Concrete Mix Design Calculations

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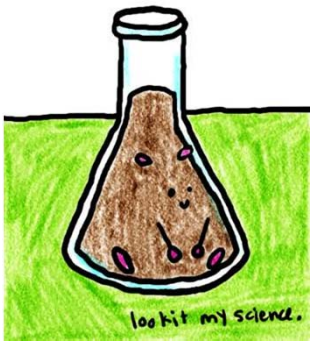
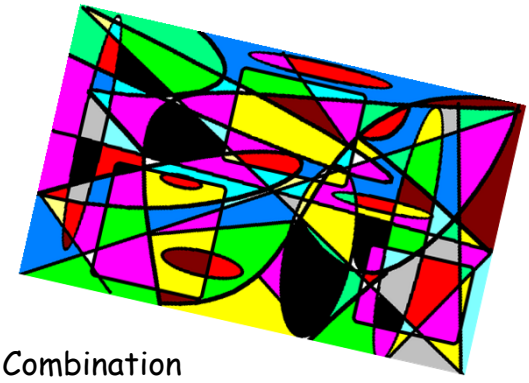
Concrete Mix Design

- Wet Cast (Slump)
- Dry Cast (no Slump)





Combination of Art and Science…

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Water, Cement, & Aggregate

- As the water to cement ratio increases, the strength of a concrete mix decreases.
- As the surface area of the aggregate increases the more water will be needed to maintain a given slump.
  - Coarser Surface Texture
  - Particle Shape
  - Particle Size Distribution
- As the air content increases, the strength of the concrete decreases.

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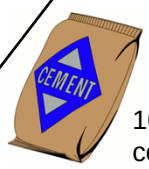
Water / Cementitious Ratio

- It's a calculation:
  - w/c ~ lbs. of water / lbs. of cement
  - w/c_m ~ lbs. of water / lbs. of cementitious

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

45 lbs of water



100 lbs of cement

= Water cement ratio

0.45 expressed as decimal

Water needs to be drinkable or meet ASTM 1602

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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
- 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

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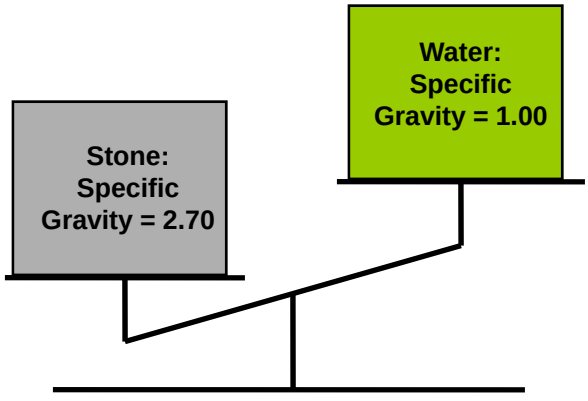
Specific Gravity



Same Volume, but 2.70 Times More Mass

Cement – 3.15
Steel – 7.85

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Calculations for SSD Bulk Specific Gravity

Coarse Aggregate Using Basket Suspended in water:

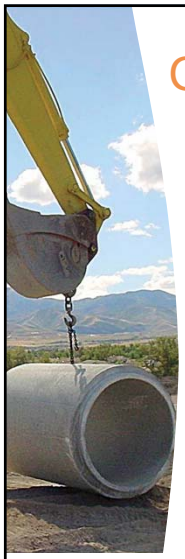
B / (B - C) = SSD Bulk Specific Gravity

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

Field Calculation of SSD Bulk Specific Gravity:

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

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



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Concrete Mix Design

- It's always about volume!
  - What is absolute volume?

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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

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

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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

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

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

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

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

0.055 X 27

Water / Cement Ratio = W/C

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			-
Total Cementious	**667**		
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Evert Sand	1242	2.65	7.51
Water	300	1	4.81
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w / cm	0.45	Unit Wt.	140.72

Water / Cement $\frac{300}{667}$ Weight (mass)

Density (unit weight)

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			-
Total Cementious	**667**		
Miller Stone	1590	2.6	9.80
Evert Sand	1242	2.65	7.51
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Air	5.5%		1.485
Total	3799		27.00
w / cm	0.45	Unit Wt.	140.72

Design (unit weight) $\frac{3799}{27.0}$

@ 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	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	-

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

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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		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
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Air	1.5%		0.405
Total	962		8.72
w / cm	0.44	Unit Wt.	110.33
		Sand/Agg	-

Volume without aggregate = 8.72

27.00 - 8.72 =

18.28 ft^3 **required**

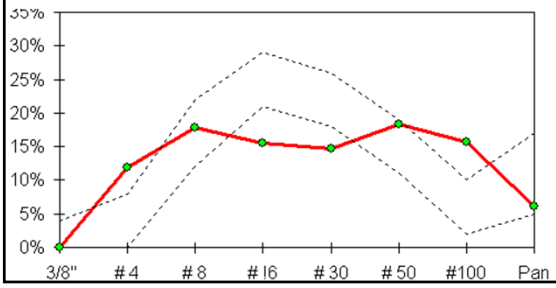
It's about volume!

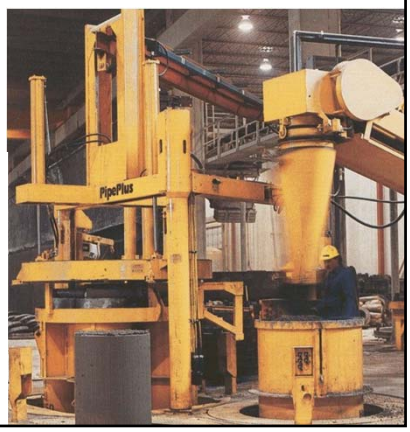
Sand to Aggregate Ratio

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

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**

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

$$\frac{\text{Volume of Sand}}{18.28\ ft^3} = 0.42$$

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 *pounds* of stone

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

$$\frac{\text{Pounds of Material (stone)}}{\text{2.60 X 62.4}} = 18.28 - 7.68 = 10.60\ ft^3$$

Total Aggregate Volume

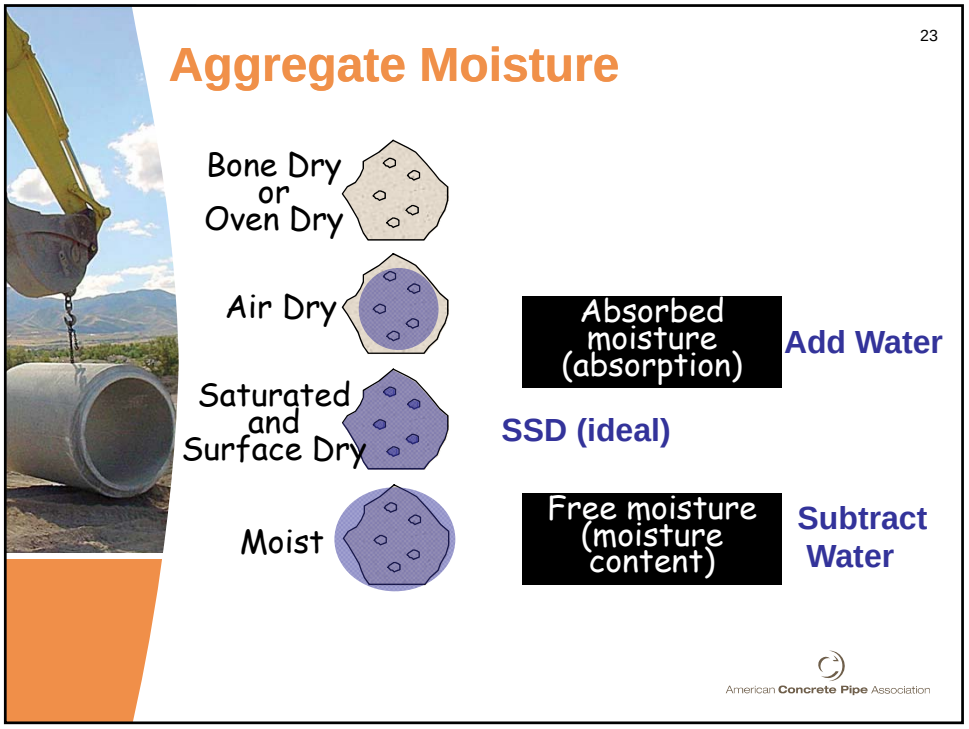
Sand Volume

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



Moisture Adjustments

Moisture Management is Critical (How much free water)

Total aggregate moisture = aggregate absorption + free water

STONE (TM = absorption + free water)

3.0% = 1.5% + free water, (% free water = 1.5%)

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

Sand

5.5% = 0.85% + free water, (% free water = 4.65%)

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

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

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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

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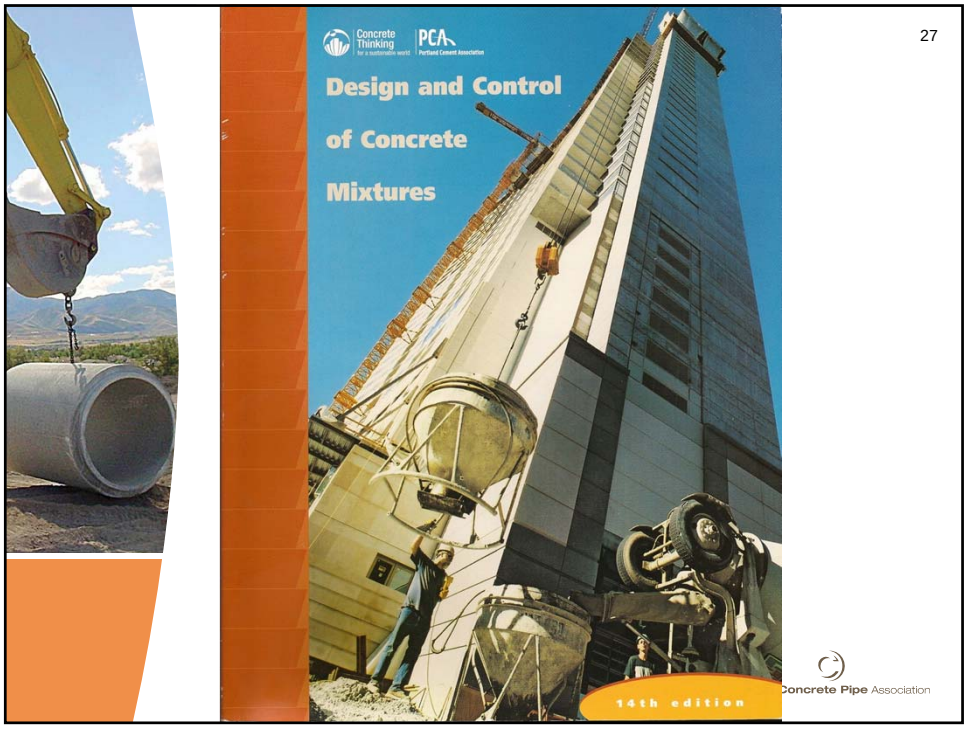
Moisture Adjustment

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

Total moisture = Free moisture + Aggregate absorption



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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

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QUESTIONS?