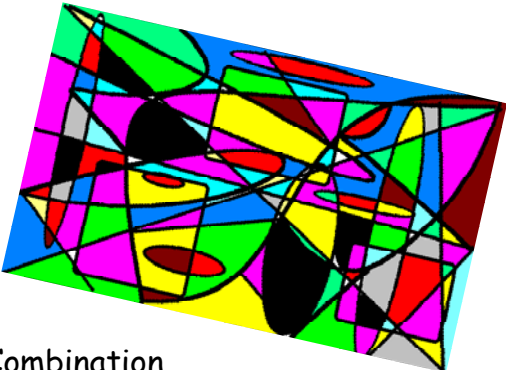
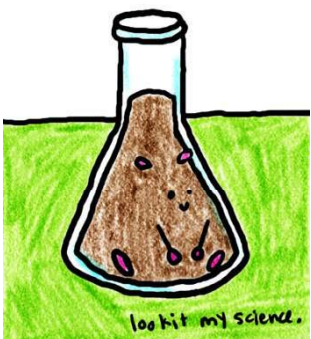


Concrete Mix Design Calculations

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Concrete Mix Design

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




Combination of Art and Science...

3




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:
 - $w/c \sim \text{lbs. of water} / \text{lbs. of cement}$
 - $w/c_m \sim \text{lbs. of water} / \text{lbs. of cementitious}$

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

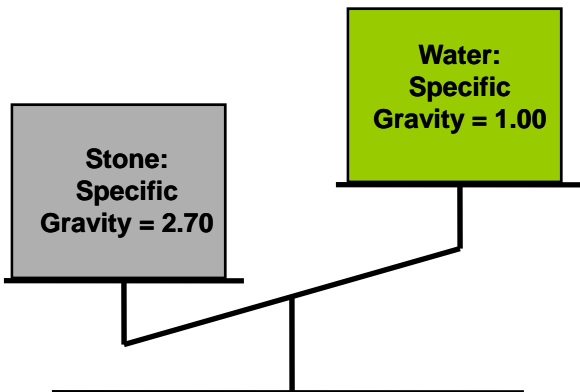
- **Specific Gravity**
 - The relative density of a material compared to water
 - The ratio of a material's weight to the weight of an equal volume of water
- **Bulk specific gravity (SSD):**
 - Used to determine the "solid volume" (absolute volume) of a material going into concrete
 - It is determined 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:

$$B / (B - C) = \text{SSD Bulk Specific Gravity}$$

where:

B = weight of SSD sample in air

C = weight of SSD sample in water

Field Calculation of SSD Bulk Specific Gravity:

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

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




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Concrete Mix Design

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

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What is Absolute Volume?

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- 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

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






Basic Concrete Mix Design

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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

Materials	Pounds of material	S.G.	Abs Volume
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			-
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$$\frac{667}{3.15 \times 62.4}$$

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

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

Basic Concrete Mix Design

Materials	Pounds of material	S.G.	Abs Volume
Cement	667	3.15	3.39
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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

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

$$0.055 \times 27$$

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	9.80
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

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		
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

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 Cementitious	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
Fly Ash	133	2.45	0.87
Total Cementitious	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	-

Proportion the mix to yield 27 ft³ ... 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
Total Cementitious	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. Sand/Agg	110.33
			-

Volume without aggregate = 8.72

27.00 - 8.72 =

18.28 ft³ **required**

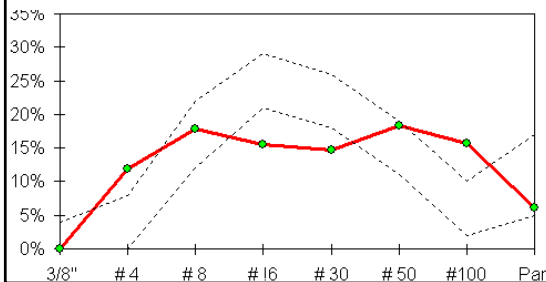
It's about volume!

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 27ft³ of concrete

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

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

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

$$\text{Volume of Sand} = 7.68 \text{ ft}^3$$



Calculating pounds of sand

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

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

Sand = 1270 lbs

$$\text{Evert Sand S.G.} = 2.65$$



Calculating pounds of stone

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


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

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 Cementitious	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



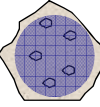
23

Aggregate Moisture

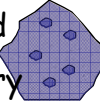
Bone Dry
or
Oven Dry



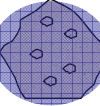
Air Dry



Saturated
and
Surface Dry



Moist




Absorbed
moisture
(absorption)

Add Water

SSD (ideal)

Free moisture
(moisture
content)

Subtract
Water



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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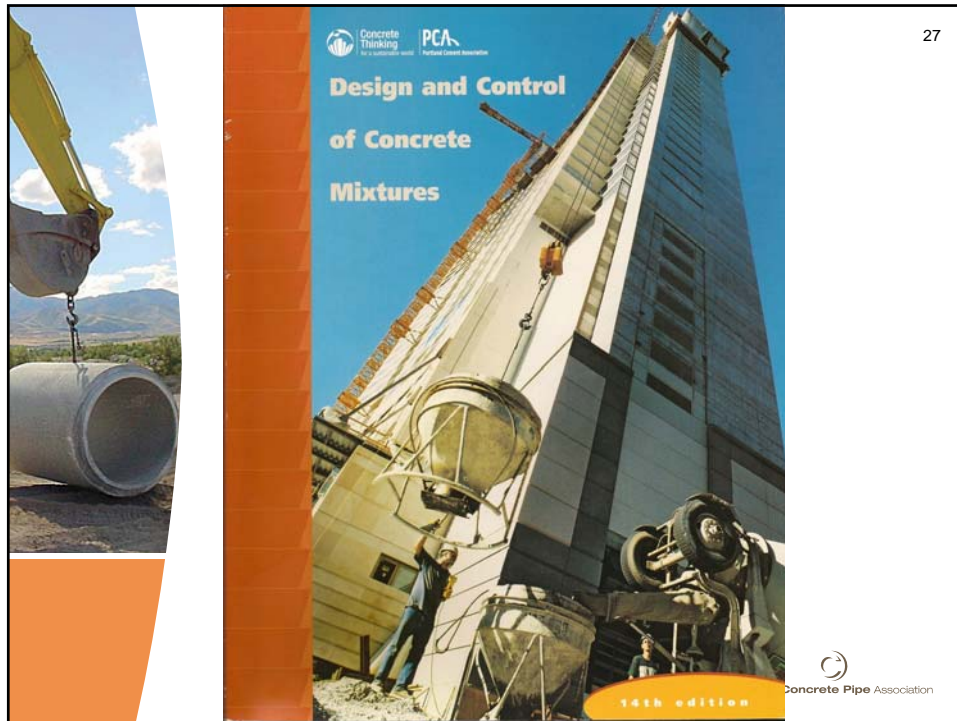
Moisture Adjustment

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



Concrete Thinking
Portland Cement Association

**Design and Control
of Concrete
Mixtures**

14th edition

Concrete Pipe Association

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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

