53th Quality Concrete School
New Mexico State University
Concrete Mix Design Workshop
January 13 – 14, 2017

CONCRETE MIX DESIGN WORKSHOP FOR NORMAL CONCRETE MIXTURES
Mix Design is the Recipe for the Concrete (Stew)

• The basic materials are (ingredients).
  - Cement (flour, thickener)
  - Fine aggregate (rice)
  - Coarse Aggregate (vegetables)
  - Water (water)
Range in Proportions

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix 1</td>
<td>15%</td>
<td>18%</td>
<td>8%</td>
<td>28%</td>
<td>31%</td>
</tr>
<tr>
<td>Mix 2</td>
<td>7%</td>
<td>14%</td>
<td>4%</td>
<td>24%</td>
<td>51%</td>
</tr>
<tr>
<td>Mix 3</td>
<td>15%</td>
<td>21%</td>
<td>3%</td>
<td>30%</td>
<td>31%</td>
</tr>
<tr>
<td>Mix 4</td>
<td>7%</td>
<td>16%</td>
<td>1%</td>
<td>25%</td>
<td>51%</td>
</tr>
</tbody>
</table>

Air-entrained concrete

Non-air-entrained concrete
Cement “What Does it Do?”

• Cement sets and hardens by reacting chemically with water.

• The reaction is called Hydration.

• Forms a stone like mass called PASTE
Cement ASTM C150 or C1157 for most Concrete Const.

I- For General Construction
II-Moderate protection against Sulfate attack
III-Used to achieve faster setting - Early Strength Gain.
V- For severe exposure to Sulfate, if anticipated
Cement

- One cubic foot of Cement is 94 lbs
- One bag of Cement is 94 lbs
- 4 bags = 1 Barrel of cement
- 200 Barrel silo x 4 = 800 sack x 100# = 80,000# / 2000#/ton = 40 ton silo / 25 ton loads = 1.6 loads of cement
- Specific Gravity is 3.15
New Type of Cement ASTM C1157

- Blended cement used in Residential Construction

- Combination of cement and supplementary cement materials.

- Called a “Green” cement
Supplementary Cementitious Materials

• Fly Ash Class C
• Fly Ash Class F
• Natural Pozzolans Class N
• GGBFC - a ground granulate blast furnace slag - Grade 80,100 & 120
• Calcined Clay or Metakaolin
• Silica Fume
Supplementary Cementitious Materials

From left to right:
Fly ash (Class C)
Metakaolin (calcined clay)
Silica fume
Fly ash (Class F)
Slag
Calcined shale
Class C Ash adds strength to the concrete by reducing the amount of cement when added to the mix design. Class C Ash does not offset the ASR requirement. In the West we have class F fly ash from the power plants.
Fly Ash
FLY ASH
Mix Design

• Cement is replaced with a % of Fly Ash

Example

Cement -- 500 lbs = 81 %
Fly ash -- 120 lbs = 19 % of the total
Total -- 620 lbs / 94 lb/bag = 6.6 bags
Coarse, Intermediate and Fine Aggregate
Aggregates
Fine and Coarse

Coarse aggregate is 1” to No. 4

This means the coarse aggregate passes the 1” screen opening and screened over a #4 or ¼” opening.

Fine aggregate is No. 4 to pan
Testing Coarse Aggregate Sieve Shaker w/7 Screens
Coarse Aggregate Sieve
Aggregate size

• 1.5” means the square opening of the screen is 1.5”.
• 1.0” is a opening of 1”
• ¾” is a opening of ¾”
• ½” is a opening of ½’
• 3/8” is a opening of 3/8”
• #4 screen has 4 openings per inch.
Fine Aggregate Sizes

• # 8 there are 8 openings per inch each way
• #16 there are 16 openings per inch
• #30 there are 30 openings per inch
• #50 there are 50 openings per inch
• #100 there are 100 openings per inch
• #200 there are 200 openings per inch
A nest of sieves #4 to #200
Fine Aggregate Testing
Fine Aggregate at SSD Breaks off after being compacted by the tamper

ASTM C128-07a  25 drops about 5mm ¼”= 6.35 mm
Fine agg. Mold and Tamper
Measures the SSD condition

ASTM C128-07a  25 drops about 5mm ¼”= 6.35 mm
Coarse Aggregate SSD & Dry

SSD Aggregate

Dry Aggregate
Total Moisture Content of material

- Wet weight: 2106.8 gm, 2496.0 gm
- Dry weight: 2031.0 gm, 2371.0 gm
- Wt of water: 75.8 gm, 125.0 gm
  - $\frac{75.8}{2031.0} = 3.7$, $\frac{125}{2371} = 5.3$
- SSD % example: -2.7, SSD = -1.5
- Excess water: +1.0 %, +3.8 %

3/21/2017
Potable Water Recommended
Water

- Should be potable
  - Has no pronounced taste or odor. Can be used as mixing water for concrete.
  - Some recycled water is being used in the market, but producers are checking this so it does not have adverse problems on the concrete.
  - We have to recycle.
- ASTM C 1602 regulates mixing water.
Water

• Quality of concrete is influenced by the amount of water used with the amount of cement.

• Higher water content dilutes the cement paste (the glue of concrete).
Why Reduce the Water Content?

- Increased compressive strength
- Increased resistance to weathering
- Lower permeability increases water tightness and lower absorption.
Water-cement ratio experiment
Air voids left by evaporation of excess water are responsible for varying densities.
Why Reduce the Water Content?

• Better bond between concrete and reinforcement

• Reduces volume change from wetting and drying

• Reduced shrinkage and cracking
Chemical Admixtures

DEFINITION

Ingredients in concrete other than Portland cement, water, and aggregates- Are added to the mixture immediately before and during mixing.
Chemical Admixtures

- Air-entrained agents
- Normal water reducers
- Retarding water reducers
- Midrange water reducers
- High range water reducing admixtures (supers plasticizers)
- Viscosity modifying admixtures
- Accelerating water reducers
- Accelerators
Admixture Colors
Chemical Admixtures

• AIR ENTRAINING ADMIXTURE (AEA)

Stabilize microscopic bubbles in concrete which can provide freeze thaw resistant and improve resistance to de-icer salt scaling. Do not trowel finish with entrained air over 3%.
Entrained Air in Concrete
Chemical Admixtures

HIGH RANGE WATER REDUCING ADMIXTURES (Super Plasticizers)

Reduces the water content by 12% to 30% while maintaining slump.

Produces flowing concrete without the addition of water.
Chemical Admixtures

HIGH RANGE WATER REDUCING ADMIXTURES

Example:
36 gal / yd x 8.33 lb/gal = 300 lb/yd
36 gal x 12% = 4.3 gal x 8.33 = 36 lbs
36 gal x 30% = 10.8 gal x 8.33 = 90 lbs

This is ASTM Type F (Normal Set) and Type G (Retarding Set).
High range water reducing admixtures added at the site
High range water reducing admixtures added at the site

- Generally there is a 3- to 4-inch slump concrete at the job site. Add 3 gallons of Super Plasticizer to the mix and you will get 7- to 8-in slump concrete without any water added. One hour later the concrete reverts to the original 3- to 4- inch slump.
High range water reducing admixtures added at the site

High range increases the slump from a 4” to a 8” with 3 gallons in a 10 cuyd load. Normally it would have taken 4 gals of water per yard to increase the slump 4” or 40 gallons of water to increase the slump in a 10yd load

$36 \text{ gal} \times 12\% = 4.3 \text{ gal} \times 8.33 = 36 \text{ lbs}$
Slump Test
High Range Water Reducer
no Water added
Flow able Concrete
Factors in the Proportioning of Quality Concrete Mixtures

Workability
Durability
Strength
Appearance
Economy
Strength and Durability
Mix Characteristics

- Strength
- Water-cementing materials ratio
- Aggregate size and volume
- Air content
- Slump and workability
- Water content
- Cementing materials content and type
- Admixtures
Determination of Cement Content

Cement Content = \frac{\text{Required Water Content}}{\text{Water-Cement Ratio}}

Example: air-entrained concrete
1-in. max. size aggregate
3-in. slump

\frac{295 \text{ lb/yd}^3 \text{ Water}}{0.53 \text{ W/C-ratio}} = 557 \text{ lb. cement per yd}^3 \text{ of concrete}
Methods for Proportioning Concrete Mixtures

- Water-cement ratio method
- Weight method
- Absolute volume method
- Field experience (statistical data)
- Trial mixtures
Design an Air Entrained Concrete Mix by Absolute Volume Computations

• Use Designing and Proportioning Normal Concrete Mixtures. PCA 16\textsuperscript{th} edition EB0012.14 (Hand Out)
• PCA 16\textsuperscript{th} edition chapter 15
• Material Properties

  Water: Unit Weight 62.4 pcf: 8.33 lb/gal
  Cement: Specific Gravity 3.15: 94 lb /sk or cuft
  Coarse Agg. Oven dry 0%, SG 2.62 Max. size 1”

  Dry-rodded Unit Wt. 96 pcf Abs.0.5%
  Total Moist. Cont of CA 1.5%

3/21/2017
Mix Design for 2017

The mix design will require $f'c = 4000$ psi with entrained air a F1 exposure per table 15-15-1 and a S1 Exposure class per 15-2. No test data available

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.1</td>
<td>Water specific gravity</td>
<td>1.00</td>
</tr>
<tr>
<td>1.2.1</td>
<td>Cement brand for example</td>
<td>GCC</td>
</tr>
<tr>
<td>1.2.2</td>
<td>Type of cement</td>
<td>I-II, LA</td>
</tr>
<tr>
<td>1.2.3</td>
<td>Cement specific gravity</td>
<td>3.15</td>
</tr>
<tr>
<td>1.3.1</td>
<td>Other material (fly ash type F)</td>
<td>2.10</td>
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<tr>
<td>1.4</td>
<td>Coarse Aggregate</td>
<td></td>
</tr>
<tr>
<td>1.4.1</td>
<td>Specific Gravity Oven Dry (OD)</td>
<td>2.62</td>
</tr>
<tr>
<td>1.4.2</td>
<td>Nominal Maximum size</td>
<td>1.0 inch</td>
</tr>
<tr>
<td>1.4.3</td>
<td>Dry rodded unit weight</td>
<td>96 pcf</td>
</tr>
<tr>
<td>1.4.4</td>
<td>Absorption of the rock</td>
<td>0.5 %</td>
</tr>
<tr>
<td>1.4.5</td>
<td>Total moisture of the Coarse aggregate</td>
<td>1.5%</td>
</tr>
</tbody>
</table>
### Fine Aggregate

<table>
<thead>
<tr>
<th>1.5</th>
<th>Fine Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5.1</td>
<td>Specific Gravity oven Dry (OD)</td>
</tr>
<tr>
<td>1.5.2</td>
<td>Fineness Modulus (FM)</td>
</tr>
<tr>
<td>1.5.3</td>
<td>Dry rodded unit weight</td>
</tr>
<tr>
<td>1.5.4</td>
<td>Absorption of the fine aggregate</td>
</tr>
<tr>
<td>1.5.5</td>
<td>Moisture of the fine aggregate</td>
</tr>
</tbody>
</table>

### Admixture’s

<table>
<thead>
<tr>
<th>1.6</th>
<th>Admixture’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6.1</td>
<td>Type</td>
</tr>
<tr>
<td>1.6.2</td>
<td>Dosage per 100 weight (cwt)</td>
</tr>
<tr>
<td>1.6.3</td>
<td>Type</td>
</tr>
<tr>
<td>1.6.4</td>
<td>Dosage per 100 weigh of cement (cwt)</td>
</tr>
</tbody>
</table>
Concrete Mix Design & Proportioning

Portland Cement Association

16th Edition English

PCA Method by absolute volume

Similar to example 2 on page 373

1.-(Materials)

1.1.- (Water) \( W \)

1.1.1.- (Specific Gravity) ________

unit wt. of water 62.4 pcf water weighs 8.33 lb/gal @ 60F

1.2. – (Cement) \( C \)

1.2.1.- (Brand of Cement) __________

1.2.2.- (Standard, Type) __________

1.2.3.- (Specific Gravity) ________

1.3 – (Other Materials)

1.3.1. – (Fly ash) Class F ________

1.3.2. – (Silica fume) ________

1.3.3. – (Slag gbfs) ________
1.4.- (Coarse Aggregate) ASTM C-33

1.4.1.- (Specific gravity oven dry (OD)) _________
1.4.2.- (Nominal Maximum size agg) _________
1.4.3.- (Bulk Density(OD) (unit wt.)) _________pcf
1.4.4.- (Absorption) % _________ %
1.4.3.- (Moisture) % _________ %

1.5. – (Fine Aggregates) ASTM C-33

1.5.1.- (Specific Gravity (OD)) _________
1.5.2.- (Fineness Modulus FM) _________
1.5.3.- (Bulk Density OD)(unit wt) _________pcf
1.5.4. – (Absorption) % _________ %
1.5.5. – (Moisture) % _________ %
1.6--- Admixture

1.6.1 – (Type)  
______________

1.6.2. – (Dosages)  
_________oz /cwt

1.6.3 – (Type)  
______________

1.6.4 – (Dosages)  
_________oz/cwt
2. - (Design Specifications)

2.1. – (Specified Strength) $f'c$  

2.1.a required avg strength $f'cr$ over design ______ psi

This is from table 15-10

2.1.b sum 2.1 + 2.1.b = $f'cr$  

2.2. – (Age)  generally 28 days  

2.3. – (Exposure conditions) table 15-1

2.3a- (Exposure conditions table 15-2)

2.3b –w/c from table 15-3 interpolated  

(Weight calculations) Mixing water/Water-cement ratio  (choose the lowest w/c)

2.4. – (Air content) table 15-5  

(Class F1) 1”agg  

2.5. – (Slump) from table 15-5  

2.6. – (Nominal Maximum Size)  

2.7. – (Other)
3. – (Data from tables or figures)(hand out) 16th edition
   3.1. – Water Cement Ratio) W/C
   Use the lowest w/c of 2.3, 2.3a, & 2.3b above
   3.1.1. – lowest water /cement ratio
   3.2. – (Entrapped air) (Table) 15-5
   3.3. – (Air Content) (Table) 15-5
   3.4. – (Mixing water) (Table) 15-5
   3.5. – (Coarse aggregate bulk volume) (table) 15-4) nominal maximum size aggregate and the FM of the fine aggregate
## Requirements for Exposure Conditions

<table>
<thead>
<tr>
<th>Exposure condition</th>
<th>Table 15-1</th>
<th>Maximum w/c-ratio by mass</th>
<th>Min. strength, $f'_c$, MPa (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No freeze-thaw, deicers, aggressive substances</td>
<td>Select for strength, workability, and finishing needs</td>
<td>Select for structural requirements</td>
<td></td>
</tr>
<tr>
<td>Concrete with low permeability; exposed to water</td>
<td>0.50</td>
<td>28 (4000)</td>
<td></td>
</tr>
<tr>
<td>Concrete exposed to freezing and thawing in a moist condition or deicers</td>
<td><strong>F2, S2 ---0.45</strong></td>
<td>31 (4500)</td>
<td></td>
</tr>
<tr>
<td>For corrosion protection for reinforced concrete exposed to chlorides</td>
<td>0.40</td>
<td>35 (5000)</td>
<td></td>
</tr>
</tbody>
</table>
Table 15-1  see F1 = 0.55

<table>
<thead>
<tr>
<th>Exposure category</th>
<th>Exposure condition</th>
<th>Maximum water-cementitious material ratio by mass for concrete</th>
<th>Minimum design compressive strength $f_c$, MPa (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0, S0, W0, C0</td>
<td>Concrete protected from exposure to freezing and thawing, application of deicing chemicals, or aggressive substances</td>
<td>Select water-cementitious ratio on basis of strength, workability, and finishing needs</td>
<td>Select strength based on structural requirements</td>
</tr>
<tr>
<td>W1, S1</td>
<td>Concrete intended to have low permeability when exposed to water (W1) or moderate sulfates (S1)</td>
<td>0.50</td>
<td>28 (4000)</td>
</tr>
<tr>
<td>F1</td>
<td>Concrete exposed to freezing and thawing with limited exposure to moisture</td>
<td>0.55</td>
<td>25 (3500)</td>
</tr>
<tr>
<td>F2, S2</td>
<td>Concrete exposed to freezing and thawing with exposure to moisture (F2) or severe sulfates (S3)</td>
<td>0.45</td>
<td>31 (4500)</td>
</tr>
<tr>
<td>F3*, S3</td>
<td>Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals (F3) or very severe sulfates (S3)</td>
<td>0.40</td>
<td>35 (5000)</td>
</tr>
<tr>
<td>C2</td>
<td>For corrosion protection for reinforced concrete exposed to chlorides from deicing salts, salt water, brackish water, seawater, or spray from these sources</td>
<td>0.40</td>
<td>35 (5000)</td>
</tr>
</tbody>
</table>

Adapted from ACI 318-14. The following four exposure categories determine durability requirements for concrete: (1) F – Freezing and Thawing; (2) S – Sulfates; (3) W – Water; and (4) C – Corrosion. Increasing numerical values represent increasingly severe exposure conditions.

* For plain concrete, the maximum w/cm shall be 0.45 and the minimum design strength shall be 31 MPa (4500 psi).
## Requirement for Concrete Exposed to Sulfates

### Table 15-2 S1 in the example

<table>
<thead>
<tr>
<th>Sulfate exposure</th>
<th>Sulfate (SO₄) in soil, % by mass</th>
<th>Sulfate (SO₄) in water, ppm</th>
<th>Cement type</th>
<th>Maximum w/c-ratio, by mass</th>
<th>Minimum strength, f'ᵢ, MPa (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Less than 0.10</td>
<td>Less than 150</td>
<td>No special type required</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.10 to 0.20</td>
<td>150 to 1500</td>
<td>II, MS, IP(MS), IS(MS), P(MS), I(PM)(MS), I(SM)(MS)</td>
<td>0.50</td>
<td>28 (4000)</td>
</tr>
<tr>
<td>Severe</td>
<td>0.20 to 2.00</td>
<td>1500 to 10,000</td>
<td>V, HS</td>
<td>0.45</td>
<td>31 (4500)</td>
</tr>
<tr>
<td>Very severe</td>
<td>Over 2.00</td>
<td>Over 10,000</td>
<td>V, HS</td>
<td>0.40</td>
<td>35 (5000)</td>
</tr>
<tr>
<td>Exposure class</td>
<td>Sulfate exposure**</td>
<td>Cementitious materials requirements†</td>
<td>Maximum w/cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------</td>
<td>-------------------------------------</td>
<td>--------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water-soluble sulfate in soil, % by mass</td>
<td>Dissolved sulfate in water, ppm</td>
<td>C150</td>
<td>C595</td>
<td>C1157</td>
</tr>
<tr>
<td>S0</td>
<td>Negligible</td>
<td>SO$_4$ &lt; 0.10</td>
<td>SO$_4$ &lt; 150</td>
<td>NSR</td>
<td>NSR</td>
</tr>
<tr>
<td>S1</td>
<td>Moderate†</td>
<td>0.10 &lt; SO$_4$ &lt; 0.20</td>
<td>150 &lt; SO$_4$ &lt; 1500</td>
<td>II or II(MH)</td>
<td>IP(MS)</td>
</tr>
<tr>
<td>S2</td>
<td>Severe</td>
<td>0.20 &lt; SO$_4$ &lt; 2.00</td>
<td>1500 &lt; SO$_4$ &lt; 10,000</td>
<td>V</td>
<td>IP(HS)</td>
</tr>
<tr>
<td>S3§</td>
<td>Very severe</td>
<td>SO$_4$ &gt; 2.00</td>
<td>SO$_4$ &gt; 10,000</td>
<td>V</td>
<td>IP(HS)</td>
</tr>
</tbody>
</table>

* Adapted from Bureau of Reclamation Concrete Manual, ACI 201 and ACI 318. “NSR” indicates no special requirements for sulfate resistance.

** Soil is tested per ASTM C1580 and water per ASTM D516.

† Pozzolans and slag that have been determined by testing according to ASTM C1012 or by service record to improve sulfate resistance may also be used in concrete. Maximum expansions when using ASTM C1012: Moderate exposure – 0.10% at 6 months; Severe exposure – 0.05% at 6 months or 0.10% at 12 months; Very Severe exposure – 0.10% at 18 months. Refer to ACI 201.2R and ACI 318 for more guidance.

‡ Includes seawater.

§ ACI 318 requires SCMs (tested to verify improved sulfate resistance) with Types V, IP(HS), IS(< 70)(HS) and HS cements for exposure class S3. ACI 318 requires a maximum water:cement ratio of 0.45 for exposure class S3.
### Relationship between W/C-Ratio and Strength

**Table 15-3**

<table>
<thead>
<tr>
<th>Compressive strength at 28 days, psi</th>
<th>Water-cementitious materials ratio by mass</th>
<th>Non-air-entrained concrete</th>
<th>Air-entrained concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>7000</td>
<td>0.33</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6000</td>
<td>0.41</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>5200</td>
<td>0.38</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td>0.48</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td>0.57</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>0.68</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>0.82</td>
<td>0.74</td>
<td></td>
</tr>
</tbody>
</table>
## Water and Air Requirements for Different Slumps and Sizes of Aggregate

**Table 15-5**

<table>
<thead>
<tr>
<th>Slump, in.</th>
<th>3/8 in.</th>
<th>1/2 in.</th>
<th>3/4 in.</th>
<th>1 in.</th>
<th>1 1/2 in.</th>
<th>2 in.</th>
<th>3 in.</th>
<th>6 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>350</td>
<td>335</td>
<td>315</td>
<td>300</td>
<td>275</td>
<td>260</td>
<td>220</td>
<td>190</td>
</tr>
<tr>
<td>3 to 4</td>
<td>385</td>
<td>365</td>
<td>340</td>
<td>325</td>
<td>300</td>
<td>285</td>
<td>245</td>
<td>210</td>
</tr>
<tr>
<td>6 to 7</td>
<td>410</td>
<td>385</td>
<td>360</td>
<td>340</td>
<td>315</td>
<td>300</td>
<td>270</td>
<td>—</td>
</tr>
</tbody>
</table>

Approximate amount of entrapped air in non-air-entrained concrete, percent

<table>
<thead>
<tr>
<th>Size</th>
<th>3/8 in.</th>
<th>1/2 in.</th>
<th>3/4 in.</th>
<th>1 in.</th>
<th>1 1/2 in.</th>
<th>2 in.</th>
<th>3 in.</th>
<th>6 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
<td>3</td>
<td>2.5</td>
<td>2</td>
<td><strong>1.5</strong></td>
<td>1</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Non-air-entrained concrete
## Water and Air Requirements for Different Slumps and Sizes of Aggregate

**Table 15-5**

<table>
<thead>
<tr>
<th>Slump, in.</th>
<th>3/8 in.</th>
<th>½ in.</th>
<th>¾ in.</th>
<th>1 in.</th>
<th>1½ in.</th>
<th>2 in.</th>
<th>3 in.</th>
<th>6 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>305</td>
<td>295</td>
<td>280</td>
<td>270</td>
<td>250</td>
<td>240</td>
<td>205</td>
<td>180</td>
</tr>
<tr>
<td>3 to 4</td>
<td>340</td>
<td>325</td>
<td>305</td>
<td><strong>295</strong></td>
<td>275</td>
<td>265</td>
<td>225</td>
<td>200</td>
</tr>
<tr>
<td>6 to 7</td>
<td>365</td>
<td>345</td>
<td>325</td>
<td>310</td>
<td>290</td>
<td>280</td>
<td>260</td>
<td>—</td>
</tr>
</tbody>
</table>

**Recommended average total air content, percent, for level of exposure**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.5</td>
<td>6.0</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>5.5</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>3.5</td>
<td>5.0</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td><strong>4.5</strong></td>
<td><strong>6.0</strong></td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>4.5</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>3.5</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Air-entrained concrete
# Bulk Volume of Coarse Aggregate

<table>
<thead>
<tr>
<th>Maximum size of aggregate, mm (in.)</th>
<th>Fineness modulus of sand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.40</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>0.50</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>0.59</td>
</tr>
<tr>
<td>19 (3/4)</td>
<td>0.66</td>
</tr>
<tr>
<td>25 (1)</td>
<td>0.71</td>
</tr>
<tr>
<td>37.5 (1 1/2)</td>
<td>0.75</td>
</tr>
<tr>
<td>50 (2)</td>
<td>0.78</td>
</tr>
<tr>
<td>75 (3)</td>
<td>0.82</td>
</tr>
<tr>
<td>150 (6)</td>
<td>0.87</td>
</tr>
</tbody>
</table>
4. – (Weight calculations) Mixing water/Water-cement ratio
(choose the lowest w/c)

You can change the amount of cement if the concrete is Used for flatwork or a severe exposure. See Tables 15-1, 15-2 or 15-6. Might be a combination of several cementitious materials

4.1. – (Cement) (3.4)/(3.1) = lbs/yard

____ lbs water / 0.____ = ______lb of cement ______ lbs / cu.yd

Bags of cement (4.1) / 94 lb/sack

____ / 94 =____ sacks of cement

4.2. – (Coarse aggregate)

Bulk Density OD X Coarse aggregate volume

(1.4.3) x (3.5) = coarse agg. ln lb./cy. ___________lb/cu.yd

____ pcf x ____ cuft x 27 cu ft = ______ lb / cuyd
5. – (Absolute Volume Calculations)

5.1. – Water W (3.4)/(______) / 1.0 x 62.4 = __________ cuft

5.2. – Cement C (4.1)/(1.2.2)

(______) / 3.15 x 62.4 = __________ cuft

5.3. – Coarse Aggregate G (4.2)/(1.3.1)

(______) / 2.62 x 62.4 = __________ cuft

5.4. – Air (Select) (3.2) or (3.3)

(______) x 27 cuft / cuyd = __________ cuft

5.5. – (Sub-total) __________ cuft

5.6. – Fine Aggregate S (Volume Unit – 5.5)

27 cuft – 5.5

27 – ______ = _____ cu ft of fine aggregate __________ cuft

5.7. – Fine aggregate weight S (5.6)x1.4.1)

(___________) x 2.60 x 62.4 = __________ lb/cu
6. – Density (unit Weight)

6.1. – Cement       C

6.2. – Water        W

6.3. – Coarse Aggregate  G  0% moisture

6.4. – Fine Aggregate   S  0% moisture

6.5. – Weight   for a yard of concrete
7. –Absorption Corrections

7.1. – Cement  
C

7.2. - Coarse Aggregate. ssd
From 6.3 see 1.3.4 +
______ # ssd
______ x 1.00 = ______ lbs/ cuyd ssd

7.3. – Fine Aggregate S
From 6.4 see 1.4.4 or 1.4.5 +/-
______ # ssd
______ x 1.0 = ______ lbs/ cuyd @ ssd

7.4. – Water W Take 6.2 and
______ lbs
Total wt /cuyd _______ # cuyd

Unit weight is ______ / 27 cu ft  
------------------------  __________ cu ft
8. - Using a Water Reducer Admixture

8.1. – Set the new amount of water
base in____% reduction ______ x 100- ___= ____ %
_____ x 0._____ = ____ new water ______

8.2. – Adjust the cement to w/c in 3.1 ______
_____/ 0.____ = _____lbs of cement vs _____ = ____lbs savings

8.3. – Adjust aggregate volumes
to the new cement
_____

9. - Final Mix

9.1. – Try your mix

9.2. – Test your mix against the first one

9.3. – Amend your mix

10. – Good Luck
Concrete Mix Design & Proportioning
Portland Cement Association
16th Edition English
PCA Method by absolute volume
Similar to example2 on page 373

1.- (Materials)
   1.1.- (Water) W
      1.1.1.- (Specific Gravity) _____1____
      unit wt. of water 62.4 pcf water weighs 8.33 lb/gal @ 60F
   1.2. – (Cement) C
      1.2.1.- (Brand of Cement) GCC
      1.2.2.- (Standard, Type) I-II,L.A.
      1.2.3.- (Specific Gravity) 3.15
   1.3 – (Other Materials)
      1.3.1. – (Fly ash) Class F 2.10
      1.3.2. – (Silica fume) ________
      1.3.3. – (Slag gbfs) ________
1.4.- (Coarse Aggregate) ASTM C-33

1.4.1.- (Specific gravity oven dry (OD)) 2.62
1.4.2.- (Nominal Maximum size agg) 1 “
1.4.3.- (Bulk Density(OD) (unit wt.)) 96 pcf
1.4.4.- (Absorption) % 0.5 %
1.4.3.- (Moisture) % 1.5 %

1.5. – (Fine Aggregates) ASTM C-33

1.5.1.- (Specific Gravity (OD)) 2.60
1.5.2.- (Fineness Modulus FM) 2.60
1.5.3.- (Bulk Density OD)(unit wt) 100 pcf
1.5.4. – (Absorption) % 1.0 %
1.5.5. – (Moisture) % 5.0 %
1.6--- Admixture

1.6.1 – (Type)  entrained air

1.6.2. – (Dosages)  1.0 oz /cwt

1.6.3 – (Type)  water reducer

1.6.4 – (Dosages)  5.0 oz/cwt
2. - (Design Specifications)

2.1. – (Specified Strength) $f'c$  
\[ f'c = 4000 \text{ psi} \]

2.1.a required avg strength $f'cr$ over design  
\[ f'cr = 1200 \text{ psi} \]
This is from table 15-10

2.1.b sum 2.1 + 2.1.b = $f'cr$  
\[ f'cr = 5200 \text{ psi} \]

2.2. – (Age) generally 28 days  
\[ 28 \text{ days} \]

2.3. – (Exposure conditions) table 15-1  
\[ 0.55 \]

2.3a- (Exposure conditions table 15-2)  
\[ 0.50 \]

2.3b –w/c from table 15-3 interpolated  
\[ 0.38 \]

2.4. – (Air content) table 15-5  
(Class F1) 1”agg  
\[ 6.0 \% \]

2.5. – (Slump) from table 15-5  
\[ 3 - 4 \text{ inches} \]

2.6. – (Nominal Maximum Size)  
\[ 1” \]

2.7. – (Other)
## Relationship between W/C-Ratio and Strength

**Table 15-3**

<table>
<thead>
<tr>
<th>Compressive strength at 28 days, psi</th>
<th>Water-cementitious materials ratio by mass</th>
<th>Non-air-entrained concrete</th>
<th>Air-entrained concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>7000</td>
<td>0.33</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6000</td>
<td>0.41</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>5200</td>
<td>0.38</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td>0.48</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td>0.57</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td>3000</td>
<td>0.68</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>0.82</td>
<td>0.74</td>
<td></td>
</tr>
</tbody>
</table>
3. – (Data from tables or figures)(hand out)16th edition

3.1. – Water Cement Ratio) W/C

Use the lowest w/c of 2.3, 2.3a, & 2.3b above

3.1.1. – lowest water /cement ratio 0.38

3.2. – (Entrapped air) (Table) 15-5 1.5%

3.3. – (Air Content) (Table) 15-5 4.5 %

3.4. – (Mixing water) (Table) 15-5 295 lb

3.5. – (Coarse aggregate bulk volume) (table) 15-4) nominal maximum size aggregate and the FM of the fine aggregate 0.69
### Water and Air Requirements for Different Slumps and Sizes of Aggregate

#### Table 15-5

<table>
<thead>
<tr>
<th>Slump, in.</th>
<th>3/8 in.</th>
<th>½ in.</th>
<th>¾ in.</th>
<th>1 in.</th>
<th>1½ in.</th>
<th>2 in.</th>
<th>3 in.</th>
<th>6 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>305</td>
<td>295</td>
<td>280</td>
<td>270</td>
<td>250</td>
<td>240</td>
<td>205</td>
<td>180</td>
</tr>
<tr>
<td>3 to 4</td>
<td>340</td>
<td>325</td>
<td>305</td>
<td><strong>295</strong></td>
<td>275</td>
<td>265</td>
<td>225</td>
<td>200</td>
</tr>
<tr>
<td>6 to 7</td>
<td>365</td>
<td>345</td>
<td>325</td>
<td>310</td>
<td>290</td>
<td>280</td>
<td>260</td>
<td>—</td>
</tr>
</tbody>
</table>

**Recommended average total air content, percent, for level of exposure**

<table>
<thead>
<tr>
<th>Level of exposure</th>
<th>4.5</th>
<th>4.0</th>
<th>3.5</th>
<th>3.0</th>
<th>2.5</th>
<th>2.0</th>
<th>1.5</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate exposure</td>
<td>6.0</td>
<td>5.5</td>
<td>5.0</td>
<td><strong>4.5</strong></td>
<td>4.5</td>
<td>4.0</td>
<td>3.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Severe exposure</td>
<td>7.5</td>
<td>7.0</td>
<td>6.0</td>
<td><strong>6.0</strong></td>
<td>5.5</td>
<td>5.0</td>
<td>4.5</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Air-entrained concrete
## Bulk Volume of Coarse Aggregate

### Table 15-4

<table>
<thead>
<tr>
<th>Maximum size of aggregate, mm (in.)</th>
<th>Fineness modulus of sand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.40</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>0.50</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>0.59</td>
</tr>
<tr>
<td>19 (3/4)</td>
<td>0.66</td>
</tr>
<tr>
<td>25 (1)</td>
<td>0.71</td>
</tr>
<tr>
<td>37.5 (1 1/2)</td>
<td>0.75</td>
</tr>
<tr>
<td>50 (2)</td>
<td>0.78</td>
</tr>
<tr>
<td>75 (3)</td>
<td>0.82</td>
</tr>
<tr>
<td>150 (6)</td>
<td>0.87</td>
</tr>
</tbody>
</table>
4. – (Weight calculations) Mixing water/Water-cement ratio (choose the lowest w/c)

You can change the amount of cement if the concrete is used for flatwork or severe exposure. See Tables 15-1, 15-2 or 15-6. Might be a combination of several cementitious materials.

4.1. – (Cement) \( \frac{3.4}{3.1} = \text{lbs/yd} \)

\[
295 \text{ lbs water} / 0.38 = 776 \text{ lb of cement} \quad \text{lbs / cu.yd}
\]

\[
\text{Bags of cement (4.1) / 94 lb/sack} \quad 8.25 \text{ sacks}
\]

\[
776 / 94 = 8.25 \text{ sacks of cement}
\]

4.2. – (Coarse aggregate)

Bulk Density \( \text{OD} \times \text{Coarse aggregate volume} \)

\[
(1.43) \times (3.5) = \text{coarse agg. in lb/cy.} \quad 1788 \text{ lb/cu.yd}
\]

\[
96 \text{ pcf x 0.69 cuft x 27 cu ft} = 1788 \text{ lb / cuyd}
\]
5. – (Absolute Volume Calculations)

5.1. – Water W (3.4) \( \frac{295}{1.0 \times 62.4} = 4.73 \text{ cuft} \)

5.2. – Cement C (4.1)/(1.2.2)
\[ \frac{776}{3.15 \times 62.4} = 3.95 \text{ cuft} \]

5.3. – Coarse Aggregate G (4.2)/(1.3.1)
\[ \frac{1788}{2.62 \times 62.4} = 10.94 \text{ cuft} \]

5.4. – Air (Select) (3.2) or (3.3)
\[ \frac{0.045 \times 27}{\text{cuft/cuyd}} = 1.22 \text{ cuft} \]

5.5. – (Sub-total)
\[ 20.84 \text{ cuft} \]

5.6. – Fine Aggregate S (Volume Unit – 5.5)

27 cuft – 5.5

27 – 20.84 = 6.16 cu ft of fine aggregate
\[ 6.16 \text{ cuft} \]

5.7. – Fine aggregate weight S (5.6)x1.4.1)
\[ \frac{6.16 \times 2.60 \times 62.4}{\text{lb/cuyd}} = 999 \text{ lb/cuyd} \]
<table>
<thead>
<tr>
<th>Section</th>
<th>Component</th>
<th>Unit Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Cement</td>
<td>776</td>
</tr>
<tr>
<td>6.2</td>
<td>Water</td>
<td>295</td>
</tr>
<tr>
<td>6.3</td>
<td>Coarse Aggregate</td>
<td>1788</td>
</tr>
<tr>
<td>6.4</td>
<td>Fine Aggregate</td>
<td>999</td>
</tr>
<tr>
<td>6.5</td>
<td>Weight for a yard of concrete</td>
<td>3858</td>
</tr>
</tbody>
</table>
7. – Absorption Corrections

7.1. – Cement  \( C \)  776 \# 

7.2. - Coarse Aggregate  ssd

From 6.3 see 1.3.4 +

\[
1788 \times 1.005 = 1797 \text{ lbs/ cuyd ssd}
\]

7.3. – Fine Aggregate S

From 6.4 see 1.4.4 or 1.4.5 +/-

\[
999 \times 1.01 = 1009 \text{ lbs/ cuyd @ ssd}
\]

7.4. – Water W Take 6.2 and

\[
295 \text{ lbs}
\]

Total wt/cuyd  3877 \# cuyd

Unit weight is 3877 / 27 cu ft  ------------------ 143.36 cu ft
8. - Using a Water Reducer Admixture

8.1. – Set the new amount of water

base in 6% reduction \( \frac{295 \times 100 - 6}{295} = 94\% \)

\[ 295 \times 0.94 = 277 \text{ new water} \]

8.2. – Adjust the cement to w/c in 3.1

\( \frac{277}{0.38} = 729 \text{ lbs of cement vs 776} = 47 \text{ lbs savings} \)

8.3. – Adjust aggregate volumes

to the new cement

\[ 729 \] #

9. - Final Mix

9.1. – Try your mix

9.2. – Test your mix against the first one

9.3. – Amend your mix

10. – Good Luck
Moisture Content of aggregate blank sheet in book for your use

<table>
<thead>
<tr>
<th>Date</th>
<th>Material</th>
<th>Time</th>
<th>Wet wt.(A)</th>
<th>Dry wt.(B)</th>
<th>water (A)-(B)=C</th>
<th>%Moisture C/B</th>
<th>SSD %</th>
<th>Wet + dryer -</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/21/2017</td>
<td>1&quot;</td>
<td>3/8</td>
<td>2673</td>
<td>2106</td>
<td>5</td>
<td>0.9</td>
<td>1.2</td>
<td>-0.3</td>
</tr>
<tr>
<td></td>
<td>3/8</td>
<td></td>
<td>2106</td>
<td>2371</td>
<td>8</td>
<td>3.8</td>
<td>2.7</td>
<td>+1.1</td>
</tr>
<tr>
<td></td>
<td>wcS</td>
<td></td>
<td>2496</td>
<td>2371</td>
<td>8</td>
<td>53</td>
<td>1.5</td>
<td>+3.8</td>
</tr>
</tbody>
</table>
Moisture Content of Aggregate

- Wet weight of Material – Dry Weight of material = Weight of water
- Weight of Water / Dry Weight = Moisture content
ACI 211 Proportioning

+ 3/8” Coarse

-3/8’ + # 8 Intermediate

- #8 Fines
Optimal for 1/2” stone

Optimal area

Gap-Graded

Too Fine
Moderate Weather (Type 3)

Drive ways, curbs, walkways, ramps, patios, porches, steps, and stairs exposed to weather and garage floor slabs.

F’c = 3500 psi
Maximum Slump - 5”
Slump flow 24” to 28”
With High Range WRA
Severe Weather (Type 3)

Drive ways, curbs, walkways, ramps, patios, porches, steps, and stairs exposed to weather and garage floor slabs.

F’c = 4500 psi
Maximum Slump - 5”
Slump flow 24” to 28”
With High Range WRA
Proportions to Make 1 ft$^3$ of Concrete for Small Jobs

<table>
<thead>
<tr>
<th>Nominal maximum size coarse aggregate, in.</th>
<th>Air-entrained concrete</th>
<th>Wet fine aggregate, lb</th>
<th>Wet coarse aggregate, lb</th>
<th>Water, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td>29</td>
<td>53</td>
<td>46</td>
<td>10</td>
</tr>
<tr>
<td>1/2</td>
<td>27</td>
<td>46</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>3/4</td>
<td>25</td>
<td>42</td>
<td>65</td>
<td>10</td>
</tr>
<tr>
<td>1</td>
<td>24</td>
<td>39</td>
<td>70</td>
<td>9</td>
</tr>
<tr>
<td>1½</td>
<td>23</td>
<td>38</td>
<td>75</td>
<td>9</td>
</tr>
</tbody>
</table>

3/21/2017
Proportions by Bulk Volume of Concrete for Small Jobs

<table>
<thead>
<tr>
<th>Nominal maximum size coarse aggregate, mm (in.)</th>
<th>Air-entrained concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cement</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>1</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>1</td>
</tr>
<tr>
<td>19.0 (3/4)</td>
<td>1</td>
</tr>
<tr>
<td>25 (1)</td>
<td>1</td>
</tr>
<tr>
<td>37.5 (1½)</td>
<td>1</td>
</tr>
</tbody>
</table>
Proportions to Make 1 ft$^3$ of Concrete for Small Jobs

<table>
<thead>
<tr>
<th>Nominal maximum size coarse aggregate, in.</th>
<th>Non-air-entrained concrete</th>
<th>Non-air-entrained concrete</th>
<th>Non-air-entrained concrete</th>
<th>Non-air-entrained concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cement, lb</td>
<td>Wet fine aggregate, lb</td>
<td>Wet coarse aggregate, lb</td>
<td>Water, lb</td>
</tr>
<tr>
<td>3/8</td>
<td>29</td>
<td>59</td>
<td>46</td>
<td>11</td>
</tr>
<tr>
<td>1/2</td>
<td>27</td>
<td>53</td>
<td>55</td>
<td>11</td>
</tr>
<tr>
<td>3/4</td>
<td>25</td>
<td>47</td>
<td>65</td>
<td>10</td>
</tr>
<tr>
<td>1</td>
<td>24</td>
<td>45</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>1 1/2</td>
<td>23</td>
<td>43</td>
<td>75</td>
<td>9</td>
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</tbody>
</table>
Proportions by Bulk Volume of Concrete for Small Jobs

<table>
<thead>
<tr>
<th>Nominal maximum size coarse aggregate, in.</th>
<th>Non-air-entrained concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cement</td>
</tr>
<tr>
<td>9.5 (3/8)</td>
<td>1</td>
</tr>
<tr>
<td>12.5 (1/2)</td>
<td>1</td>
</tr>
<tr>
<td>19.0 (3/4)</td>
<td>1</td>
</tr>
<tr>
<td>25 (1)</td>
<td>1</td>
</tr>
<tr>
<td>37.5 (1½)</td>
<td>1</td>
</tr>
</tbody>
</table>
Ordering Concrete

• ASTM C94, *Standard Specification for Ready-Mixed Concrete*

• Ordering concrete
  – Purchaser specifies slump, nom. max. size aggregate, and one of:
    • Option A – designates strength
    • Option B – selects proportions
    • Option C – designates strength and cement content
# Mix Design Report

## Cost summary

<table>
<thead>
<tr>
<th>Material name</th>
<th>Unit cost</th>
<th>Quantity</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Type I/II L.A. (GCC Cement)</td>
<td>$125.00 / short ton</td>
<td>451 lb</td>
<td>$28.19</td>
</tr>
<tr>
<td>Mineral Additive Class F from 4 Corners (ABC)</td>
<td>$75.00 / short ton</td>
<td>113 lb</td>
<td>$4.24</td>
</tr>
<tr>
<td>Water Well Water (City Water supply)</td>
<td>$0.01 / gal (US)</td>
<td>250 lb</td>
<td>$0.30</td>
</tr>
<tr>
<td>Coarse Aggregate 3/8&quot; VV's (Gallup Sand &amp;)</td>
<td>$13.00 / short ton</td>
<td>362 lb</td>
<td>$2.35</td>
</tr>
<tr>
<td>Coarse Aggregate Coarse Agg 2 (Gallup)</td>
<td>$12.00 / short ton</td>
<td>509 lb</td>
<td>$3.06</td>
</tr>
<tr>
<td>Coarse Aggregate Coarse agg 1 (Gallup Sand)</td>
<td>$11.00 / short ton</td>
<td>1012 lb</td>
<td>$5.57</td>
</tr>
<tr>
<td>Fine Aggregate 3/8&quot; Cr. Sand (Gallup Sand &amp;)</td>
<td>$1.30 / short ton</td>
<td>202 lb</td>
<td>$0.13</td>
</tr>
<tr>
<td>Fine Aggregate WCS Alb (Way Core)</td>
<td>$25.40 / short ton</td>
<td>921 lb</td>
<td>$11.69</td>
</tr>
<tr>
<td>Admixture Entrained Air (BASF)</td>
<td>$10.00 / gal (US)</td>
<td>8.46 floz</td>
<td>$0.66</td>
</tr>
</tbody>
</table>

**Mix cost**  $56.19
### Mix Design Report

**Full gradation analysis - Percent passing**

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Agg. 1</th>
<th>Agg. 2</th>
<th>Agg. 3</th>
<th>Agg. 4</th>
<th>Agg. 5</th>
<th>Paste</th>
<th>Total</th>
<th>Aggr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2&quot;</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.5</td>
<td>100.0</td>
<td>99.9</td>
</tr>
<tr>
<td>1&quot;</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
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<td>99.9</td>
</tr>
<tr>
<td>3/4&quot;</td>
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<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
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<tr>
<td>1/2&quot;</td>
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<td>100.00</td>
<td>100.5</td>
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<tr>
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<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.5</td>
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<td>64.1</td>
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<tr>
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<td>44.00</td>
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<td>0.90</td>
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<td>5.40</td>
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<td>4.50</td>
<td>2.80</td>
<td>100.5</td>
<td>34.4</td>
<td>2.0</td>
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<tr>
<td># 325</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>99.0</td>
<td>33.0</td>
</tr>
</tbody>
</table>

**Liquid**

| Pan        |        |       |       |       |       | 65.3 | 21.5 |

**F.M.**

|        |        |       |       |       |       | 7.19 | 6.14 |

**% Agg**

|        |        |       |       |       |       | 33.15| 16.79 |

**% Total**

|        |        |       |       |       |       | 22.17| 11.23 |

---

Agg. 1: Coarse agg 1 (Gallup Sand & Gravel)  
Agg. 2: Coarse Agg 2 (Gallup Sand & Gravel)  
Agg. 3: 3/8" VV's (Gallup Sand & Gravel LLC)  
Agg. 4: 3/8" Cr. Sand (Gallup Sand & Gravel)  
Agg. 5: WCS Alb (Way Core)
## Mix Design Report

**Full gradation analysis - Individual percent retained**

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Agg. 1</th>
<th>Agg. 2</th>
<th>Agg. 3</th>
<th>Agg. 4</th>
<th>Agg. 5</th>
<th>Paste</th>
<th>Total</th>
<th>Aggr.</th>
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</thead>
<tbody>
<tr>
<td>1 1/2&quot;</td>
<td></td>
<td></td>
<td></td>
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<td>3.7</td>
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<td>0.90</td>
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<td>0.9</td>
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</tr>
<tr>
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<tr>
<td>Liquid</td>
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<tr>
<td>% Agg</td>
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<td>% Total</td>
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<td>4.49</td>
<td>20.95</td>
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</tbody>
</table>

Agg. 1: Coarse agg 1 (Gallup Sand & Gravel)  
Agg. 2: Coarse Agg 2 (Gallup Sand & Gravel)  
Agg. 3: 3/8" VV's (Gallup Sand & Gravel LLC)  
Agg. 4: 3/8" Cr. Sand (Gallup Sand & Gravel)  
Agg. 5: WCS Alb (Way Core)
Comparison of Immersed vs exposed cylinder curing first 24 hrs
Curing Concrete test Cylinders

Thermal curing  (7) 3878 psi       (28)  4857 psi
Immersed water  (7) 3818 psi       (28)  4846 psi
Exposed to air  (7) 3090 psi       (28)  4107 psi
Wet Burlap      (7) 3258 psi       (28)  4042 psi

In summary you can loose 800 psi when testing cylinders at 28 days if not cured properly for the first 24 hours.