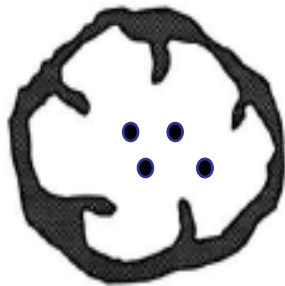


Specific gravity and density of aggregate

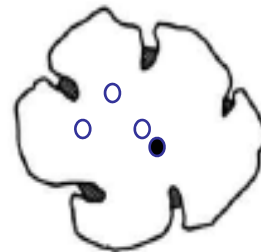
- Specific gravity?
- Four moisture conditions of aggregate
 - Damp or Wet or moist (more than 100%)
 - Saturated surface dry (SSD) (100%)
 - Air-dry (less than 100%)
 - Oven-dry or bone dry (0%)



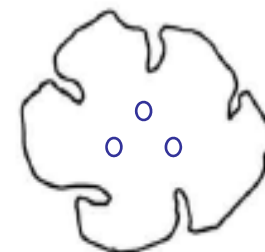
Damp or wet



Saturated
Surface-dry



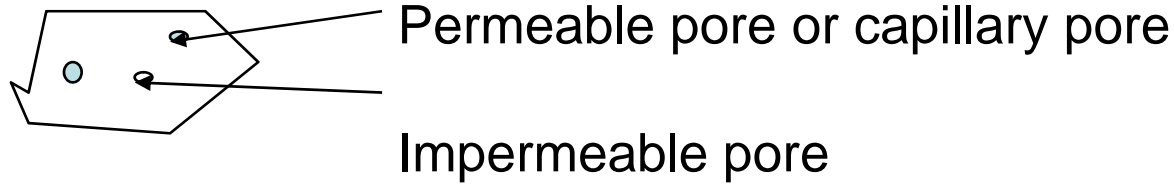
Air-dry



Oven-dry

Fig. 5—Moisture condition of aggregates.

Specific gravity of aggregate



Capillary pores are interconnected and extended upto surface

- Absolute specific gravity
 - All pores are excluded from V
- Apparent specific gravity
 - Impermeable pores are included
 - Permeable pores are excluded from V
- Bulk specific gravity (OD weight is used)
 - All pores are included in V
- Bulk specific gravity SSD (SSD weight is used)

Bulk density

- Loose or compacted (rodding, jiggling)
- Batching by volume
- Bulk density = Mass/volume
 - (volume includes all kind of voids; permeable, impermeable, inter-particle)
- Factors affecting the bulk density
 - Moisture content, FA+CA
 - Grading, specific gravity, surface texture, shape and angularity
- Rodded bulk density = 1200 – 1760 kg/m³
 - (75 – 110 lb/ft³)

$$\text{bulk density} = \frac{\text{mass}}{\text{bulk volume}}$$

- Bulk density = Unit weight

Absorption Capacity and Moisture Content

- Total Moisture Content
- Surface Moisture = Free Moisture
- Absorption Capacity
- Total Moisture = Absorbed water + Surface water

$$\text{Absorption Capacity} = \frac{SSD - OD}{OD} \times 100$$

Examples explaining use of specific gravity and moisture content

Example 9: *Calculation of volume of a batch of concrete*

The following masses of materials are used to produce a batch of concrete. What is the volume of the concrete if the air content is 3%? (Air content is the volume of air expressed as a percentage of the concrete volume.)

In SI units:

<u>Material</u>	<u>Mass, kg</u>	<u>Specific gravity</u>
Cement	279	3.15
Water	166	1.00
SSD fine aggregate	760	2.60 (bulk SSD)
SSD coarse aggregate	1044	2.63 (bulk SSD)

Examples explaining use of specific gravity and moisture content

Material	Mass, kg	Specific gravity	Absolute density, kg/m ³	Absolute volume, m ³
Cement	279	3.15	3150	0.089
Water	166	1.00	1000	0.166
SSD fine aggregate	760	2.60	2600	0.292
SSD coarse aggregate	1044	2.63	2630	0.397
				Total absolute volume = 0.944 m ³

$$V_c = 0.944 + V_a$$

By definition of air content, $V_a = 0.03V_c$

$$\text{so } V_c = 0.944 + 0.03V_c.$$

Example 12: *Calculation of mixing water and water-cementitious material ratio*

In SI units:

What is the mixing water content and water-cementitious material ratio for the following 1-m³ batch of concrete?

<u>Material</u>	<u>Batch mass, kg</u>
Cement	267
Fly ash	89
Wet sand (absorption 1.0%, total moisture content, 6.1%)	943
Wet gravel (absorption 0.7%, total moisture content 1.3%)	1092
Water (added through batching system)	146

For sand:

Total moisture content =

$$\frac{943 - W_{OD}}{W_{OD}} \times 100 = 6.1 \%$$

$$943 - W_{OD} = 0.061 W_{OD}$$

$$W_{OD} = \frac{943}{1.061} = 889 \text{ kg}$$

Surface moisture content of sand = $6.1 - 1.0 = 5.1\%$

Surface moisture content of gravel = $1.3 - 0.7 = 0.6\%$

Free moisture on sand = $0.051 \times 889 = 45.3 \text{ kg}$

Free moisture on gravel = $0.006 \times 1078 = 6.5 \text{ kg}$

Total free moisture on aggregate = $45.3 + 6.5 = 51.8 \text{ kg}$

Mixing water = $146 + 51.8 = 197.8 \text{ kg}$
or 198 kg

Water-cementitious material ratio = $198 / (267 + 89) = 0.55$

Example 13: *Adjustment of batch masses for aggregate moisture*

In SI units:

<u>Material</u>	<u>Batch mass, kg</u>
Cement	267
Fly ash	89
Oven-dry fine aggregate (absorption 1.0%)	770
Oven-dry coarse aggregate (absorption 2.0%)	1127
Total mixing water	190

However, at the batch plant, the stockpiled fine aggregate has a total moisture content of 6.0%, and the coarse aggregate has a total moisture content of 3.0%. Compute the adjusted batch masses.

$$\text{Mass of fine aggregate} = (0.06 \times 770) + 770 = 816 \text{ kg}$$

$$\text{Mass of coarse aggregate} = (0.03 \times 1127) + 1127 = 1161 \text{ kg}$$

Free moisture content = total moisture content – absorption

$$\text{Fine aggregate} = 6.0 - 1.0 = 5.0\% \text{ free moisture}$$

$$\text{Coarse aggregate} = 3.0 - 2.0 = 1.0\% \text{ free moisture}$$

Fine aggregate

$$\text{free moisture content} = 0.05 \times 770 = 38.5 \text{ kg}$$

Coarse aggregate

$$\text{free moisture content} = 0.01 \times 1127 = 11.3 \text{ kg}$$

Total aggregate

$$\text{free moisture content} = 38.5 + 11.3 = 49.8 \text{ kg}$$

Water to be added

$$\text{at the mixer} = 190 - 49.8 = 140.2 \text{ or } 140 \text{ kg}$$

$$190 + (770*0.01) + (1127*0.02) = 220$$

	<i>OD**</i>	<i>SSD</i>	<i>OD</i>	<i>field</i>
<i>W</i>	190	<i>190</i>	<i>220</i>	<i>140</i>
<i>C</i>	267	<i>267</i>	<i>267</i>	<i>267</i>
<i>PFA</i>	89	<i>89</i>	<i>89</i>	<i>89</i>
<i>FA</i>	770	<i>778</i>	<i>770</i>	<i>816</i>
<i>CA</i>	1127	<i>1150</i>	<i>1127</i>	<i>1161</i>
<u><i>sum</i></u>	<u>2443</u>	<u><i>2473</i></u>	<u><i>2473</i></u>	<u><i>2473</i></u>

Example 14: *Adjustment of batch masses for aggregate moisture*

In SI units:

The following masses of material are required for 1 m³ of concrete. The stockpiled sand has a total moisture content of 6.0% and the stone has a total moisture content of 3.0%. Compute adjusted batch masses.

<u>Material</u>	<u>Batch mass, kg</u>
Cement	267
Fly ash	89
SSD sand (absorption 1.0%)	779
SSD stone (absorption 2.0%)	1150
Total mixing water	190

From the definition of absorption, $W_{OD} = \frac{W_{SSD}}{(1 + Abs/100)}$

$$\text{Oven-dry mass of sand} = \frac{779}{1 + 0.01} = 771 \text{ kg}$$

$$\text{Oven-dry mass of stone} = \frac{1150}{1 + 0.02} = 1127 \text{ kg}$$

Free moisture content = total moisture content – absorption

$$\text{Sand} = 6.0 - 1.0 = 5.0\% \text{ free moisture}$$

$$\text{Stone} = 3.0 - 2.0 = 1.0\% \text{ free moisture}$$

$$\text{Sand free moisture content} = 0.05 \times 771 = 38.5 \text{ kg}$$

$$\text{Stone free moisture content} = 0.01 \times 1127 = 11.3 \text{ kg}$$

$$\text{Total aggregate free moisture content} = 38.5 + 11.3 = 49.8 \text{ kg}$$

$$\text{Water to be added at the mixer} = 190 - 49.8 = 140.2 \text{ kg}$$

$$\text{Wet fine aggregate mass} = 779 \text{ (SSD)} + 38.5 = 817 \text{ kg}$$

$$\text{Wet coarse aggregate mass} = 1150 \text{ (SSD)} + 11.3 = 1161 \text{ kg}$$

		<i>SSD</i>	<i>OD</i>	<i>field</i>
W		<i>190</i>	<i>220</i>	<i>140</i>
C		<i>267</i>	<i>267</i>	<i>267</i>
PFA		<i>89</i>	<i>89</i>	<i>89</i>
FA		<i>779</i>	<i>771</i>	<i>817</i>
CA		<i>1150</i>	<i>1127</i>	<i>1161</i>
<u>sum</u>		<u><i>2474</i></u>	<u><i>2474</i></u>	<u><i>2474</i></u>

Homework – 2:

Following masses of materials are used to produce a batch of concrete. Moisture content of fine aggregate and coarse aggregate is 3.5% and 0.5%. Absorption capacity of aggregates is 2%.

1. What is the volume of compacted concrete if the assumed air content is 3%?
2. Calculate the w/c ratio.
3. Calculate the density of compacted concrete.

Material	Mass (kg)	Specific Gravity
Water	150	1.00
Cement	400	3.15
Fine Aggregate	700	2.50 (bulk SSD)
Coarse Aggregate	1150	2.60 (bulk SSD)