CONCRETE TECHNOLOGY MODULE SEMESTER 1 – LECTURE 8

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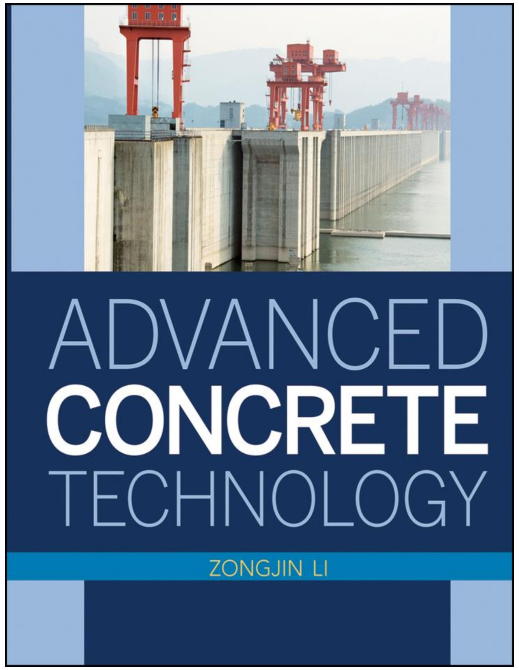
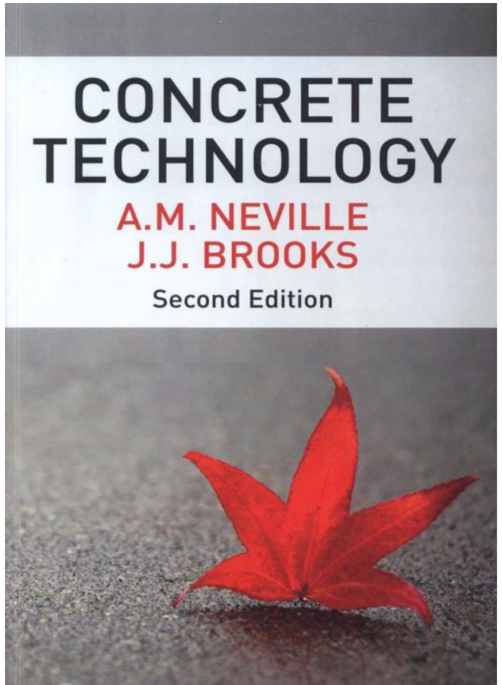
SEMESTER 1 OUTLINE

Item	Subject	Item	
1	**Introduction: Cement and Aggregate**		
2	**Manufacturing of concrete** - Mixing - Transportation - Placing and compaction - Curing - Finishing	**4**	**Strength of Concrete** - Compressive strength - Tensile strength - Modulus of rupture - Bond strength with steel reinforcement - Factors affecting concrete strength - Factor affecting concrete test
3	**Properties of Fresh Concrete** - Workability and Consistency - Segregation and Bleeding - Pressure on form work - Stripping of form	**5**	**Deformation of Concrete** - Creep - Shrinkage - Modulus of elasticity and Poisson's ratio

REFERENCES

- Concrete technology by Dr. Moaid Nory
- Advanced concrete technology by Zongjin Li
- Concrete Technology -2dn Ed by A.M. NEVILLE





LECTURE CONTENTS

1. **2.1 AGGREGATES**
2. 2.1.3 Properties of aggregates
   - ✓ 2.1.3.1 Moisture conditions
   - ✓ 2.1.3.2 Moisture content (MC) calculations
   - ✓ 2.1.3.3 Density and specific gravity
   - ✓ Example Problems

2.1.3.4 Unit weight (UW)

The unit weight is defined as the weight per unit bulk volume for bulk aggregates. In addition to the pores inside each single aggregate, the bulk volume also includes the space among the particles. According to the weight measured at different conditions, the unit weight can be divided into UW(SSD) and UW(OD):

$$\mathrm{UW\ (SSD)} = \frac{W_{\mathrm{SSD}}}{V_{\mathrm{solid}} + V_{\mathrm{pores}} + V_{\mathrm{spacing}}}$$

$$\text{and} \quad \mathrm{UW\ (OD)} = \frac{W_{\mathrm{OD}}}{V_{\mathrm{solid}} + V_{\mathrm{pores}} + V_{\mathrm{spacing}}}$$

The percentage of spacing (voids) among the aggregates can be calculated as:

$$\text{Spacing (void)} = \frac{\mathrm{BD} - \mathrm{UW}}{\mathrm{BD}} \times 100\%$$

2.1.3.5 Measurement of moisture content

Once the $\mathbf{BSG_{SSD}}$ is obtained for a type of aggregate, the moisture content of the aggregate under different moisture conditions can be conveniently determined using the following equation:

$$\mathrm{MC\ (SSD)} = \frac{W_{\mathrm{stock}} - \dfrac{W_{\mathrm{water}} \times \mathrm{BSG_{SSD}}}{\mathrm{BSG_{SSD}} - 1}}{\dfrac{W_{\mathrm{water}} \times \mathrm{BSG_{SSD}}}{\mathrm{BSG_{SSD}} - 1}}$$

where $\boldsymbol{W_{stock}}$ is the weight of the sample under the stockpile condition, and $\boldsymbol{W_{water}}$ is the short form of $\boldsymbol{W_{SSD}}$ in water.

If AC is known for the aggregate, MC(SSD) can also be calculated using the absorption capability of aggregates as

$$\mathrm{MC\ (SSD)} = \frac{W_{\mathrm{stock}} - W_{\mathrm{OD}}(1 + \mathrm{AC})}{W_{\mathrm{OD}}(1 + \mathrm{AC})}$$

2.1.4 Grading aggregates

2.1.4.1 Grading and size distribution

The particle size distribution of aggregates is called grading.

Grading determines the paste requirement for a workable concrete since the amount of voids among aggregate particles requires the same amount of cement paste to fill out in the concrete mixture.

To obtain a grading curve for an aggregate, sieve analysis has to be conducted. The commonly used sieve designation is listed in Table 2-1.

As shown in Figure 2-5, five size distributions are generally recognized: **dense, gap graded, well-graded, uniform graded, and open graded.**

The dense and well-graded types are essentially the wide size ranges with smooth distribution. They are the desired grading for making concrete. **The dense graded is for coarse aggregate and well-graded for fine aggregate.**

Gap grading is a kind of grading that **lacks one or more intermediate size;** hence, a nearly flat horizontal region appears in the grading curve.

For uniform grading, only a **few sizes dominate the bulk materials,** and the **grading curve falls almost vertically** at the dominating size.

Open grading is defined as being under compact conditions, the voids among the aggregate are still relatively large. In open grading, usually the smaller size of aggregate dominates the bulk and can be easily disturbed by a small cavity.

Open-grade material is not suitable to be used for subgrade construction of a road.

Table 2-1 Commonly used sieve designation and the corresponding opening size

Sieve Designation	Nominal Size of Sieve Opening
3 in.	75 mm
1.5 in.	37.5 mm
3/4 in.	19 mm
3/8 in.	9.5 mm
No. 4	4.75 mm
No. 8	2.36 mm
No. 16	1.18 mm
No. 30	600 μm
No. 50	300 μm
No. 100	150 μm
No. 200	75 μm

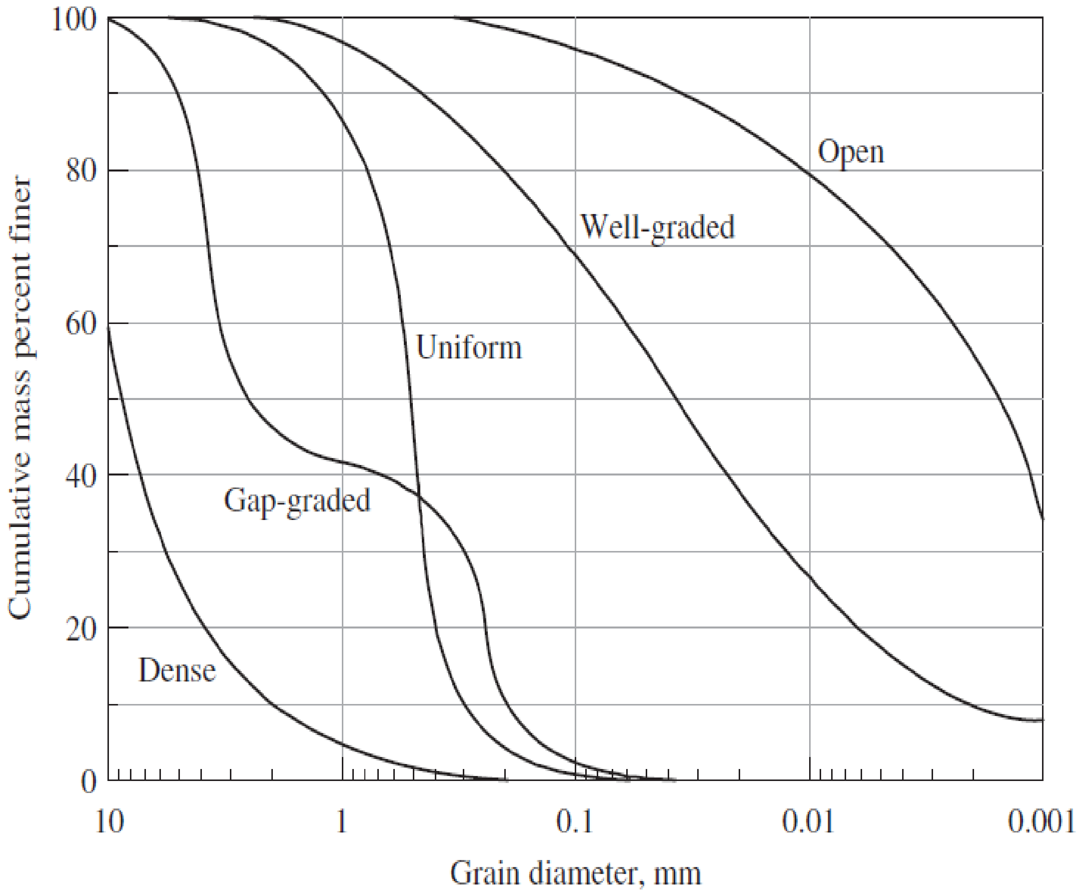


Figure 2-5 Five types of aggregate gradation

2.1.4.2 Fineness modulus

To characterize the overall *coarseness* or *fineness* of an aggregate, the concept of a fineness modulus is developed. The fineness modulus is defined as

$$\text{fineness modulus} = \frac{\sum (\text{cummulative retained percentage})}{100}$$

The fineness modulus for fine aggregate should lie between 2.3 and 3.1.

A small number indicates a fine grading, whereas a large number indicates a coarse material.

The fineness modulus can be used to check the constancy of grading when relatively small changes are expected, **but it should not be used to compare the gradings of aggregates from two different sources.**

The fineness modulus of fine aggregates is required for the mix proportion **since sand gradation has the largest effect on workability.**

A fine sand (low fineness modulus) has much higher paste requirements for good workability.

2.1.4.3 Fineness modulus for blending of aggregates

Blending of aggregates is undertaken for a variety of purposes, such as to remedy deficiencies in grading. A desired value of the fineness modulus can be calculated if the characteristics of the component aggregate are known.

If two aggregates, designated A and B, are mixed together, having a fineness modulus of FMA and FMB, respectively, the resultant blend will have the following fineness modulus:

$$FM_{blend} = FM_A \times \frac{P_A}{100} + FM_B \times \frac{P_B}{100} \qquad (2\text{-}15)$$

where P_A and P_B are the percentages, by weight, of aggregates A and B in the blend.

2.1.5 Shape and texture of aggregates

2.1.5.1 Shape of aggregates

The aggregate shape affects the workability of concrete due to the differences in surface area caused by different shapes. Sufficient paste is required to coat the aggregate to provide lubrication. The typical shapes of aggregates are shown in Figure 2-6.

Among these, spherical, cubical, and irregular shapes are good for application in concrete because they can benefit the strength.

Flat, needle-shaped, and prismatic aggregates are weak in load-carrying ability and easily broken. Besides, the surface-to-volume ratio of a spherical aggregate is the smallest.

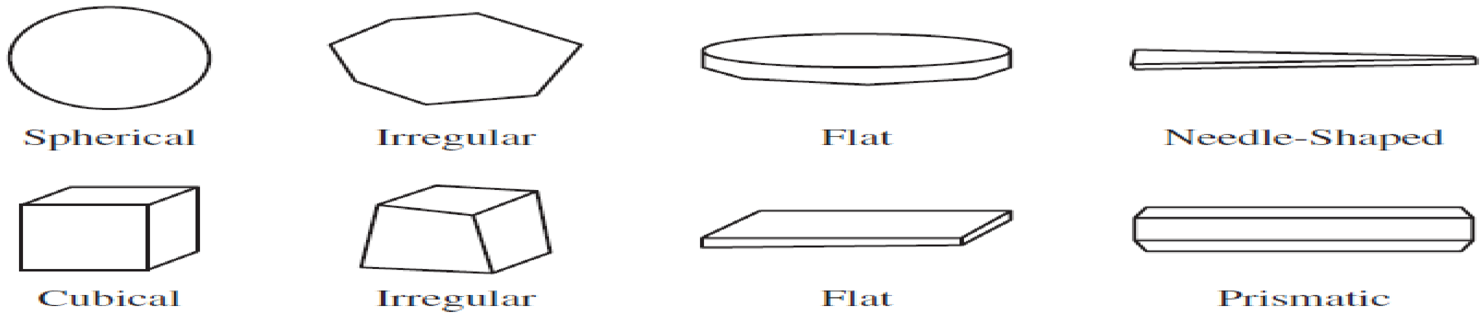


Figure 2-6 Different basic shapes of aggregates

2.1.5.2 Texture of aggregates

The surface texture of aggregates can be classified in 6 groups: glassy, smooth, granular, rough, crystalline, and honeycombed. The surface texture of aggregates has significant influence on the fluidity of fresh concrete and the bond between aggregate and cement paste of hardened concrete.

According to experimental statistics, the relative effects of the shape and surface texture of aggregates on concrete strength are summarized in Table 2-2 (Waddall and Dobrowolski, 1993).

Table 2-2 Effects of aggregate shape and surface texture on concrete strength

	Relative Effect (%) of	
Affected Strength	**Shape**	**Surface Texture**
Compressive	22	44
Flexural	31	26

Problems

1. A sample of sand weighs 490 g in stock and 475 g in OD condition, respectively. If absorption capability of the sand is 1.1%, calculate MC(SSD) for the sand.

Solution:

$$\mathrm{MC\ (SSD)} = \frac{W_{\mathrm{stock}} - W_{\mathrm{OD}}(1 + \mathrm{AC})}{W_{\mathrm{OD}}(1 + \mathrm{AC})}$$

$MC_{(SSD)}$=490-475(1+1.1%)/475(1+1.1%) = **+** 0.0204 = 2.04%

The sand will Give water.

2. The sieve results of a batch of aggregate are as follows: retained on 1.5” sieve: 0.3 kg; retained on 1” sieve: 1.2 kg; retained on 0.75” sieve: 7.6 kg; retained on 0.5” sieve: 6.2 kg; retained on 3/8” sieve: 4.2 kg; retained on No. 4 sieve: 0.8 kg; retained on No. 8 sieve: 0.1 kg. Calculate the fineness modulus for the aggregate. Is it coarse or fine aggregate?

Solution: from the table below:

$$\text{fineness modulus} = \frac{\sum \text{(cummulative retained percentage)}}{100} = 423.53/100 = 4.24\%$$

(Coarse aggregate)

Sieve No.	Amount Retained	% Retained	Cummulitive % Retained
1.5"	0.3	1.47	1.47
1"	1.2	5.88	7.35
0.75"	7.6	37.25	44.61
0.5"	6.2	30.39	75.00
3/8"	4.2	20.59	95.59
No. 4	0.8	3.92	99.51
No. 8	0.1	0.49	100.00
Sum	20.4	100.00	423.53

2.1 Using the sieve results of a batch of sand and gravel shown in the table below, calculate the fineness modulus for the Sand and Gravel **blend** if the ***P*** sand is 40% and ***P*** Gravel is 60%.

Sieve No.	% Retained **(Sand)**	Sieve No.	% Retained **(Gravel)**
3/8"	0	1.5"	2
No. 4	0	1"	6
No. 8	3	0.75"	29
No. 16	15	0.5"	35
No. 30	39	3/8"	26.5
No. 50	30	No. 4	1
No. 100	12	No. 8	0.5
No. 200	1	No. 16	0

Solution

% Retained	% Retained	Cum % Retained Sand	Cum % Retained Gravel
(Sand)	**(Gravel)**	***P sand*** **= 40%**	***P gravel*** **= 60%**
0	2	0	2
0	6	0	8
3	29	3	37
15	35	18	72
39	26.5	57	98.5
30	1	87	99.5
12	0.5	99	100
1	0	100	100
Sum Cum % Retained		364	517
FM Sand = Sum Cum% Retained Sand/100		3.64	
FM Gravel= Sum Cum% Retained Sand/100		5.17	
FM Blend= FM Sand * ***P*** **sand + FM Gravel *** ***P*** **gravel**		4.55	

3. A 1000g sample of coarse aggregate in the SSD condition in air weighed 633g when immersed in water.

A) Calculate the BSG of the aggregate.

B) If some sample from same batch of aggregate after being exposed to air dry condition for some time weighed 978g in air and weighed 630 g after they immersed in water for 2 hours, calculate the moisture content, MC(SSD), of the air dried aggregate at that time.

Solution: A) $W_{SSD\ in\ air} = 1000g,\ W_{SSD\ in\ water} = 633g$

$$BSG_{SSD} = \frac{W_{SSD\ in\ air}}{W_{displacement}} = \frac{W_{SSD\ in\ air}}{W_{SSD\ in\ air} - W_{SSD\ in\ water}}$$

=1000/(1000-633)= 2.72

B) $$MC\ (SSD) = \frac{W_{stock} - \frac{W_{water} \times BSG_{SSD}}{BSG_{SSD} - 1}}{\frac{W_{water} \times BSG_{SSD}}{BSG_{SSD} - 1}}$$

=(978 – (630x2.72)/(2.72-1))/((630x2.72)/(2.72-1))

= - 1.83

4. A mixture of 1800 g of gravel (OD) with an absorption of 1.3% and 1200 g of sand (Stock) with a surface moisture of 2.51% was added into a concrete mix. Compute the adjustment of water that must be made to maintain a constant w/c ratio.

Solution 1:

Gravel

W = 1800g, AC = 1.3%

The amount of water that can be absorbed by gravel = **1800x1.3/100= 23.4 g**

Sand

W = 1200g, $MC_{(OD)}$ -AC= 2.51%

The amount of water that can be added to the mix by the sand = **1200x2.51/100= 30.12 g**

Adjustment amount = **30.12-23.4 = 6.72g** need to be subtracted from the designed amount of water

4. A mixture of 1400 g of gravel (OD) with an absorption of 1.5% and 1000 g of sand with a moisture Content (SSD) of 2.6% was added into a concrete mix. Compute the adjustment of water that must be made to maintain a constant w/c ratio.

Solution 2:

Gravel

W = 1400g, AC = 1.5%

$$AC = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\%$$

➡ **0.015 = W_{SSD} – 1400/1400**

➡ **W_{SSD} = 1421g**

The amount of water that can be absorbed by the gravel = **1421-1400= 21 g**

Sand

W = 1200g, MC_{SSD}= 2.6%

$$MC\,(SSD) = \frac{W_{stock} - W_{SSD}}{W_{SSD}} \times 100\%$$

➡ **0.026 = 1000 – W_{SSD}/W_{SSD}**

➡ **W_{SSD} = 974.66g**

The amount of water that can be added to the mix by the sand = **1000-974.66= 25.34 g**

Adjustment amount = **25.34-21 = 4.34g** need to be subtracted from the designed amount of water

5. The material ratio for concrete mix is 1:1.5:2 (C: Sand: Coarse Aggregate by weight). The BSG for cement is 3.15, for sand is 2.5 and for coarse aggregate is 2.7. Air content is 4.8%. The gel/space ratio is 0.72. Calculate the water cement ratio for α=0.8?

Solution:

X= 0.72, α=0.8

$$X = \frac{\text{volume of gel (including gel pores)}}{\text{volume of gel} + \text{volume of capillary pores}} = \frac{0.68\alpha}{0.32\alpha + w/c}$$

w/c = 0.68α/ x – 0.32α = 0.4995 = ~0.5


Thank you for
your
attention!