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BUILDING MATERIALS – THEORETICAL BACKGROUND

Lab 2 – GEOMETRICAL PROPERTIES OF AGGREGATES

Determination of particle shape – flakiness index and shape index

European Standard

PN-EN 933-3:2012 Tests for geometrical properties of aggregates. Part 3: Determination of particle shape. Flakiness index.

PN-EN 933-4:2008 Tests for geometrical properties of aggregates. Part 4: Determination of particle shape. Shape index.

PN-EN 12620+A1:2010 Aggregates for concrete.

PN-EN 13055:2016-07 Lightweight aggregates.

PN-EN 13139:2003 Aggregates for mortar.

Terms, definitions and requirements

Aggregate – granular material of natural, manufactures or recycled origin used in construction.

Natural aggregate – aggregate from mineral sources which has been subjected to nothing more than mechanical processing.

Lightweight aggregate – granular material of mineral origin having a particle density not exceeding 2000 kg/m^3 or a loose bulk density not exceeded 1200 kg/m^3. Lightweight aggregate can be natural, manufactured from natural sources, manufactured from by-products or recycled source materials and by-products aggregate.

All-in aggregate – aggregate consisting of a mixture of coarse and fine aggregates with D greater than 4 mm and d=0. It can be produced without separating into coarse and fine fractions or it can be produced by combining coarse and fine aggregates.

Manufactured aggregate – aggregate of mineral origin resulting from an industrial process involving thermal or other modification.

Recycled aggregate – aggregate resulting from the processing in inorganic or mineral previously used on construction.

By-product aggregate – aggregate of mineral origin from an industrial process which subsequently has been subject to nothing more than mechanical processing.

Filler aggregate – aggregate, most of which passes a 0,063 mm sieve, which can be added to construction materials to provide certain properties.

Aggregate size – designation of aggregate in terms of lower (d) and upper (D) sieve sizes expressed as d/D. This designation accepts the presence of some particles which are retained on the upper sieve (oversize) and some which pass the lower sieve (undersize).

Undersize – in accordance with EN 13055 (Lightweight aggregates) the quantity of the undersize passing the lower sieve (d) shall not exceed 15% by mass.

Oversize – in accordance with EN 13055 (Lightweight aggregates) the quantity of the oversize retained on the upper sieve (D) shall not exceed 10% by mass. When required, the sieve trough which 100% of the aggregate passes shall be declared.

Fine aggregate – designation given to the smaller aggregate sizes with D less than or equal to 4 mm and d=0. Fine aggregate can be produced from natural disintegration of rock or gravel and/or by the crushing of rock or gravel or processing of manufactured aggregate.

Coarse aggregate – designation given to the larger aggregate sizes with D greater than 4 mm and d greater than or equal to 2 mm.

Natural graded 0/8 mm aggregate – designation given to natural aggregate of glacial and/or fluvial origin with D less than or equal to 8 mm. This aggregate can also be produced by blending processed aggregate.

Batch – production quantity, a delivery quantity, a partial quantity (railway wagon-load, lorry-load, ship's cargo) or a stockpile produced at one time under conditions that are presumed uniform.

Fines – particle size fraction of an aggregate that passes the 0,062 mm sieve. Fines shall be considered non-harmful when any of the four following conditions apply:

a) the total fines content of the fine aggregates is less than 3% or other value according to the provisions valid in the place of use of the aggregate;

b) the sand equivalent value (SE) when tested in accordance with EN 933-8 exceeds a specified lower limit;

c) the methylene blue test (MB) when tested in accordance with EN 933-9 gives a value less than a particular specified limit;

d) equivalence of performance with known satisfactory aggregate is established or there is evidence of satisfactory use with no experience of problems.

Grading – particle size distribution expressed as the percentages by mass passing as a specified set of sieves. In this standard grading categories are used and expressed as G_nX/Y in which:

n = type of grading defined as followed: C – coarse, CA – coarse for asphalt only, G – grit (D<4 and d>1), F – fine, NG – natural graded, A – all-in;

X = lower limit passing D;

Y = upper limit passing d;

Category – level of a property of an aggregate expressed as a range of value or a limiting value.

Aggregate	Size	Percantage passing by mass					Category G
		2D	1,4D	D	d	d/2	
Coarse	D/d≤ 2 or D≤ 11,2mm	100 100	98 to 100 98 to 100	85 to 99 80 to 99	0 to 20 0 to 20	0 to 5 0 to 5	$G_C85/20$ $G_C80/20$
	D/d> 2 and D> 11,2 mm	100	98 to 100	90 to 99	0 to 15	0 to 5	$G_C90/15$
Fine	D≤ 4 mm and d=0	100	95 to 100	85 to 99	-	-	G_F85
Natural graded 0/8	D= 8 mm and d=0	100	98 to 100	90 to 99	-	-	$G_{NG}90$
All-in	D≤ 45 mm and d = 0	100 100	98 to 100 98 to 100	90 to 99 85 to 99	-	-	G_A90 G_A85

The fitness of aggregate for concrete based on its properties. Three group of properties can be distinguished: geometrical, physical and chemical.

Geometrical properties of aggregate:

- aggregate size – all aggregates shall be described in terms of aggregate size using the designations d/D, aggregate size shall have D/d not less than 1,4;
- grading – based on aggregate grading the aggregate category can be determined;
- shape of coarse aggregate – when required the shape of coarse aggregate shall be determined in terms of the flakiness index (FI) and shape index (SI); the relevant category of FI (SI) shall be declared;

Flakiness index	Category FI
≤ 15	FI_{15}
≤ 20	FI_{20}
≤ 35	FI_{35}
≤ 50	FI_{50}
> 50	$FI_{declared}$
No requirement	FI_{NR}

Shape index	Category SI
≤ 15	SI_{15}
≤ 20	SI_{20}
≤ 40	SI_{40}
≤ 55	SI_{55}
> 55	$SI_{declared}$
No requirement	SI_{NR}

- fines content

Aggregate	0,063 mm sieve Percentage passing by mass	Category f
Coarse aggregate	≤ 1,5	$f_{1,5}$
	≤ 4	f_4
	> 4	$f_{declared}$
	No requirement	f_{NR}
Natural graded 0/8 mm aggregate	≤ 3	f_3
	≤ 10	f_{10}
	≤ 16	f_{16}
	> 16	$f_{declared}$
	No requirement	f_{NR}
All-in aggregate	≤ 3	f_3
	≤ 11	f_{11}
	> 11	$f_{declared}$
	No requirement	f_{NR}
Fine aggregate	≤ 3	f_3
	≤ 10	f_{10}
	≤ 16	f_{16}
	≤ 22	f_{22}
	> 22	$f_{declared}$
	No requirement	f_{NR}

- shell content of coarse aggregate

Shell content %	Category SC
≤ 10	SC_{10}
> 10	$SI_{declared}$
No requirement	SC_{NR}

Physical properties of aggregate:

- resistance to fragmentation of coarse aggregate – aggregates usually have a higher strength than concrete, and for combinations of aggregates and cement with or without admixtures, which have satisfactory service record, the normal control strengths obtained from production concrete generally provide a sufficient guide to aggregate strength. However, if very high strength concrete is required the strength of the aggregate can need to be considered. A category LA_{15} or LA_{20} aggregate is generally only required in special cases (e.g. regions where studded tyres are in use or for special regional road finish requirements). A category LA_{30} aggregate can be required for

road pavements and floor finishes which are subject to impact stresses. Aggregate with Los Angeles coefficients exceeding 40 should be assessed on the basis experience of use.

Los Angeles coefficient	Category LA
≤ 15	LA_{15}
≤ 20	LA_{20}
≤ 25	LA_{25}
≤ 30	LA_{30}
≤ 35	LA_{35}
≤ 40	LA_{40}
≤ 50	LA_{50}
> 50	$LA_{deklarowane}$
No requirement	LA_{NR}

- resistance to wear of coarse aggregate;
- resistance to polishing and abrasion of coarse aggregate to be used for surface courses;
- water absorption;
- bulk density – the mass of many particles of the material divided by the total volume they occupy. The total volume includes particle volume, inter-particle void volume, and internal pore volume. For aggregates loose or tapped bulk density can be distinguished;
- particle density – the weight of an individual aggregate particles (without voids) per unit volume
- freeze/thaw resistance of coarse aggregate – the freezing and thawing resistance of concrete is related to the degree of water saturation, the constituent materials and their proportions used in concrete. The degree of air entrainment is a particularly important factor and it is therefore essential to assess the freezing and thawing resistance of concrete by testing samples of the concrete. The susceptibility of an aggregate to damage from freezing and thawing action depends primarily on climate, end use, petrographic type and on the size distribution of the pores within the aggregates particles. The severity of any damage is related to the frequency of freeze thaw cycles, the degrees of freezing and thawing and the degree of saturation of the aggregate particles. Aggregates are susceptible to damage from freezing and thawing action under partially or fully saturated environmental conditions or in high humidity situations. The risk of damage is significantly increased where the aggregate is exposed to seawater or to the action of de-icing salts. When the water absorption of the aggregate determined accordance with EN 1097-6 is not greater than 1% the aggregate can be considered resistant to freeze-thaw attack. However, many satisfactory aggregates have higher absorption values. For example some Jurassic limestones and sandstones frequently have absorption values in excess of 4% whilst

blastfurnace slags, Permian limestones, dolomites and Carboniferous sandstones frequently have absorption values in excess of 2% but these materials can still nave adequate freeze-thaw resistance. Freeze-thaw resistance can be determined in accordance with EN 1367-1 (F category) or EN 1367-2 (Magnesium sulfate test – MS category)

Freeze-thaw Percentage loss of mass	Category F
≤ 1	F_1
≤ 2	F_2
≤ 4	F_4
> 4	$F_{declared}$
No requirement	F_{NR}

Magnesium sulfate value Percentage loss of mass	Category MS
≤ 18	MS_{18}
≤ 25	MS_{25}
≤ 35	MS_{35}
> 35	$MS_{declared}$
No requirement	MS_{NR}

- volume stability (drying shrinkage) – where disruptive shrinkage cracking of concrete occurs due to the properties of the aggregate, the drying shrinkage associated with aggregates to be used in structural concrete shall, when required, not exceed 0,075%;
- alkali-silica reactivity.

Chemical properties of aggregates:
- the water-soluble chloride ion content;
- the acid-soluble sulfate content;
- the total sulfur content;
- constituents which alter the rate of setting and hardening of concrete;
- carbonate content of fine aggregate.