MIX DESIGN

American
Concrete Pipe
Association

Concrete Mix Design

Wet Cast (Slump)

Concrete Mix Design

Wet Cast (Slump)

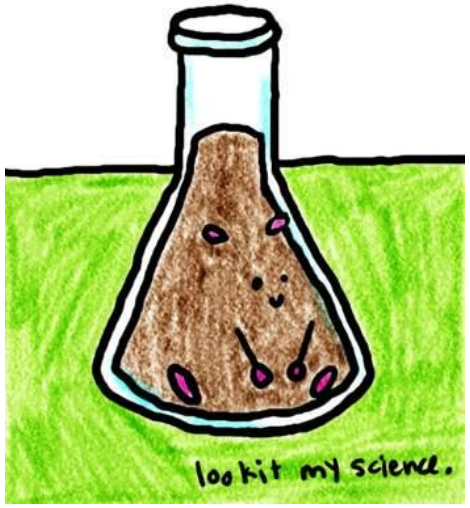
Concrete Mix Design

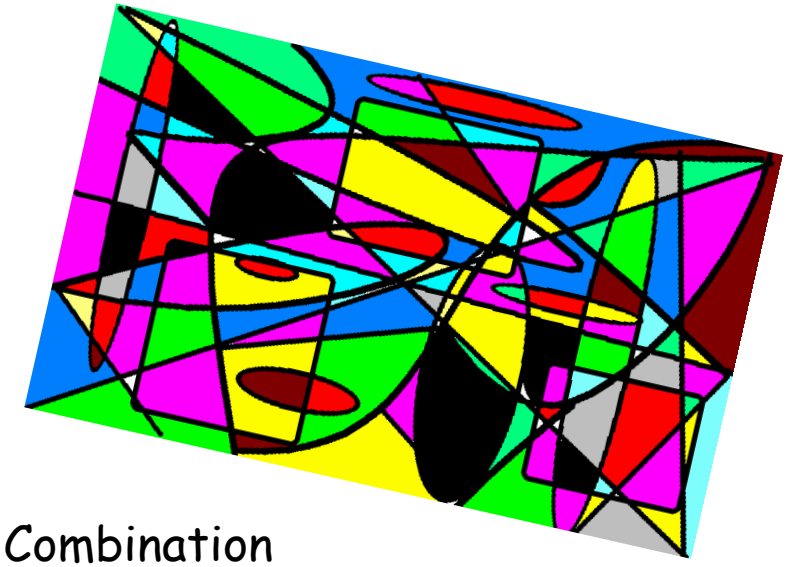
Dry Cast (no Slump)

Concrete Mix Design

Dry Cast (no Slump)

Concrete Mix Design

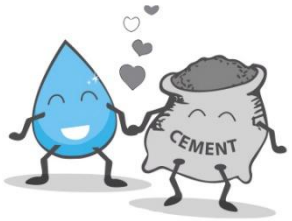


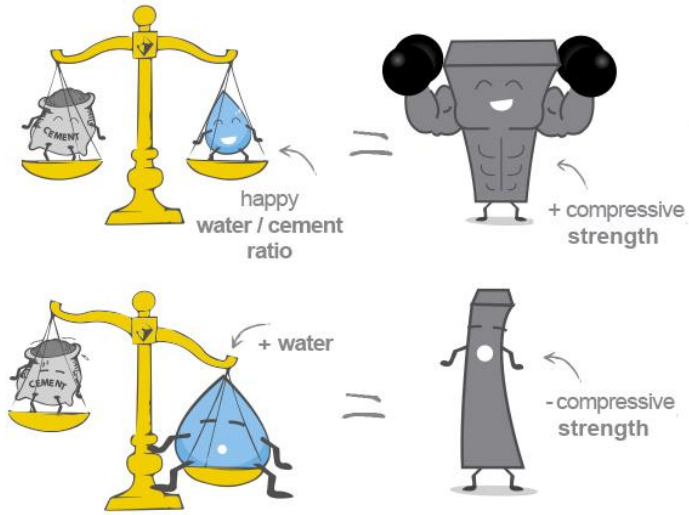


Combination of Art and Science…

Water, Cement, & Aggregate

- As the water to cement ratio increases, the strength of a concrete mix decreases.

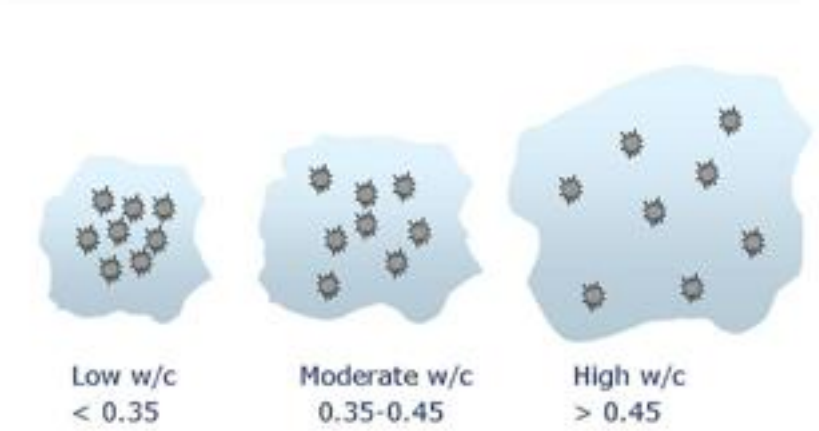




+ water
loss of compressive strength

Water, Cement, & Aggregate

- As the water to cement ratio increases, the strength of a concrete mix decreases.



Water, Cement, & Aggregate

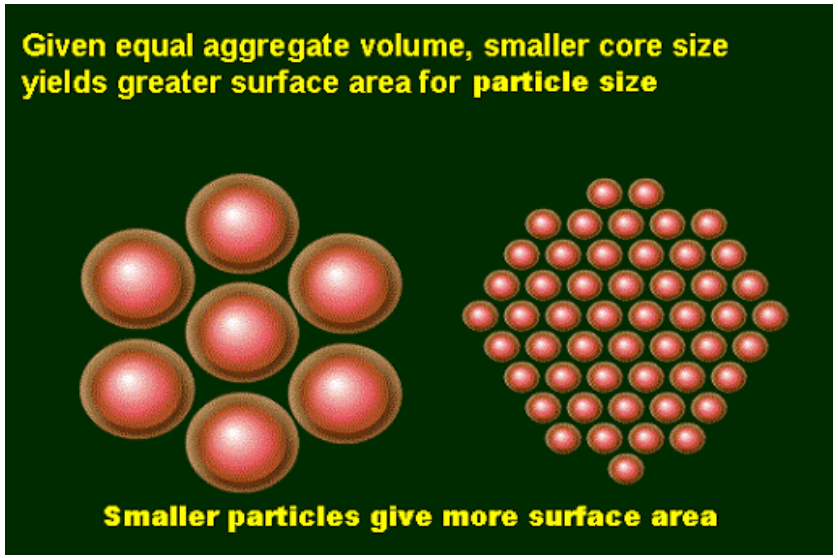
As the surface area of the aggregate increases more water will be needed to maintain a given slump.

- Coarser Surface Texture
- Particle Shape

Water, Cement, & Aggregate

As the surface area of the aggregate increases more water will be needed to maintain a given slump.

- Particle Size Distribution



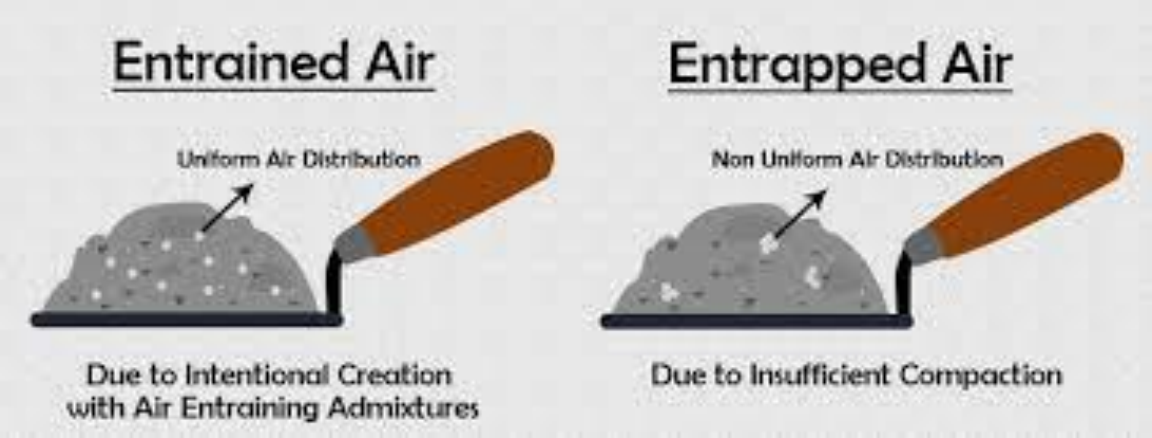
Water, Cement, & Aggregate

As the surface area of the aggregate increases more water will be needed to maintain a given slump.

- Particle Size Distribution

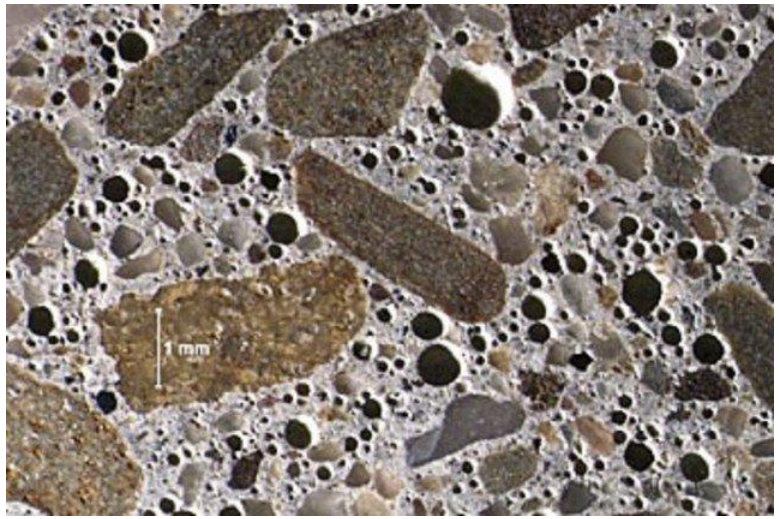
Water, Cement, & Aggregate

As the air content increases, the strength of the concrete decreases.



Water, Cement, & Aggregate

As the air content increases, the strength of the concrete decreases.



Water/Cement Ratio

It's a calculation:

w/c ~ lbs. of water / lbs. of cement

45 lbs of water

100 lbs of cement

= Water cement ratio

= 45 lbs ÷ 100 lbs

= 0.45 expressed as decimal

Water/Cementitious Ratio

It's a calculation:

w/c_m ~ lbs. of water / lbs. of cementitious

45 lbs of water

80 lbs of cement

20 lbs of Flyash

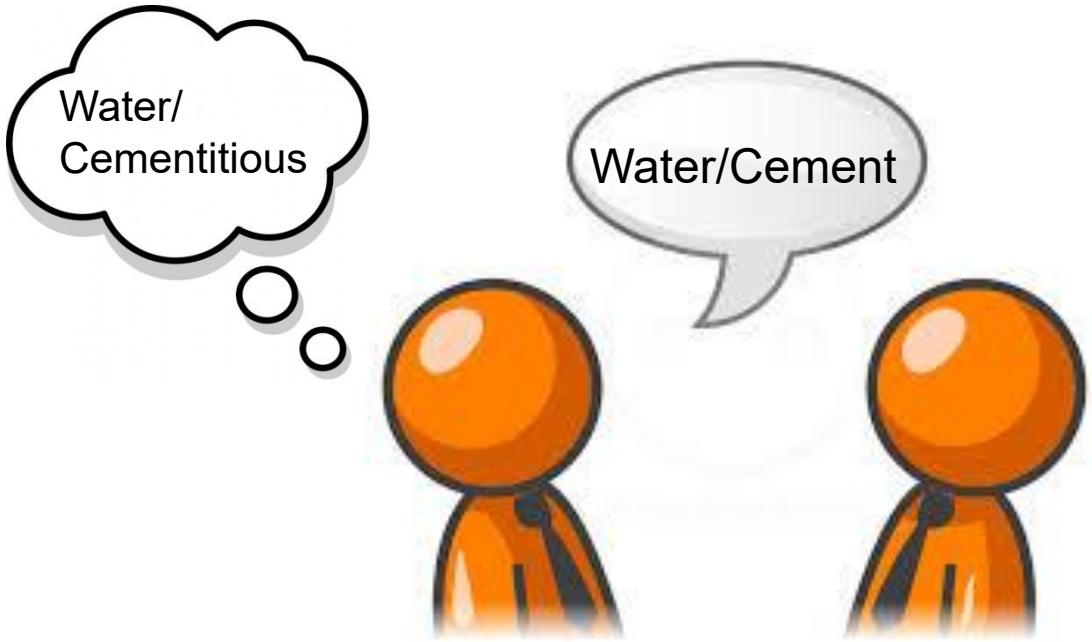
= Water cementitious ratio

= 45 lbs ÷ (80lbs + 20 lbs)

= 0.45 expressed as decimal

Water/Cementitious Ratio

Often when w/c is discussed its really w/c_m that is intended as the reference

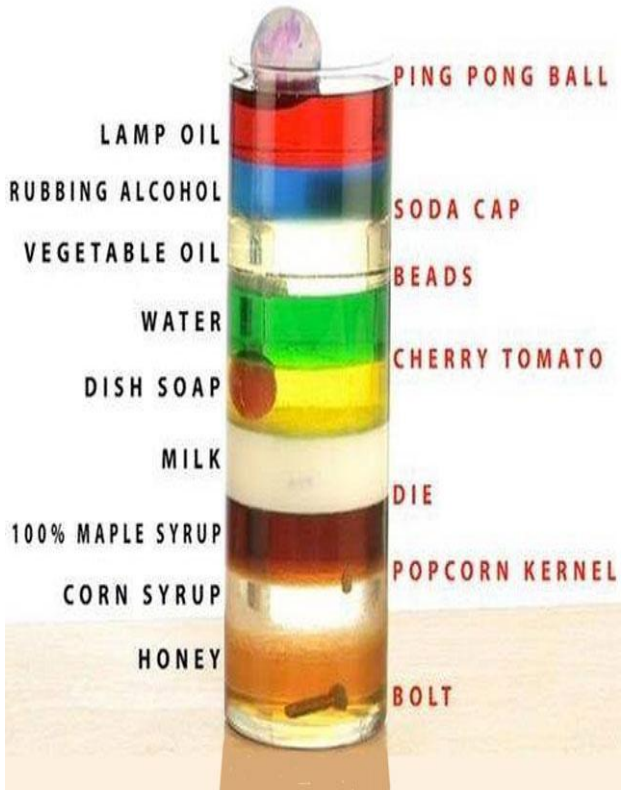


Water/Cementitious Ratio

Water needs to be drinkable or meet ASTM 1602

Terminology

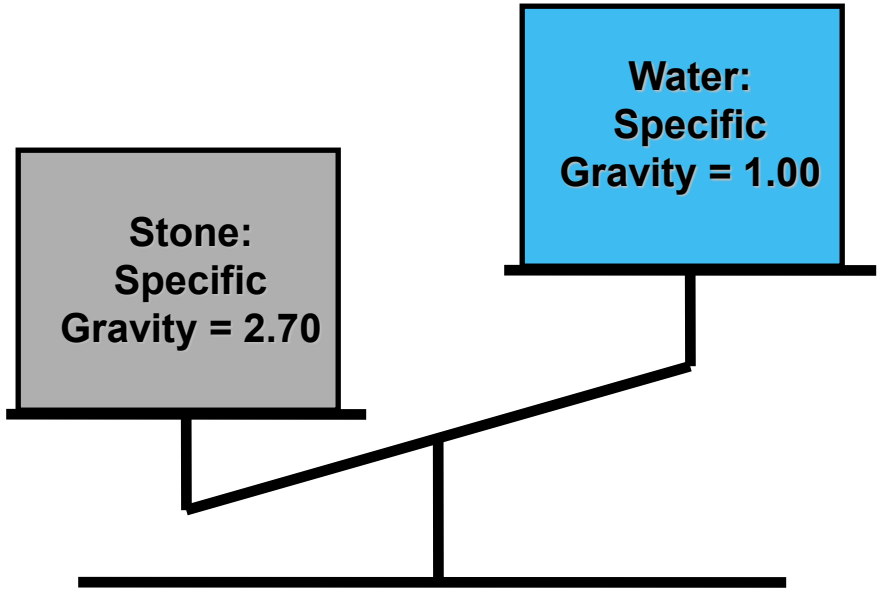
- Specific Gravity
  - The relative density of a material compared to water
  - The ratio of a material's weight to the weight of an equal volume of water



Specific Gravity

What about you?

Specific Gravity



Same Volume, but 2.70 Times More Mass

Cement – 3.15
Steel – 7.85
You - ???

Terminology

Bulk Specific Gravity (SSD):

- Used to determine the “solid volume” (absolute volume) of a material going into concrete
- It is determined by submerging the material in water for 24 hours in order to fill any permeable voids

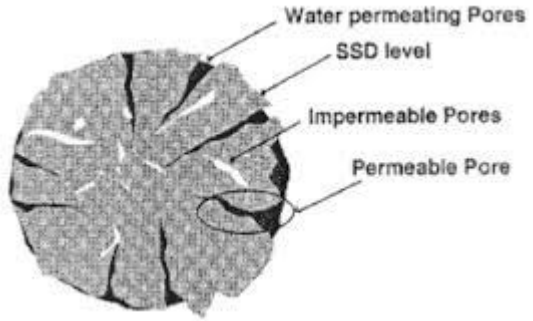
Calculations for SSD Bulk Specific Gravity

Coarse Aggregate Using Basket Suspended in water:

B / (B - C) = SSD Bulk Specific Gravity

where:

B = weight of SSD sample in air
C = weight of SSD sample in water

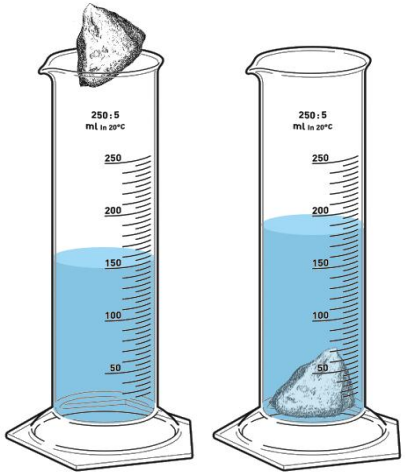


Calculations for SSD Bulk Specific Gravity

Field Calculation of SSD Bulk Specific Gravity:

$$\frac{\text{Weight of Aggregate @ SSD}}{\text{Weight of equal volume of water displaced}} = \text{Specific Gravity}$$

$$\frac{1245\text{g of SSD aggregate}}{469.81\text{g of water displaced}} = 2.65$$



Concrete Mix Design

It’s always about volume!

What is absolute volume?

What is Absolute Volume?

- Relationship of Materials to Volume
  - specific gravity of Type I Cement = 3.15
  - specific gravity of water = 1.0
  - 1 gallon of water weights 8.33 pounds
  - water weights 62.4 pounds / cubic foot

$$\frac{\text{Pounds of Material}}{\text{S.G. X 62.4}} = \text{Absolute Volume}$$

Basic Concrete Mix Design

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
			-
Total Cementious	667		
Miller Stone	1590	2.6	9.80
Evert Sand	1242	2.65	7.51
Water	300	1	4.81
Air	5.5%		1.485
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

Basic Concrete Mix Design

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Cement	667	3.15	3.39
			-
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Water	300	1	4.81
Air	5.5%		1.485
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

$\frac{667}{3.15 \times 62.4}$

$\frac{1590}{2.60 \times 62.4}$

$\frac{1242}{2.65 \times 62.4}$

Basic Concrete Mix Design

$$\frac{\text{Lbs Material}}{\text{S.G. x 62.4}} = \text{Absolute Volume}$$

$$\text{S.G. x 62.4 x Abs. Volume} = \text{Lbs. of Material}$$

Basic Concrete Mix Design

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
			-
Total Cementious	667		
Miller Stone	1590	2.6	9.80
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Water	300	1	4.81
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Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

$\frac{300}{1.0 \times 62.4}$

0.055 X 27

Basic Concrete Mix Design

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
			-
Total Cementious	**667**		
Miller Stone	1590	2.6	9.80
Evert Sand	1242	2.65	7.51
Water	36 Gal	1	4.81
Air	5.5%		1.485
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

$$\frac{36 \text{ gal}}{1.0 \times 62.4}$$

Basic Concrete Mix Design

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
			-
Total Cementious	667		
Miller Stone	1590	2.6	9.80
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Water	36 Gal	1	4.81
Air	5.5%		1.485
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

36 gal x 8.33 lbs/gal
1.0 X 62.4

Water/Cement Ratio = W/C

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
			-
Total Cementious	667		
Miller Stone	1590	2.6	9
Evert Sand	1242	2.65	7.51
Water	300	1	4.81
Air	5.5%		1.485
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

Water / Cement

$\frac{300}{667}$

Weight (mass)

Density (Unit Weight)

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
Total Cementious	667		
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Air	5.5%		1.485
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

Design (unit weight)
3799
27.0

@ 1.5% air, unit weight (density) = 147.26

Mix Design with Cement & Fly Ash

Materials	Pounds of material	S.G.	Abs Volume
			-
Cement	534	3.15	2.72
Fly Ash	133	2.45	0.87
Total Cementious	667		
Miller Stone		2.60	
Evert Sand		2.65	0.00
Water	295	1.0	4.73
Air	1.5%		0.405
Total	962		8.72
w / cm	0.44	Unit Wt.	110.33
		Sand/Agg	-

133 lbs. fly ash / 667 Total lbs. Cm = 20% ash

It's about volume!

Mix Design with Cement & Fly Ash

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			-
Cement	534	3.15	2.72
Fly Ash	133	2.45	0.87
Total Cementious	667		
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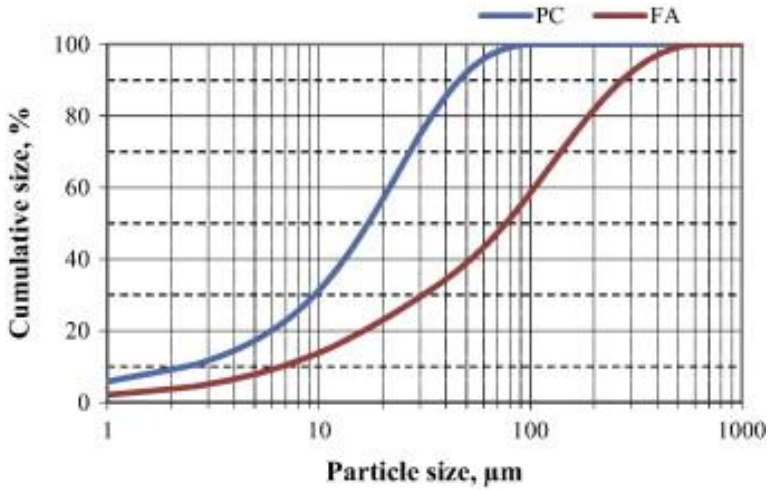
Water	295	1.0	4.73
Air	1.5%		
Total	962		8.72
w / cm	0.44	Unit Wt.	110.33
		Sand/Agg	-



Note: lower water demand due to fly ash - for same slump

It's about volume!

Mix Design with Cement & Fly Ash

Materials	Pounds of material	S.G.	Abs Volume
			-
Cement	534	3.15	2.72
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Air	1.5%		0.405
Total	962		8.72
w / cm	0.44	Unit Wt.	110.33
		Sand/Agg	-

Proportion the mix to yield 27 ft^3 … but how much sand, stone … what ratio?

Sand / Aggregate ratio is by volume

It's about volume!

Mix Design with Cement & Fly Ash

Materials	Pounds of material	S.G.	Abs Volume
			-
Cement	534	3.15	2.72
Fly Ash	133	2.45	0.87
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Air	1.5%		0.405
Total	962		8.72
w / cm	0.44	Unit Wt.	110.33
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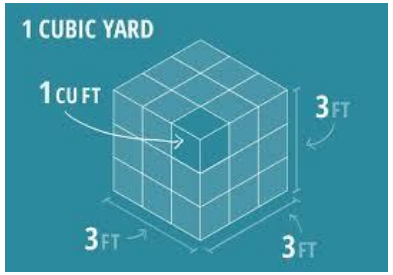


Volume without aggregate = 8.72

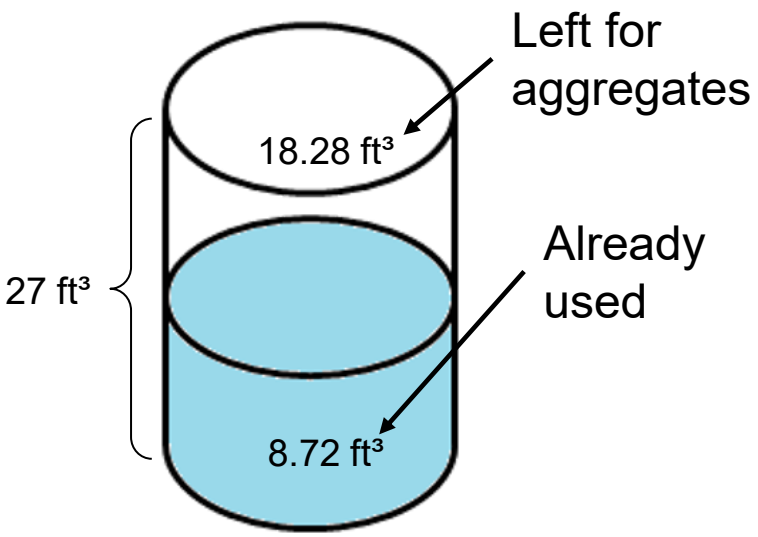
27.00 - 8.72 =

18.28 ft^3 **required**

It's about volume!

Mix Design with Cement & Fly Ash

Materials	Pounds of material	S.G.	Abs Volume
			-
Cement	534	3.15	2.72
Fly Ash	133	2.45	0.87
Total Cementious	667		
Miller Stone		2.60	0.00
Evert Sand		2.65	0.00
Water	295	1.0	4.73
Air	1.5%		0.405
Total	962		8.72
w / cm	0.44	Unit Wt.	110.33
		Sand/Agg	-



18.28 ft³ + 8.72 ft³ = 27 ft³

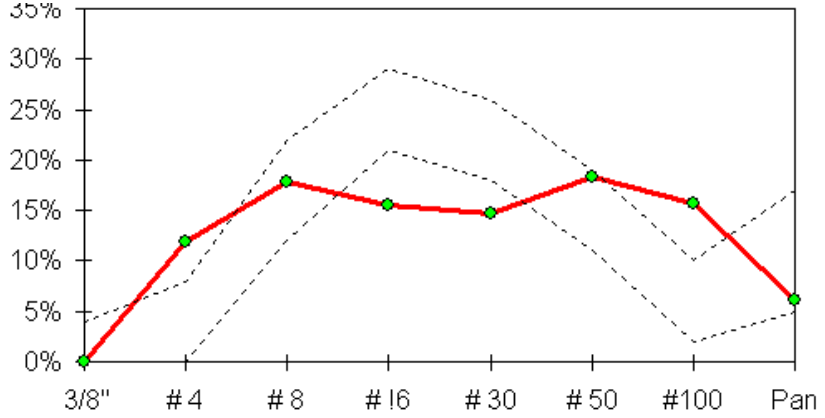
It's about volume!

Sand to Aggregate Ratio

$$\frac{\text{Volume of Sand}}{\text{Volume of Total Aggregate}} =$$

Rules of thumb ?

Manufactured Concrete Pipe
60-80% Packerhead Mix
45-65% Dry Cast



Calculating Sand & Stone to Yield 27ft^3 of Concrete

Assume this concrete needs to have Sand / Aggregate ratio of 0.42

$$\frac{\text{Volume of Sand}}{\text{Total Volume of Aggregate}} = 0.42$$

$$\frac{\text{Volume of Sand}}{18.28} = 0.42$$

Volume of Sand = 7.68 ft^3

Calculating *Pounds* of Sand

$$\frac{\text{Pounds of Material}}{\text{S.G. X 62.4}} = \text{Absolute Volume}$$

$$\frac{\text{Pounds of Material (Sand)}}{\text{2.65 x 62.4}} = 7.68\ ft^3$$

Sand = 1270 lbs

Evert Sand S.G. = 2.65

Calculating *Volume* of Stone

Total Aggregate Volume

Total Volume Left for Stone

18.78 - 7.68 = 10.60 ft³

Sand Volume

Calculating *Pounds* of Stone

$$\frac{\text{Pounds of Material}}{\text{S.G. X 62.4}} = \text{Absolute Volume}$$

$$\frac{\text{Pounds of Material (stone)}}{\text{2.60 x 62.4}} = 10.60\ \text{ft}^3$$

Stone = 1720 lbs

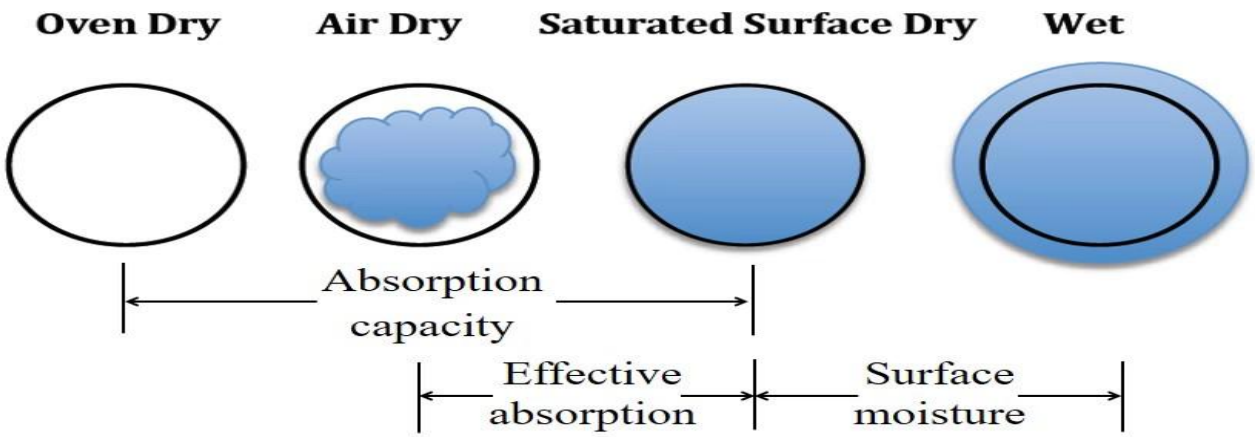
Miller Stone S.G. = 2.60

SSD Mix Design

Materials	Pounds of material	S.G.	Abs Volume
			-
Cement	534	3.15	2.72
Fly Ash	133	2.45	0.87
Total Cementious	**667**		
Miller Stone	1720	2.60	10.60
Evert Sand	1270	2.65	7.68
Water	295	1.0	4.73
Air	1.5%		0.405
Total	3952		27.00
w / cm	0.44	Unit Wt.	146.36
		Sand/Agg	0.42

Aggregate Moisture

Aggregate Moisture



Absorbed moisture (absorption)

SSD (ideal)

Free moisture (moisture content)

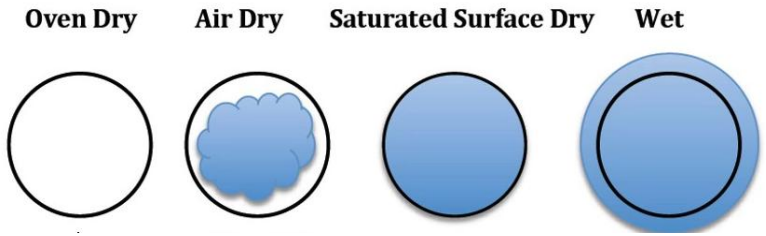
Add Water

Subtract Water

Moisture Adjustments

Moisture Management is Critical (How much free water)

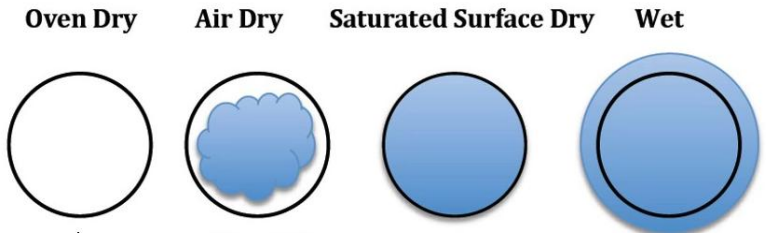
Total aggregate moisture = Aggregate absorption + Free water



Moisture Adjustments

Moisture Management is Critical (How much free water)

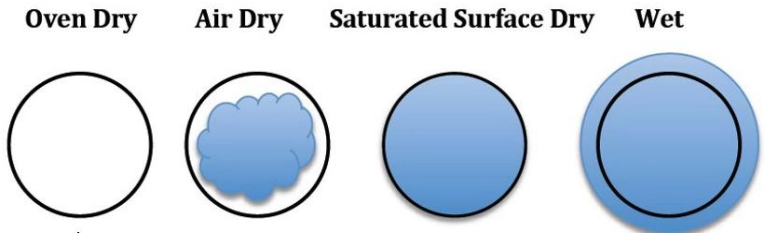
Aggregate Absorption = Total aggregate moisture - Free water



Moisture Adjustments

Moisture Management is Critical (How much free water)

Free Water = Total aggregate moisture - Aggregate absorption



Moisture Adjustments

What if we do not make moisture corrections

Moisture Adjustments

Moisture Management is Critical (How much free water)

Total aggregate moisture = aggregate absorption + free water

Stone $3.0\% = 1.5\% + \text{free water}, \quad (\%\ \text{free water} = 1.5\%)$

0.015 X 1720 = 26 pounds of free water on the Stone

Sand $5.5\% = 0.85\% + \text{free water}, \quad (\%\ \text{free water} = 4.65\%)$

0.0465 X 1270 = 59 pounds of free water on the Sand

Moisture Adjustments

Moisture Management is Critical (How much free water)

Total aggregate moisture = aggregate absorption + free water

	Total Moisture %	Absorption %	Free %	Moisture Adjustment
Miller Stone	3.00	1.50	1.50	26
Evert Sand	5.50	0.85	4.65	59

Water Adjustment

If 26 + 59 pounds of water rides in on the aggregates you must take that amount of water out of the BATCH water.

Design water	295
Water on aggregates	-85
Batch water	210

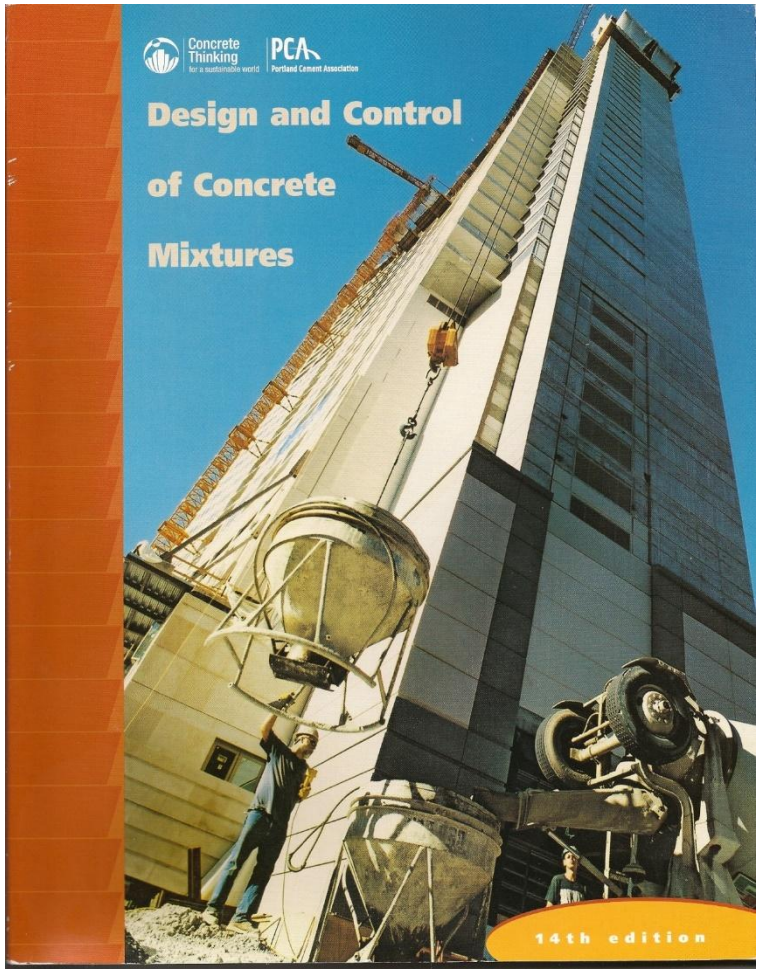
Moisture Adjustment

Total moisture = Free moisture + Aggregate absorption

Materials	Pounds of material	S.G.	Abs Volume	SSD	Moisture Adjustment	Batch Weight yard
Cement	534	3.15	2.72	534		534
Type F ash	133	2.45	0.87	133		133
Miller Stone	1720	2.6	10.60	1720	26	1746
Evert Sand	1270	2.65	7.68	1270	59	1329
Water	295	1.0	4.73	295	-85	210
Air	1.5%		0.405	1.5%		
Total	3952		27.00	3952		3952
Density	146.4					146.4

	Total Moisture %	Absorption %	Free %	Moisture Adjustment
Miller Stone	3.00	1.50	1.50	26
Evert Sand	5.50	0.85	4.65	59

SSD & batch totals will be the same



Where Can I Get This?

- Portland Cement Association (PCA)
  5420 Old Orchard Road
  Skokie, IL 60077-1083

  847 966-6700 PH
  847 966-8389 FX
  Info @ cement.org