NGU Report 97.026

Testing of natural stone: methods and recommendations to EIGS

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REPORT

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Title:

Testing of natural stone: methods and recommendations for EIGS

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Summary:

This report gives a review of test methods for natural stone, and enclosed are detailed description of the most relevant test methods. Enclosed are also diagrams showing average test results for different rock types.

Keywords:	Mineral resources	Natural stone
Dimension stone	Tests	Scientific report

CONTENTS

APPENDIX

I. INTRODUCTION

Testing of the relevant properties of rocks is an important part of any geological investigation of natural stone deposits. However, test methods should be used with care; the geological investigation, petrographical examination and sampling procedures represent the most important part of a deposit investigation, and tests should be used as a supplement. The basic tests are also an important part of sales promotion.

This report gives a brief description of different test methods used for natural stone. Detailed descriptions are given in appendices 2 - 7. Appendix 1 is a collection of test results obtained from different laboratories.

II. TESTING OF NATURAL STONE

The term «natural stone» covers almost any type of rock used building purposes. Rocks behave in different ways when exposed to varying climatic conditions, pollution, load, abrasion and aggressive chemicals. Furthermore, one type of rock suitable for certain applications in a given environment may not be suitable for other applications.

The need for standardised testing of pertinent rock properties is obvious. Standardised tests make it possible to compare certain indicators of quality between different rock types and ease the customers' selection of stone to a specific purpose.

Natural stone tests may be divided into two main groups:

- *Testing of general properties of rocks* (e.g. strength, porosity, water absorption, frost resistance, skid resistance)
- *User-specified testing* (e.g. bending strength for stone slabs for a specific application)

Testing of the general properties can be further divided into *testing of physical properties*, *petrographical examination* and *durability testing.*

In any case, one must not look blindly at the test results and consider them to be exact measurements of rock quality. Decay in stone is a very complicated process influenced by variables such as climate, pollution, interaction with other materials, biological activity, rock fabric, mineralogy, maintenance, etc. Thus, the importance of good «qualitative» geological work and field studies of weathering at the deposits and in existing masonry and buildings cannot be underestimated.

Most rocks are not isotropic and homogenous. Samples should be carefully selected and assured to be representative of the deposit/quarry. For instance, if samples are taken in the weathering zone, tests will generally indicate a poorer quality than what would be found in samples from a quarry in production. In such cases one might be better off doing no tests or waiting until fresh samples are provided. Furthermore, some properties require testing of different directions in rocks. The more foliated or layered the rock, the more variation in directional properties.

III. STANDARDS

There are many national standards for testing of natural stone. Most widely used are the German (DIN) and American (ASTM) standards. In some cases, completely different methods are used, and correlation between them is difficult. But for the most important tests, correlation factors exist between the standards.

During recent years, much work on European standardisation of tests has been carried out, and the work is still in progress (CEN; European Standardisation Committee). This will result in an EN-standard, which most likely will be adopted by ISO (International standards organisation). The EN standards include both testing of rock properties and specifications of tolerances for different types of stone products.

From our point of view, a test lab should be equipped and prepared for doing the EN standards. Until these are ready, combined ASTM/DIN tests or DIN tests should be used.

IV. PETROGRAPHICAL EXAMINATION

Most likely, a petrographical description will in the near future be required information accompanying all important natural stone distributed in the international market. Both a macroscopic (colour, structure, fabric) and a microscopic (mineral distribution, fabric, alteration) description should be given, and rocks should be classified according to internationally accepted geological classification schemes.

A description of a proposed petrographical examination is given in appendix 3 (CEN-proposal EN (WI 00246 013)[1]).

V. PHYSICAL PROPERTIES

The most widely used tests of physical properties are given in table 1.

TEST	ASTM	DIN	EN-PROPOSAL	CORRELATION
Density, apparent density	ASTM C97-83	DIN 52102	prEN 1936	All
Water absorption and open porosity	ASTM C97-83	DIN 52103	identical to DIN 52103	All
Compressive strength (crushing strength)	ASTM C170-50	DIN 52105	prEN1926	All
Flexural strength (bending strength)	ASTM C99-52	DIN 52112	EN WI 00246 008	All[2]
Abrasion resistance	ASTM D1242-87	DIN 52108	EN WI 00246 014	Not clear
Water absorption due to capillary action			prEN 1925	
Breaking load of the dowel hole			EN WI 00246 010	

Table 1

The first four tests are today widely accepted and correlation between them is easy. Determination of water absorption due to capillary action will probably be more relevant in the future, since this test is more relevant for «real life» conditions than the old absorption test.

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[1] WI=working item; 00246=Technical Committee 246

[2] DIN and ASTM are based on three point loading of the specimen, while the EN proposal is based on four points

Water absorption/density/porosity can be done with standard equipment in most laboratories. For compressive and flexural strength a servo-controlled hydraulic press is needed, and special equipment is also required for the abrasion and the dowel hole tests.

Other relevant tests that could be of increasing interest in the future are *sound velocity* and *thermal expansion.*

VI. DURABILITY

There is a wide spectrum of more or less useful tests of the durability of stone. In most cases, these tests represent cyclic and quite brutal exposure of rocks to various chemicals and salts.

Most common is *frost resistance* (cyclic freeze-thawing of water-saturated specimens) and *resistance to salt crystallisation* (cyclic soaking-drying of specimens using soluble salts in the water).

Other durability tests include determination of *resistance to acids*, *resistance to staining* of different types, «shock»-treating with heat and water and some more qualitative tests such as exposure of rocks to simulated climatic conditions in the laboratory.

With the exception of the latter, all these tests are easy to do in most laboratories.

VII. USER-SPECIFIED TESTS

In many large building projects with extensive use of stone, the user might specify additional tests to ensure that the stone type in question is of the quality needed for the application. If an architect wants to use large, thin slabs on a facade, he could check if the flexural strength is high enough for use as such thin slabs (there is, especially for coarse grained rocks, no linear relationship between strength and thickness of the slabs). The user might also wish to check if the thermal expansion in the given climatic conditions is within safety limits.

VIII. OTHER TESTS

There are other special tests which are not standardised, but in the future some of them probably will be.

Many rocks contain radioactive minerals (some black slates, thorium-rich granites and orthogneisses). This is a sensitive subject and we know of several cases where companies have been asked to document whether their stone products are radioactive or not. One can measure *direct radiation or leaching of radon.* The level of radiation or radon gas is dependent on many factors such as thickness and volume of stone used, porosity and permeability of rocks, size of rooms, type of ventilation, etc. It is very difficult to establish test procedures which give a correct picture of the real danger involved in using rocks containing radioactive minerals. However, radiation is only relevant for indoor applications.

Other tests dealing with health and security include determination of *asbestiform minerals* like tremolite and serpentine. Here one should be aware that these minerals are asbestiform only when the length/thickness ratio of the grains exceeds a certain value. Especially soapstone, serpentinite and highly metamorphic carbonates may contain asbestos minerals.

Other tests that might be relevant for stone are *adhesion to mortar and glue*, quantitative measurement of *colour and polishing*, *E-module*, etc.

IX. HOW USABLE ARE THE TESTS?

The main purpose of testing stone is to get information on whether a rock is good or bad for a certain purpose. If we use the right selection of tests combined with geological knowledge and experience from using the stone, we will get a good indication of quality. This is not how things work in real life. Tests are mainly used as a «licence to sell», that is to supply some figures to the customer whether he understands their meaning or not.

Even today, after many years of standardisation work we basically use the same tests as 100 years ago, though slightly modified. Even if there are many interesting new tests, industry and laboratories tend not to use them, since their basic interest is to limit the cost of testing to a minimum and make only the most necessary number of tests. For 90% of the stone types on the market that means density, porosity, water absorption, compressive strength and flexural strength.

For instance, the water absorption test is based on specimens that are completely soaked with water. The test tells us something about the amount of water that can be trapped in the stone, but it tells nothing about pore size and distribution and permeability which are very important factors in many applications. Water absorption by capillary action is far more relevant (only lower part of specimen soaked in water), but not frequently used.

The European standardisation work tries to solve this problem by recommending tests for different applications and introducing new tests and methodology. Industry and laboratories press to avoid costly changes, and it could thus be difficult to maintain the intentions for doing standardisation work.

X. RECOMMENDATIONS

For any geological survey, it should be possible to supply the most widely used tests for natural stone, either from their own laboratories or by buying services from nearby laboratories.

For EIGS the following tests should be included:

1. Petrographical description (based on EN proposal - appendix 3)
2. Density and porosity (DIN or EN proposal - appendix 4)
3. Water absorption (DIN - appendix 2)
4. Compressive strength (DIN or EN proposal - appendix 6)
5. Flexural strength (DIN or EN proposal - appendix 7)

1 is easy to introduce at EIGS, and 2 and 3 are already done regularly. 4 has been done at the university, and possibly 5 can be done with the same equipment. A hydraulic press is very expensive (+/- 1 million birr), and it is recommended that these services be done externally also in the future.

EIGS is also equipped to do certain durability tests like frost and salt resistance, if this is required. However, for stone used in Ethiopia these tests are not very relevant.

A standardised test report is important, both for internal reasons, and to make it easier to promote testing of stone as a commercial service. An example of a test report from a Norwegian laboratory is enclosed in appendix 8.

Good specimens are of great importance, and EIGS should be equipped with better sawing facilities than today. A minimum is a manually operated disk saw capable of cutting 20 cm. pieces.

Polishing equipment is not necessary for making specimens, but is vital for making small slabs for presentation and evaluation of colour and polishing properties. EIGS should be equipped with a small hand polishing machine for this purpose.

XI. SAMPLING AND DESCRIPTION OF STONE DEPOSITS

Sampling procedures are of vital importance for good and relevant test results. There are today no accepted standards for sampling, but they will probably come in the near future. Until then, we recommend the following:

- Samples should be fresh (not weathered)
- Each sample or collection from the sample locality should be of a size and shape that make testing of several directions possible
- Samples should reflect the workable rock's typical appearance within a quarry site or deposit. For very homogenous rocks one sample locality may be enough, while several might be necessary in inhomogenous deposits
- Samples should be oriented

Testing is expensive, and one should avoid wasting time and money on testing of a large selection of samples from a number of possibly interesting deposits. In the first stages of deposit investigation, testing could be limited to petrographical description and key properties of the rock type in question (e.g. porosity/water absorption for sandstone, flexural strength for anisotropic rock types, etc.).

XII. REFERENCES

Alnæs, L. 1995: *Kvalitet og bestandighet av naturstein. Påvirkningsfaktorer og prøvemetoder*. Unbupl. PhD Thesis, NTNU

Currier, L.W. 1960: *Geological appraisal of dimension-stone deposits.* US Geological Survey Bulletin 1109.

Müller, F. 1991: *Gesteinskunde.* Ebner Verlag

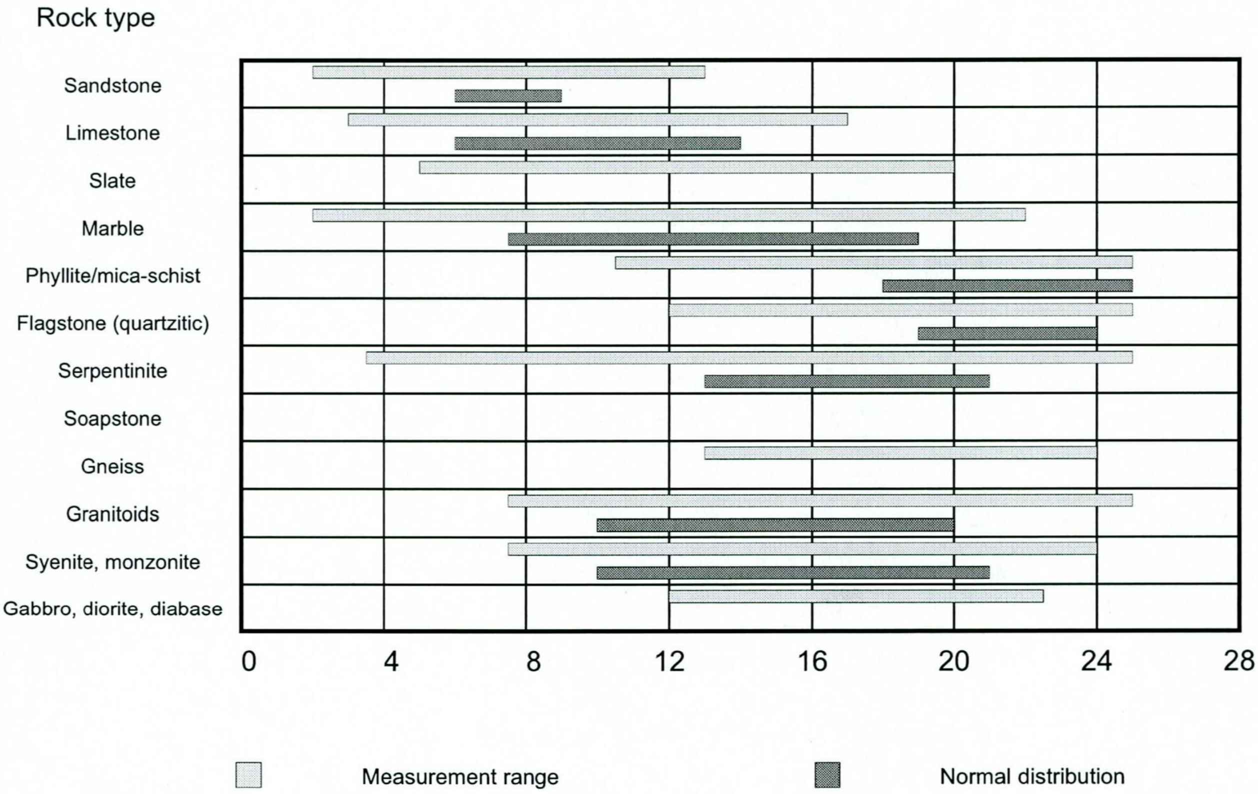
Winkler, E.M. 1973: *Stone: properties, durability in Man's environment.* Springer Verlag N.Y.

and: various unpublished papers from European Satandardisation Committee CEN TC 246.

APPENDIX 1
Test results for different rock types

Bending strength for different rock types

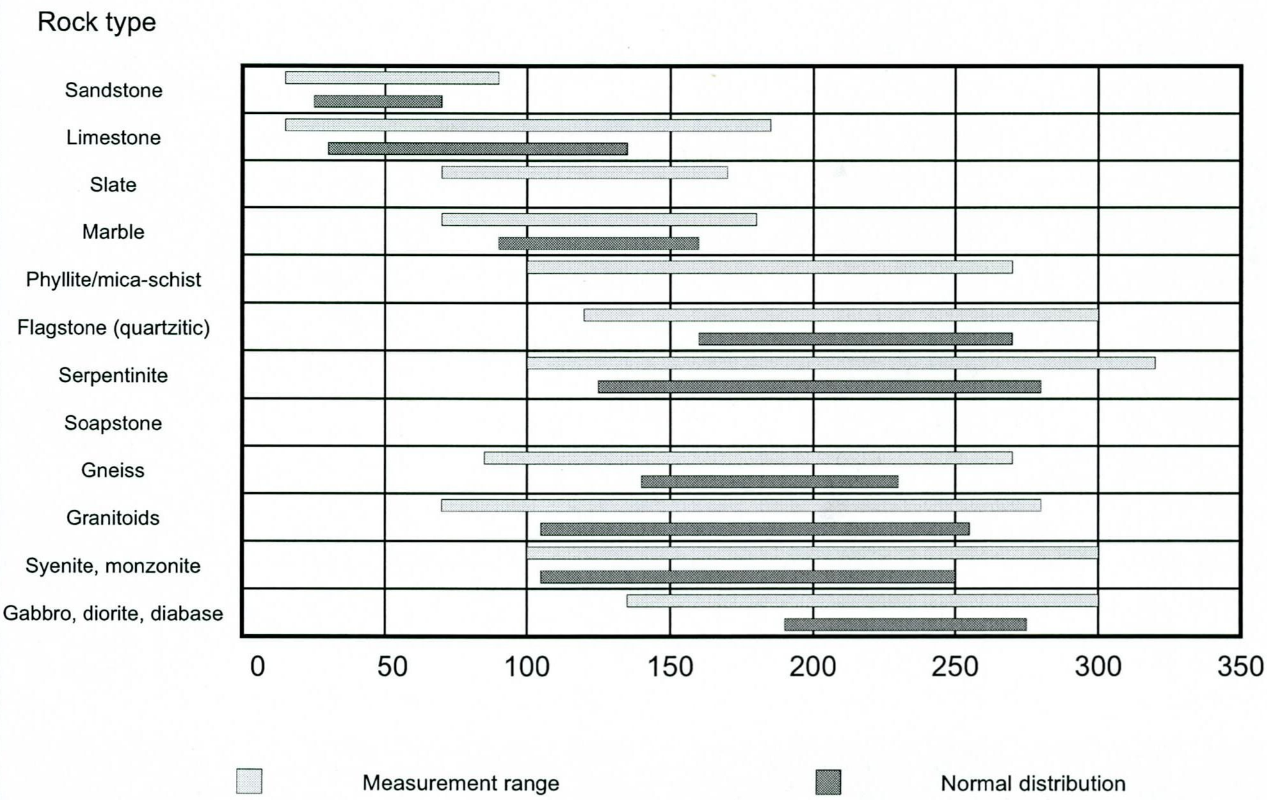
values in N/mm2



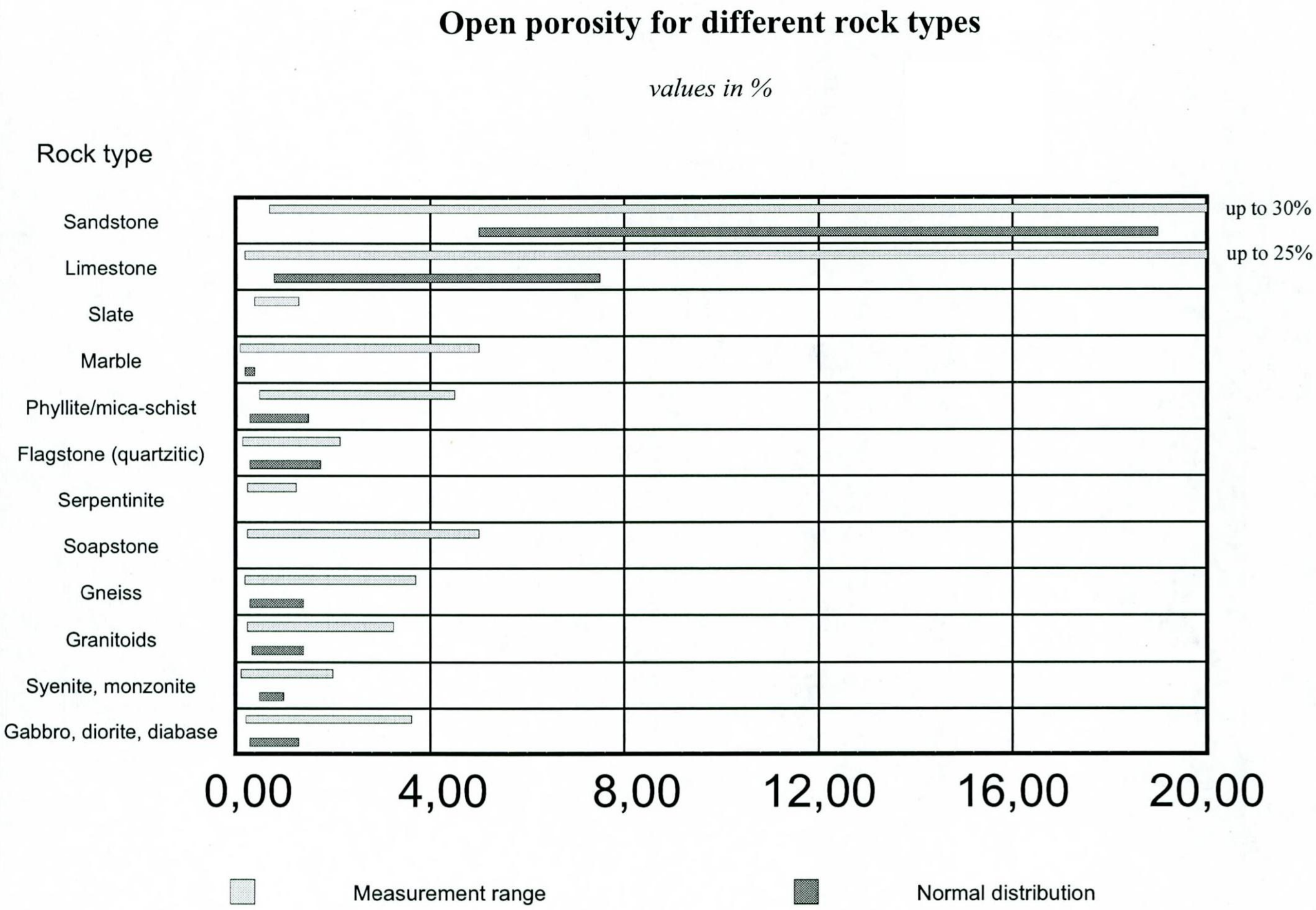
Proposed classification: <5=very low; 15-10=low; 10-15=medium; 15-20=high; >20=very high (Alnæs 1995, PhD Thesis) NORWEGIAN LABORATORY

Crushing strength for different rock types

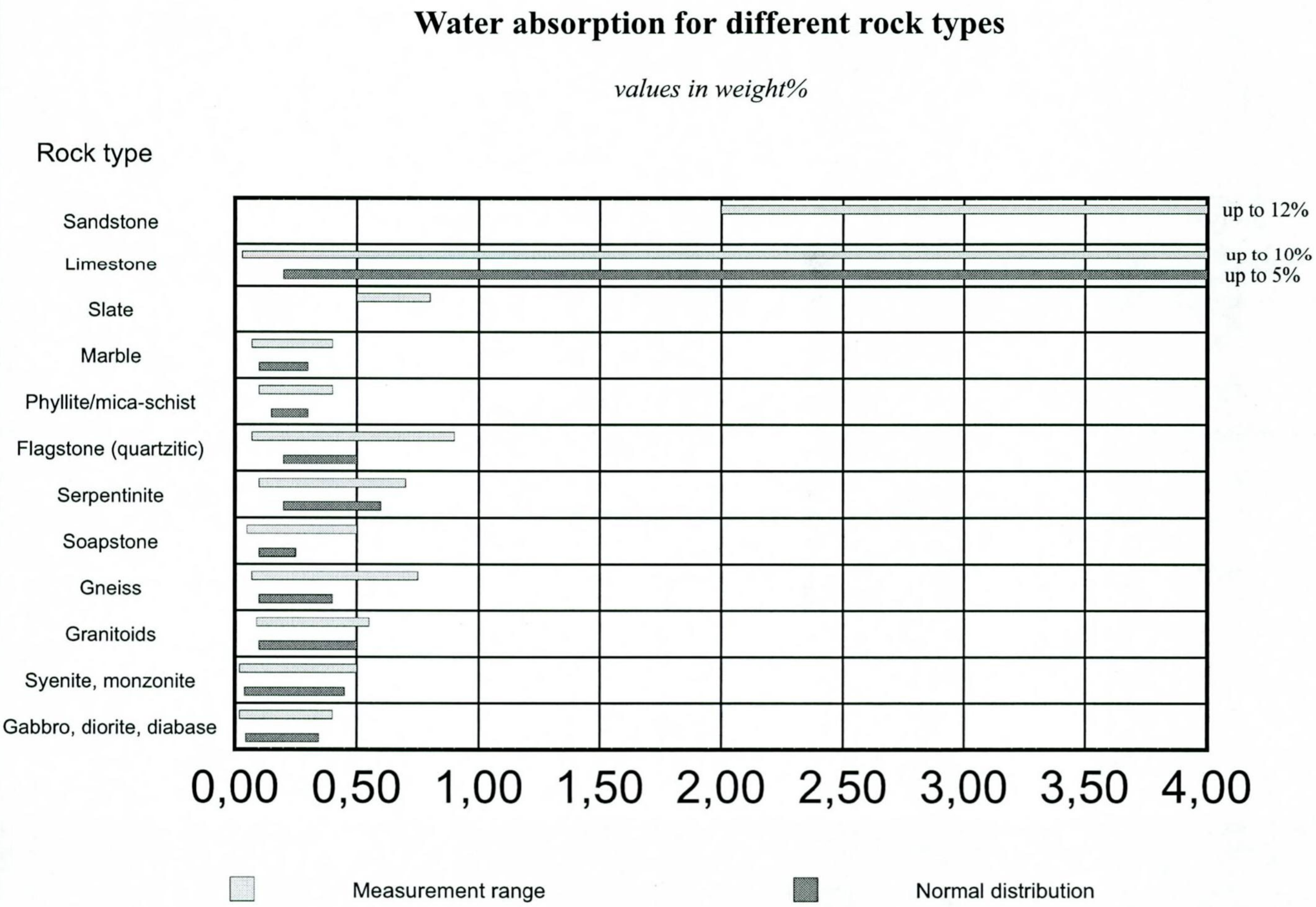
values in N/mm2



Proposed classification: <15=very low; 15-20=low; 50-120=medium; 120-150=high; >250=very high (Brown 1981, intern. soc.) for Rock Mechanics)



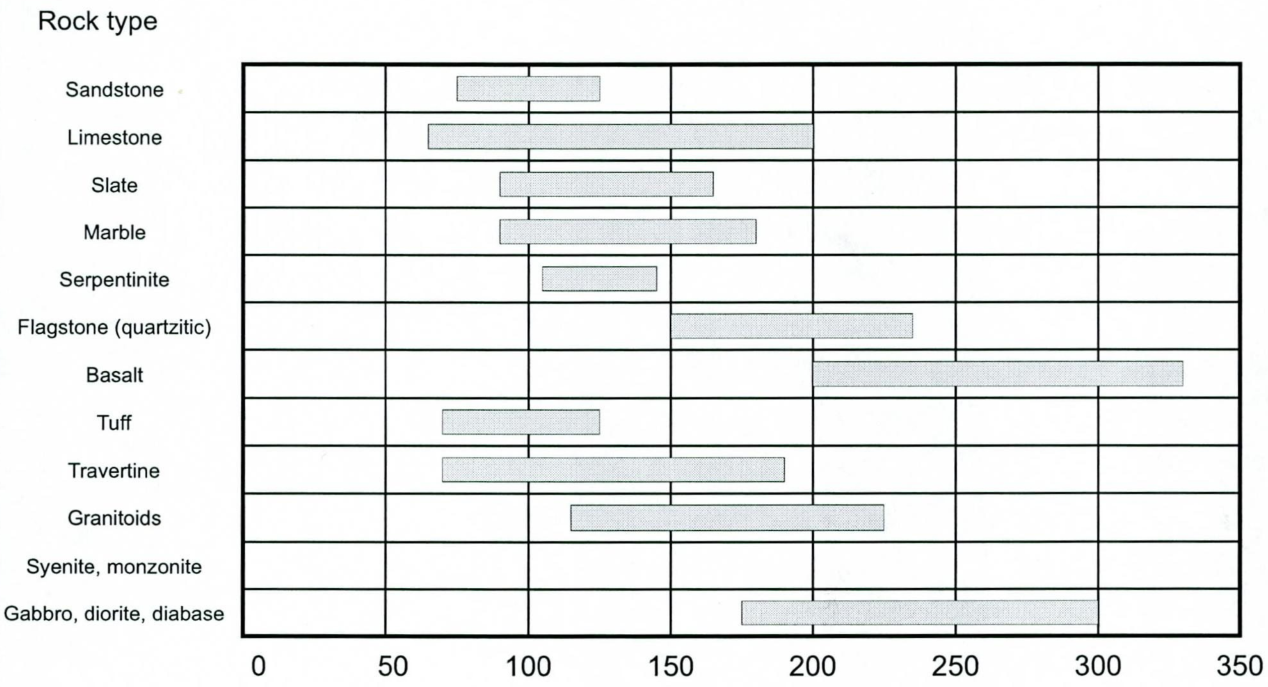
Proposed classification: <0,5=very low; 0,5-2=low; 2-5=medium; 5-20=high; >20=very high (Alnæs 1995, PhD Thesis) NORWEGIAN LABORATORY



Proposed classification: <0,1=very low; 0,1-0,5=low; 0,5-1=medium; 1-10=high; >10=very high (Alnæs 1995, PhD Thesis) NORWEGIAN LABORATORY

Crushing strength for different rock types

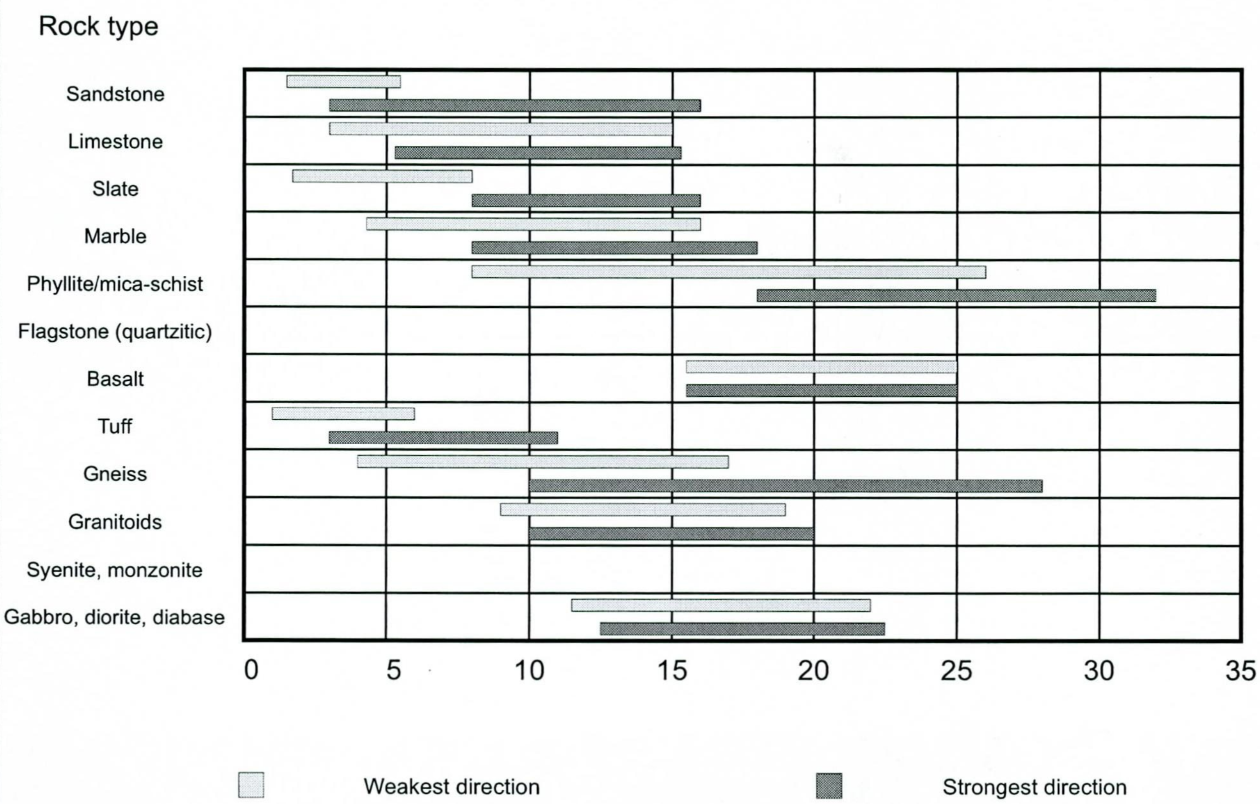
values in N/mm2



After Müller 1991, Gesteinskunde, Ebner Verlag. GERMAN LABORATORIES

Bending strength for different rock types

values in N/mm2



After Müller 1991, Gesteinskunde, Ebner Verlag. GERMAN LABORATORIES.

APPENDIX 2

DETERMINATION OF WATER ABSORPTION - DIN 52103

Specimen: cubes - >40 cm (50 x 50 x 50 widely used)

No. of specimens: min. 5

The absorption is measured in atmospheric pressure. Absorbed water is measured after 48 hours soaking.

Water absorption = $((M_v - M_t) / M_t) \times 100\%$

M_t = weight of dry specimen

M_v = weight of water saturated specimen

Contents

APPENDIX 3

Petrographical description: EN proposal

APPENDIX 3

1

EUROPEAN STANDARD

NORME EUROPEENNE

EUROPÄISCHE NORM

DRAFT
prEN 12407

May 1996

ICS

Descriptors :

English version

Test on natural stone - Petrographic description of natural stone

Méthode d'essai pour les éléments en pierre naturelle - Description pétrographique des pierres naturelles

Prüfung von Naturstein - Petrographische Beschreibung von Naturstein

This draft European Standard is submitted to the CEN members for CEN enquiry. It has been drawn up by Technical Committee CEN/TC 246 .

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. prEN 12407:1996 E

Foreword

This draft European standard has been prepared by TC 246 "Natural Stone", the Secretariat of which is held by UNI, to be submitted to CEN enquiry.

It was prepared by Working Group 2 - Test Methods.

This draft standard is one of the series of draft standards for natural stone products and has been produced to meet the Essential requirements laid down in the Construction Products Directive (89/106 (EEC)).

No existing European standard is superseded.

In accordance with the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European standard:

Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

0 Introduction

A petrographic description of natural stone is important not only for the purposes of petrographic classification but also in order to highlight features influencing its chemical, physical and mechanical behaviuor. It is therefore necessary to characterize the natural stones not only from the point of view of their mineralogical components and of their fabric and structure but also in terms of any features.

To ensure that the petrographic classification is objective, the characterization of the material must, as far as possible, be quantitative.

1 Scope

This European standard specifies methods for making technical petrographic descriptions of natural stone.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

WI 00246004 "Natural stone - Terminology of products and characteristics" 1)
WI 00246029 "Natural stones - Denomination" 1)

3 Principle

First a macroscopic description of the sample is undertaken. Then one or more thin sections prepared from the sample are examined using a petrographic microscope in order to give a microscopic description of the sample. In addition, chemical or physical methods of analysis may be required for some stone types, but this will not be described in this standard.

4 Apparatus

Petrographic microscope, point counter.

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1) under preparation

5 Preparation of thin and polished sections

The sampling is not responsibility of the test laboratory except where specially requested.
The dimensions of the sample must be large enough to be representative of the petrographic characteristics of the stone being examined.
One or more thin sections are then prepared. A thin section is a portion of material mechanically reduced to a thin sheet measuring (0,025 ± 0,005)mm in thickness, and then mounted on a slide (normally protected by a slide cover). Polished sections or polished thin sections have one side polished with alumina polishing paste (5 µm to 12 µm grade) and diamond paste (6 µm, 3µ and 1µm). The polished side remains uncovered.
The section normally measures about 3 cm x 2 cm, but in special cases different dimensions may be used or several sections of normal dimensions can be prepared. If the rock is anisotropic it is necessary to prepare at least two sections with different orientation with respect to the anisotropy (e.g. parallel and perpendicular to bedding planes, cleavage planes).
The sample must be sufficiently coherent so as not to disintegrate when cut. If the stone is brittle or fragile, it will be necessary to strenghten it by means of impregnation, preferably in a vacuum, with resins with an index of refraction approximately 1,54 (e.g. epoxy resins).

6 Macroscopic description

The following items shall be included in the macroscopic description.

6.1 The general colour or range of colours of the hand specimen

6.2 Fabric

6.3 Grainsize (e.g. coarse, medium or fine)

6.4 Open and refilled macroscopic cracks, pores and cavities

6.5 Evidence of weathering and alteration

7 Microscopic description

The following items shall be included in the microscopic description

7.1 Fabric

7.2 Constituents

NOTE: For the determination of the opaque minerals polished sections become necessary"

7.2.1 Minerals/Grains

For each mineralogical type identified, the characteristics listed below must be specified.

7.2.1.1 Percentage by volume, specifying the method used (e.g. estimate, point counter).

7.2.1.2 Dimensions: mean value and range of variation (if necessary for the groundmass and also for the larger crystals or grains).

7.2.1.3 Habit (e.g. idiomorphic, anhedral)

7.2.1.4 Shape (e.g. isometric, anisometric, flattened, elongated).

7.2.1.5 Outline (e.g. straight, lobate, veined).

7.2.1.6 Type of contact (e.g. by points, by lines, within matrix or groundmass).

7.2.1.7 Distribution and orientation (e.g. homogeneous, heterogeneous, in layers, in patches).

7.2.1.8 Evidence of weathering and alteration

7.2.2 Groundmass/matrix (e.g. homogeneous, crystallized, vitreous, amorphous, with crystal inclusions, with centres or areas of crystallization).

7.2.3 Organogenic remains (e.g. fossils or other organic remains)

7.3 Discontinuities

7.3.1 Pores, microcavities (size, shape, relative abundance and filling material if present)

7.3.2 Cracks and fractures

a) Aperture or width (most frequent value, minimum and maximum);
b) length (most frequent, minimum and maximum);
c) type (intergranular, intragranular, transgranular);
d) filling (extent, nature, structure);
e) orientation;
f) distribution.

8 Petrographic definition

Using the data generated from the thin section examination relating to mineralogical composition and abundance an accurate petrographic classification of the rock sample examined can be obtained using prEN 246004.
Rock samples examined in thin section should be classified on the basis of grain size fabric and mineralogical composition using the diagrams presented in prEN 246004 and reproduced here in Annex. For each rock the petrological family must be assigned on the basis of the simplified scientific classification charts given in clause 4.2, using the diagrams of clause 4.2.1, 4.2.2 or 4.2.3 depending on whether the sample is an igneous, sedimentary or metamorphic rock. If requested, a more detailed name can be allocated on the basis of the detailed scientific classification charts given in clause 4.3. If the thin section examination provides insufficient data to assign a petrological family, further testing may be necessary.

9 Test report

The test report shall contain the following information:

a) unique identification number for the report;

b) the name, number and date of issue of this European standard;

c) name and address of the testing laboratory and the address of where the examination was carried out if different from the testing laboratory;

d) name and address of the client;

e) it is responsibility of the client to supply the following information:

- petrographic nature of the stone;
- traditional name: country and area of extraction according to prEN 246029
- commercial name of the stone;
- corporate name of the supplier;
- the name of the organization which carried out the sampling;

f) the date of delivery of the sample;

g) the date of preparation of the thin sections and the date of the examination;

h) the number and dimensions of the thin sections;

i) the macroscopic description of the stone;

l) the microscopic description of the stone;

m) the petrographic definition of the stone;

n) any deviation from this standard and the reasons for any such deviation.

The test report shall contain the signature(s) and role(s) of the responsible(s) for the testing. It shall not be partially reproduced without the written consent of the laboratory.

ANNEX A
(NORMATIVE)

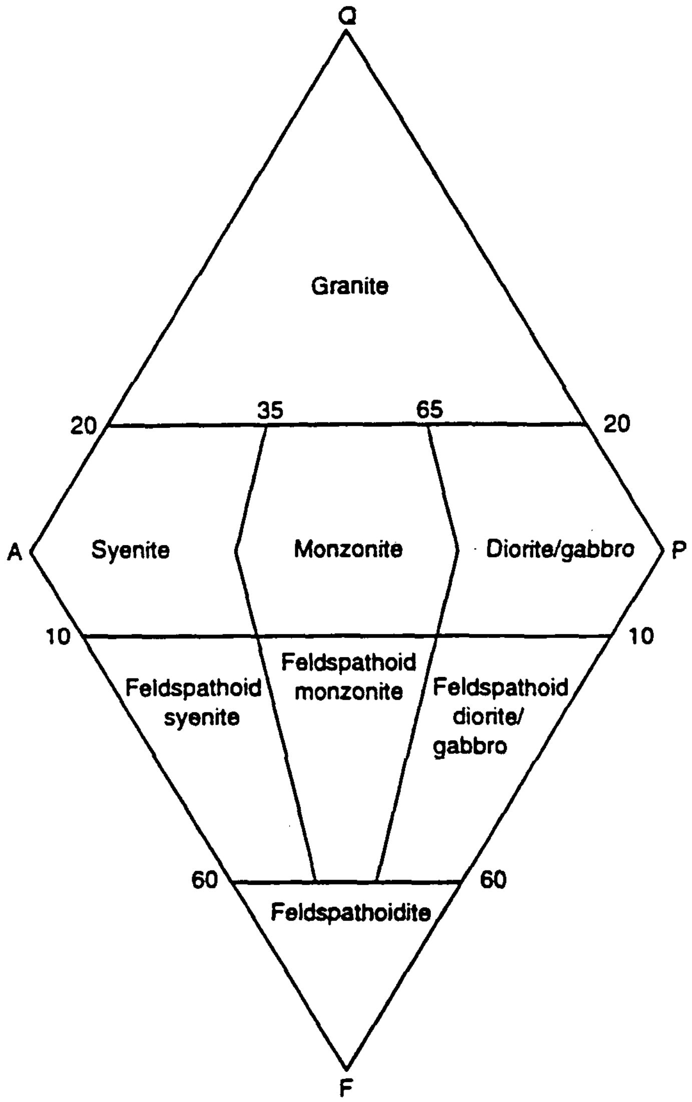
CLASSIFICATION OF NATURAL STONE

(ABSTRACT FROM prEN 246004)

4.2 Simplified Scientific Classification Charts

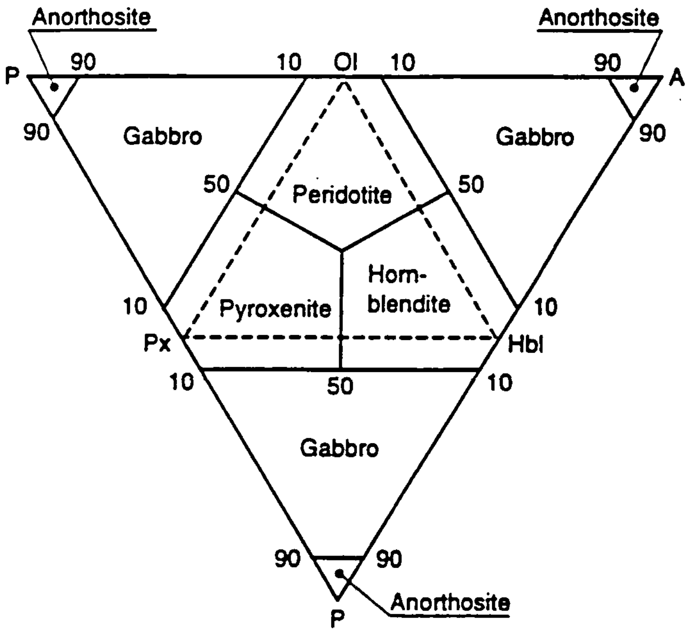
4.2.1 Igneous Rocks Classification Charts

4.2.1.1 Plutonic Rocks/Acid-Basic



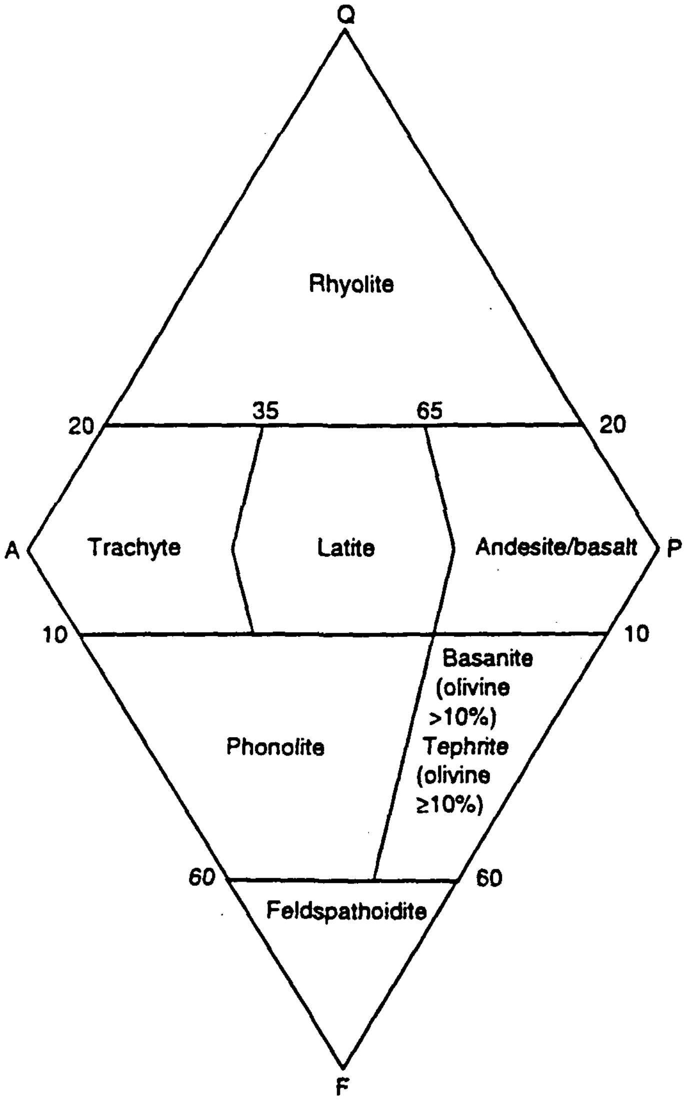
Q=Quartz
A=Alkali felspar
F=Feldspathoid
P=Plagioclase

4.2.1.2 Plutonic Rocks/Ultrabasic



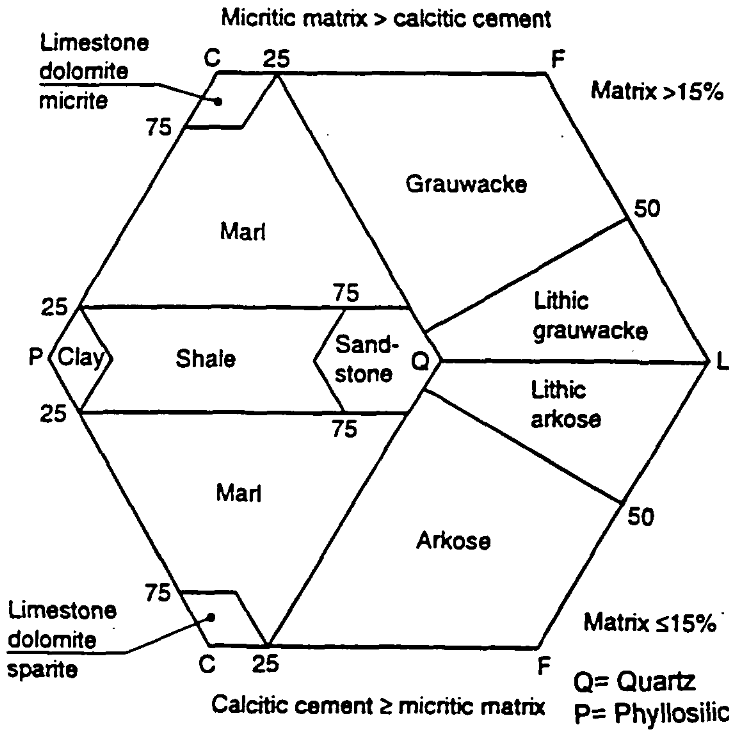
P=Plagioclase
OL=Olivine
Px=Piroxene
Hbl=Hornblende

4.2.1.3 Volcanic Rocks



P= Plagioclase
F= Feldspathoid
A= Alkali Feldspar
Q= Quartz

4.2.2 Sedimentary Rocks Classification Charts



Q= Quartz
P= Phyllosilicates
C= Carbonates
F= feldspar & feldspar/quartz fragments
L= Lithic fragments

Classification of carbonate rocks according to the clay content

% CaCO3

100 95 85 75 65 35 25 15 5

Pure Limestone	Marly Limestone	Limely Marl	Marl	Clayey Marl	Marly Clay	Pure Clay

0 5 25 35 65

75 95

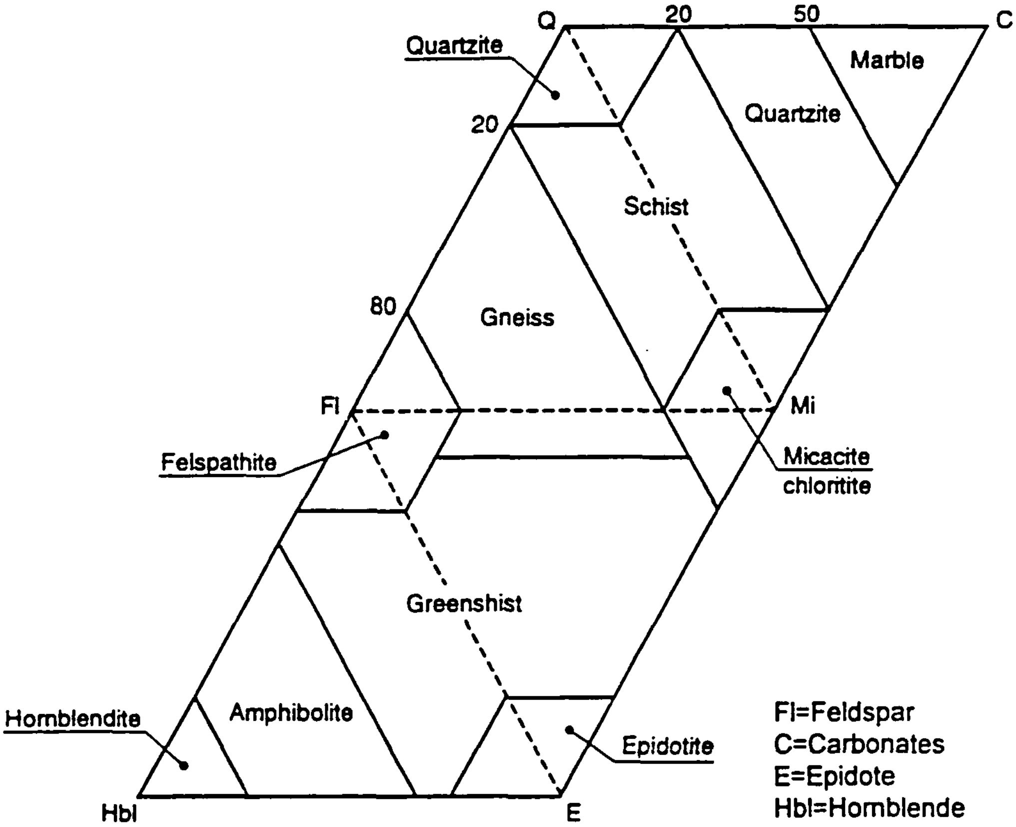
% Non carbonates

Classification of carbonates according to dolomite content

Limestone	0 to 9% Dolomite
Dolomitic Limestone	10 to 49% Dolomite
Calcitic Dolomite	50 to 89% Dolomite
Dolomite	90 to 100% Dolomite

4.2.3 Metamorphic Rocks Classification Chart

(For the following not included terms: eclogite, granulite, leptite, migmatite, ophicalcite, phyllite, serpentinite, slate, see chapter 3.2 Glossary.)



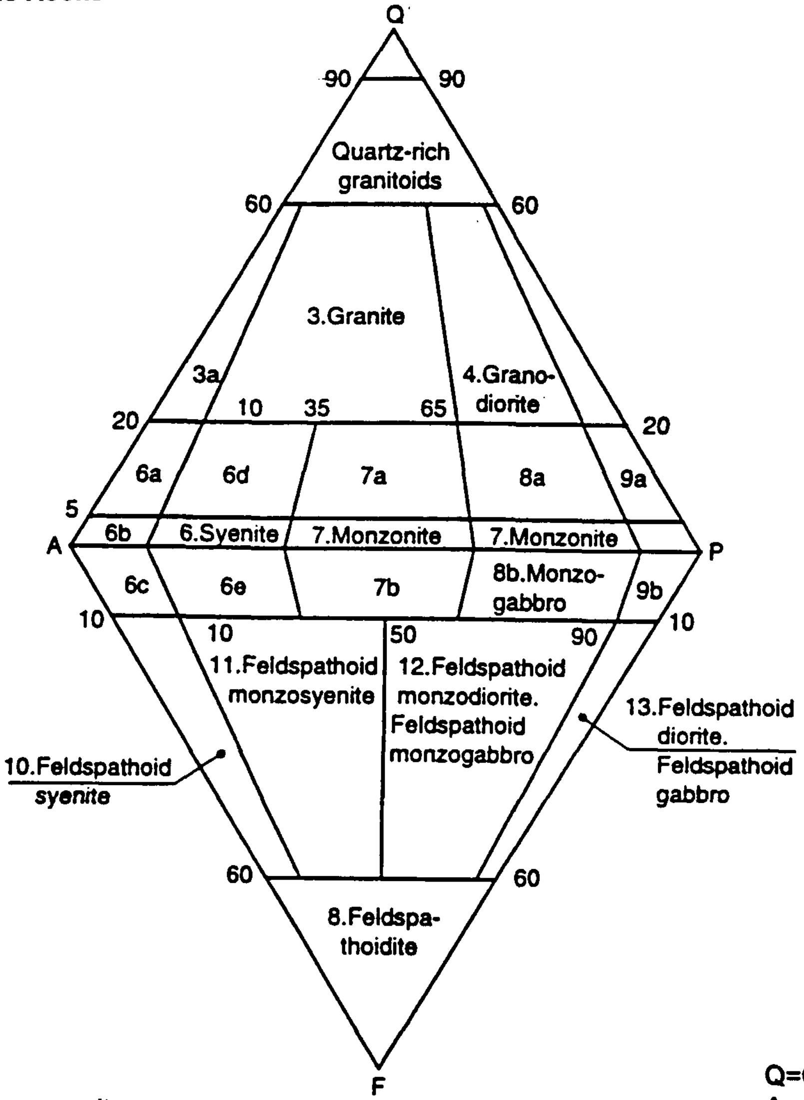
Fl=Feldspar
C=Carbonates
E=Epidote
Hbl=Hornblende
Mi=Mica, Chlorite
Q=Quartz

4.3 Detailed Scientific Classification Charts

Based in Le Maitre, R.W. (Editor), 1989, with authorization of Blackwell Scientific Publications. Oxford, United Kingdom.

4.3.1 Igneous Rocks Classification Charts

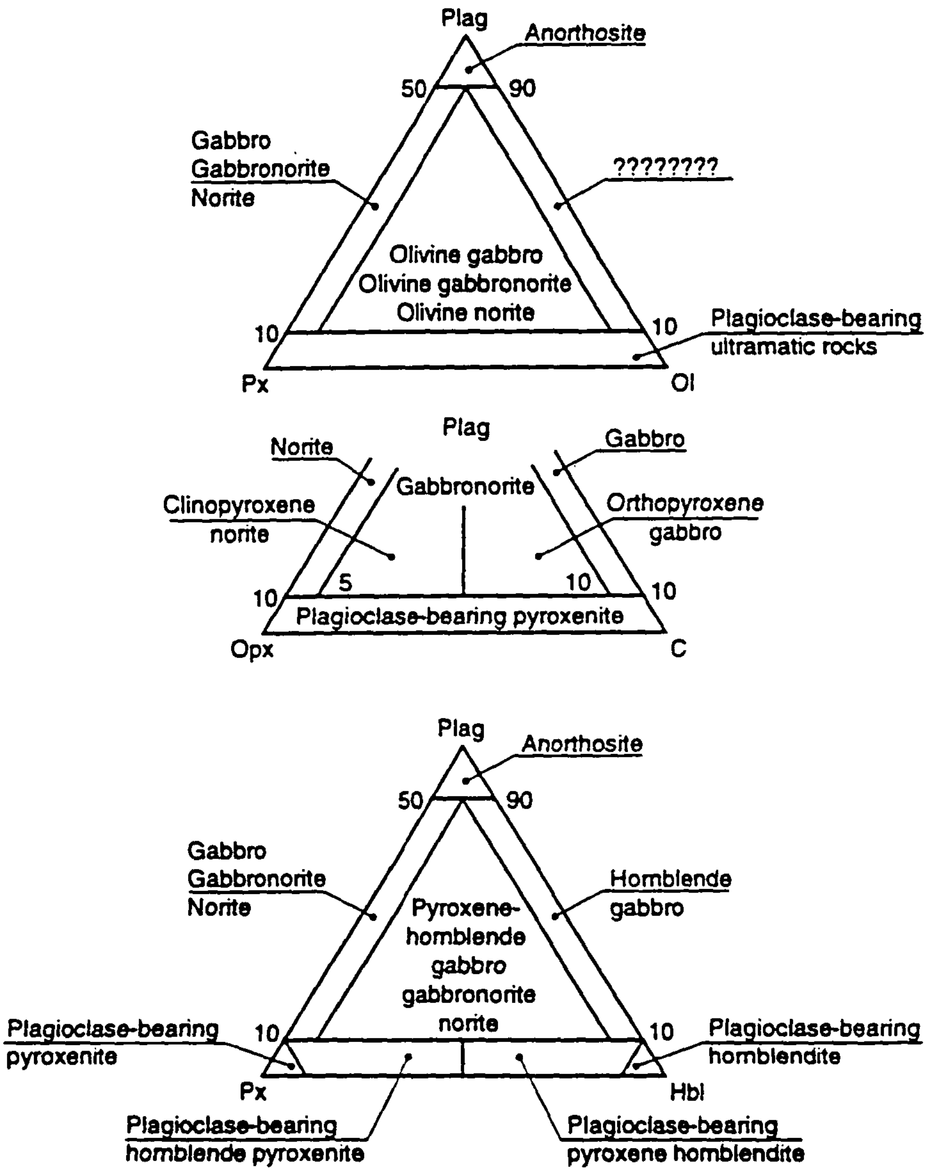
4.3.1.1 Plutonic Rocks

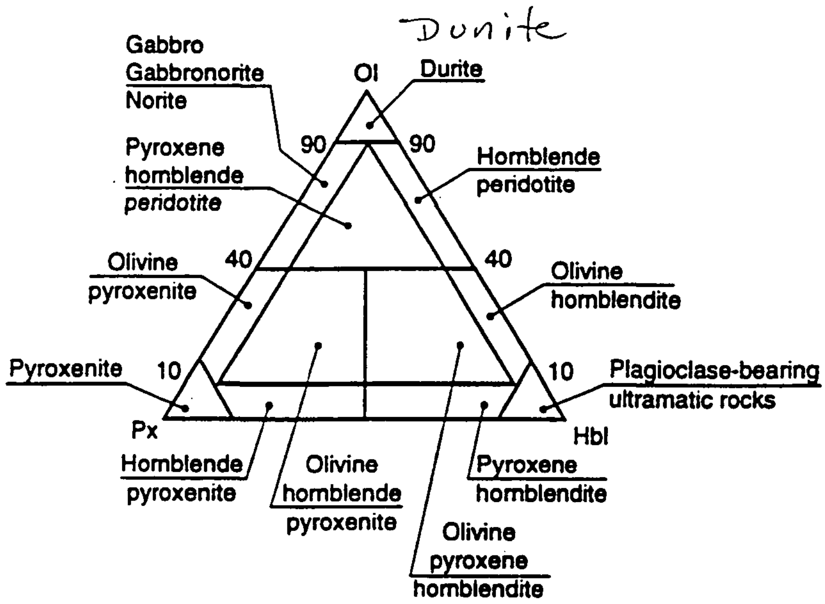


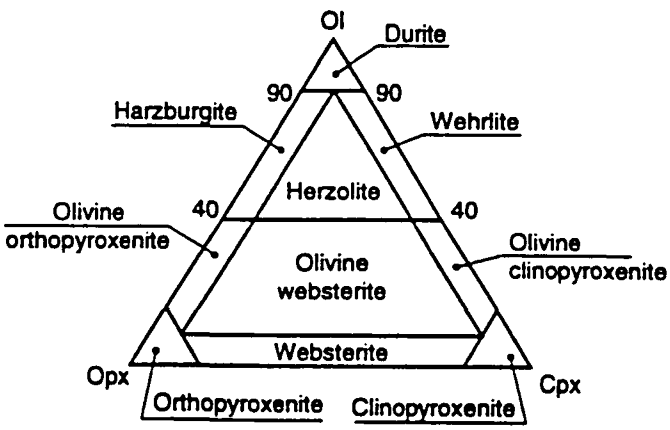
Q=Quartz
A=Alkali feldspar (K-feldspar, albite)
P= Plagioclase
F=Feldspathoid

3a: Alkali feldspar granite
6a: Quartz-alkali feldspar syenite
6b: Alkali feldspar syenite
6c: Feldspathoid-bearing alkali feldspar syenite
6d: quartz syenite
6e: Feldspathoid-bearing syenite
7a: Quartz monzonite
7b: Feldspathoid-bearing monzonite
8a: Quartz monzodiorite; Quartz monzogabbro
8b: Feldspathoid-bearing monzodiorite; Feldspathoid-bearing monzogabbro
9a: Quartz diorite; Quartz gabbro; Quartz anorthosite
9b: Feldpathoid-bearing diorite; Feldspathoid-bearing gabbro; Feldpathoid-bearing anorthosite

Detail of field 9 (DIORITE, GABBRO & ANORTHOSITE):

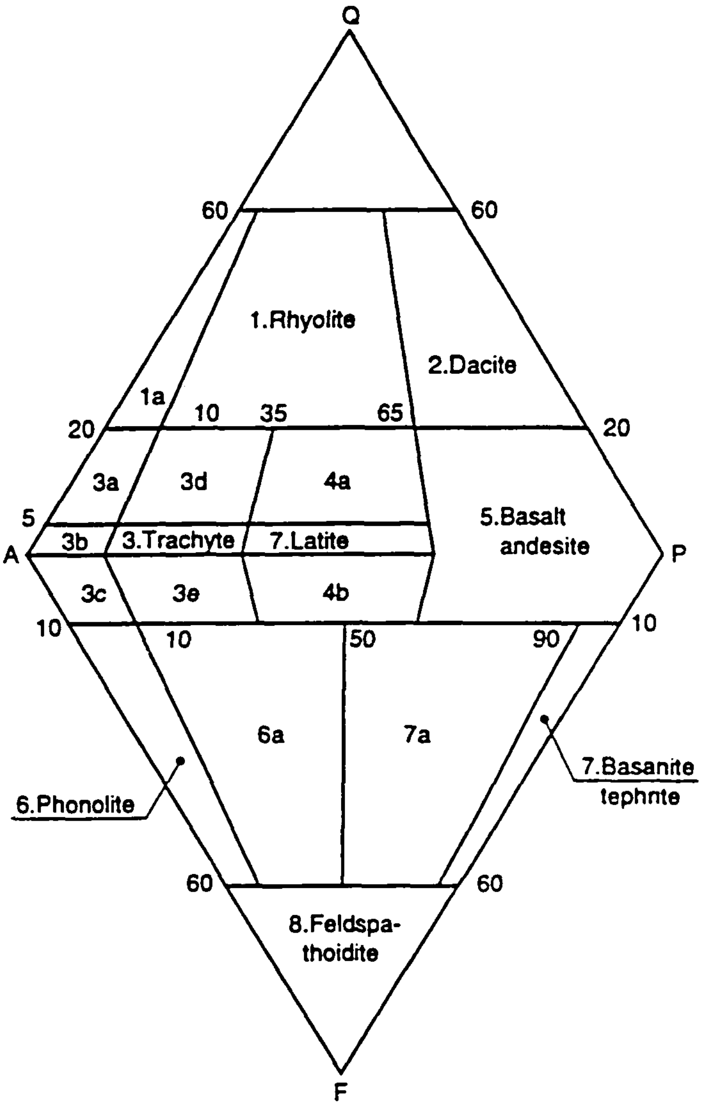






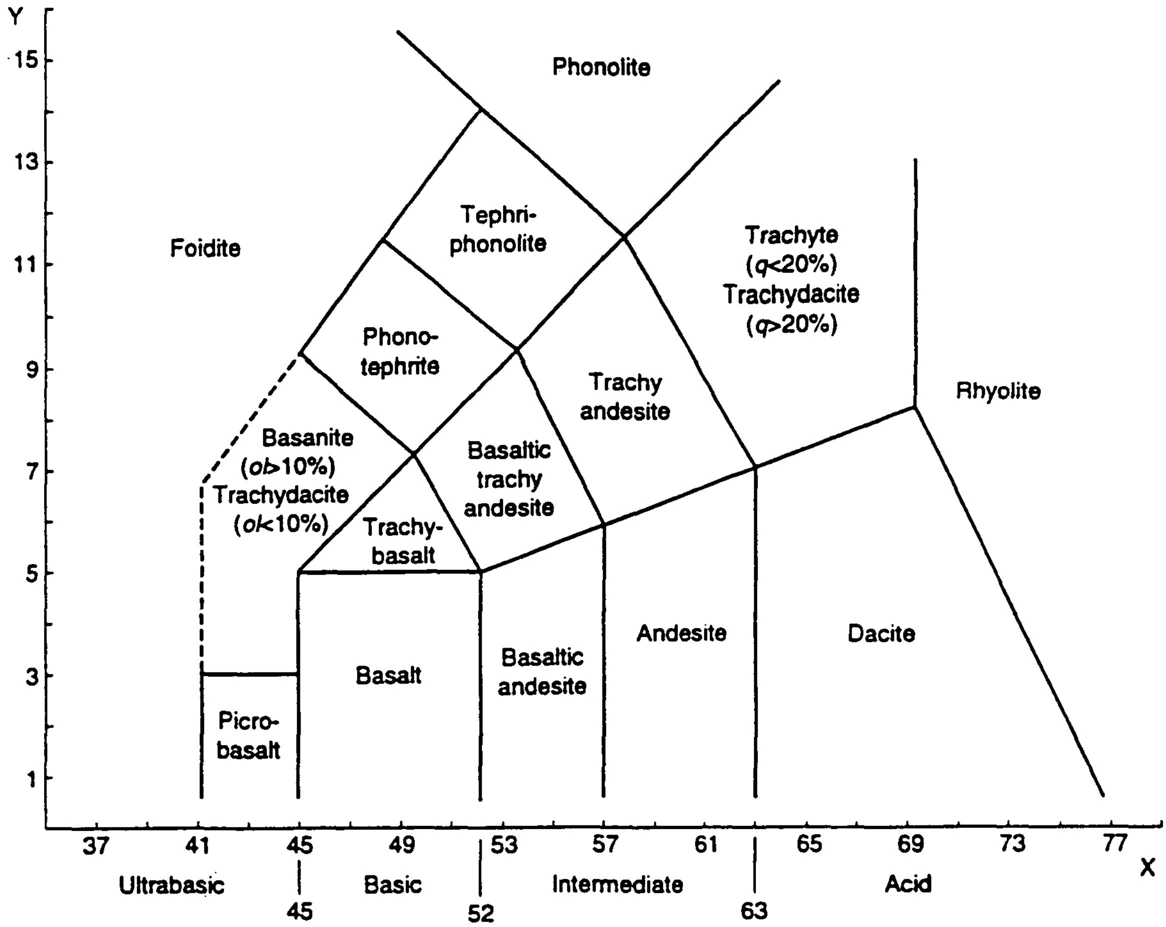
A=Alkali feldspar (K-feldspar and albite, An_0 to An_5)
Cpx=Clinopiroxeue
F=Feldespatois
Hbl=Hornblende
Ol=Olivine
Opx=Ortopiroxene
P=Plagioclase (An_5 to An_{100} and scapolite)
Px=Piroxene
Q=Quartz

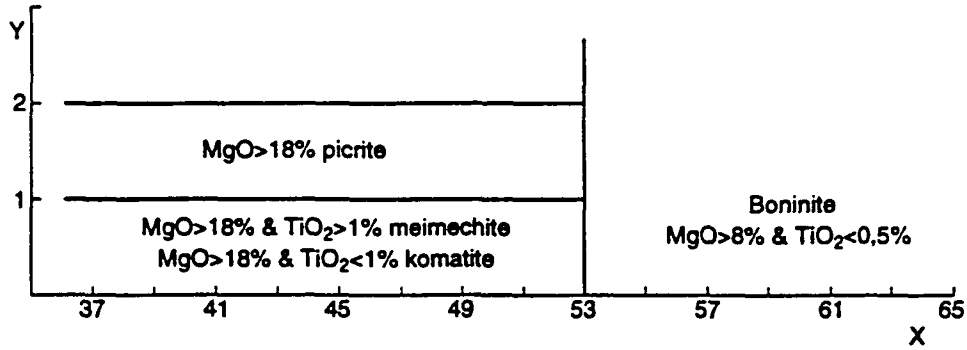
4.3.1.2 Volcanic Rocks



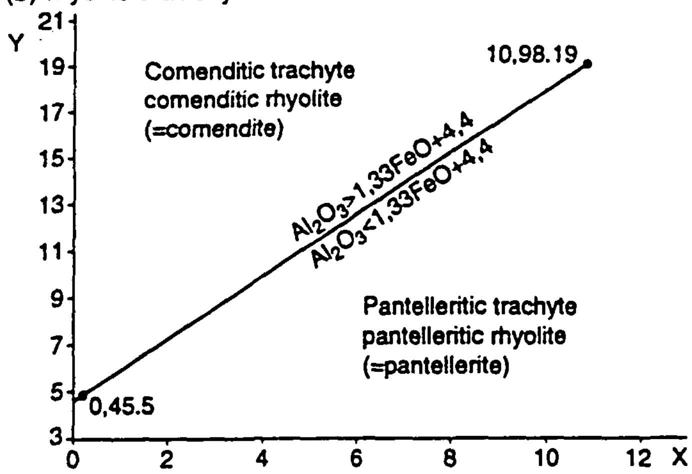
1a: Alaklite feldspar rhyolite
3a: Quartz alkali feldspar trachyte
3b: Alkali feldspar trachyte
3c: Feldspathoid-bearing alkali feldspar trachyte
3d:Quartz trachyte
3e: Feldpathoid-bearing trachyte
4a: Quartz latite
4b: Feldspathoid-bearing latite
6a: tephritic phonolite
7b: phonolitic basanite phonolitic tephrite

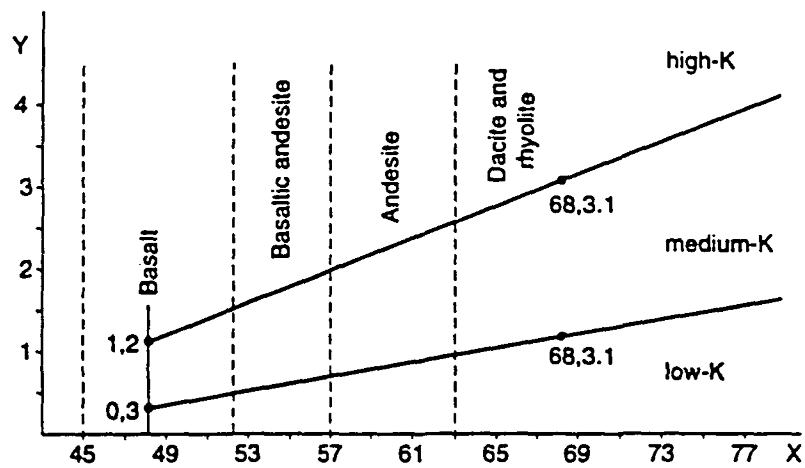
Q=Quartz
A=Alkali feldspar
(K-feldspar, albite)
P=Plagioclase
F=Feldspathoid


Y
15
13
11
9
7
5
3
1
Phonolite
Tephri-
phonolite
Foidite
Phono-
tephrite
Trachyte
(q<20%)
Trachydacite
(q>20%)
Trachy
andesite
Rhyolite
Basanite
(ol>10%)
Trachydacite
(ol<10%)
Basaltic
trachy
andesite
Trachy-
basalt
Basalt
Basaltic
andesite
Andesite
Dacite
Picro-
basalt
37
41
45
49
53
57
61
65
69
73
77
X
Ultrabasic
Basic
Intermediate
Acid
45
52
63


Y
2
1
MgO>18% picrite
MgO>18% & TiO2>1% meimechite
MgO>18% & TiO2<1% komatite
Boninite
MgO>8% & TiO2<0,5%
37
41
45
49
53
57
61
65
X

(b) rhyolite & trachyte



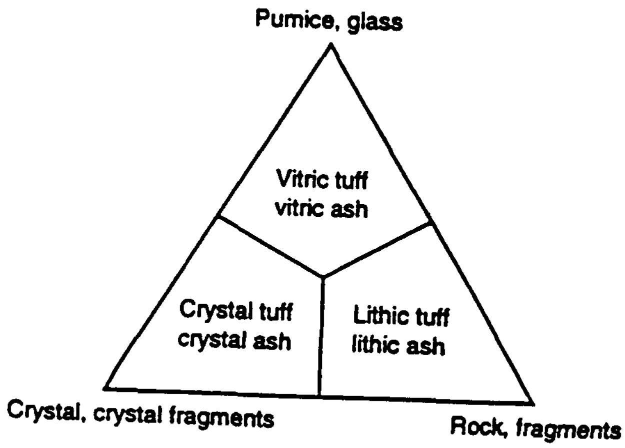


(c) basalt, basaltic andesite, andesite, dacite & rhyolite

(a) trachybasalt, basaltic trachyandesite & trachyandesite

	trachybasalt	basaltic trachyandesite	trachyandesite
Na_20-20_K_20	hawaiite	mugearite	benmoreite
Na_20-20_K_20	potassic trachybasalt	shoshonite	latite

Average clast size in mm.	Pyroclastic	Tuffites (mixed pyroclastic -epiclastic)	Epiclastic (volcanic and/or nonvolcanic)
	Agglomerate, agglutinate, pyroclastic breccia	Tuffaceous conglomerate, tuffaceous breccia	Conglomerate, breccia
64			
	Lapilli tuff		
2			
	coarse	Tuffaceous sandstone	Sandstone
1/16	(Ash) tuff		
	fine	Tuffaceous siltstone	Siltstone
1/256			
		Tuffaceous mudstone, shale	Mudstone, shale
Amount pyroclastic material	100% to 75%	75% to 25%	25% to 0%



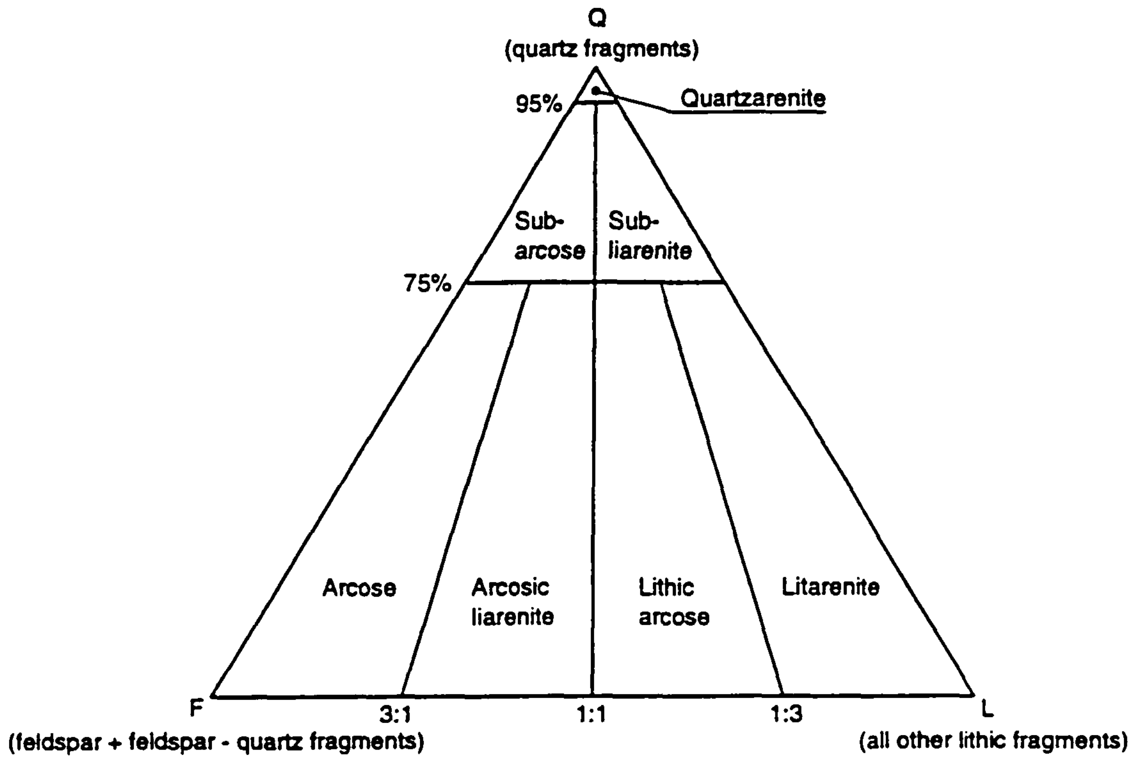
Clast size in mm.	Pyroclast	Pyroclastic deposit	
		Mainly unconsolidated: tephra	Mainly consolidated: pyroclastic rock
	bomb, block	agglomerate bed of blocks or bomb, block tephra	agglomerate pyroclastic breccia
64			
	lapillus	layer, bed of lapilli or lapilli tephra	lapilli tuff
2			
	coarse ash grain	coarse ash	coarse (ash) tuff
1/16			
	fine ash grain (dust grain)	fine ash (dust)	fine (ash) tuff (dust tuff)

4.3.2 Sedimentary Rocks

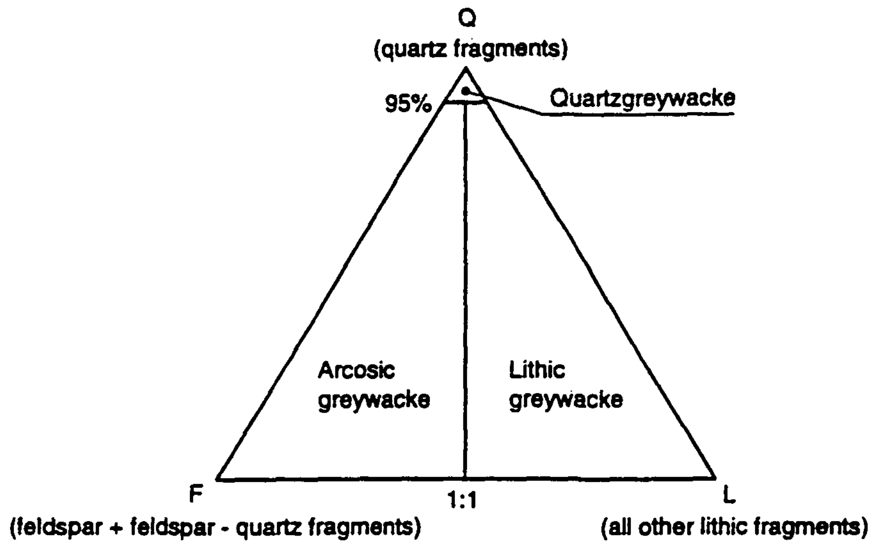
Classification of limestones. Based in Folk 1959.1962

<table>
<tr><td colspan="3" rowspan="2">Alochems per volume</td><td colspan="2">More than 10% Alochems</td><td colspan="2">Less than 10% Alochems</td><td rowspan="2">Undisturbed bioherm limestone</td></tr>
<tr><td>Sparry calcite predominant</td><td>Micritic matrix predominant</td><td>1-10% Alochems</td><td>Less than 1% Alochems</td></tr>
<tr><td colspan="3">more than 25% Intraclasts</td><td>Intrasparite</td><td>Intramicrite</td><td>Intraclast bearing micrite</td><td rowspan="5">Micrite or Dismicrite</td><td rowspan="5">Biolithite</td></tr>
<tr><td rowspan="4">less than 25% Intraclasts</td><td colspan="2">more than 25% Ooids</td><td>Oosparite</td><td>Oomocrite</td><td>Ooid-bearing Micrite</td></tr>
<tr><td rowspan="3">less than 25% Ooids</td><td>3:1</td><td>Biosparite</td><td>Biomicrite</td><td>Fossiliferous Micrite</td></tr>
<tr><td>3:1 to 1:3</td><td>Biopelsparite</td><td>Biopelmicrite</td><td rowspan="2">Pelletiferous Micrite</td></tr>
<tr><td>1:3</td><td>Pelsparite</td><td>Pelmicrite</td></tr>
</table>

Sandstone Classification. After Folk



4.3.2.3 Classification of Greywackes. After Folk



APPENDIX 4
Determination of density and porosity: EN proposal

APPENDIX 4

DRAFT
prEN 1936

EUROPEAN STANDARD

NORME EUROPEENNE

EUROPAISCHE NORM

May 1995

ICS

Descriptors :

English version

Methods of test for natural stone units - Determination of real density and apparent density and of total and open porosity

Méthodes d'essai pour éléments en pierre naturelle - Détermination des masses volumiques réelle et apparente et des porosités ouverte et totale

Prüfung von Naturstein - Bestimmung der Reindichte, der Rohdichte, der offenen Porosität und der Gesamtporosität

This draft European Standard is submitted to the CEN members for CEN enquiry. It has been drawn up by Technical Committee CEN/TC 246 .

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. prEN 1936:1995 E

Contents

Foreword

This draft European standard has been prepared by CEN/TC 246 "Natural stone", the Secretariat of which is held by UNI.

This draft European standard is currently submitted to the Public Enquiry.

It was prepared by Working Group 2, Test Methods.

No existing European Standard is superseded.

According to the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European standard:

1 Scope

This draft European standard specifies methods of determining the real density, the apparent density, and the open and total porosity of natural stone.

2 Normative references

This European Standard incorpotares by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

EN ... WI 004: "Natural stone - Terminology (of products and characteristics)"

3 Principle

After drying to constant mass, the apparent density and open porosity is determined by vacuum assisted water absorption and submerged weighing of specimens. The real density and total porosity requires the speciment to be pulverised.

4 Terminology

4.1 apparent density (b): ratio between the mass of the dry specimen and its bulk volume (i.e. the volume limited by the external surface)

4.2 real density (r): ratio between the mass of the dry specimen and the volume of its solid part (which is the same as the difference between the apparent volume and the volume of pores)

4.3 open porosity: ratio (as a percentage) between the volume of the open pores and the apparent volume of the specimen

4.4 total porosity: ratio (as a percentage) between the volume of pores (open and closed) and the apparent volume of the specimen

5 Symbols

m_d mass of the dry specimen, in grams
m_h mass of the specimen immersed in water, in grams
m_s mass of the saturated specimens, in grams
m_e mass of the sample ground and dried (for the test using the volumenometer), in grams
V_b apparent volume, in millilitres
V_o volume of open pores, in millilitres
V_s volume of liquid displaced by the mass m_e (volumenometer test)

9 Expression of results

9.1 General

The volume of the open pores (in millilitres) is expressed by equation:

$$V_o = \frac{m_s - m_d}{r_h} \cdot 1000 \qquad (1)$$

The bulk volume (in millilitres) is expressed in equation:

$$V_b = \frac{m_s - m_h}{r_h} \cdot 1000 \qquad (2)$$

which can alternatively be calculated on the basis of the dimensions of the specimen.

NOTE: The value of the density of water r_h at 20 °C is 998 kg/m^3

9.2 Apparent density

The apparent density (in kilograms, per cubic metre) is expressed by the ratio of the mass of the dry specimen and its bulk volume, by equation:

$$b = \frac{m_d \cdot r_h}{m_s - m_h} \qquad (3)$$

9.3 Open porosity

The open porosity is expressed by the ratio (as a percentage) of the volume of open pores and the bulk volume of the specimen, by the formula:

$$p_o = \frac{m_s - m_d}{m_s - m_h} \cdot 100 \qquad (4)$$

9.4 Real density

The real density (in kilograms, per cubic metre) is expressed by the ratio of the mass of the ground dry sample m_e to the volume of liquid displaced by the mass m_e, by the equation:

$$r = \frac{m_e}{V_s} \cdot 1000 \qquad (5)$$

9.5 Total porosity

The total porosity is expressed by the ratio (as a percentage) of the volume of pores (open and closed) and the bulk volume of the specimen, by the equation:

$$p = \frac{\frac{1}{b} - \frac{1}{r}}{\frac{1}{b}} \cdot 100 = (1 - \frac{b}{r}) \cdot 100 \qquad (6)$$

10 Test report

The test report shall contain the following information:

a) the number of identification of the report;

b) the number, title and date of issue of this draft European standard;

c) the name and address of the test laboratory;

d) the name and the address of the client;

e) it is the responsibility of the client to supply the following information:

- petrographic nature of the stone;
- traditional name, country and area of extraction;
- commercial name of the stone;
- the corporate name of the supplier
- the direction of any bedding or anisotropic features should be clearly indicated on the samples by means of two parallel lines;
- the name of the organization which carried out the sampling.

f) the date of delivery of the samples;

g) the date when the specimens were prepared and the date of testing;

h) the number of specimens in the sample;

i) the dimensions of the specimens;

j) for each sample: the real density and the apparent density to the nearest 10 kg/m^3, the open porosity and the total porosity to the nearest 0,1%;

k) the arithmetic mean of the individual values for the real density and for the apparent density (to the nearest 10 kg/m^3), for the open porosity and for the total porosity (to the nearest 0,1%);

l) Remarks

b apparent density, in kilograms, per cubic metre
r real density, in kilograms, per cubic metre
r_h density of water
p_o open porosity (as a percentage)
p total porosity (as a percentage)

6 Apparatus

6.1 A ventilated oven which can maintain a temperature of (70 ± 5) °C.

6.2 An evacuation vessel which can maintain a pressure of (2,0 ± 0,7) k Pa (=(15 ±5) mm Hg) and allow gradual imersion of the contained specimens.

6.3 A weighing instrument which has an accuracy of at least 0,01 % of the mass to be weighed, capable to weigh the sample in water.

6.4 A linear measuring device with an accuracy of 0,1 mm.

6.5 A Le Chatelier type volumenometer consisting of a flat-bottomed flask with a tube graduated from 0 to 24 ml in 0,1 ml graduations.

6.6 A sieve with a 0,1 mm mesh.

7 Preparation of the specimens

7.1 Sampling

The method of sampling is not the responsibility of the testing laboratory except where specially requested. At least five specimens should be selected from an homogeneous batch.

7.2 Test specimens

The test specimens can have the form of a cylinder, cube or prism and must be obtained by diamond sawing or coring. Their volume shall be at least 25 ml.
In addition, the surface area to volume ratio shall be between 10 and 20 mm^{-1}.

> NOTE: The same specimens prepared for the determination of compressive or flexural strength can be used when they satisfy the afore mentioned ratio surface/volume.This is not possible when also the real density test is performed.

7.3 Drying the specimens

The specimens are to be dried at a temperature of (70 ± 5) °C until a constant mass is reached. This is assumed to have been attained when the difference between two weighings at an interval of (24 ± 2) h is not greater than 0,1 % of the mass of the specimen.

8 Test procedure

8.1 Open porosity and apparent density

Weigh the specimens (m_d(in grams)), then put the specimens into an evacuation vessel and lower the pressure gradually to (2,0 ± 0,7) kPa (=(15 ± 5) mm Hg).

Maintain this pressure constant for 24 h in order to eliminate the air contained in the open pores of the specimens.

Introduce demineralized water at (20 ± 5) °C slowly into the vessel (the rate at which the water rises shall be such that the samples are completely immersed in not less than 15 min).
Maintain pressure of (2,0 ± 0,7) kPa during introduction of water and for 24 h afterwards.

After this time return the vessel to atmospheric pressure and leave the specimens under water for another 24 h at atmospheric pressure.

For each specimen:

- record the weight in water: m_h (in grams);

- quickly wipe the specimen with a dampened cloth and determine tha mass m_s(in grams) of the specimen saturated with water.

In the case of natural stones with visible cavities (e.g. travertine) the apparent volume is determined by measuring their dimensions to the nearest millimetre.

8.2 Real density

For each specimen, after having determined the apparent density and the open porosity, grind the specimen separately until the particles will pass through a sieve with 0,1 mm mesh.

Dry the ground specimen to a constant mass and set apart a mass m_e of approximately 50 g (weighed to an accuracy of ± 0,1 g).

Introduce deionised water into the Le Chatelier volumenometer until the level is up to the 0 graduation. Then add the weighed sample of 50 g of each specimen into the volumenometer in five fractions in the region of 10 g each, ensuring that all of each fraction falls into the liquid. After the introduction of each fraction, agitate the liquid to disperse the crushed specimen. Read the graduations to determine the V_s (in millilitres to the nearest 0,1 ml) of liquid displaced by the mass m_e of ground sample.

Before taking the initial at 0 level and final volume readings make sure that the ambient air temperature is (20 ± 5) ° C.

The test report should contain the signatures and roles of the responsible(s) for the testing and the date of issue of the report.

It should also state that the report should not be partially reproduced without written consensus of the test laboratory(ies) and the responsible(s) for the testing.

APPENDIX 5

Determination of water absorption due to capillary action: EN proposal

APPENDIX 5

EUROPEAN STANDARD

NORME EUROPEENNE

EUROPÄISCHE NORM

DRAFT
prEN 1925

May 1995

ICS

Descriptors :

English version

Methods of test for natural stone units - Determination of water absorption coefficient due to capillary action

Méthodes d'essais pour éléments en pierre naturelle - Détermination du coefficient d'absorption d'eau due à l'action capillaire

Prüfung von Naturstein - Bestimmung des Wasseraufnahmekoeffizienten infolge Kapillarwirkung

This draft European Standard is submitted to the CEN members for CEN enquiry. It has been drawn up by Technical Committee CEN/TC 246

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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This draft European Standard is currently submitted to the Public enquiry.

It was prepared by Working Group 2, Test Methods.

No existing European standard is superseded.

According to the CEN/CENELEC Internal Regulations, the following countries are bound to implement this draft European standard:

1 Scope

The present draft European standard specifies a method of determining of the water absorption coefficient of natural stone due to capillary action.

2 Normative references

The present European standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed below. For dated references, subsequent amendments or revisions of any of these publications apply to this European standard only when incorporated in it by amendment or revision. For undated references, the last edition of the publication referred to applies.

WI ... Specification for brickwork elements - Natural stone brickwork elements *

3. Principle

After drying to a constant mass, the sample is immersed in 3 mm of water on one of its sides (never the worked side) and the increase in mass is measured.

4 Symbols

m_d: mass of the dry specimen, in grams
m_i: successive masses of the specimen during testing, in grams
A: area of the side immersed in water, in square meters
t_i: time at which the masses were measured, in seconds
C_1: water absorption due to capillary action perpendicular to the natural anisotropy of the stone, in grams per square meters per second under square root
C_2: water absorption due to capillary action parallel to the natural anisotropy of the stone, in grams per square meters per second under square root

5 Apparatus

5.1 A covered tank with flat base comprising small non-oxidising and non-absorbent supports for the samples.

5.2 A time counter accurate to 1 s.

5.3 A ventilated oven which can maintain a temperature of (70 ± 5) °C.

5.4 A weighing instrument which has an accuracy of 0,01% of the mass to be weighted.

5.5 A linear measuring device with an accuracy of 0,02 mm.

5.6 A room air which can be maintained at (20 ± 5) °C.

5.7 A device able to maintain a constant water level.

---

* In preparation

6. Preparation of the specimens

6.1 Sampling

The method of sampling has to be indicated in the test report.
The method of sampling is not under the responsibility of the test laboratory except where specially requested. At least five specimens should be selected from an homogenous batch and tested for each direction of rise of water in relation to the position of any natural anisotropy. This or any observed anisotropy shall be marked on all samples by at least two parallel lines.

6.2 Dimensions of test specimens

Depending on their mean compressive strength, the specimens must have the following dimensions (table 1):

Table 1 - Dimensions of the specimens

Shape of Specimen	Mean compressive strength less than 40 MPa	Mean compressive strength greater than or equal to 40 MPa
Cubic	Each side 70 mm (±5mm)	Each side 70 mm (±5 mm) or each side 50 mm (± 5 mm)
Cylindrical	Diameter 70 mm (±5 mm) Height 70 mm (± 5 mm)	Diameter 70 mm (± 5 mm) Height 70 mm (±5 mm) or Diameter 50 mm (±5 mm) Height 50 mm (±5 mm)

The samples can be rough, cut or may have one polished or finished face. This face is to be placed vertically; the worked face should never be the immersed face.

6.3 Drying the specimens

The test specimens are to be dried to constant mass in a ventilated warming cupboard at a temperature of (70 ± 5) °C. Constant mass is reached if, during the drying process, at two successive weighing at an interval of 24h ± 2h, the mass loss between these two weighing is less than 0,1 % of the mass.

7 Test procedure

The test must be carried out after cooling the samples to 20 °C ± 5 °C in a room air conditioned to the same temperature.

Weigh the samples after drying (m_d) to an accuracy of 0,01 g and calculate the area of the base to be immersed by measurement of 2 mediants to the nearest 0,1 mm. Express this area in m^2. Place the samples in the tank on the thin supports provided such that they only rest partially on their base. Ensure that the position of any natural anisotropy in relation to the rising water matches the requirements. Immerse the base in the water to a depth of 3 mm ± 1 mm. Start the timer device. Maintain the water level constant throughout the test by adding water as necessary, and close the container to avoid evaporation of the damp samples. At time intervals, initially very short then very long, remove each sample in succession, lightly dry the immersed part using a damp cloth and weigh immediately to the nearest 0,01 g, then replace in the container. Note the time elapsed since the start of the test until the time of weighing.

NOTE: The choice of times depends on the type of stone. For highly absorbent stone, the times t are: 1, 3, 5, 10, 15, 30, 60, 480 and 1440 min. For a low absorption stone, the times are: 30, 60, 180, 480, 1440, 2880 and 4320 min. These times should be observed to within 5%. A minimum of 7 measurements is necessary.

8 Expression of results

Show as a graph the mass of water absorbed (in grams) divided by the horizontal area of the base (square metre) of the sample as a function of the square root of time expressed in s.

NOTE: In general, curves are obtained as shown in figure 1. These generally comprise a straight line for the first part.

The water absorption coefficient due to capillary action C_1 or C_2 (in grams per square meter and per second under square root) for each specimen is represented by the angular coefficient of the first straight part of the graph. It can be calculated as the ratio between the ordinate and abscissa of any point using the following formula:

$$C_1 \text{ or } C_2 = \frac{m_i - m_d}{A \cdot \sqrt{t_i}}$$

Express the result to three significant figures.

9 Test report

The test report shall contain the following information:

a) The identification number of the report;

b) The number, title and date of issue of this European Standard;

c) The name and address of the test laboratory;

d) The name and the address of the client;

e) It is the responsibility of the client to supply the following information:

- the type of stone
- the commercial name of the stone
- the country and region of extraction
- the name of the supplier
- the direction of any bedding or anisotropic features should be clearly indicated on the samples by means of at least two parallel lines (on all supplied samples)
- the method of sampling and by which organization

f) The date of delivery of the samples

g) The date when the specimens were prepared and the date of testing

h) The number of specimens in the sample

i) The dimensions of the specimens

j) For each sample, the water coefficient C_1 perpendicular to or C_2 parallel to an anisotropy observed or the natural grain, expressed to three significant figures

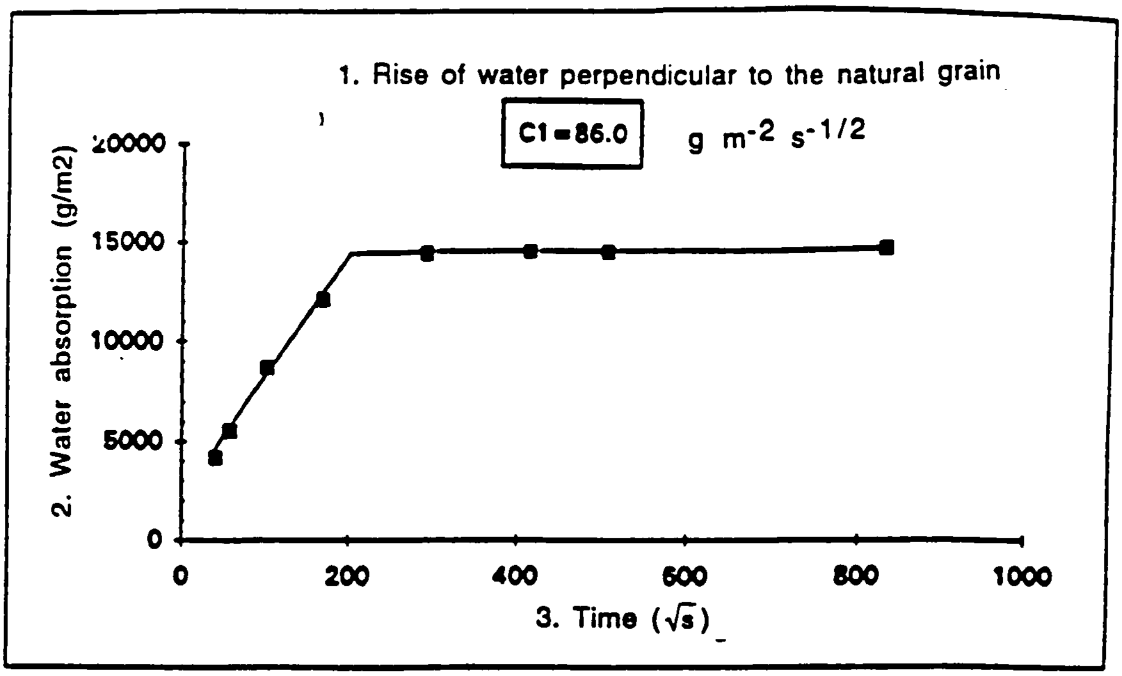
k) The arithmetic mean of the water absorption coefficients C_1 and/or C_2 expressed to three significant figures.

l) Any deviation from this standard and the reasons for any such deviation

m) Remarks

The test report shall contain the signatures and roles of the (those) responsible (s) for the testing and the date of issue of the report.

It shall also state that the report should not be partially reproduced without written consent of the test laboratory (ies) and the (those) responsible(s) for the execution of the test.



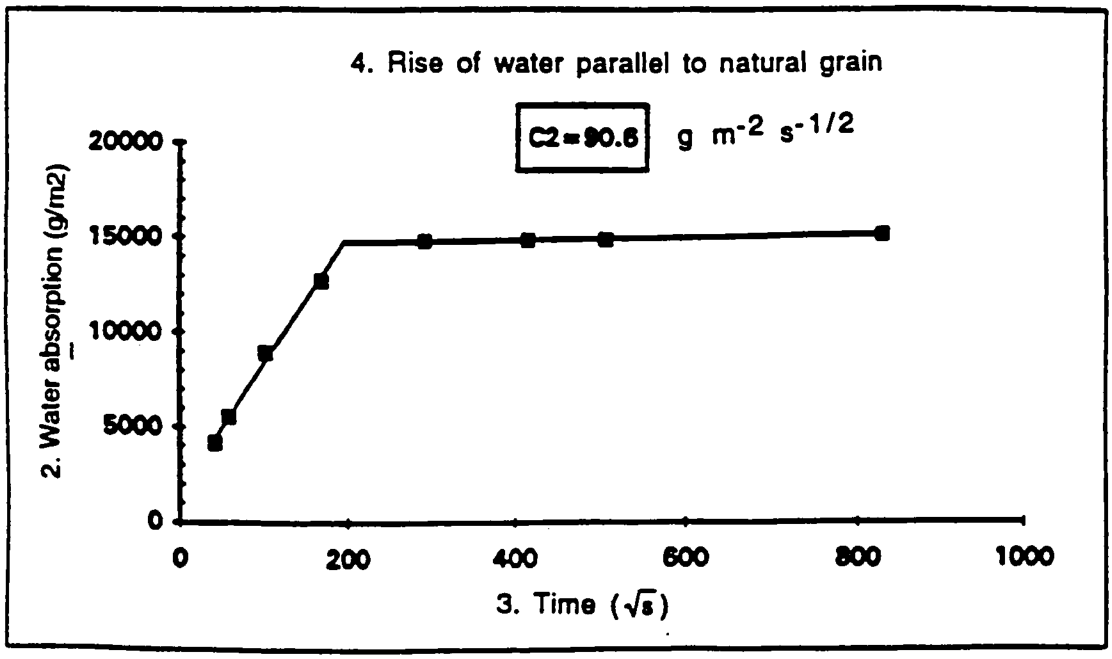


Figure 1 - Water absorption due to capillary action of two specimens of a low absorption stone: a) rise of water perpendicular to the natural anisotropy
b) rise of water parallel to the natural anisotropy

APPENDIX 6

Determination of compressive strength: EN proposal

APPENDIX 6

DRAFT
prEN 1926

EUROPEAN STANDARD

NORME EUROPEENNE

EUROPÄISCHE NORM

May 1995

ICS

Descriptors :

English version

Methods of test for natural stones - Determination of compressive strength

Méthodes d'essai pour pierres naturelles - Détermination de la résistance en compression

Prüfung von Naturstein - Bestimmung der Druckfestigkeit

This draft European Standard is submitted to the CEN members for CEN enquiry. It has been drawn up by Technical Committee CEN/TC 246

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. prEN 1926:1995 E

Contents Page

Foreword

This draft European standard has been prepared by CEN/TC 246, Natural Stone, the Secretariat of which is held by UNI.

This draft European standard is currently submitted to CEN Public Enquiry.

It was prepared by Working Group 2 - Test Methods.

No existing European standard is superseded.

According to CEN/CENELEC Internal Regulations the following countries are bound to implement this draft European standard:

1 Scope

This draft European standard specifies the method for determining the compressive strength of natural stones.

2 Normative references

This European standard incorporates by dated or undated references, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

ISO 4012/2 Compressive strength test machines (*)

EN WI 004 Natural stone - Terminology (of products and characteristics)(*)

EN WI N. ... Statistical evaluation for natural stone products (*)

3 Principle

The specimens, after mechanical preparation of surfaces or, if needed, after capping, are laid and centred on the plate of a testing machine. An uniformly distributed load is applied and increased continuously up to failure.

4 Symbols

h height of the specimen;
l mean value of the lateral dimension, i.e. the distance between opposite vertical faces of the specimen (if cubic);
d mean value of the diameter of the specimen (if cylindrical);
A cross-sectional area of the specimen before testing;
F failure load;
R uniaxial compressive strength of the specimen;
R mean value of the uniaxial compressive strength;
s standard deviation;
v coefficient of variation

(*) in course of preparation

5 Apparatus

A lathe or a surface grinder.

A lapping machine if a final touching of the specimens is needed.

A coating equipment if coating of specimens is needed.

A test machine of appropriated force, in accordance with ISO 4012/2 and calibrated according to this standard.

A time counter accurate to 1 second.

A ventilated oven which can maintain a temperature of (70 ± 5) °C.

A weighing instrument which has an accuracy of 0,01 % of the mass to be weighted.

A linear measuring device with an accuracy of 0,02 mm.

A room air which can be maitained at (20 ± 2) °C.

6 Preparation of specimens

6.1 Sampling

The method of sampling is not the responsibility of the testing laboratory except where it is especially requested to undertake this.
From an homogeneous batch at least five specimens are to be tested and the direction of bedding or anisotropy recorded.

6.2 Test specimens

Test specimens shall be cubes with 70mm ± 5 mm edge or right circular cylinders whose diameter and height are equal to 70 mm ± 5 mm. For the natural stones whose average compressive strength is higher than or equal to 40 MPa, with all the results higher than or equal to 30 MPa, it is also allowed to use cubes with 50 mm ± 5 mm edge or right circular cylinders whose diameter and height are equal to 50 mm ± 5 mm.

The lateral dimension of the diameter of the specimen should be related to the size of the largest grain in the rock by the ratio of at least 10:1. Cubes or cylinders having an edge or a diameter > 70 mm are admitted for coarse-grain materials. In this case, the maximum dimension of the grains shall be indicated in the test report.

The axis of the specimen shall be normal to specimen anisotropy, e.g. bedding planes, foliation, etc. (fig. 1a and 2a). If a test with orientation of loading parallel to the anisotropy is required, another set of specimens with the same dimensional characteristics shall be prepared (fig. 1b and 2b).

6.3 Surface preparation

6.3.1 General

The faces through which the load is to be applied shall be plane to a tolerance of 0,1 mm and shall not depart from perpendicularity to the axis of the specimen by more than 0,01 radian or 1 mm in 100 mm. The sides of the specimen shall be smooth and free of abrupt irregularities and straight to within 0,3 mm over the full length of the specimen.

To meet the above mentioned requirements the specimens shall be finished on either lathe or surface grinder, with final touching on a lapping machine if needed.

Coating with sulphur or capping with mortar according to the procedures indicated in 6.3.2 or in 6.3.3 is admitted in the case of soft stones, only if the indicated tolerances are not obtainable with the prescribed mechanical preparation. This condition shall be clearly indicated in the test report.

6.3.2 Coating with sulphur

6.3.2.1 Equipment

The coating equipment shall consists mainly of:

- a base which is a ground, horizontal surface to take the coating substance which is made up to the required consistency beforehand;
- a device for guiding the specimen vertically, fixed to the base to allow the specimen to come into contact with the coating substance.

The base of the coating apparatus can be made from:

- either a surface plate with a ring laid on top
- or a flat plinth on which is centred a removable dish with a ground base
- or a plate hollowed out to form a dish with a ground base.

The area formed on the ground horizontal surface by the ring or the dish is the area of coating.

The ring or the dish is 4 mm to 10 mm deep; the internal diameter of the ring or the diameter of the base of the dish is 3 mm more than the diagonal or diameter of the lower side of the specimen. The internal surface of the ring or the dish forms an angle of approximately 135° with the coating plane.

The guiding device must ensure that the sides of the specimen to be coated are parallel to each other and perpendicular to the axis of the specimen.

The following accessories are required:

- a receptacle, heated electrically with a thermostat, the inside of which does not react with liquid sulphur; the temperature needed to maintain the required consistency of the coating substance is between +120 °C and + 130 °C;
- a ladle to homogenize the mixture and allow measurement of the quantity of the substance required to coat one side of the specimen;
- a non-metallic mallet.

All of the above is placed under an extract hood.

Collection of the fumes must be accomplished bearing in mind that sulphur fumes are heavier than air and should be constantly maintained to avoid choking.

6.3.2.2 Preparation of coating substance

A mixture of sulphur and granular materials shall be prepared with the following composition by mass:

- high quality sulphur: 60%;
- fine, hard sand, granules less than 0,5 mm: 40%.

Fill the receptacle three quarters full with the coating substance, thoroughly mixed beforehand. The thermostat shall be turned to a temperature of +150 °C and the mixture stirred from time to time with the ladle until completely melted; as soon as the required consistency is reached, the thermostat shall be reduced to a temperature between +120 °C and +130 °C.

6.3.2.3 Coating method

If necessary fettle the edge of the level surface. Carefully wipe the surface to be coated. Apply a thin coat of oil on the base of the coating apparatus and on the inclined surface.

Use the ladle to homogenize the coating substance heated to a temperature between +120 °C and +130 °C. Remove the required quantity in a single measure and pour, spreading it over the base of the coating apparatus.

Lower the specimen slowly using the guiding device. Once the substance has solidified knock the specimen by hand or with the mallet to remove it from the base of the apparatus.

Repeat the above proceedings to coat the second side of the specimen.

Check carefully that the coating substance has adhered correctly to the whole surface, by tapping the surface in different places with fingers. If the coating layer sounds hollow, break it with the hammer and begin the coating operation again.

The thickness of the coating layer must be even and thin, from 2 mm to 4 mm. This thickness is a result of the consistency of the substance and the way in which the specimen is lowered.

6.3.3 Capping with mortar

It is also possible to cap the specimen utilizing a mortar made up with a high strength portland cement and waiting as much as needed for hardening.

6.4 Conditioning of specimen before testing

Either uncoated or coated specimens shall be dried at 70 °C ± 5 °C to constant mass. Constant mass shall be considered to have been reached when the difference between two weighings made at an interval of 24 h ± 2h is no greater than 0,1% of the mass of the specimen. After drying and prior to testing the specimens shall be stored at 20 °C ± 2 °C until the thermal equilibrium is reached. After that, the tests must be performed within 24 hours.

7 Procedure

7.1 Measuring the specimen

The cross-sectional dimension of the test specimen (lateral dimension or diameter according to its shape) shall be measured to the nearest 0,1 mm by averaging two measures taken at right angles to each other at about the upper-height and the lower-height h of the specimen. The average lateral dimension l or the average diameter d shall be used for calculating the cross-sectional area. The height of the specimen shall be determined to the nearest 1,0 mm.

7.2 Placing the specimen in the testing machine

Wipe the bearing surfaces of the testing machine clean and remove any loose grit from the bed faces of the specimen. Align the specimen carefully with the centre of the ball-seated platen, so that a uniform seating is obtained. Do not use any packing material.

7.3 Loading

Load on the specimen shall be applied continuously at a constant stress rate of 0,75 ± 0,25 MPa/s. The maximum load on the specimen shall be recorded to the nearest 1%.

8 Expression of results

The uniaxial compressive strength R of each specimen shall be calculated by dividing the maximum load F carried by the specimen during the test by the original cross-sectional area A. The result shall be expressed in Pa or its multiples to the nearest 0,1 MPa if the strength is lesser than or equal to 40 MPa and to the nearest 1 MPa if the strength is greater than 40MPa. The mean value R shall be calculated to the nearest 0,1 MPa if the strength is lesser than or equal to 40 MPa and to the nearest 1 MPa if the strength is greater than 40 MPa.

9 Test report

The test report shall contain the following information:

a) unique identification number for the report;

b) the name, number and date of issue of this European standard, namely EN xxxx: 199x;

c) name and address of the testing laboratory and the address of where the test was carried out if different from the testing laboratory;

d) name and address of the client;

e) a description of the sample to the relevant standard. To include:

- petrographic nature of the stone;
- commercial name of the stone;
- country and area of extraction;
- corporate name of the supplier;
- any bedding or anisotropic feature if relevant to the test, to be clearly indicated on each specimen delivered by parallel lines;

f) the method of sampling and by which organization;

g) the date of delivery of the specimens;

h) the date of preparation of the specimens and the date of testing;

i) the number of specimens in the sample;

j) the surface preparation of the specimens and their conditioning before testing;

k) the dimensions l (or d) and h in mm and the failure load F of each specimen, in N or its multiples;

l) the orientation of the axis of loading with respect to the rock anisotropy;

m) the duration of the test in min;

n) the compressive strength R of each specimen, in Pa or its multiples to the nearest 0,1 MPa if the strength is lesser than or equal to 40 MPa and to the nearest 1 MPa if the strength is greater than 40 MPa;

o) the mean value $\underline{R}$ of compressive strength, in Pa or its multiples to the nearest 0,1 MPa if the strength is lesser than or equal to 40 MPa and to the nearest 1 MPa if the strength is greater than 40 MPa;

p) the standard deviation s, in Pa or its multiples to the nearest 0,1 MPa, and the variation coefficient v;

q) any deviation from this standard and the reasons for any such deviation.

The test report shall contain the signature(s) and role(s) of the responsible(s) for the testing. It shall not be partially reproduced without the written consent of the laboratory.

a) load vertical to anisotropy

b) load parallel to anisotropy

Figure 1: Cubic test specimens

a) load vertical to anisotropy

b) load parallel to anisotropy

Figure 2: Cylindrical test specimens

APPENDIX 7

Determination of flexural strength: EN proposal

APPENDIX 7

CEN/TC 246
Natural stones

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

DOC.CEN/TC 246 N.164
APRIL 1996

prEN WI 00246037

METHODS OF TEST FOR NATURAL STONE - DETERMINATION OF FLEXURAL STRENGTH, CONSTANT MOMENT

SECRETARIAT UNI

Via Battistotti Sassi 11B • 20133 MILANO
Tel: +39 2 700 241 • Fax: + 39 2 70106106

CEN/TC246-WG6
N 258

ENGLISH VERSION

prEN: METHODS OF TEST FOR NATURAL STONES

PART: DETERMINATION OF FLEXURAL STRENGTH, CONSTANT MOMENT

Contents

Foreword

This draft European standard has been prepared by TC 246, Natural Stone, and was approved by the TC on to go forward to the CEN enquiry stage.

This draft is one of the series of draft standards for natural stone products and has been produced to meet the Essential Requirements laid down in the Construction Products Directive (89/106 (EEC)).

It was prepared by working group 2 - Test methods.

No existing European Standard is superseded.

1 Scope

This European standard specifies the method to determine the flexural strength of natural stones under constant moment.

2 Normative references

This European standard incorporates by dated or undated references, provision from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or reversions of any of these publications apply to this European standard only when incorporated in it by amendments or reversion. For undated references the latest edition of the publication referred to applies.

EN XXX	Natural stone - Terminology
EN XXX	Natural stone - Denomination
EN XXX	Method of test of natural stone - Part: Flexural strength under concentrated load
EN XXX	Method of test of natural stone - Part: Petrographic description
EN XXX	Method of test of natural stone - Part: Determination of dimensions
EN XXX	Method of test of natural stone - Part: Statistical evaluation
EN XXX	Method of test of natural stone - Part: Sampling
ISO	Flexural strength (Constant moment) test machines

3 Principle

After appropriate preparation a specimen of the rock to be tested is laid and centred between two supports. Thereafter the specimen is subjected to two line loads acting on the top of the specimen and so that each load is located at a distance of one third of the length of span. The loads are steadily increased until failure.

4 Symbols

Rt_c	=	Flexural strength at constant moment (N/mm^2)
F	=	Load at failure (N)
b	=	Specimen width (mm)
h	=	Specimen thickness (mm)
l	=	Specimen length (mm)
L	=	Length of span between supports (mm)

5 Apparatus

A lathe or a surface grinder.

A lapping machine if a final touching of the specimens is needed.

A test machine in accordance with ISO .... and calibrated according to this standard. The test machine shall have an appropriate force and be capable of providing a uniform load. The line loads and supporting cylinders shall have a radius of 10 mm and the two loading cylinders must be adjustable in order to gain uniform contact and load between the cylinders and the specimen. The distance between the two support cylinders is called the length of span and is designated (L), see figure 1..

A ventilated oven capable of maintaining a temperature of 70°C ± 5°C.

A weighing instrument that has an accuracy of 0,01 % of the mass to be weighted.

A linear measuring device with an accuracy of 0,01 mm.

A room which can be maintained at a temperature of 20°C ± 5°C.

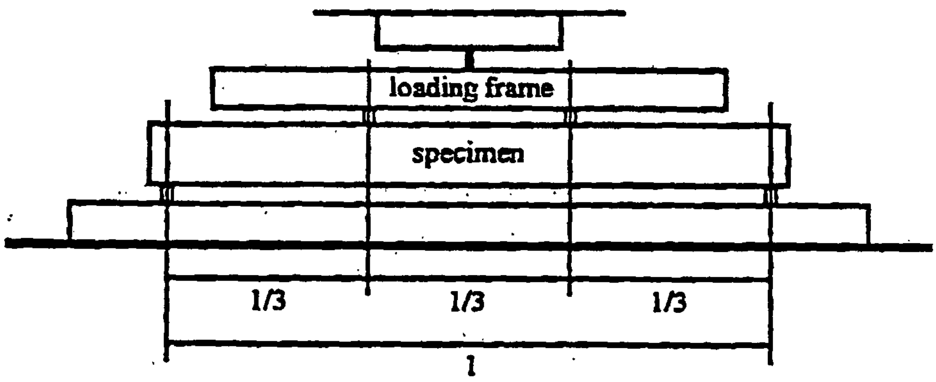


Figure 1 Arrangement for flexural strength test under constant moment.

6 Preparation of specimens

6.1 Sampling

Sampling must be performed following EN XXX.

The sampling is not the responsibility of the testing laboratory except when it is especially requested to undertake this.

6.2 Test specimens

6.2.1 Specimens for identification test

In general, at least 6 specimens shall be tested. In case of bedding or other types of directional anisotropy in the rock, at least 6 specimens shall be tested for each direction in relation to the position of the natural anisotropy. The anisotropy directions must be marked on each specimen by at least two parallel lines.

The direction(s) chosen to be tested depends on the intended use direction. If the intended use direction(s) is not known, all the three directions drawn in figure 2-4 shall be tested.

The loading surfaces of the specimen shall be sawn, honed or polished.

The specimen height (h) shall at least measure twice the largest grain size of the rock and/or lie between 25 mm and 100 mm.

The specimen length (l) shall equal 6 times the specimen height.

The specimen width (b) shall be between 50 mm and three times the height (50 mm≤b≤3h).

The length of span (L) shall be five times the specimen height.

The faces shall not depart from perpendicularity to the axis of the specimen by more than 2% with a maximum of 2 mm differences when measuring in any direction.

6.2.2. Specimens for product test

At least 6 specimens shall be tested for the relevant product direction.

The specimens may be final products or sawn from final products. The surface intended for use shall be in contact with the two supporting cylinders (facing downwards).

Any signs of fracturing or fissuring or any surface irregularities within the specimens shall be noticed and mentioned in the test report.

The specimen height (h) is normally as for the final product.

The specimen length (l) shall equal six times the specimen height.

The specimen width (b) shall be between 50 mm and three times the height (50 mm≤b≤3h).

The length of span (L) shall be five times the specimen height.

The faces shall not depart from perpendicularity to the axis of the specimen by more than 2% with a maximum of 2 mm differences when measuring in any direction.

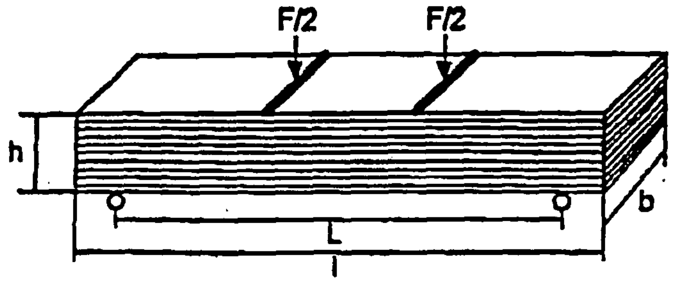


Figure 2 Test arrangement for a specimen with the load applied perpendicular to the bedding plane or other anisotropic feature.

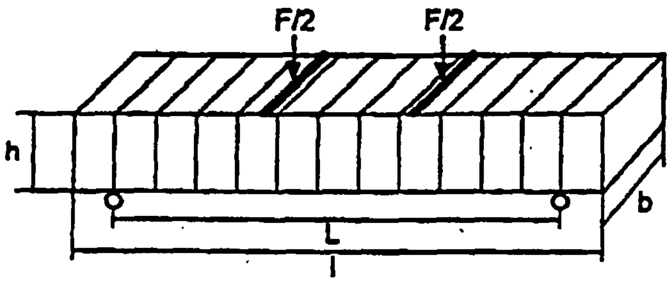


Figure 3 Test arrangement for a specimen with the load applied parallel to the bedding plane or other anisotropic feature.

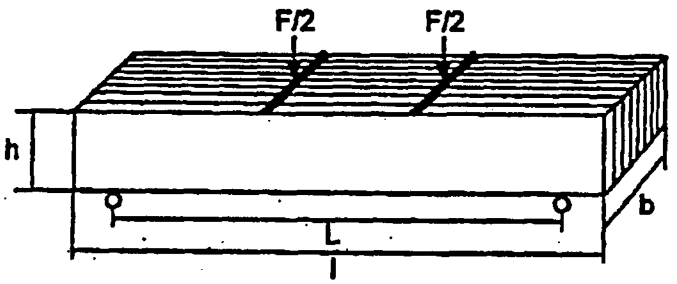


Figure 4 Test arrangement for a specimen with the load applied perpendicular to the edges of the bedding plane or other anisotropic feature.

6.3 Tolerances

The tolerance of the dimensions h, b, L and l shall be ± 1 mm of the nominal dimensions.

6.4 Conditioning before testing

The specimens shall be dried at 70°C ± 5°C to constant mass in a ventilated oven. Constant mass shall be considered to have been reached when the difference between two measurements made at an interval of 24 h ± 2 h is not greater than 0,1 % of the previous mass measurement.

After drying and before testing the specimens shall be stored at 20°C ± 5°C for thermal equilibrium to be reached, and the test shall be performed within 24 hours after removal from the oven.

7 Test procedure

The test shall be performed at 20°C ± 5°C.

Wipe the bearing supports of the testing machine and remove any loose grits from the loading faces of the specimen. Align the specimen carefully and centrally between the supports and the loading cylinders such to gain uniform setting as shown in figure 1. Specimen position regarding anisotropy directions is visualized in figures 2, 3 and 4.

The load is increased steadily at a rate of 0,25 N/mm^2 ± 0,05 N/mm^2 per second until failure. The maximum load on the specimens shall be recorded to the nearest 10 N and the place and mode of the fracture shall be recorded if the failure has occured outside the two line loads.

8 Expression of results

For each relevant direction the flexural strength (N/mm^2) at constant moment is expressed by the equation:

$$Rt_{ci} = \frac{F\,L}{b\,h^2}$$

where Rt_{ci} is the individual value of one of the six specimens.

9 Test report

The test report shall contain the following information:

a) Unique identification number of the report.
b) The name, number and date of issue of this European standard, namely EN XXX 199x.
c) The name and address of the testing laboratory and the address of where the test was carried out if different from the testing laboratory.
d) The name and address of the client.
e) A description of the sample to the relevant standard. The information shall include:

- petrographical name and nature of the stone
- commercial name of the stone
- country and area of extraction
- corporate name of the supplier
- any bedding or anosotropic feature if relevant to the test
- descriptions of the stone material from which the specimens shall be prepared (dimensions, surface finish etc.).

f) The method and description of sampling and name and address of the responsible for the sampling.
g) Delivery date of the samples.
h) The date of preparation of the specimens and the date of testing.
i) The number of specimens in the sample.
j) The surface finish of the specimens.
k) Perpendicularity to the axis of the specimen
l) For each specimen, record the:

width (b) and height (h) to accuracy 0,1 mm
length (l) and the length of span (L) to accuracy 1 mm
failure load to accuracy 10 N
loading speed in N/mm^2 per second
loading direction in relation to any anisotropy
mode and place of the fracture when outside the line loads.

m) For each relevant direction the mean value for flexural strength in N/mm^2 to the nearest 0,1 N/mm^2, the standard deviation and the coefficient of variation.
n)Any deviation from this standard and the reason for such deviation.

The test report shall contain the signature(s) and the role(s) of the responsible(s) for the testing. It shall mention the following note: "It shall not be partially reproduced without the written consent of the laboratory".

************** -KOMM JOURNAL- ******************** DATO 10-JAN-1997 ****** TID 15:37 *** S.01

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INTERNATIONAL UNION OF GEOLOGICAL SCIENCES

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DATE: January 10, 1997

PAGES INCL. COVER:

RE: Meeting Report and Financial Statement Request

Dear Dr. Turner:

Our records show that we have not received meeting reports or financial statements for IGCP Project 328. Please send them as soon as possible.

If you have any questions or concerns, please contact me at the numbers listed above or by e-mail (IUGS.Secretariat@ngu.no). Thank you in advance.

Sincerely,

Emily June Høsøien
IUGS Secretariat

APPENDIX 8
Example of test report

APPENDIX 8

STEINFORSK

NORSK FORSKNINGSSENTER FOR NATURSTEIN
NORWEGIAN CENTRE FOR STONE RESEARCH

SINTEF ROCK AND MINERAL ENGINEERING (SECREATARIAT)
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Report No.:	**93105**
Pages:	**10**
Date:	**94.01.07**
Scope of work:	**Testing of Li-skifer**
Agreement date:	**93.12.01**

Responsible for sampling: Client

Responsible for cutting of test specimens:

Client

Tests performed in the following institutions:

SINTEF Rock and Mineral Engineering
Norwegian Building Research Institute

REPORT

STEINFORSK

NORWEGIAN CENTRE FOR NATURAL STONE RESEARCH

SECRETARY:

SINTEF Rock and Mineral Engineering
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TITLE OF REPORT

**Testing of Li-skifer.
Report from STEINFORSK**

AUTHOR(S)

Several

CLIENT/SPONSOR OF PROJECT

Liskifer A/S

FILE CODE	CLASSIFICATION	CLIENT'S REF.	
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		Lisbeth Alnæs, SINTEF Rock and Mineral Engineering	
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UTM-COORDINATES

QUARRY/LOCALITY

COUNTRY Nord-Trøndelag
MUNICIPALITY Lierne
NAME Dalbrekken

GEOLOGICAL NAME

Quartzite schist

TRADE NAME

Li-skifer

WORK DONE

Bulk density, open porosity, water absorption, flexural strength, compressive strength, abrasion resistance.

WORK PERFORMED IN THE FOLLOWING LABORATORIES

SINTEF Rock and Mineral Engineering
Norwegian Building Research Institute

INDEXING TERMS	ENGLISH	NORWEGIAN
GROUP 1	Norw. Centre for Stone Research	STEINFORSK
GROUP 2	Rock and Mineral Engineering	Bergteknikk
SELECTED BY AUTHOR(S)	Natural stone	Naturstein
	Testing	Prøving

Summary

The Norwegian Centre for Natural Stone Research has performed several laboratory investigations of the quartzite schist.

The following average values apply to the rock:

Bulk density, DIN 52102	2.71 g/cm^3
Open porosity, DIN 52103	0.5 %
Water absorption, DIN 52103	0.19 %
Flexural strength, DIN 52112	
Normal to schistosity and lineation	45.3 N/mm^2
Compressive strength, DIN 52105	
Normal to schistosity (natural load faces)	140 N/mm^2
Normal to schistosity (sawn load faces)	310 N/mm^2
Parallel to schistosity (sawn load faces)	199 N/mm^2
Abrasion value, ASTM D1242-87	3.9 mm

For the abrasion resistance, two specimens had natural load faces and one had sawn load face (see appendix 1). This gives an initial smaller abrasion for the sawn specimen, but after 2000 revolutions, the results are comparable.

For comparison some data for other Norwegian quartzite schists are given below.

Properties	Rock types			
	Oppdal	Alta	Snåsa	Voss
Density (g/cm^3)	2.73	2.69		2.72
Water absorption (weight %)	0.25	0.1	0.15	0.13
Flexural strength (N/mm^2)	25.0 - 47.0	30.0 - 42.5	31.5	35.0
Compressive strength (N/mm^2)	175 - 260	180 - 280		302.5
Abrasion resistanse (mm)	2.0 - 2.7	1.8 - 2.7		3.2

Source: STENHÅNDBOKEN 1993, Norway

TEST REPORT

SINTEF

SINTEF Rock and Mineral Engineering

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Fax: +47 73 59 47 78
Telex: 55 620 sintf n

Enterprise no.: 948007029

PROPERTIES INVESTIGATED

Bulk density and open porosity, DIN 52102
Water absorption, DIN 52103

FILE CODE	CLASSIFICATION	FILE NO.	PROJECT NO.	DATE
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ROCK MATERIAL

Name given by supplier: Li-skifer

5 cubes with dimension 50 x 50 x 50 mm.

Table 1. Bulk density, open porosity and water absorption

Specimens	Bulk density g/cm^3	Open porosity %	Water absorption % weight
1	2.71	0.5	0.20
2	2.71	0.5	0.19
3	2.71	0.5	0.20
4	2.71	0.5	0.18
5	2.71	0.5	0.19
average	2.71	0.5	0.19

Torill Sørløkk
Torill Sørløkk
Technician

TEST REPORT

SINTEF

SINTEF Rock and Mineral Engineering

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PROPERTIES INVESTIGATED

Flexural strength, DIN 52112
Compressive strength, DIN 52105

FILE CODE	CLASSIFICATION	FILE NO.	PROJECT NO.	DATE
93105	Restricted	93105	361510.00	1994-01-07
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C:\STEINFOR\93105ENG.BOY		Lisbeth Alnæs *Lisbeth Alnæs*		2

ROCK MATERIAL

Name given by supplier: Li-skifer

Flexural strength

Bending tests were perfomed in a three-point load on 50 x 50 x 300 mm prisms (dry conditions). The distance between the two supporting knife edges was 175 mm, and the prisms were loaded by a cylinder centred between and parallel to the supporting knifes until failure. The figures in table 1 refer to two directions and sawn faces or faces with natural splitting planes.

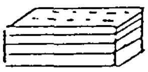
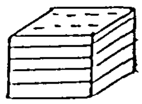
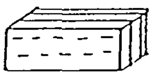
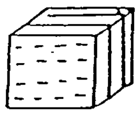
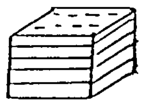
Compressive strength

Compressive strength was measured on 50 x 50 x 50 mm cubes (dry conditions), both parallel and normal to schistosity.

Discussion

As would be expected, the flexural strength is somewhat higher normal to schistosity than the other directions tested (**). The condition of the surfaces in the bending test seem not to be as critical as with the compression tests. The measurements indicate a doubling of the strength if the cubes have sawn faces instead of natural splitting planes.

Table 1. Flexural strength and compressive strength

Specimens	Loading figure	Flexural strength N/mm²	Loading figure	Compres. strength N/mm²
1	* 	41.4	* 	161.9
2		45.2		135.4
3		45.7		143.2
4		46.8		143.2
5		47.4		118.3
average		45.3		140.4
1	** 	33.9	** 	242.9
2		45.6		221.1
3		42.8		217.9
4				175.9
5				135.4
average		40.8		198.6
1			** 	351.8
2				353.4
3				236.6
4				325.4
5				284.9
average				310.4
total average		43.1		216.5

* Load face: 1 natural splitting plane and 1 sawn
** Load face: Sawn
- - - Lineation
—— Schistosity

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Project no./J.no.: 0 3738/361510.00
Type of project: Resistance to abrasion, Test metod ASTM D1242-87

Resposible for test preparation: SINTEF Division of Rock and Mineral Engineering
Responsible for the testing: Norwegian Building Reseasch Institute

The test is a part of Steinforsk-report no.: 93105

TEST MATERIAL Li-skifer

RESULTS See table

Test specimens	Abrasion loss in mm after				Loss of weight in gram after			
	1000 revolutions test cycles		2000 revolutions test cycles		1000 revolutions test cycles		2000 revolutions test cycles	
		Average		Average		Average		Average
1	2,03	2,27	3,56	3,88	19,23	21,09	34,69	37,42
2	2,50		4,20		22,94		40,16	

CONCLUSION The characteristic value of abrasion for Li-skifer after ASTM D1242-87: 3,9 mm.

COMMENTS List of corresponding abrasion values are enclosed.

Oslo 27.12.93

Bjørn Bakken

List of corresponding abrasion values

Test material		Abrasion values in mm	
	Largest value	Minimum value	Average
Concrete	11.9	2.3	5.7
Quartzite slatestone	4.2	2.1	3.2
Granite	2.2	1.6	1.9
Marble	12.7	3.9	6.3
Clay slatestone	8.7	3.0	4.8
Acryl coating	2.8	1.7	
Epoxy coating	5.8	1.0	3.3

 Appendix 1

NOTAT

Til: Lisbeth Alnæs, NBI Trondheim
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Kopi:
Dato: 27.12.93

SAK: Ekstra slitasjeprøve - prosjektnr. 361510.00/93105

Etter avtale med Lisbeth Alnæs har vi i tillegg til prøve 1 og 2, hvor resultatene er er angitt i vedlagte rapport, utført forsøk på et prøvestykke med saget flate (prøve 3). Vi har dessuten målt slitasjen etter 300 omdreininger på prøve 1 og 2. Da var den ru overflaten slitt bort. Samtlige resultater for slitasje i mm er gjengitt i tabell 1. Tabell 2 angir vekttapet i gram for prøve 3.

Tabell 1

Prøve-stykke nr	Bortslitt i mm etter					
	0-300	300-1000	0-1000	Beregnet 0-1000[1]	1000-2000	0-2000
1	0,89	1,14	2,03	1,63	1,53	3,56
2	1,13	1,37	2,50	1,96	1,70	4,20
3			1,67		1,73	3,40

[1] Beregnet ut fra resultatet fra 300-1000 omdr. ved å forutsette at slitasjen er liniær.

Tabell 2

Prøve-stykke nr	Vekttap i gram etter					
	0-300	300-1000	0-1000	Beregnet 0-1000[1]	1000-2000	0-2000
3			17,11		17,92	35,03