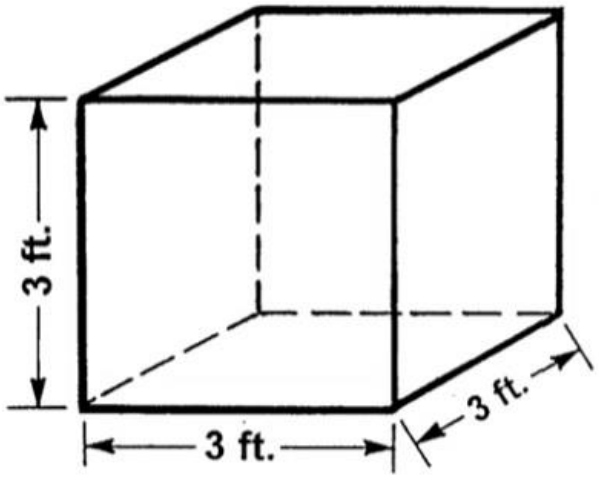
Design for 1 YD^3



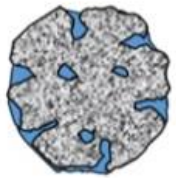
$27\ ft^3 = 1\ yd^3$

$$\text{Volume} = \frac{\text{Batch Weight of Material}}{\text{Sp.Gr. of Material} \times \text{Unit Weight of Water}}$$

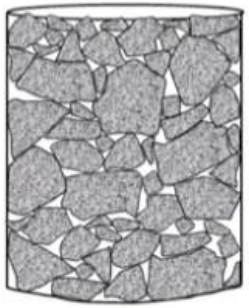
Material Properties of Aggregate

- Absorption, Unit Weight, and Specific Gravity are properties of the aggregate.
- The aggregate suppliers has these numbers.

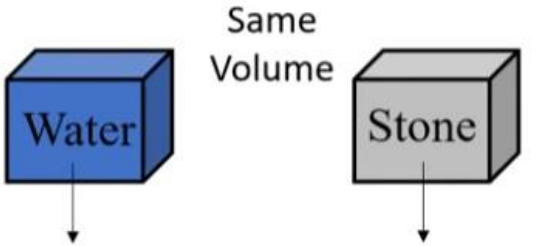
Absorption



Unit Weight

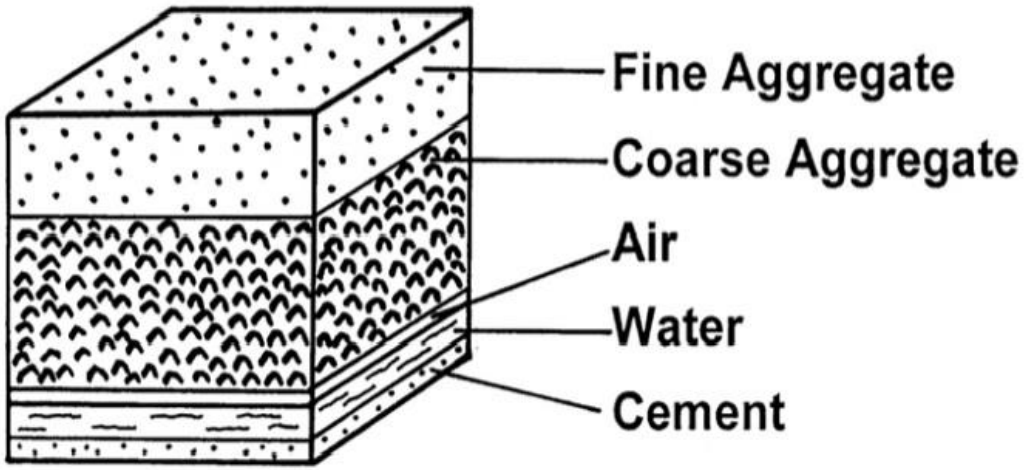


Specific Gravity



$$\text{Specific Gravity Of Stone} = \frac{270 \text{ lbs.}}{100 \text{ lbs.}} = 2.7$$

WE USE THE SAME PROCESS TO FILL UP OUR BOX !



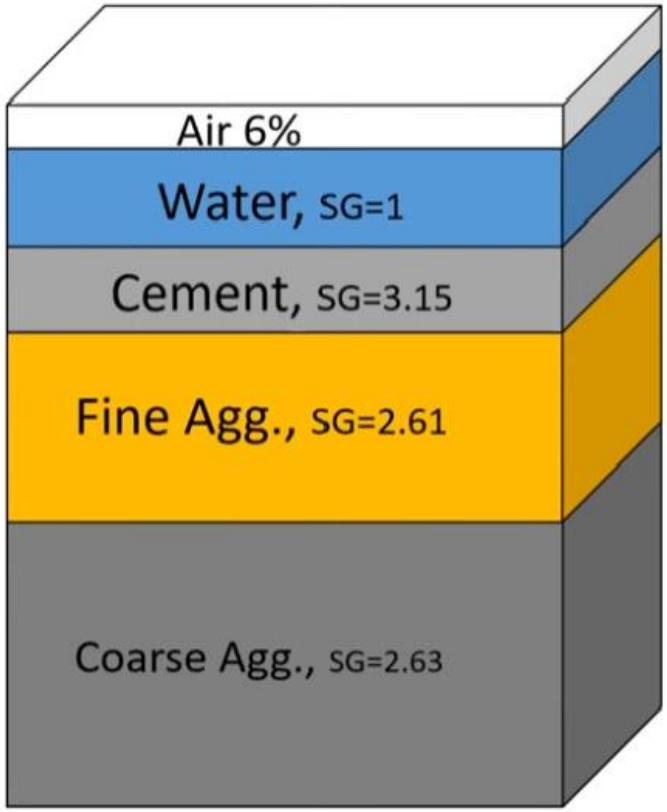
Example 1: Converting Batch Weights to Volume

Material	Weight	Specific Gravity
Cement	564 lbs.	3.15
Stone	1800 lbs.	2.63
Water	250 lbs.	1.00
Sand	1226 lbs.	2.61
Air	6%	-------

$$\text{Abs. Vol.} = \frac{\text{Weight of Material}}{\text{(Sp. Gr. Of Material)X(Unit Wt. Of Water)}}$$

A.) Cement	=	564 lbs. / 3.15 X 62.4 lbs/cu. ft.	=	2.87	ft^3
B.) Stone	=	1800 lbs. / 2.63 X 62.4 lbs/cu. ft.	=	10.97	ft^3
C.) Water	=	250 lbs. / 1.00 X 62.4 lbs/cu. ft.	=	4.01	ft^3
D.) Sand	=	1226 lbs. / 2.61 X 62.4 lbs/cu. ft.	=	7.53	ft^3
E.) Air	=	6 % of air X 27 cu.ft.	=	1.62	ft^3

Design Wt. (lbs.)	**Material**	**Volume** (ft^3)
---	Air 6%	1.62 ft^3
250 lbs.	Water, SG=1	4.01 ft^3
564 lbs.	Cement, SG=3.15	2.87 ft^3
1226 lbs.	Fine Agg., SG=2.61	7.53 ft^3
1800 lbs.	Coarse Agg., SG=2.63	10.97ft^3
		27.00 ft^3



Steps of ACI 211 Method

Step 1: Choice of Slump

Step 2: Maximum Size of Aggregate

Step 3: Water and Air content

Step 4: Water/Cement Ratio

Step 5: Cement Content

Step 6: Coarse Aggregate Content

Step 7: Fine Aggregate Content

Step 8: Adjustment for Aggregate Moisture

Step 9: Trial Batch Adjustment



Mix Design for Exterior Column
Strength-5000 Psi for 28 days
Cement-Type 1
Sp. Gr of Cement 3.15
Size of CA-20 mm (3/4”)
FM modulus- 2.70
CA (SSD)- 2.70
FA (SSD)-2.65
Absorption capacity CA-1%, FA-1.3%
Moisture content CA-0%, FA 3%
Dry rodded unit wet of CA- 100 lb/ft3

Information Before Designing a Mixture

- Slump (step 1)
- Entrained Air or Non-Air Entrained
- Compressive Strength (step 4)
- Specific Gravities of cement is 3.15
- Aggregate information
  - Maximum coarse aggregate size (step 2)
  - Dry-rodded unit weight of coarse aggregate
  - Fineness modulus of fine aggregate
  - Specific gravity & absorption of aggregates

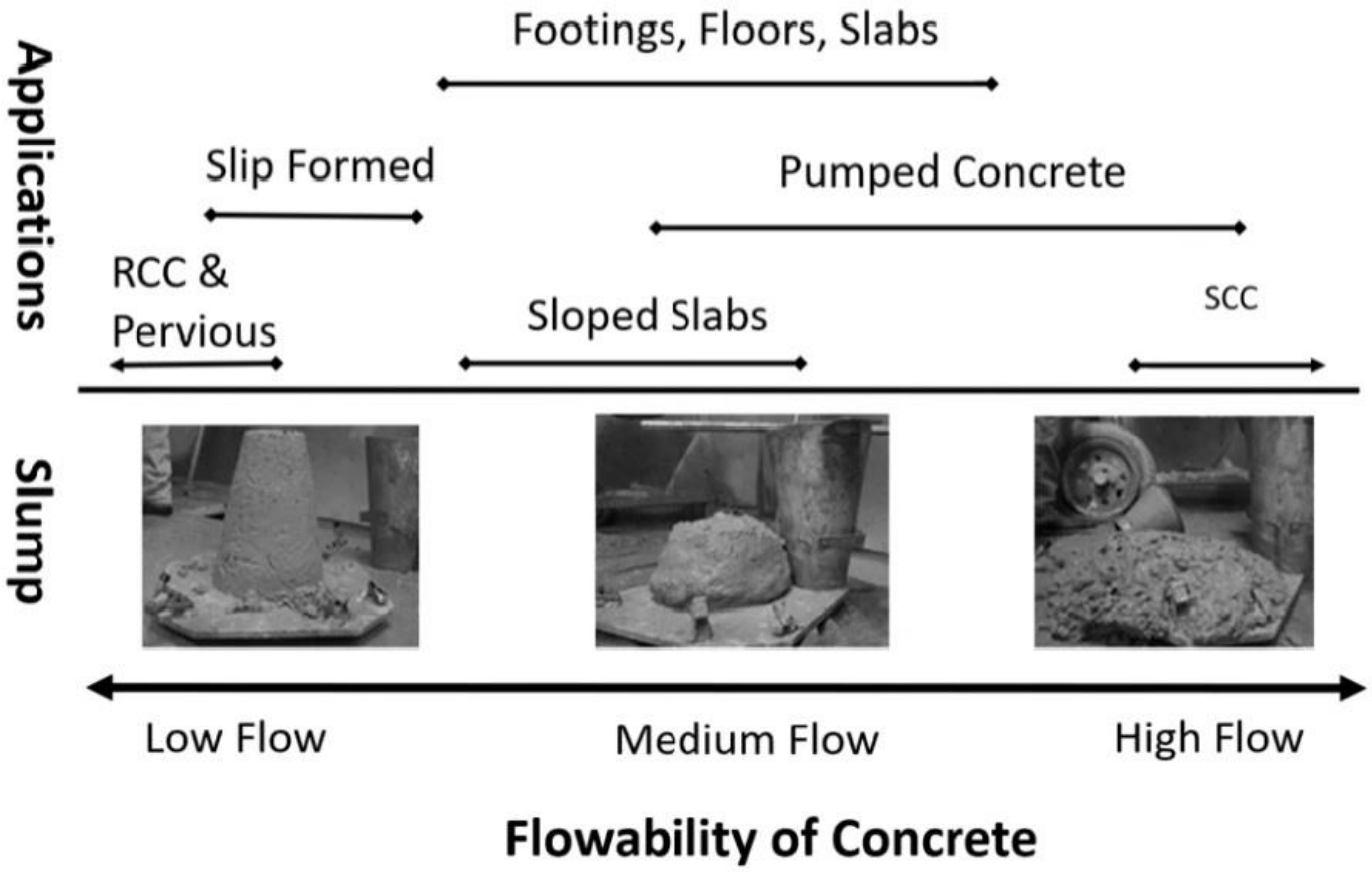
Step 1: Choice of Slump



Table. Recommended slumps from ACI 211

Type of Construction	Slump (in)	
	Max.	Min
Reinforced foundation walls and footings	3	1
Plain footing, caissons, and substructure walls	3	1
Beams and reinforced walls	4	1
Building columns	4	1
Pavements and slabs	3	1
Mass concrete	3	1

Range of Workability



Step -2: Maximum Aggregate Size
20 mm (3/4”)

Step 2: Max. Size of Coarse Agg

- Use Nominal Max.
- Usually either a 3/4 in. (#67), 1 in. (#57), or 1.5 in. (#467).
- Largest maximum aggregate size should not be larger than:
  - ❖ 1/5” minimum dimension of element
  - ❖ 1/3” thickness of slab
  - ❖ ¾” clearance between rebar and forms

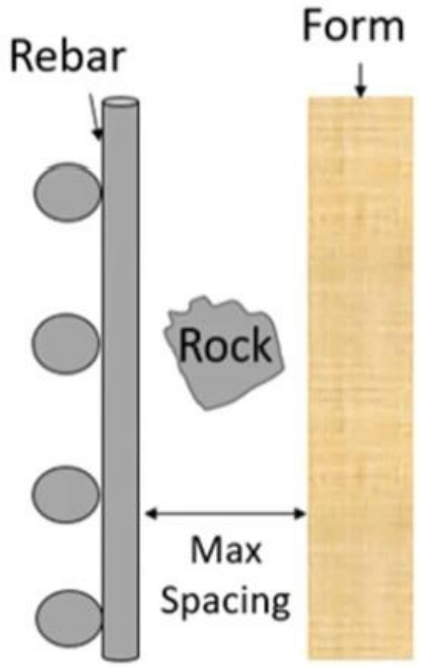


Table Used to Determine Nominal Max. Size of C. A. vs. Size

ASTM C - 33

TABLE 2 Grading Requirements for Coarse Aggregates

Size Number	Nominal Size (Sieves with Square Openings)	Amounts Finer than Each Laboratory Sieve (Square-Openings), Weight Percent												
		4 in. (100 mm)	3½ in. (90 mm)	3 in. (75 mm)	2½ in. (63 mm)	2 in. (50 mm)	1½ in. (37.5 mm)	1 in. (25.0 mm)	¾ in. (19.0 mm)	½ in. (12.5 mm)	⅜ in. (9.5 mm)	No. 4 (4.75 mm)	No. 8 (2.36 mm)	No. 16 (1.18 mm)
1	3½ to 1½ in. (90 to 37.5 mm)	100	90 to 100	...	25 to 60	...	0 to 15	...	0 to 5	...	...	...	...	...
2	2½ to 1½ in. (63 to 37.5 mm)	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...	...
3	2 to 1 in. (50 to 25.0 mm)	...	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...
357	2 in. to No. 4 (50 to 4.75 mm)	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	...	0 to 5	...	...
4	1½ to ¾ in. (37.5 to 19.0 mm)	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	0 to 5	...	...	...
467	1½ in. to No. 4 (37.5 to 4.75 mm)	...	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	0 to 5	...	...
5	1 to ½ in. (25.0 to 12.5 mm)	...	...	...	...	...	100	90 to 100	20 to 55	0 to 10	0 to 5	...	...	...
56	1 to ⅜ in. (25.0 to 9.5 mm)	...	...	...	...	...	100	90 to 100	40 to 85	10 to 40	0 to 15	0 to 5	...	...
57	1 in. to No. 4 (25.0 to 4.75 mm)	...	...	...	...	...	100	95 to 100	...	25 to 60	...	0 to 10	0 to 5	...
6	¾ to ⅜ in. (19.0 to 9.5 mm)	...	...	...	...	...	...	100	90 to 100	20 to 55	0 to 15	0 to 5	...	...
67	¾ in. to No. 4 (19.0 to 4.75 mm)	...	...	...	...	...	...	100	90 to 100	...	20 to 55	0 to 10	0 to 5	...
7	½ in. to No. 4 (12.5 to 4.75 mm)	...	...	...	...	...	...	...	100	90 to 100	40 to 70	0 to 15	0 to 5	...
8	⅜ in. to No. 8 (9.5 to 2.36 mm)	...	...	...	...	...	...	...	...	100	85 to 100	10 to 30	0 to 10	0 to 5

Step 3: Water & Air Content

No Air

Or

Air Entrained

Table 6.3.3 — Approximate mixing water and air content requirements for different slumps and nominal maximum sizes of aggregates

Slump, in.	Water, lb/yd³ of concrete for indicated nominal maximum sizes of aggregate							
	⅜ in.*	½ in.*	¾ in.*	1 in.*	1-½ in.*	2 in.*†	3 in.†‡	6 in.†‡
Non-air-entrained concrete								
1 to 2	350	335	315	300	275	260	220	190
3 to 4	385	365	340	325	300	285	245	210
6 to 7	410	385	360	340	315	300	270	—
More than 7*	—	—	—	—	—	—	—	—
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-entrained concrete								
1 to 2	305	295	280	270	250	240	205	180
3 to 4	340	325	305	295	275	265	225	200
6 to 7	365	345	325	310	290	280	260	—
More than 7*	—	—	—	—	—	—	—	—
Recommended averages§ total air content, percent for level of exposure:								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5**,††	1.0**,††
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5**,††	3.0**,††
Severe exposure‡‡	7.5	7.0	6.0	6.0	5.5	5.0	4.5**,††	4.0**,††

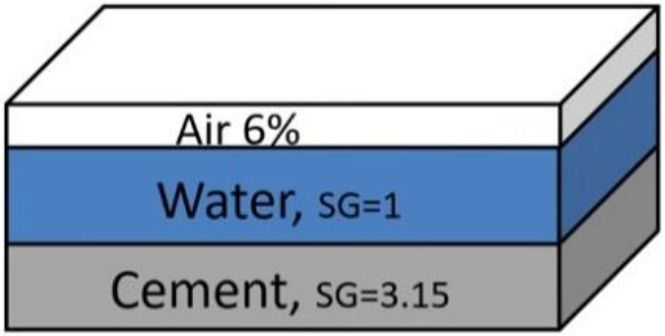
Step 4: W/CM Ratio

Table 9-3 (Inch-Pound Units). Relationship Between Water to Cementitious Material Ratio and Compressive Strength of Concrete

Compressive strength at 28 days, psi	Water-cementitious materials ratio by mass	
	Non-air-entrained concrete	Air-entrained concrete
7000	0.33	—
6000	0.41	0.32
5000	0.48	0.40
4000	0.57	0.48
3000	0.68	0.59
2000	0.82	0.74

Strength is based on cylinders moist-cured 28 days in accordance with ASTM C 31 (AASHTO T 23). Relationship assumes nominal maximum size aggregate of about ¾ in. to 1 in.
Adapted from ACI 211.1 and ACI 211.3.

Design Wt. (lbs.)	**Material**	**Volume** (ft^3)
---	Air 6%	1.62 ft^3
250 lbs.	Water, SG=1	4.01 ft^3
564 lbs.	Cement, SG=3.15	2.87 ft^3



27.00 ft^3

Step 5: Cement Content

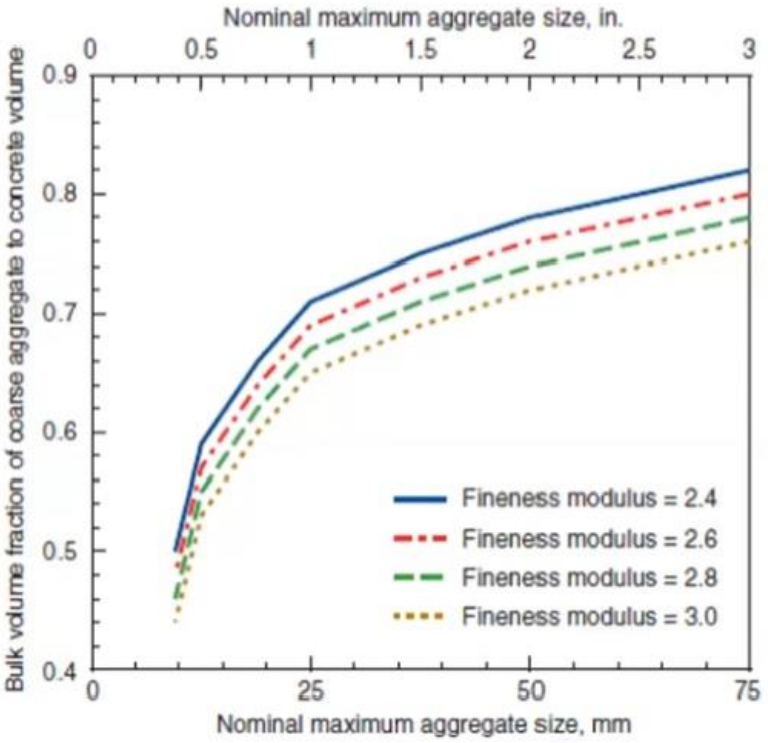
$$weight\ of\ cement = \frac{weight\ of\ water}{w/c}$$

However, a minimum cement content is required to ensure good finishability, workability, and strength.

Step 6: Coarse Agg. Content

Table 9-4. Bulk Volume of Coarse Aggregate Per Unit Volume of Concrete

Nominal maximum size of aggregate, mm (in.)	Bulk volume of dry-rodded coarse aggregate per unit volume of concrete for different fineness modull of fine aggregate*			
	2.40	2.60	2.80	3.00
9.5 (⅜)	0.50	0.48	0.46	0.44
12.5 (½)	0.59	0.57	0.55	0.53
19 (¾)	0.66	0.64	0.62	0.60
25 (1)	0.71	0.69	0.67	0.65
37.5 (1½)	0.75	0.73	0.71	0.69
50 (2)	0.78	0.76	0.74	0.72
75 (3)	0.82	0.80	0.78	0.76
150 (6)	0.87	0.85	0.83	0.81



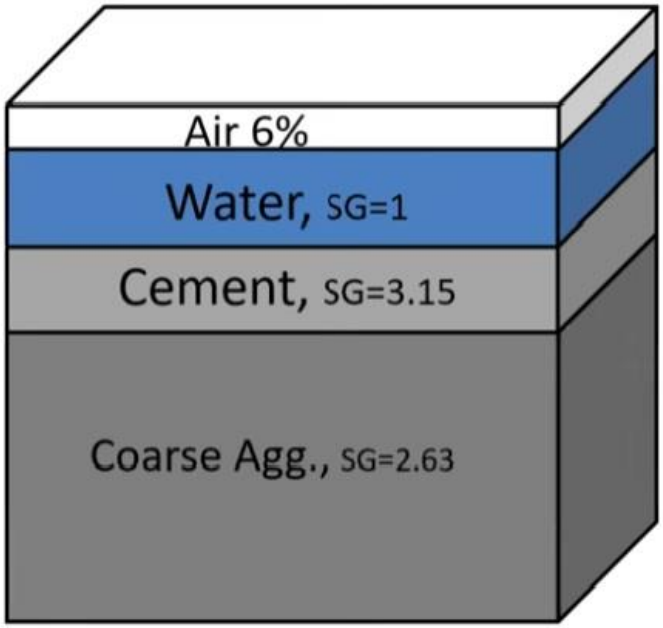
Step 6: Coarse Aggregate Content

Calculating Coarse Aggregate Weight

Coarse Aggregate Weight = Volume Percent of CA X Dry-rodded unit wt of CA X 27

- Volume Percent of CA: Found in previous table/figure
- Dry-rodded unit wt of CA: Given Aggregate Property
- 27: Conversion of ft^3 to yd^3

Design Wt. (lbs.)	**Material**	**Volume** (ft^3)
---	Air 6%	1.62 ft^3
250 lbs.	Water, SG=1	4.01 ft^3
564 lbs.	Cement, SG=3.15	2.87 ft^3
1800 lbs.	Coarse Agg., SG=2.63	10.97ft^3
		27.00 ft^3



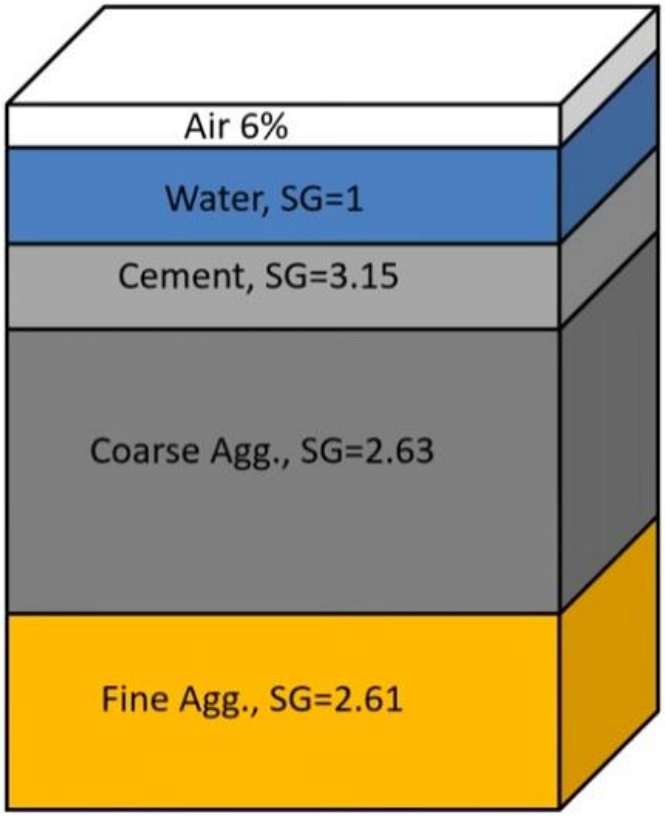
From [1]

$$\text{Abs. Vol.} = \frac{\text{Weight of Material}}{\text{(Sp. Gr. Of Material)X(Unit Wt. Of Water)}}$$

A.) Cement	=	564 lbs. / 3.15 X 62.4 lbs/cu. ft.	=	2.87	ft^3
B.) Stone	=	1800 lbs. / 2.63 X 62.4 lbs/cu. ft.	=	10.97	ft^3
C.) Water	=	250 lbs. / 1.00 X 62.4 lbs/cu. ft.	=	4.01	ft^3
D.) Sand	=	1226 lbs. / 2.61 X 62.4 lbs/cu. ft.	=	7.53	ft^3
E.) Air	=	6 % of air X 27 cu.ft.	=	1.62	ft^3

Step 7: Fine Agg. Content

Design Wt. (lbs.)		**Volume** (ft^3)
	Air 6%	1.62 ft^3
---	Water, SG=1	4.01 ft^3
250 lbs.	Cement, SG=3.15	2.87 ft^3
564 lbs.	Coarse Agg., SG=2.63	10.97 ft^3
1800 lbs.	Fine Agg., SG=2.61	?????
???????		**27.00** ft^3



From [1]

Step 7: Fine Agg. Content

Therefore, the fine aggregate must occupy a volume of:

$$27\ \text{ft.}^3 - \boxed{Volume}\ \text{ft.}^3 = \boxed{Volume_{FA}}\ \text{ft.}^3$$

The SSD weight of the fine aggregate is:

$$\boxed{Volume_{FA}}\ \text{ft.}^3 \times \boxed{SG_{FA}} \times 62.4\ \text{lb./ft.}^3 = \boxed{FA_{SSD}}\ \text{lb.}$$

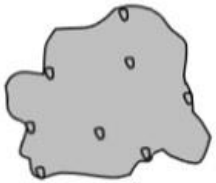
Specific Gravity of Fine Aggregate

Unit Weight of Water

Step 8: Adjust for Agg Moisture

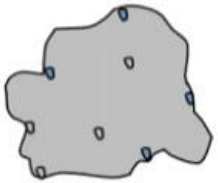
- Absorption of aggregate is the moisture content at **SSD condition**.
- Free water is **leftover water** not absorbed by aggregate (more than SSD).

Completely Dry



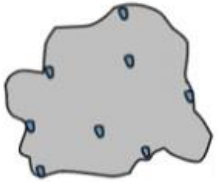
0%

Partially Wet



Between 0% and 100%

Surface Saturated Dry (SSD)



100%

Free Water



Greater than 100%

$$Absorption\ (\%) = \frac{W_{SSD} - W_{dry}}{W_{dry}} x100$$

$$Moisture(\%) = \frac{W_{wet} - W_{dry}}{W_{dry}} x100$$

Step 8: Adjust for Agg Moisture

Given: **ABS of Rock (%)** = 0.5%

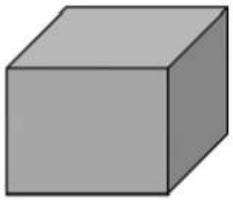
Calculated: **Moisture (%)** = 2.19%

Free water (%) = 1.69%



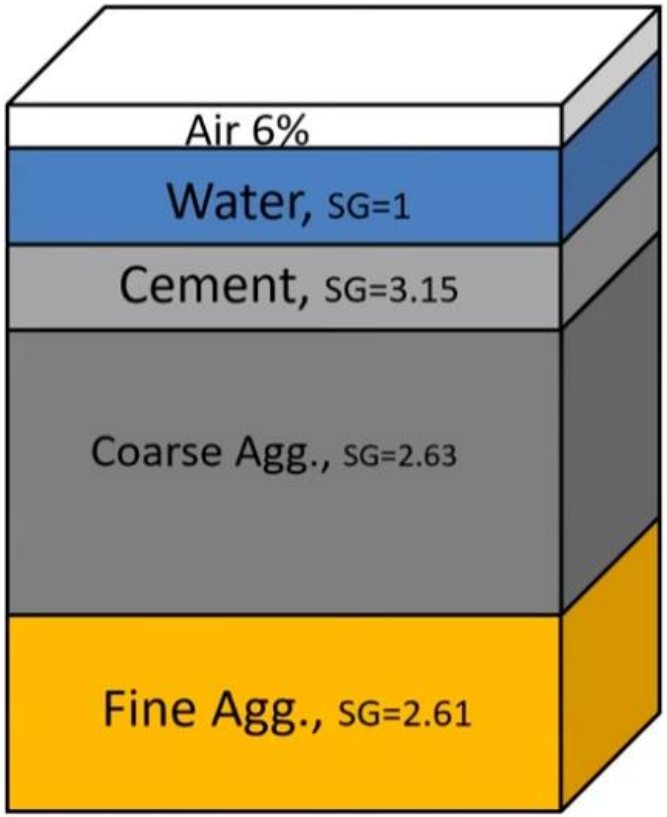
Batch 1830 lbs. of stone

=



1800 lbs. of Stone

Design Wt. (lbs.)	**Material**	**Volume** (ft^3)
---	Air 6%	1.62 ft^3
250 lbs.	Water, SG=1	4.01 ft^3
564 lbs.	Cement, SG=3.15	2.87 ft^3
1800 lbs.	Coarse Agg., SG=2.63	10.97ft^3
1226 lbs.	Fine Agg., SG=2.61	7.53 ft^3
		27.00 ft^3



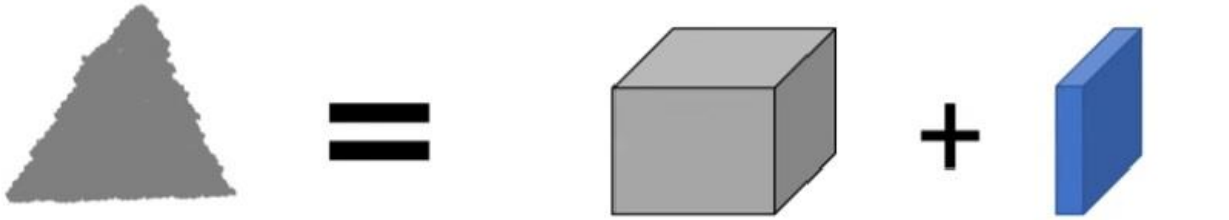
From [1]

Step 8: Adjust for Agg Moisture

Given: **ABS of Rock (%)** = 0.5%

Calculated: **Moisture (%)** = 2.19%

Free water (%) = 1.69%



Batch 1830 lbs. of stone

1800 lbs. of Stone

30 lbs. of Water

Step 9: Trial Batch Adjustments

It may look good on paper but…





Problems with ACI 211

- Not Current with Materials
  - cementitious materials *(fly ash, slag, silica fume)*
  - admixtures *(WRA, acc, ret, vis mod, etc)*
  - multiple aggregate bins *(intermediate agg)*
- No water adjustments
  - Aggregate characteristics (angularity, shape, etc)
  - Admixtures & SCM replacement


3 THINGS IN LIFE
WE CAN'T ESCAPE..
DEATH, TAXES, AND CONCRETE CRACKS

Concrete Mix Design - Practical Problem

Concrete is required for casting the interior large columns in the ground floor of a multi-storied buildings structural consideration specify a mean cylinder strength of 250 kg/cm^2 at 28 days. The coarse aggregate locally available is well graded having a maximum size of 40 mm and a dry rodded unit weight of 1600 kg/cm^3. Fineness modulus of sand available at site 2.80. Slump specified for the job is 80-100 mm. Specific gravity of cement, coarse and fine aggregate are 3.15, 2.68 and 2.64 respectively. Type of cement of available at site is Ordinary Portland (Type-I). Do mix design for the job.