Lecture 3: Grading, Fineness Modulus, Blending of Aggregates

Question: What is aggregate grading? Why is grading important for any aggregate construction?

Grading; Fineness Modulus

Grading: The distribution of particle sizes (d) within any batch of aggregate is called grading or gradation.

- Expressed as a cumulative% of particles that are smaller than each of a series of sieve openings
- The percentages are customarily presented in graphical form known as grading curve or sieve curve
- Theoretically, $y = f(d)$
- Grading types
  - Continuous
  - Well graded [$p = (d/D)^{0.5} \times 100$]
  - Skip or gap graded
  - Uniform
  - Single graded

Grading of Aggregates is done by sieving the material by designated sieves.

Types of gradation

Dense gradation

A dense gradation refers to a sample that is approximately of equal amounts of various sizes of aggregate. By having a dense gradation, most of the air voids between the material are filled with particles. A dense gradation will result in an even curve on the gradation graph.

Narrow gradation

Also known as uniform gradation, a narrow gradation is a sample that has aggregate of approximately the same size. The curve on the gradation graph is very steep, and occupies a small range of the aggregate.

Gap gradation

A gap gradation refers to a sample with very little aggregate in the medium size range. This results in only coarse and fine aggregate. The curve is horizontal in the medium size range on the gradation graph.

Open gradation

An open gradation refers an aggregate sample with very little fine aggregate particles. This results in many air voids, because there are no fine particles to fill them. On the gradation graph, it appears as a curve that is horizontal in the small size range.

Rich gradation

A rich gradation refers to a sample of aggregate with a high proportion of particles of small sizes.

SIEVES:

A **sieve**, or **sifter**, is a device for separating wanted elements from unwanted material or for characterizing the particle size distribution of a sample, typically using a woven screen such as a mesh or net or metal.[1] The word "sift" derives from "sieve". In cooking, a sifter is used to separate and break up clumps in dry ingredients such as flour, as well as to aerate and combine them. A **strainer** is a form of sieve used to separate solids from liquid.

Table 4.3 Sieve designations

British standards (millimeters)	*American standards*	*Nominal openings (inches)*
75	3 in	3
37.5	1 ½	1.5
20	¾	0.75
12.5	½	0.5
6.3	¼	0.25
4.75	No 4	0.187
2.36	No 8	0.0937
1.18	No 16	0.0469
0.600	No 30	0.0234
0.300	No 50	0.0117
0.150	No 100	0.0059
0.075	No 200	0.0029

Table 4.4 The weight of reduced samples for sieving.

Nominal Size of Material (mm)	Minimum weight of sample to be taken for sieving (kg)
63	50
50	35
40	15
28	5
20	2
14	1
10	0.5
6 or 5 or 3	0.2
Less than 3	0.1

Sieve analysis

A **sieve analysis** (or **gradation test**) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called *gradation*) of a granular material.

The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.



Sieves used for gradation test.



A mechanical shaker used for sieve analysis.

Gradation Test:

A gradation test is performed on a sample of aggregate in a laboratory. A typical sieve analysis involves a nested column of sieves with wire mesh cloth (screen). See the separate Mesh (scale) page for details of sieve sizing.

A representative weighed sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. At the base is a round pan, called the receiver.

The column is typically placed in a mechanical shaker. The shaker shakes the column, usually for some fixed amount of time. After the shaking is complete the material on each sieve is weighed. The weight of the sample of each sieve is then divided by the total weight to give a percentage retained on each sieve.

The size of the average particles on each sieve then being analysis to get the cut-point or specific size range captured on screen.

The results of this test are used to describe the properties of the aggregate and to see if it is appropriate for various civil engineering purposes such as selecting the appropriate aggregate for concrete mixes and asphalt mixes as well as sizing of water production well screens.

The results of this test are provided in graphical form to identify the type of gradation of the aggregate. The complete procedure for this test is outlined in the American Society for Testing and Materials (ASTM) C 136 and the American Association and State Highway and Transportation Officials (AASHTO) T 27

A suitable sieve size for the aggregate should be selected and placed in order of decreasing size, from top to bottom, in a mechanical sieve shaker. A pan should be placed underneath the nest of sieves to collect the aggregate that passes through the smallest. The entire nest is then agitated, and the material whose diameter is smaller than the mesh opening pass through the sieves. After the aggregate reaches the pan, the amount of material retained in each sieve is then weighed.

Preparation

In order to perform the test, a sample of the aggregate must be obtained from the source. To prepare the sample, the aggregate should be mixed thoroughly and be reduced to a suitable size for testing. The total weight of the sample is also required.

Results

The results are presented in a graph of percent passing versus the sieve size. On the graph the sieve size scale is logarithmic. To find the percent of aggregate passing through each sieve, first find the percent retained in each sieve. To do so, the following equation is used,

$$\%\text{Retained} = \frac{W_{Sieve}}{W_{Total}} \times 100\%$$

where W_{Sieve} is the weight of aggregate in the sieve and W_{Total} is the total weight of the aggregate. The next step is to find the cumulative percent of aggregate retained in each sieve. To do so, add up the total amount of aggregate that is retained in each sieve and the amount in the previous sieves. The cumulative percent passing of the aggregate is found by subtracting the percent retained from 100%.

%Cumulative Passing = 100% - %Cumulative Retained.

The values are then plotted on a graph with cumulative percent passing on the y axis and logarithmic sieve size on the x axis.

Fineness Modulus (F.M)

F.M. is a numerical characteristics of aggregates, especially for fine aggregates.

The **Fineness modulus** (FM) is an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing the sum by 100. The sieve sizes are 150 μm, 300 μm, 600 μm, 1.18 mm, 2.36 mm, 4.75 mm, 9.5 mm, 19.0 mm, 38.1 mm and larger increasing ..

Fineness Modulus,

- Represents an average particle size representing coarseness or fineness
- Proportional to the logarithmic avg. particle size of grading
- Fundamental parameter of the particle size distribution

Q. Find the FM of the sand with the following sieve analysis results. Draw grading curve

Sieve No.	Sieve size, mm	Material retained (gm)	Percent of material retained	Total percent retained	
#4	4.75	0	0	**0**	
#8	2.36	10	10	**10**	
#16	1.18	25	25	**35**	
#30	0.60	30	30	**65**	
#50	0.30	20	20	**85**	
#100	0.15	5	5	**90**	
#200	0.075	5	5	95	
PAN	-	5	5	100	

Question: What is the difference between grading and fineness modulus?

Therefore, fineness modulus of aggregate = (cumulative % retained) / 100 = (285/100) = **2.85**

Fineness modulus of fine aggregate is 2.85. It means the average value of aggregate is in between the 2nd sieve and 3rd sieve. It means the average aggregate size is in between 0.3mm to 0.6mm as shown in below figure.

Limits of Fineness Modulus:

Fineness modulus of fine aggregate varies from 2.0 to 3.5mm. Fine aggregate having fineness modulus more than 3.2 should not considered as fine aggregate. Various values of fineness modulus for different sands are detailed below.

Type of sand	**Fineness modulus range (depends on different organization)**
Fine sand	1.2 – 2.0
Medium sand	2.0 – 2.9
Coarse sand	2.9 – 3.5

Blending of Aggregates:

- What is it?
- Why is needed?
- **How is done? (mix design methods)**

Blending of Aggregates:

- Numerical method
–Trial and error
- Graphical method

Basic formula of Blending of Aggregates

· P = Aa + Bb + Cc + ….

–Where:
• P = % of material passing a given sieve for the blended aggregates (Specified Grading)

• A, B, C, …= % material passing a given sieve for each aggregate

• a, b, c, …. = Proportions (decimal fractions) of aggregates to be used in blend