14. AGGREGATES

Aggregate is a collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium (such as water, bitumen, portland cement, lime, etc.) to form compound materials (such as asphalt concrete and portland cement concrete). Aggregate is also used for base and subbase courses for both flexible and rigid pavements.

Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often the byproduct of other manufacturing industries.

14.1 Definitions (EN 12320):

Aggregate -granular material used in construction. Aggregate may be natural, manufactured or re-cycled

natural aggregate - aggregate from mineral sources which has been subjected to nothing more than mechanical processing

all-in aggregate - aggregate consisting of a mixture of 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 of inorganic material previously used in construction

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 less than or equal to 4 mm

coarse aggregate - designation given to the larger aggregate sizes with D greater than or equal to 4 mm and d greater than or equal to 2 mm

fines - particle size fraction of an aggregate which passes the 0,063 mm sieve

grading - particle size distribution expressed as the percentages by mass passing a specified set of sieves

14.2 Methods for Sampling

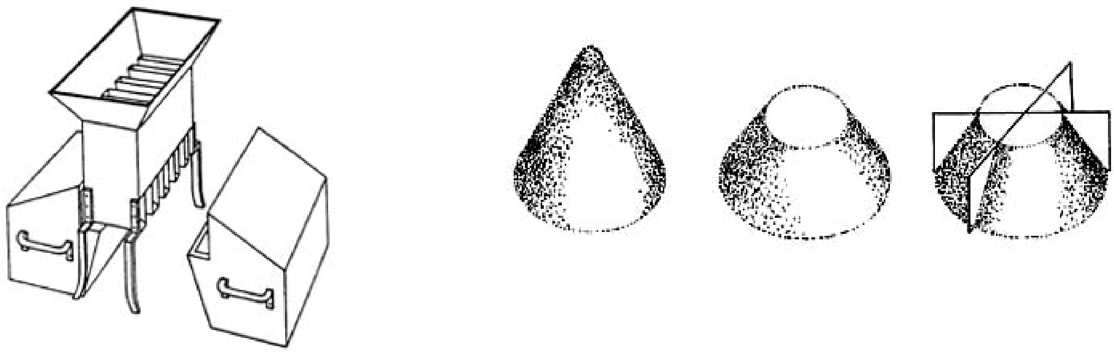
The objective of sampling is to obtain a bulk sample that is representative of the average properties of the batch, it is important to remember that information obtained from test samples is only as representative of the material as the samples on which the tests are undertaken.

Bulk samples can be reduced to sample sizes suitable for testing by two principal methods, by using a riffle box or by coning and quartering.

Riffle box: There are several sizes of riffle box to suit different sizes of aggregate, one of which is illustrated in Fig. 36. The box consists of an even number of chutes discharging in alternate directions. The material is passed through the riffle box, which divides it into two portions, one of which is discarded. The other portion is passed through again and the process repeated until the sample has been reduced to the required size. It should be noted that a riffle box can only be used on dry material.

Coning and quartering: This method of sample reduction involves shovelling the bulk sample to form a cone, the cone is turned over three times and then flattened. The sample is then divided into four quarters and two of the diagonally opposite quarters discarded.

Fig.:36 : a) Riffle box *b) quartering*



14.3 Determination of Particle Size Distribution – Sieving Method (EN 933-1)

In a sieve analysis, a sample of dry aggregate of known weight is separated through a series of sieves with progressively smaller openings. Once separated, the weight of particles retained on each sieve is measured and compared to the total sample weight. Particle size distribution is then expressed as a percent retained by weight on each sieve size. Results are usually expressed in tabular or graphical format.

The test consists of dividing up and separating, by means of series of sieves, a material into several particle size classification of decreasing sizes. The aperture sizes and the number of sieves are selected in accordance with the nature of the sample and the accuracy required.

The mass of the particles retained on the various sieves is related to the initial mass of the material. The cumulative percentages passing each sieve are reported in numerical form or in graphical form.

Individual retained – the mass or percentage retained on one sieve after test

Cumulative retained – sum of the mass or percentages retained on the sieve and on all coarser sieves.

Cumulative passing – sum of the mass or percentage passing the sieve (e.g. sum of the retained on all finer sieves and pan)

Test sieves – set of sieves with given aperture sizes and shape.

The basic series of sieves (according EN 933-2) :

0,063 mm;	0,125 mm;	0,250 mm;	0,500 mm;	1 mm;	2 mm;
4 mm;	8 mm;	16 mm;	31,5 mm;	63 mm;	125 mm

Sieves with aperture size of 4 mm and above are perforated plate with square holes and sieves below 4 mm are from woven wire.

Test portions - depends on maximum aggregate size and is specified in tab.32

Tab.:32

Aggregate size D (maximum) [mm]	Test portion mass (minimum) [kg]
63	40
32	10
16	2,6
8	0,6
≤ 4	0,2

14.3.1 Procedure

- Pour the washed and dried material (or directly the dry sample) into sieving column. The column comprises a number of sieves fitted together and arranged, from top to bottom, in order of decreasing aperture sizes with pan and lid.
- Shake the column, manually or mechanically, then remove the sieves one by one, and shake each sieve manually ensuring no material is lost.
- Transfer all the material, which passes each sieve onto the next sieve in the column before continuing the operation with that sieve.
- To avoid overloading sieves, the fraction retained at the end of the sieving operation on each sieve shall not exceeded:

$$\frac{A \times \sqrt{d}}{200}$$

where A is the area of the sieve [mm^2]
d is the aperture sieze of the sieve [mm]

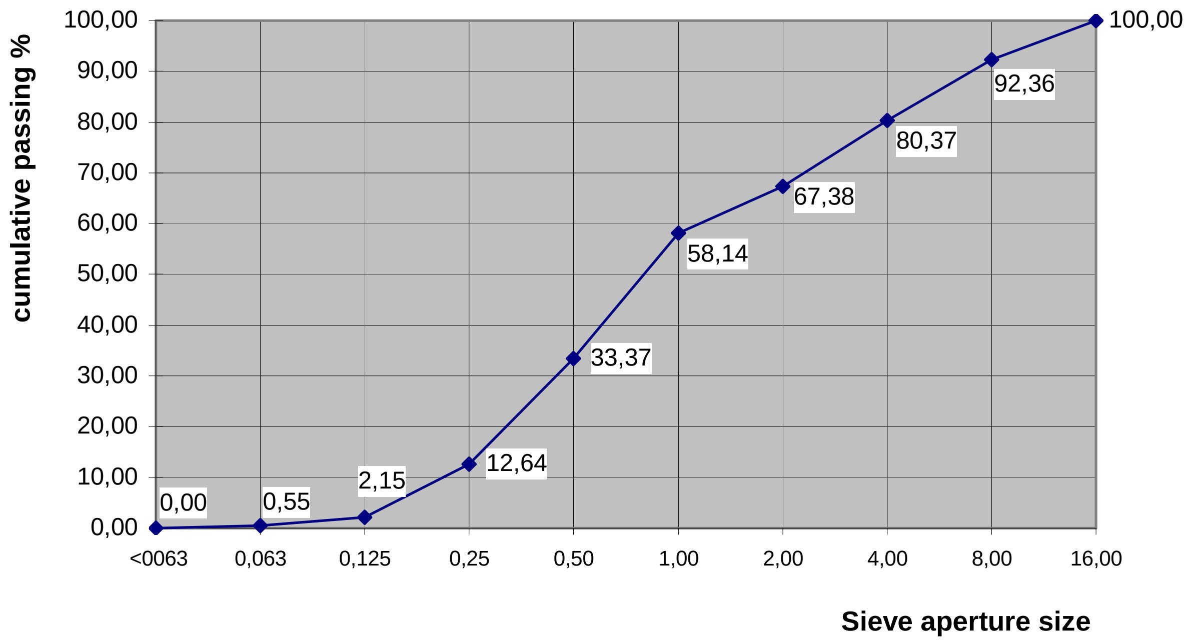
- Weigh the retained material for the sieve with the largest aperture and record its mass as R_1. Carry out the same operation for all the sieves……R_2, R_3, R_4….
- Record the various masses on test data sheet as mass of material retained
- Calculate the mass retained on each sieve as percentage of the original dry mass M
- Calculate the cumulative percentage of the original dry mass passing each sieve down
- If the sum of the masses retained $R_1 + R_2 +$ ….. differs more than 1% from the mass M, the test shall be repeated

14.3.2 Example

Tab.33

Sieve aperture size [mm]	Mass of material retained [g]	Percentage of materials retained [%]	Cumulative percentages passing [%]
16	0,0	0,00	100,00
8	153,0	7,64	92,36
4	240,0	11,99	80,37
2	260,0	12,99	67,38
1	185,0	9,24	58,14
0.5	496,0	24,78	33,37
0,25	415,0	20,73	12,64
0,125	210,0	10,49	2,15
0,063	32,0	1,60	0,55
<0,063 (pan)	11,0	0,55	0,00
sum	2002,0	100,00	
FM	3,46		

Tab.34 : **Particle size distribution curve**



14.3.3 Fineness Modulus

Fineness Modulus (FM) is used in determining the degree of uniformity of the aggregate gradation. It is an empirical number relating to the fineness of the aggregate. The higher the FM is, the coarser the aggregate is.

Fineness Modulus is defined as the sum of the cumulative percentages retained on specified sieves divided by 100.

$$F.M. = \frac{\sum(\text{cumulative percentage retained on specified sieves})}{100}$$

According EN 12620 is FM calculated on the following sieves: 4mm; 2 mm; 1 mm; 0,5 mm; 0,25 mm; 0,125 mm .

$$\text{FM} = \frac{\sum\{(\rangle 4) + (\rangle 2) + (\rangle 1) + (\rangle 0{,}5) + (\rangle 0{,}25) + (\rangle 0{,}125)\ \}}{100}$$

14.3.4 Design of Blended Aggregate Gradation.

Often, aggregates from more than one source or stockpile are used to obtain the final aggregate gradation. There is not necessary to make sieve analysis of the mixture to obtain desirable gradation. Trial blends of different gradations are usually calculated until an acceptable final mix design gradation is achieved.

Example:

Calculate the gradation of the mixture of aggregates A, B, C in proportions a : b : c.

Procedure:

- Make a sieve analysis of individual aggregates
- Calculate cumulative percentage passing for each aggregate :

Tab.35

Sieve aperture size [mm]	Cumulative percentages passing		
	Aggregate A	Aggregate B	Aggregate C
64	A_{64}	B_{64}	C_{64}
.	.	.	.
.	.	.	.
i	$\mathbf{A_i}$	$\mathbf{B_i}$	$\mathbf{C_i}$
.	.	.	.
.	.	.	.
Pan	A_p	B_p	C_p

- Calculate cumulative percentage passing for the blended aggregate according the formula:

$$S_i = \frac{a.A_i + b.B_i + c.C_i}{(a + b + c)}$$

where S_i is cumulative percentage passing on i- sieve for the mixture
A_i, B_i, C_i are cumulative percentage passing on i- sieve for the individual aggregates A, B, C
a, b, c are the mixing proportions

14.4 Cleanliness and Deleterious Materials.

Aggregates must be relatively clean. Vegetation, soft particles, clay lumps, excess dust and vegetable matter may affect performance by quickly degrading, which causes a loss of structural support and/or prevents binder-aggregate bonding.

14.4.1 Clay

Determination of clay, silt, and dust in fine and coarse aggregate can be tested by sedimentation method. The aggregate is carefully mixed with water in volumometric cylinder and then let to settle . The clay particles will form layer with different color and structure on the surface of aggregate.

14.4.2 Organic Impurities

Decaying vegetation may result in aggregates being contaminated with organic matter. This material may have a retarding effect on the setting of cementitious material and may result in lower strengths of the hardened material at all ages. Organic impurities can be tested by colorimetric test. Tested aggregate is mixed with sodium hydroxide (NaOH) or potassium hydroxide (KOH) to prepare colored solution. The color of solution is compared with color of standard solution, prepared according the standard. If the color of the test solution is darker than the standard solution, than aggregate have to be reject.

14.5 Determination of Particle Shape of Coarse Aggregates*.*

Particle shape and surface texture are important for proper compaction, deformation resistance and workability. Rounded particles create less particle-to-particle interlock than angular particles and thus provide better workability and easier compaction. Flat or elongated particles tend to impede compaction or break during compaction and thus, may decrease strength. Particle shape can be described by flakiness index or shape index (according EN 933-3, EN 933-4).

14.5.1 Flakiness Index

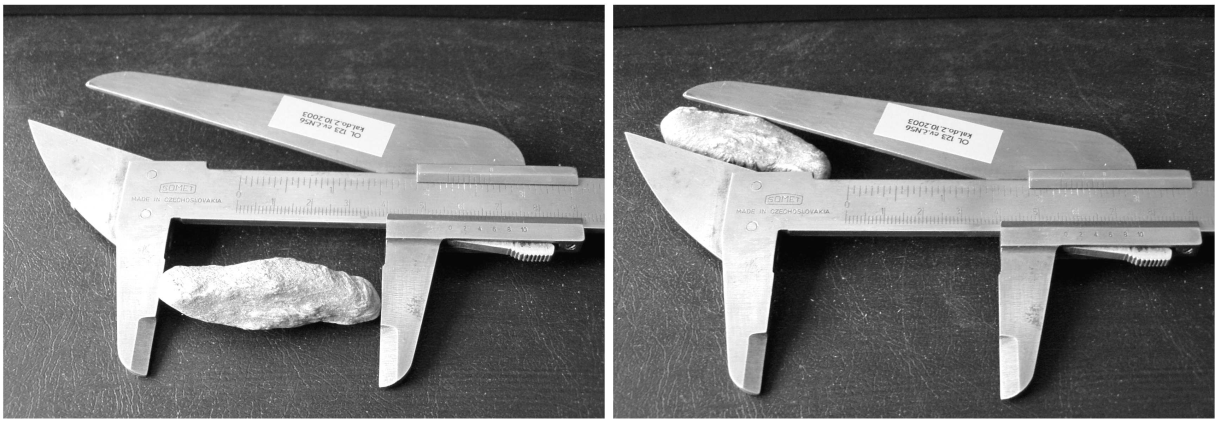
The flakiness index (FI) is calculated as the mass of particles that pass the bar sieves with parallel slots , expressed as a percentage of the mass of the test portion.

14.5.2 Shape Index

Shape index is determined only on the coarse aggregates. The principle of determination of shape index is to measure the thickness E and length L of each grain in a sample of several hundred stones and then to calculate the ratio L/E between the thickness and the length of each particle. If this ratio is higher than 3, than the particle is too long (non-cubic particle). EN 933-4 sets down the amount of measured grains to minimum 100 grains from each size of the coarse aggregate.

Shape index SI is defined as a ratio between the weight of particles with L/E > 3 and weight of all measured particles in percents.

Fig.:37 Shape index caliper



Vocabulary

aggregate :	*kamenivo :*
fine	*jemné*
coarse	*hrubé*
crusted	*drcené*
natural	*přírodní*
manufactured	*umělé*
lightweight	*lehké*
distribution grade	*čára zrnitosti*
fineness modulus	*modul jemnosti*
fines	*jemné částice*
flakiness index	*index plochosti*
grading	*zrnitost*
passing	*propad*
retained	*zbytek na sitě*
individual	*dílčí*
cumulative	*celkový*
shape index	*tvarový index*
sieve	*síto*
sieve analysis	*prosévací zkouška*