CHAPTER 3: AGGREGATES

3.1. Definitions

Aggregate:	granular material used in concrete production. Aggregate may be natural, manufactured or recycled.
natural aggregate:	aggregate from mineral sources, which been subjected to nothing more than mechanical processing
aggregate size:	designation of aggregate in terms of lower (d) and upper (D) sieve sizes expressed as d/D
fine aggregate:	designation given to the smaller aggregate sizes with D ≤ 4mm
coarse aggregate:	designation given to the larger aggregate sizes with 4mm and d ≥ 2mm
filler aggregate:	aggregate, most of which passes a 0,063mm sieve.
all-in aggregate:	consisting of a mixture of coarse and fine aggregate
crushed aggregate:	designation of query origin
manufactured:	aggregate of mineral origin resulting from an industrial process
recycled:	aggregate resulting from the processing of inorganic material previously used in construction.
grading:	particle size distribution expressed as the percentages by mass passing a specified set of sieves
synthetic:	make use of wastes or by-products or may be manufactured by technically treatment (mainly thermal) of rocks or other materials

3.2. Geometry of aggregates

The aggregate for concrete have to satisfy the following requirements:

3.2.1. Size

It is specified using a basic set of sieves, according EN 12620:2002

3.2.2. Grading

The grading of the aggregate, when determined in accordance with EN 933–1 shall comply with the requirements of § 4.3 to 4.3.6 as appropriate to its aggregate size d/D (EN 12620:2002).

Table 3.1 includes the general grading requirements

Table 3.1: General grading requirements

Aggregate	Size	Percentage passing (by mass)				
		2D	1.4D	D	d	d/2
Coarse	D/d ≤ 2 or D≤ 11,2mm	100 100	98-100 98-100	85-99 80-99	0-20	0-5
	D/d > 2 and D>11,2mm	100	98-100	90-99	0-15	0-5
Fine	D≤4mm and d=0	100	95-100	85-99	–	–
All-in	D≤45mm and d=0	100 100	98-100 98-100	90-99 85-99	–	–

3.2.3. Shape

Fig. 3.1 is the graphical presentation of aggregate shape

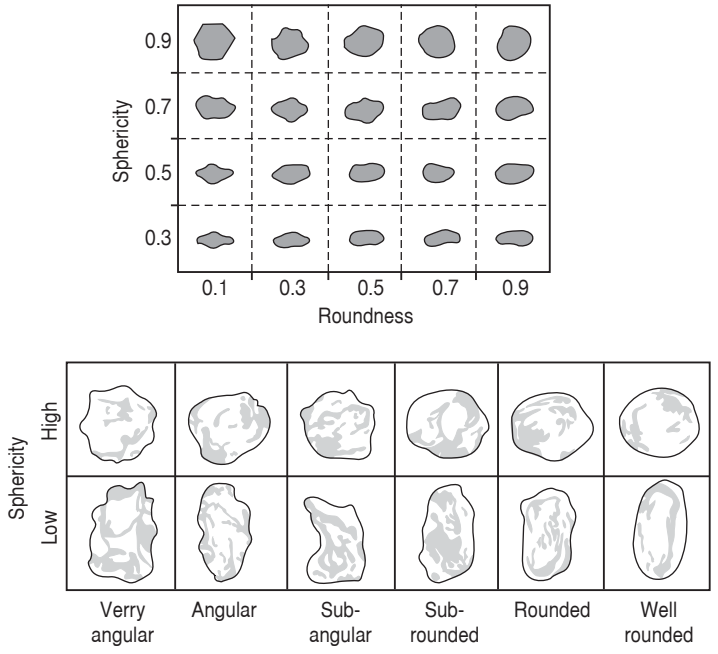

Fig. 3.1: Comparable chart for the assessment of particle shape

The EN 12620:2002 describes in detail the shape for each type of aggregate, (coarse fine)

3.3. Physical requirements

3.3.1. Density

The dry density of aggregate varies between 300 to more than 1700 kg/m^3. According to it, aggregates are classified as

ultra-lightweight (rarely)	<	300 kg/m^3
lightweight	≤	1000 kg/m^3
dense	≤	1700 kg/m^3
extra dense	>	1700 kg/m^3

The lightweight aggregate for concrete is covered by the EN 13055-1

Table 3.2. summarizes the grain density of various materials which are distinguished as synthetic (see definitions) or natural.

Table 3.2: Grain density of synthetic raw materials

Naturals/synthetic	Aggregate	Grain density (t/m^3)
Synthetic	Vermiculite	0.35-0.8
Synthetic	Perlite	0.1-0.2
Natural	Pumice	0.8-1.3
Natural	Scoria	0.95-1.45
Synthetic	Expanded Clay, Shale, Slate	0.4-1.9
Synthetic	Sinter stranded Expanded Clay	1.45-2.0
Synthetic	Expanded Slag (Huttenbims)	0.5-1.5
Synthetic	Fuel Ash	1.45-2.0
Natural	Natural pumice	0.4-0.7
Synthetic	Foamed lava	0.7-1.5
Synthetic	Foamed glass spheres	0.5-1.5
Natural	Diatomenous earth (Kieselgur)	0.2-0.4
Synthetic	Expanded Mica	0.1-0.3

3.3.2. Resistance to fragmentation

The resistance to fragmentation is a property for the coarse aggregate. The resistance shall be determined in terms of the Los Angeles coefficient.

3.3.3. Resistance to wear

It is also a property for coarse aggregate and it is determined by the micro-Deval coefficient (MDE), (EN 1097-1).

3.3.4. Polished Stone Value (PSV)

It is the measure of the resistance to polishing. It is used for concrete in highway engineering (EN 1097-8)

3.3.5. Aggregate Abrasion Value (AAV)

It describes the resistance to surface abrasion. It is a property mainly used in concrete roads (EN 1097-8 1999, annex A).

3.3.6. Water absorption

The water absorption is an important factor for the mix-design of the concrete (EN 1097-6). It can be said that the crushed aggregates present higher water absorption value in comparison to the natural ones.

Table 3.3 summarizes the water absorption of selected aggregate material.

Table 3.3: Range of water absorption of selected aggregate

Aggregate type	Basalt	Granite	Gabbro	Limestone
Range of water absorption (%)	0.1 – 1.7	0.2-1.6	0.2 – 5.7	0.2 – 75

3.3.7. Porosity

It is defined as the volume of voids in the total volume of the aggregate.

Table 3.4: Range of porosity (%)

Aggregate type	Basalt	Granite	Gabbro	Limestone*
Range of values	0.2 – 0.9	0.5 -1.6	0 – 2.0	0.2 – 3.0

** it depends on the origin of limestone. Marble or dolomite present values between 0.2 – 0.6*

3.4. Chemical requirements

The chemical composition of the main raw materials used as aggregates (natural rocks) is given in Table 3.5

Table 3.5: Chemical composition of natural rocks (main constituents)

Constituents	Natural rock						
	Basalt	Granite	Diorite	Gabbro	Andesit	Limestone	Periodite
SiO_2	45-48	74	58	49	54	5-7	40
MgO	21	–	–	7	–	1-7	49
CaO	6-10	–	4	10	7	42-55	–
CO_2	–	–	–	–	–	30-44	–
Al_2O_3	8-13	14	18	16	17	–	–
FeO/Fe_2O_3	10	2	6	15	4	–	7
K_2O	–	6	4	–	4	–	–
Na_2O	–	3	4	3	4,5	–	–

The chemical properties of aggregates is of great importance for the concrete quality. The following chemical constituents have to be tested, (EN 12620:2000).

3.4.1. Chlorides

The water soluble chloride content of aggregates shall be determined in accordance with EN 1744-1:1998 or shall be declared by the producer (on request).

3.4.2. Sulfur containing compounds

3.4.2.1. Acid – soluble sulfate

The range of values are given in Table 3.6

Table 3.6: Categories for maximum values of acid-soluble sulfate content

Aggregate	Acid soluble sulfate content (% by mass)	Category
Aggregates other than air-cooled Blastfurnace slag	≤ 0.2	$AS_{0,2}$
	≤ 0.8	$AS_{0,8}$
	≤ 0.8	$AS_{Declared}$
	no requirement	AS_{NR}
Air-cooled blast-furnace slag	≤ 1.0	$AS_{1,0}$
	> 1.0	
	no requirement	AS_{NR}

3.4.3. Total sulfur

When required the total sulfur shall not exceed (EN 1744-1: 1998)

a. 2% by mass for air-cooled blastfurnase slag aggregates
b. 1% by mass for aggregates other than air-cooled blastfurnace slag.

3.5. Mechanical (or engineering) properties

The engineering performance of aggregates can be described by the following properties namely:

- the compressive strength
- the Young's modulus of elasticity
- the crushing strength
- the impact strength

Table 3.7 summarizes the range of values of mechanical properties, for selected types of aggregate according to their petrological source.

Table 3.7: Mechanical properties of selected crushed aggregates.

Type of rock	Mechanical property			
	Compressive Strength (Mpa)	Modulus of Elasticity (MPa x 10^3)	Crushing Strength (MN.m/m^3)	Impact strength (blows)
Basalt	160-400	48-105	7,5-20	10-27
Granite	107-270	37-72	5-12	9-20
Diorite	80-345	75-120	6-20	10-15
Gabbro	80-345	75-120	6-20	10-15
Andesit	80-330	35-73	2-13	?
Peridotite	150-270	100-175	7-14	10-15
Limestone*	2-240	16-90	0,3-4	8-10
Quartz**	–	–	–	–

** the lowest values are for porous limestone*

*** it appears mainly in mixtures with other rocks, like Quartz–porphyrite, Quartz–dolerite, Quartz - diorite*

3.6. Synthetic aggregate

The discussion of such aggregate are beyond of the scope of the book. Additionally they are not included in the EN 12620:2002. In Table 3.2. it is given a number of synthetic or natural aggregates and its grain density.

3.7. Durability of aggregates

The term durability means the ability to resist weathering action, chemical attack (according to ACI 116R–85 Cement and Concrete Technology).

The term is mainly used for the concrete and less for the aggregate, all though the EN 12620 is referred to the aggregate durability.

The aggregate durability includes:

3.7.1. Freezing/thawing resistance of coarse aggregate

The frost resistance of aggregate is required for concrete used in an environment subject to freezing and thawing (EN 1367–1 or EN 1367–2).

3.7.2. Volume stability-drying shrinkage

The shrinkage of concrete, which is associated with the aggregate, has not to exceed 0.075% (EN 1367-4)

3.7.3. Alkali-silica reactivity

The reactivity is strongly depended on the place of use (EN 12620:2002-Annex G).