1}$ ) after the first heating cycle	Linear expansion coefficient ( $10^{-6} \cdot ^\circ\text{C}^{-1}$ ) after the second heating cycle
1	3	5
2	4	7
Mean values	3	6

DETERMINATION OF THE BREAKING LOAD AT DOWEL-HOLE

**Test method**

The test has been performed according to the EN 13364 - 2001 Natural stone test methods - Determination of the breaking load at dowel hole.



Dimensions in millimetres

Specimen identification number	Hole identification number	Specimen thickness (mm)	Breaking load (N)	Maximum distance from the centre of the hole to the edge of the fracture (b <sub>A</sub> )(mm)	Distance from the hole to the face in the direction of the force (d <sub>1</sub> )(mm)
1	1	30.0	2940	41	10
	2	30.0	3350	34	9
	3	30.0	2270	34	9
	4	30.0	2000	42	9
2	1	30.0	2800	28	9
	2	30.0	4020	45	12
	3	30.0	3110	51	10
3	1	30.0	2490	39	10
	2	30.0	2760	38	11
	3	30.0	2390	48	9
	4	30.0	2780	54	9
Mean values			2810	41	10

## DETERMINATION OF RESISTANCE TO SALT CRYSTALLISATION

**Test method:**

The test has been performed according to EN 12370 - 1999 Natural stone test methods - Determination of resistance to salt crystallisation.

Specimen identification number	Initial mass of the dry specimen (g)	Initial mass of the dry specimen re-weighed with label (g)	Final mass of the dry specimen weighed with label (g)	Relative mass difference (%)
1	173.34	173.85	173.75	-0.1
2	174.07	174.76	174.55	-0.1
3	172.77	173.38	173.24	-0.1
4	173.84	174.15	174.24	0.1
5	171.65	172.24	172.15	-0.1
6	170.89	171.45	171.37	0.0
Average value				-0.05



Photograph of the specimens after the crystallization test: the reference specimen is in the centre.

The test hasn't produced visible alterations.



**SUMMARY OF THE RESULTS**  
(average values)

Petrographic name:.....	limestone (intramicrite)
Apparent density:.....	2690 kg/m <sup>3</sup>
Open porosity .....	0.2 % by volume
Water absorption .....	0.07 % by mass
Flexural strength in natural conditions .....	17.3 MPa
Flexural strength after frost test.....	9.6 MPa
Compression strength in natural conditions .....	169 MPa
Compression strength after frost test .....	188 MPa
Abrasion resistance (groove length) .....	18.0 (mm)
Slip resistance value - bush hammered (dry).....	86 (SRV)
Slip resistance value - bush hammered (wet) .....	54 (SRV -USRV)
Slip resistance value - flamed (dry).....	54 (SRV)
Slip resistance value - flamed (wet) .....	56 (SRV - USRV)
Static modulus of elasticity .....	72714 MPa
Linear expansion coefficient .....	$3-6 * 10^{-6} * ^\circ\text{C}^{-1}$
Breaking load at dowel-hole.....	2810 N
Breaking load at dowel-hole, maximum fracture distance .....	41 mm
Resistance to salt crystallisation .....	- 0.05 % (relative mass difference)