Natural Stone classification and specifications review

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Abstract
Natural stone (or dimension stone) is a natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length, and thickness) and shape. Features as color, grain texture, pattern, and surface finish are required by customers and stone industries. Other properties as .durability, strength, and ability to take a polish are also used for selection. The correspondence between geological and industrial names used for the materials of natural stone is discussed. The aims of EN and ASTM standards for natural stone are compared showing that the EN-standards related to specifications for products whereas specifications for materials can be found only in ASTM standards, allowing the characterization of five main groups of classification.
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Keywords: natural stone, dimension stone, standard, material, product

1. Introduction

The quarried stone can be used in different ways in the building and construction industry: shaped and sized as dimension stone, roughly broken and used for rip-rap or rock fill, or further broken as aggregates for concrete or for tarmacadam (Barton, 1968). Natural stone is probably one of the oldest construction building material used by man as far as 3000 years BC, i.e.: blocks of limestones worked by ancients Egyptians (Prentice, 1990).
Stone is frequently used as synonymous of rock, but more properly is applied to individual blocks, masses, or fragments taken from their original formation or considered for commercial use. Dimension stone is a natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length, and thickness) and shape. Colour, grain texture and pattern, and surface finish of the stone also are required by both customers and stone industries. Durability (essentially based on mineral composition, hardness, and past performance), strength, and the ability of the stone to take a polish are also selection criteria (Dolley, 2008). According to Winkler (1975, 1995) dimension stone is a rock cut and shaped for use.
According to ASTM C119: 2006, dimension stone is a natural stone that has been selected and fabricated to specific sizes or shapes, and the definition as natural material excludes all manmade materials simulating stone, but in common practice some dimension stone are reinforced, filled or surface treated.
European standard EN 12670 states also that natural stone term concerns different types of rocks and provides a geological glossary based on references of Le Maitre et al.(1989), Folk (1959) and Kraeft (1994; 1999) as well as technical and processing terminology.
Criteria for denomination of natural stone from raw materials to products are provided in EN 12440:2000. Denomination includes a traditional name, geological denomination of the rock, references to localities, and to natural and petrographical features (according to EN 12407) and some times complementary geological information. The standard includes a non exhaustive list of European natural stones names.
In Spain for natural stone denomination are usual the terms “piedra de cantería” and “roca ornamental”,, the last one corresponding to greater finishing and greater marketing area (Bustillo et al., 2001).
The EN standards for natural stone concerns mainly to products and are focused on systems of conformity evaluation of product including

petrographical denomination, safety data, and identificative and additional properties.

2. Commercial and geological names for natural stones

Geological description of different types of stone is based on petrographical features of rocks. The denominations of geological formations include frequently toponymic names and in a similar way, commercial denominations of natural stones refer usually to a type of rock, to a toponym and to colour and appearance of the used rock.

The more widespread commercial English terms for dimension stone used in statistics and reports (i.e: Dolley, 2008) of USBM (United States Bureau of Mines) and USGS (United States Bureau of Mines) based on definitions by Currier (1960) and Barton (1968) are abridged below with some additional references.

The commercial name of granite is used for crystalline rocks including feldspars of mainly interlocking texture and with individual mineral grains that are visible to the naked eye. It includes such rock types as anorthosite, gneiss, granite, granodiorite, monzonite, syenite, and all other intermediate igneous and coarse-grained metamorphic rock types. The main colours of commercial granites are white, gray, pink, and red; commercial black granites range in color from dark gray to black, include mafic rocks, such as diabases, diorites, gabbros, and similar rocks. Green and brown are secondary colours. For dark igneous rocks too fine grained to be termed "black granite", the commercial names basalt and traprock (from trapa, step in Swedish, concerning the step like appearance of certain basalt lava fields) are used (i.e: for andesite, basalts, dacites, amphibolites, diabases, diorites, fine-grained gabbros, peridotites, and pyroxenites).

Commercial limestones are sedimentary rocks made of calcium carbonate with or without magnesium, including calcitic limestones, dolomites and dolomitic limestones.

Commercial marble includes marbles, metamorphosed limestones and serpentine rocks, capable of taking a polish. An important member of this classification is serpentine marble, also known as *verde antique*, mainly made of green-to-black serpentine (an hydrous magnesium silicate mineral) crossed by veins of lighter minerals, such as calcite or dolomite.

Commercial sandstone is mainly made of quartz or quartz and feldspar with clastic texture. Related commercial names are flagstone, brownstone and bluestone. *Flagstones*, is used for sandstones, or sandy slates red, tan or gray, splitting into large, thin slabs. *Brownstone* (sp: rodeno), for feldspathic sandstone of brown to reddish-brown colour resulting from iron oxide cement content. *Bluestone*, is used in US for a dense, hard, fine-grained feldspathic sandstone with fine black and dark-green minerals (chiefly hornblende and chlorite) and it is also applied locally to other rocks, such as dark-blue shales and blue limestones, argillaceous sandstones, and locally in Great Britain, for a hard shale or clay (as in south Wales), and even for a basalt (Klaus et al., 2005).

Commercial slate is used for microgranular metamorphic rock result of recrystallization of lutites, with excellent parallel cleavage, allowing split to easily into more or less thin slabs. Eventually also used for other cleaved roks as limestones, argillaceous limestones, and compact pelites.

Commercial greenstones made mainly of greenish minerals, such as actinolite, chlorite, or epidote, are the product of metamorphism of igneous rocks (one of the meanings of greenstones found in Klaus et al., 2005).

A miscellaneous category includes commercial dimension stone types that do not easily fall into the above categories, such as soapstone, steatite, or talc, which contain various amounts of the mineral talc (i.e several stones from Finland in EN 12440). Additional miscellaneous stones include diatomite, mylonite, pumice, schist, tripoli, tuff, porous or scoriaceous volcanic rocks, or any other rocks used as building stones.

Table 1 shows the most relevant features of commercial types for their industrial processing

Materials of natural stone are rocks which can be classified by their origin as igneous, metamorphic and sedimentary, and Table 2 includes different names of rocks of that origins.

Table 1. Main features of natural stones.

Commercial type	Composition	Mohs hardness	Polishing suitability	Cleaved
Slate	Siliceous	-	-	Yes
Quartzites and sandstones		>4	Yes	No
Granite		>4	Yes	No
Marble	Carbonated	>4	No	No
Limestone		3-4	No	No
Other	Varied	<3	-	-

.Table 2. Relationship between technical ASTMdenominations and geological words.

Commercial	*Geological*			
	Sedimentary	Igneous		Meta-morphic
		Plutonic	Volcanic	
Slate	Argillite Pelite Mica rich fine sandstones			Slates Phyllite Pelite Schist Micas-chist
Granite		Granite Granodiorite Pegmatite Sienite Tonalite Diorite Labradorite Anorthosite Gabbro sl	Andesite Basalt	Gneis Coarse grained quartzite
Sandstone and Quartzite	Sandstone			Quart-zite
Marble	Limestone Dolomite Stromatolite Travertine			Marble Dolo-mite marble ,Serpen-tinite,
Limestone	Limestone Travertine Conglomerat Breccia			Low grade marble
Alabaster	Gypsum			

The names used for commercial types of natural stones are geological names but not always both terms are equivalent. Commercial classification may include in the same group rocks with different geological name, and thus metamorphic slates are the more frequent commercial slates, but this commercial group includes also sedimentary slates and other rocks, sedimentary or not of different names (see table), and in the same way the name of granit can be commercially used for different types of igneous or metamorphic rocks suitable for polishing.
The word marble can be used for sedimentary carbonate rocks as limestones (travertines, stromatolithes,…) and dolomites or for non carbonates i.e: serpentinites whenever that rocks can be polished, and the commercial denomination is not used for a particular marble not suitable for polishing

3. Classification of natural stone materials.

Requirements internationally admitted by different geological surveys and technical manuals (i.e: Berton and Le Berre, 1983; Lefond, 1983; López Jimeno, 1995; CSIRO,2002) are those of ASTM standards, summarized in Table 3 for the different designations corresponding to commercial types.

Table 3. Summary of the classification of natural stone materials according with ASTM standards

	Material & general standard	Subcategories		Specific standard	Quartz* (%)	WA (%)**	Density** Kg/m3
1	Slate C629-03					<0,45 (I) <0.25 (E)	-
	Slate C406-06	Roofing slate	S1			<0,25	-
			S2			<0,36	-
			S3			<0,45	-
2	Granite C615-03	-		-	-	<0.40	>2560
3	Quartz-based dimension stone C616-03	I. Sandstone		-	>60	<8	>2003
		II. Quartzite sandstone		-	>90	<3	>2400
		III. Quartzite		-	>95	<1	>2560
4	Marble C503-03	I. Calcite		-	-	<0,2	>2595
		II. Dolomite		-	-	<0.2	>2800
		III. Serpentine		C1526-03	-	<0.2 (E) <0.6 (I)	>2690
		IV. Travertine		C1527-03	-	<2,5	>2305
5	Limestone C568-03	I. Low density		-	-	<12	>1760
		II. Medium density		-	-	<7,5	>2160
		III. High density		-	-	<3	>2560
	Other (alabaster, soapstone,..)	-		-	-	-	-

WA (Water absorption coefficient) and Density, by ** ASTM C97 Standard . I (internal use) E (external use).

For the main 5 commercial types there are general standards and eventually specific standards for subtypes. The Table shows limit values of the different designations for water absorption coefficient and density measured by standard procedures (the other specifications are collected in CSIRO, 2002). Those two properties are included here as very simple and

significative because of conditioning other physical properties (Winkler, 1969; 1994).
Only the designation for sandstones and quarzites (ASTM C616-03) includes ranges for compositional features (free silica content). The textural and compositional features of the main groups of this Table, as well as terminology of natural stone industry, are included in ASTM C119 standard.

4. EN classification of natural stone products.

As said above, the natural stone EN standards concerns mainly to products with scarce references to materials.

Table 4. EN specifications for covering products of natural stone

Type EN standard	Position	Use	L mm	W mm	t mm
Slabs UNE-EN 1341:2003	external indoor	P	≥A	>150 - 2xE >150	>15 >12
Setts UNE-EN 1342:2003.	external	P	50 – 300		>50
Kerbs UNE-EN 1343:2003	external	P	>300		
Plate UNE EN 12670:2003			≥A	>150	>12
Modular tiles UNE EN 12057:2004			<610	< 610	≤12
Slates UNE-EN 12326-1:2004	external roof	R			

P, paving, L, lenght, W, width t, thickness, R, roofing.

EN Specifications for covering products of natural stone are shown in Table 4 (including specified dimensional ranges) , only reference to nature of materials can be found in slates standard (EN-1326-1) distinguishing roofing slates (mainly made of sheet silicates and showing cleavage) and roofing carbonated slates (with a carbonate content above 20% and also showing cleavage)
Table 5 concerns EN 771-5 specifications elements of masonry units made of natural stone, including their specifications based on dimensional tolerances.

Table 5. Summary of specification of natural stone masonry units.

U		Specifications for dimensional tolerances					
		L	W	H	F	O	P
SR		±15		±15	±1,5%L	±1,5%L	-
R		-		-	-	-	
	D1	±5	±5	±5	0,5% L	0,5% L	
DR	D2	±2	±2	±2	0,3%L & ±1mm of H	0,3%L	
	D3	±2	±2	±1	0,3%L	0,3%L	≤1,0 %

L, lenght, W, width H, height, R, roofing, F, flatness, O, Orthogonality, P, parallelism
U (units): SR (squared rubble), R (rubble), DR (dimensioned rubbles D1, D2, D3).

5. Concluding remarks

Both (ASTM and EN) sources of standards as well as different complementary bibliographical resources can produce some confusion about classification of natural stones with results in trade and legal problems..
Classification of natural stone materials using physical and compositional specifications makes easy the task of selection for prescriptors. Selection of convenient stone materials based on ranges of physical properties combined with quality assurance based on product standards can reduce trade legal problems as well as problems related to pathologies and failurtes of natural stones.

REFERENCES

ASTM C 295. Guide for Petrographic Examinalion of Aggregates for Concrete
ASTM C 406. Specification for Roofing Slate
ASTM C 503. Specificalion for Marble Dimensión Stone
ASTM C 568. Specification for l.imestone Dimensión Stone
ASTM C6I5. Specificatión for Granite Dimensión Stone
ASTM C 616. Specification for Quartz-Based Dimensión Stone
ASTM C 629. Specification for Slate Dimensión Stone
Barton, W.R., (1968).Dimension stone: U.S. Bureau of Mines Information, Circular 8391, 147 ppASTM C 119. Terminology Relating to Dimensión Stone
Berton, Y. and Leberre, P. (1983) Guide de prospection des matériaux de carrière.

BRGM. Manuels et Methodes, Nº5, Orleans, 160 pp

Bustillo, M., Calvo, J.P. y Fueyo, L .(2001). Rocas Industriales. Ed. Rocas y Minerales, 410 pp

CSIRO (2002). Guide to the Specification of Dimension Stone. Buiding Technology File, Nr 20, april, 2002, 9 pp (accessed at http://www.dbce.csiro.au)

Currier, L.W. (1960).Geologic appraisal of dimension-stone deposits: U.S. Geological Survey Bulletin 1109, 78 p

Dolley,T (2008).Minerals Yearbook, Dimension Stone 2007, U.S.G.S, 14 pp. Accessed at URL: http://minerals.usgs.gov/minerals/pubs

Folk, R.L.(1959) Practical petrographic classification of limestones. American Association of Petroleum Geologists Bulletin, V. 43, pp. 1-38

Klaus, K.E., Neuendorf, J. P., Mehl, J., and Jackson, J.A. editors (2005) Glossary of Geology (5th edition). AGI, 800 pp. Accesed at URL http://www.agiweb.org

Kraeft, U.(1994) Was die Europaïsche Normung de Naturteinbranche (1994) Stein 5/1994, pp. 36-38

Kraeft, U. (1997). Classification of rocks and minerals. European Geologist,1997, 1,pp. 52-54.

Lefond, S.J (1983) Industrial Minerals and Rocks., AIMMPE, New York, 1433 pp.

Le Maitre,P. (1989). A classification of Igneous Rocks and Glossary of Terms: Recommendations of the IUGS Subcomisión on Systematics of Igneous Rocks, Blackwell, Oxford, U.K

López Jimeno, C (1995) Manual de rocas ornamentals. Entorno Gráfico, Madrid, 696 pp.

UNE-EN 1341:2003. Baldosas de piedra natural para uso como pavimento exterior..Requisitos y métodos de ensayo. AENOR

UNE-EN 1342:2003. Adoquines de piedra natural para uso como pavimento exterior.Requisitos y métodos de ensayo. AENOR

UNE-EN 1343:2003. Bordillos de piedra natural para uso como pavimento exterior. Requisitos y métodos de ensayo. AENOR.

UNE- EN 1469:2005. Piedra natural. Placas para revestimientos murales. Requisitos 38 pp AENOR

UNE-EN 12058:2004. Productos de piedra natural. Baldosas para pavimentos y escaleras. Requisitos. 33pp AENOR

UNE EN 12670:2003. Terminología de Piedra Natural, 52 pp. CEN

UNE 12057:2004. Productos de piedra natural. Plaquetas. Requisitos. 38pp AENOR

UNE-EN 12326-1:2004. Productos de pizarra y piedra natural para tejados y revestimientos discontinuos. Parte 1: Especificación de producto. 39pp. AENOR

UNE-EN 771-6:2006 Especificación de piezas para fábrica de albañilería. Parte 6: Piezas de piedra natural

Winkler, E. (1975). Stone: Properties, Durability in Man´s Environment. Springer- Verlag, New York.

Winkler, E.(1994). Stone in Architecture. Springer- Verlag, Berlin.