ACI Concrete Mix Design

In 1963 the Virginia Department of Transportation realized that a definite need existed to adopt a standard method of concrete design. Contractors, Producers, and the Department itself had used many varying methods of concrete designs.

The Department has adopted the ACI absolute volume method of design, and requires that this method be used in the design of all normal weight concrete mixes.

Example: Absolute Volume = \[
\frac{\text{Weight}}{(\text{Sp. Gr.}) \times 62.4 \text{ lb/ft}^3}
\]

For purposes of establishing concrete proportions and calculating yields, we will not concern ourselves with bulk yield or bulk volumes of aggregate, cement, etc., but with the absolute volume of these materials. This means the volume of material is solid and without voids.

For example: 94 lbs. of cement in a bulk state occupies approximately 1 cubic foot of volume; however, the Absolute Volume of 94 lbs. of cement is only approximately 0.48 cubic feet. (This means the cement is consolidated without voids.) It is the latter volume which 94 lbs. of cement actually occupies in a batch of concrete.

As a further explanation, we will calculate the absolute volume occupied by cement in a cubic yard of concrete which contains 588 lbs. of cement.

EXAMPLE: The weight of cement is: 588 lbs. Cement has a specific gravity of 3.15 (this means cement is 3.15 times heavier than an equal volume of water)

A solid cubic foot of cement then weighs 3.15 x 62.4 lb/ft³ of water = 196.56 lb/ft³

So the Absolute Volume, or the space occupied by 588 lbs. of cement, will be:

\[
\frac{588 \text{ lb.}}{196.56 \text{ lb/ft}^3} = 2.99 \text{ ft}^3
\]

Before calculations can be started for a concrete design, there are certain items that must be known or available to the person doing the design work. Those items are as follows:

1. Class of concrete to be designed.

2. Fine aggregate: a. Specific gravity
   b. Fineness modulus
3. Coarse aggregate:  
   a. Maximum size aggregate  
   b. Specific Gravity  
   c. Unit Weight (dry rodded unit weight)

4. From VDOT Specifications:  
   a. Cement factor (minimum cement content)  
   b. W/C. ratio (maximum W/C ratio)  
   c. Air content (mean air content)  
   d. Nominal Maximum size aggregate

5. Other information:  
   a. ACI Table A1.5.3.6 (volume of coarse aggregate per unit of volume of concrete) (Page 3-6)  
   b. Type of cement and alkali content  
   c. TL-27 (Concrete Mix Design Form)(Page 3-7)  
   d. ACI Mix design work sheet may be used (Page 3-3)  
   e. Source of all materials going into the mix

(For example purposes, the Fineness Modulus and Specific Gravity for all design problems in this study guide are taken from the Aggregate Data Sheets on Pages 3-32 and 3-33. For an updated list, please see the Aggregate Quality List, which is published annually in the Materials Division Manual of Instruction.)

HELPFUL CONVERSION FACTORS

One cubic foot of water = 7.5 gallons = 62.4 lbs.  
One bag of cement = 94 lbs. (42.6 kg)  
Specific gravity of cement is 3.15  
Specific gravity x 62.4 = Absolute Volume  
1.308 cubic yards = One cubic meter  
1 gallon of water = 8.33 lbs. = 3.78 liters  
1 gallon per yard = 5 liters per meter  
One cubic yard = 27 cubic feet  
One bag of cement = one cubic foot (loose volume)  
One bag of cement = 0.48 cubic feet (absolute volume)
ACI WORKSHEET
CLASS ___________ MIX DESIGN

MODIFIED WITH

FINE AGGREGATE
F.M. ___________
SP. GR. ___________
NOMINAL MAX. SIZE C.A. ______
OTHER DATA NEEDED FOR SPECIAL DESIGNS ________________________________

COARSE AGGREGATE
DRY RODDED UNIT WT. ___________
SP. GR. _______________________
TABLE A1.5.3.6 FACTOR _______

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 ___________ X 27 ft^3 X UNIT WT. ___________ = _________ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT
3.15 x 62.4 lbs. = ___________ ft^3

WATER
1.00 x 62.4 lbs. = ___________ ft^3

AIR
% x 27 = ___________ ft^3

C. AGGR.
SP.GR. X 62.4 Lbs. = ___________ ft^3

ADDITIONAL MATERIALS
= ___________ ft^3

TOTAL
= ___________ ft^3

- _________ ft^3

F.A. _________ ft^3 X _________ SP.GR. X 62.4 = ___________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT ___________ lbs.
WATER _________ lbs. or _______ gals.
AIR _________ %
C. AGGR. ___________ Lbs. = [_______] + [_______]
F. AGGR. ___________ Lbs. = [_______] + [_______]
ADDL. MATLS. _________ =

[_______] =
<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Design Min. Laboratory Compressive Strength at 28 days (f'c) (psi)</th>
<th>Aggregate Size No.</th>
<th>Design Max. Laboratory Permeability at 28 days (Coulombs)</th>
<th>Design Max. Laboratory Permeability at 28 days - Overtidal water (Coulombs)</th>
<th>Nominal Max. Aggregate Size (in)</th>
<th>Min. Grade Aggregate</th>
<th>Min. Cementitious Content (lb/cu.yd)</th>
<th>Max. Water/ Cementitious Mat. (lb.Water/lb. Cement)</th>
<th>Consistency (in of slump)</th>
<th>Air Content (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5 Pre-stressed and other special designs</td>
<td>5,000 or as specified on plans</td>
<td>57 or 68</td>
<td>1,500</td>
<td>1,500</td>
<td>1</td>
<td>A</td>
<td>635</td>
<td>0.40</td>
<td>0-4</td>
<td>41/2 ± 11/2</td>
</tr>
<tr>
<td>A4 General</td>
<td>4,000</td>
<td>56 or 57</td>
<td>2,500</td>
<td>2,000</td>
<td>1</td>
<td>A</td>
<td>635</td>
<td>0.45</td>
<td>2-4</td>
<td>6 1/2 ± 11/2</td>
</tr>
<tr>
<td>A4 Posts &amp; rails</td>
<td>4,000</td>
<td>7, 8 or 78</td>
<td>2,500</td>
<td>2,000</td>
<td>0.5</td>
<td>A</td>
<td>635</td>
<td>0.45</td>
<td>2-5</td>
<td>7 ± 2</td>
</tr>
<tr>
<td>A3 General</td>
<td>3,000</td>
<td>56 or 57</td>
<td>3,500</td>
<td>2,000</td>
<td>1</td>
<td>A</td>
<td>588</td>
<td>0.49</td>
<td>1-5</td>
<td>6 ± 2</td>
</tr>
<tr>
<td>A3a Paving</td>
<td>3,000</td>
<td>56 or 57</td>
<td>3,500</td>
<td>3,500</td>
<td>1</td>
<td>A</td>
<td>564</td>
<td>0.49</td>
<td>0-3</td>
<td>6 ± 2</td>
</tr>
<tr>
<td>A3b Paving</td>
<td>3,000</td>
<td>357</td>
<td>3,500</td>
<td>3,500</td>
<td>2</td>
<td>A</td>
<td>N.A.</td>
<td>0.49</td>
<td>0-3</td>
<td>6 ± 2</td>
</tr>
<tr>
<td>B2 Massive or lightly reinforced</td>
<td>2,200</td>
<td>57</td>
<td>N.A.</td>
<td>N.A.</td>
<td>1</td>
<td>B</td>
<td>494</td>
<td>0.58</td>
<td>0-4</td>
<td>4 ± 2</td>
</tr>
<tr>
<td>C1 Massive Unreinforced</td>
<td>1,500</td>
<td>57</td>
<td>N.A.</td>
<td>N.A.</td>
<td>1</td>
<td>B</td>
<td>423</td>
<td>0.71</td>
<td>0-3</td>
<td>4 ± 2</td>
</tr>
<tr>
<td>T3 Tremie seal</td>
<td>3,000</td>
<td>56 or 57</td>
<td>N.A.</td>
<td>N.A.</td>
<td>1</td>
<td>A</td>
<td>635</td>
<td>0.49</td>
<td>3-6</td>
<td>4 ± 2</td>
</tr>
<tr>
<td>Latex Hydraulic cement concrete overlay</td>
<td>3,500</td>
<td>7, 8 or 78</td>
<td>1,500</td>
<td>1,500</td>
<td>0.5</td>
<td>A</td>
<td>658</td>
<td>0.40</td>
<td>4-6</td>
<td>5 ± 2</td>
</tr>
<tr>
<td>Silica fume, Silica fume/Class F fly ash or silica fume/slag concrete overlay</td>
<td>5,000</td>
<td>7, 8 or 78</td>
<td>1,500</td>
<td>1,500</td>
<td>0.5</td>
<td>A</td>
<td>658</td>
<td>0.40</td>
<td>4-7</td>
<td>6 ± 2</td>
</tr>
<tr>
<td>Class F fly ash or slag overlay</td>
<td>4,000</td>
<td>7, 8 or 78</td>
<td>1,500</td>
<td>1,500</td>
<td>0.5</td>
<td>A</td>
<td>658</td>
<td>0.40</td>
<td>4-7</td>
<td>6 ± 2</td>
</tr>
</tbody>
</table>
Footnotes

1 When a high-range water reducer is used, the target air content shall be increased 1% and the slump shall not exceed 7 inches.
2 When Class A5 concrete is used as the finished bridge deck riding surface, or when it is to be covered with asphalt concrete with or without waterproofing, the air content shall be 5½±1½%.
3 The latex modifier content shall be 3.5 gallons per bag of cement. Slump shall be measured approximately 4½ minutes after discharge from the mixer.
4 Silica fume with a minimum of 7% by weight of cementitious material; silica fume with a range of 2.5-5% shall be combined with Class F Fly Ash in range of 15-20% minimum cement of 77.5% by weight of cementitious material; silica fume with a range of 2.5-5% shall be combined with Ground Granulated Blast Furnace Slag in the range of 30-35% and a minimum cement of 67.5% by weight of cementitious material.
5 The permeability testing does not apply to small bridges identified on the bridge plans and to concrete structures and incidental concrete as described in Sections 219, 232, 302, 415, 502, 504, 506 and 519. Curing and testing of test cylinders for permeability will be in accordance with VTM-112.
6 The contractor may use different aggregate sizes or a combination of sizes to increase the coarse aggregate content of the concrete as approved by the Engineer. The maximum size of the coarse aggregate shall not exceed 2.5 inches.

Note: With the approval of the Engineer, the Contractor may substitute a higher class of concrete for that specified at the Contractor’s expense.
## TABLE A1.5.3.6 VOLUME OF COARSE AGGREGATE PER UNIT OF VOLUME OF CONCRETE (SI)

<table>
<thead>
<tr>
<th>Nominal Maximum size of Aggregate</th>
<th>Volume of dry-rodded coarse aggregate * per unit volume of concrete for different fineness moduli** of fine aggregate</th>
<th>Metric</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5 mm 3/8</td>
<td>2.40 2.50 2.60 2.70 2.80 2.90 3.00</td>
<td>0.50</td>
<td>0.49</td>
</tr>
<tr>
<td>12.5 mm 1/2</td>
<td>0.59 0.58 0.57 0.56 0.55 0.54 0.53</td>
<td>0.59</td>
<td>0.58</td>
</tr>
<tr>
<td>19.0 mm 3/4</td>
<td>0.66 0.65 0.64 0.63 0.62 0.61 0.60</td>
<td>0.66</td>
<td>0.65</td>
</tr>
<tr>
<td>25.0 mm 1</td>
<td>0.71 0.70 0.69 0.68 0.67 0.66 0.65</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>37.5 mm 1 1/2</td>
<td>0.75 0.74 0.73 0.72 0.71 0.70 0.69</td>
<td>0.75</td>
<td>0.74</td>
</tr>
<tr>
<td>50 mm 2</td>
<td>0.78 0.77 0.76 0.75 0.74 0.73 0.72</td>
<td>0.78</td>
<td>0.77</td>
</tr>
<tr>
<td>75 mm 3</td>
<td>0.82 0.81 0.80 0.79 0.78 0.77 0.76</td>
<td>0.82</td>
<td>0.81</td>
</tr>
<tr>
<td>150 mm 6</td>
<td>0.87 0.86 0.85 0.84 0.83 0.82 0.81</td>
<td>0.87</td>
<td>0.86</td>
</tr>
</tbody>
</table>

* Volumes are based on aggregates in dry-rodded condition as described in ASTM C 29

** See ASTM Method 136 for calculation of fineness modulus
# Virginia Department of Transportation

## Materials Division

### Statement of Hydraulic Cement Concrete Mix Design

Submit one copy to the District Administrator, Virginia Department of Transportation. Approval must be received by the contractor from the Materials Division before work is begun. This mix design is approved for all projects of the Department for the class of concrete shown:

**Producer**

**Plant Location**

**Job Mix**

**Date**

**Mix Design - One Cubic Yard (Meter) Based on SSD Condition**

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Slump/</th>
<th>In.</th>
<th>mm</th>
<th>Air Content</th>
<th>%</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantities</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Type</td>
<td>lbs.</td>
<td>kg.</td>
</tr>
<tr>
<td>Min. Admixture 1</td>
<td>lbs.</td>
<td>kg.</td>
</tr>
<tr>
<td>Min. Admixture 2</td>
<td>lbs.</td>
<td>kg.</td>
</tr>
<tr>
<td>Sand (1)</td>
<td>lbs.</td>
<td>kg.</td>
</tr>
<tr>
<td>No. (1)</td>
<td>Stone</td>
<td>lbs.</td>
</tr>
<tr>
<td>Gr./No. (1)</td>
<td>Aggr.</td>
<td>lbs.</td>
</tr>
<tr>
<td>Water (2)</td>
<td>lbs.</td>
<td>gal.</td>
</tr>
<tr>
<td>Admixture (AE) (3)</td>
<td>oz.</td>
<td>ml.</td>
</tr>
<tr>
<td>Admixture (Retarder) (3)</td>
<td>oz.</td>
<td>ml.</td>
</tr>
<tr>
<td>Admixture (Other) (3)</td>
<td>oz.</td>
<td>ml.</td>
</tr>
</tbody>
</table>

### Notes:

1. The quantities of fine and coarse aggregates necessary to conform to specifications in regard to consistency and workability shall be determined by the method described in "Recommended Practice for Selecting Proportions for Normal Weight Concrete" (ACI 211.1) and the actual quantities used shall not deviate more than plus or minus 5 percent from such quantities.

2. To provide minimum slump permissible in Table 11-17 while satisfying placement and finishing requirements. A separate design shall be submitted for each slump desired.

3. The quantity of admixture will not be approved or disapproved since it varies considerably and must be initially established by trial and error by the producer or contractor with subsequent adjustment during batching to maintain the desired results within the range specified.

<table>
<thead>
<tr>
<th>Contractor</th>
<th>By</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Name of Company)</td>
<td>(Certified Technician Preparing Form)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Producer Technician's Expiration Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Do Not Use Security Sensitive Number)</td>
</tr>
</tbody>
</table>

## For Department Use Only

### Remarks:

Copies: District Materials Engineer
Project Inspector
Plant Inspector
Sub-Contractor and/or R.M. Producer

Approved tentatively subject to the production of material meeting the requirements of the Specifications and Special Provisions.

2014 v1.0 3-7
Mix designs must incorporate a mineral admixture. The amount of mineral admixture varies according to the alkali content of the cement and the type of mineral admixture selected for the concrete mix. Blended cements such as IP or IS already have mineral admixtures in them and don’t require any additional admixtures. Road and Bridge Specification Section 217.02(a) lists the percent replacement guidelines of cement with mineral admixtures based on the alkali content of the cement.

**Section 217.02(a)** Cementitious materials shall be a blend of mineral admixtures and Portland cement or a blended cement. In overlay concretes, expansive hydraulic cement is permitted in lieu of Portland cement. Portland cement (Types I, II, III) blended cements (Type IP, Type IS) or expansive cement (Type K) shall comply with Section 214. Flyash, ground granulated iron blast-furnace slag, silica fume or metakaolin shall conform to Section 215. As a portion of the cementitious material, Table 1 lists the minimum percents of specific pozzolans required by mass of the cementitious material depending on the alkali content of the cement. Any other mineral admixture or any other amount or combination of mineral admixtures may be used if approved by the Engineer. As a portion of the cementitious material, the fly ash content shall not exceed 30 percent for Class F, the ground granulated blast-furnace slag content shall not exceed 50 percent and the silica fume content shall not exceed 10 percent unless approved by the Engineer. Class C Flyash or other pozzolans may be used provided the contractor demonstrates that the percent usage of Class C Flyash or other pozzolans have a maximum expansion of 0.15% according to ASTM C227 at 56 days using borosilicate glass as aggregate. Blended cements require no further pozzolan additions to meet minimum pozzolan content to compensate for the alkali-silica reaction.

Up to 7 percent silica fume may be added to all combinations of cementitious materials to reduce early permeability without approval by the Engineer. Other silica fume additions must be approved by the Engineer.

Table 1 – Minimum percent pozzolan required by mass of cementitious material and are based upon the alkali content of the cement.

<table>
<thead>
<tr>
<th></th>
<th>Total Alkalies of Cement less than or equal to 0.75%</th>
<th>Total Alkalies of Cement greater than 0.75% and less than or equal to 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class F Flyash</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>GGBF Slag</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>Silica Fume</td>
<td>7%</td>
<td>10%</td>
</tr>
<tr>
<td>Metakaolin</td>
<td>7%</td>
<td>10%</td>
</tr>
</tbody>
</table>
EXAMPLE - Using the ACI worksheet provided, let us design a VDOT Class A-3 general use mix using Type IS cement. This mix will be for 1 yd$^3$. No pozzolan will be added as Type IS is a blended cement.

Conditions:
Minimum Cement Content: 588 lbs.(Table II-17)
Maximum Water-cement ratio: 0.49 lb water per lb cement (Table II-17)
Nominal maximum size aggregate: 1 in (Table II-17)
Air Content: 6% ± 2% (Table II-17)
Slump: 1 – 5 in (Table II-17)
Fineness Modulus of Sand: 2.70 (fine aggr. data sheet)
Sp. Gr. of Fine Aggregate: 2.66 (fine aggr. data sheet)
Sp. Gr. of Coarse Aggregate: 2.61 (coarse aggr. data sheet)
Dry-rodded Unit Weight of C.A.: 104 lb/ft$^3$(lab results)
Sp. Gr. of Type IS Cement: 3.05 (from supplier)

There are five materials going into this mix:
1. Cement
2. Water
3. Air
4. Coarse Aggregate
5. Fine Aggregate

Solve for the Absolute Volume of each of the five materials in the mix. The combined volume must total one cubic yard (27.00 ft$^3$).

Quantities for three of the five materials are given by the specification.

These are: 
1. Cement
2. Water
3. Air

This means then that you only have to solve for the quantities of two ingredients:

(1) Coarse aggregate, and (2) Fine Aggregate

Let us now solve the absolute volume of each material, remembering the total must be 27.00 cubic feet for all material.

1. **Cement**: 588 lb (by Spec.)

   \[
   \frac{588 \text{ lb (lb per 1 yd}^3\text{)}}{3.05 (\text{sp.gr. cement}) \times 62.4 (\text{weight of 1 ft}^3\text{of water})} =
   \]

   \[
   \frac{588}{3.05 \times 62.4} = 3.09 \text{ ft}^3 = \text{Absolute volume}
   \]

2. **Water**: By specifications, the maximum water is 0.49 lb water per lb cement. If the cement content for a yd$^3$ is 588 lb, the maximum design water will be:

   \[
   588 \times 0.49 = 288 \text{ lbs.}
   \]
To find absolute volume:

\[
\frac{288}{1.00 \times 62.4} = 4.62 \text{ ft}^3 = \text{Absolute volume}
\]

\[4.62 \text{ ft}^3 \times 7.5 \text{ (gallons of water in 1 ft}^3\text{)} = 34.6 \text{ gallons}\]

3. **Air**: The target air content is 6%. To find the absolute volume of air:

\[0.06 \times 27 \text{ ft}^3 = 1.62 \text{ ft}^3 \text{ (Absolute Volume)}\]

As air will not weigh anything, it will not have a specific gravity, so we have solved for the 6% volume displaced by the air in a cubic yard. As we said previously, three of the five materials are given, namely:

1. Cement
2. Water, and
3. Air

Now, we must solve for coarse aggregate:

4. **Coarse Aggregate**: From Table A1.5.3.6 of ACI, the percent of the total mix that should be coarse aggregate is found by taking the 1 inch nominal maximum size aggregate designated by the specification, and locating it on the left side of the table. The F.M. of the sand is found across the top of Table A1.5.3.6. We said that the F.M. of the sand was 2.70. Across the top of the columns, we find 2.60 and 2.80. If the F.M. happens to be 2.70, we must interpolate the value of 2.70. In this case, the value will be half way between 0.69 (F.M. = 2.60) and 0.67 (F.M. = 2.80), which for 1 inch would be 0.68. So, 68% of the cubic yard mix will be coarse aggregate in a dry-rodded condition.

To convert this to volume:

\[
0.68 \times 27.0 \text{ ft}^3 = 18.36 \text{ ft}^3 = \text{dry-rodded volume}
\]

To determine the weight of coarse aggregate going into the mix:

\[
18.36 \text{ ft}^3 \times 104 \text{ lb/ft}^3 = \text{design weight of coarse aggregate}
\]

To determine the absolute volume:

\[
\frac{1909 \text{ lbs.}}{2.61 \times 62.4 \text{ lb/ft}^3} = 11.72 \text{ ft}^3 = \text{Absolute volume}
\]
5. **Fine Aggregate**: To solve for the amount of fine aggregate, work the problem in reverse as compared to the other materials. First, total the absolute volume of the other four materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Design Volume</th>
<th>Absolute Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>588 lbs.</td>
<td>3.09 ft³</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>4.62 ft³</td>
</tr>
<tr>
<td>Air</td>
<td>6%</td>
<td>1.62 ft³</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>1909 lbs.</td>
<td>11.72 ft³</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>21.05 ft³</td>
</tr>
</tbody>
</table>

If four materials total 21.05 ft³, it is proper to assume that the fine aggregate will fill the remaining volume of a cubic yard (27.00 ft³).

To find the volume the fine aggregate will occupy:

\[
27.00 \, \text{ft}^3 - 21.05 \, \text{ft}^3 = 5.95 \, \text{ft}^3
\]

Now, multiply the volume of fine aggregate times specific gravity of fine aggregate times 62.4 (unit weight of water in lb/ft³):

\[
5.95 \, \text{ft}^3 \times 2.66 \times 62.4 = 988 \, \text{lbs.}
\]

This is the design weight of the fine aggregate.

The class A3 general use concrete mix design as shown on the TL-27 will be as follows:

- Cement 588 lbs.
- Water 288 lbs.
- Air 6%
- Coarse aggregate 1909 lbs.
- Fine Aggregate 988 lbs.
## ACI WORKSHEET
### CLASS A3- General MIX DESIGN

**MODIFIED WITH __________________**

**FINE AGGREGATE**
- F.M. 2.70
- SP. GR. 2.66
- NOMINAL MAX. SIZE C.A. 1"

**COARSE AGGREGATE**
- DRY RODDED UNIT WT. 104
- SP. GR. 2.61
- TABLE 5.3.6 FACTOR 0.68

**OTHER DATA NEEDED FOR SPECIAL DESIGNS**
- Sp. Gr. of IS 3.05

### QUANTITY OF COARSE AGGREGATE

| TABLE 5.3.6 | 0.68 | X | 27 ft$^3$ | X UNIT WT. 104 | lb/ft$^3$ | = | 1909 lbs. |

### ABSOLUTE VOLUMES

- **PORTLAND IS CEMENT**
  - $\frac{588}{3.05 \times 62.4} = \frac{3.09}{ft^3}$
- **WATER**
  - $\frac{588 \times 0.49 = 288 \text{ lbs.}}{1.00 \times 62.4} = \frac{4.62}{ft^3}$
- **AIR**
  - $\frac{6 \% \times 27}{100} = \frac{1.62}{ft^3}$
- **C. AGGR.**
  - $\frac{1909 \text{ lbs.}}{\text{SP. GR. 2.61 \times 62.4}} = \frac{11.72}{ft^3}$

### ADDITIONAL MATERIALS

![Formula for additional materials](image)

| TOTAL | = | 21.05 ft$^3$ |

- **F.A.**
  - $5.95 \text{ ft}^3 \times 2.66 \text{ SP.GR. X 62.4} = 988 \text{ lbs.}

### SUGGESTED QUANTITIES

![Suggested quantities equation](image)

- **CEMENT**
  - 588 lbs.
- **WATER**
  - 288 lbs. or 34.6 gals.
- **AIR**
  - 6 %
- **C. AGGR.**
  - 1909 lbs.
- **F. AGGR.**
  - 988 lbs.
- **ADDL. MATLS.**
  - = lbs.
GRANULATED IRON BLAST FURNACE SLAG

Specification:

Shall conform to ASTM C989, Grade 100 or 120
Replaces up to 50% of the cement

Reaction:

Reactive within itself and also reacts with the free lime in the cement

Advantages:

- Cheaper than cement
- Utilization of a waste product
- Reduces heat of hydration (less cement)
- Improves sulfate resistance
- Reduces alkali-silica reaction
- Gives higher strength at later ages

Disadvantages:

- Another mixture
- Scaling and drying shrinkage may be increased
- Early strengths retarded, particularly in cool weather

Note: When forms are stripped, the concrete will be discolored with greens, blues, and blacks, like ink blots, but will bleach fairly rapidly.
ACI Concrete Mix Design Utilizing Ground Granulated Iron Blast-Furnace Slag

When Ground Granulated Blast-Furnace Slag is utilized as an additive in concrete, it must conform to the requirements of ASTM C 989, Grade 100 or 120.

Ground Granulated Blast-Furnace Slag shall not exceed 50 percent of the total design cement weight specified in Table II-17. The method of design is very similar to that used in the previous mix design in this section.

EXAMPLE: Using the ACI worksheet provided, let us design a VDOT A3 general use mix with slag.

Conditions:
Minimum Portland Cement Content: 588 lbs. (Table II-17)
Alkali Content of Cement: 0.82 (from supplier)
Maximum Water Cement Ratio: 0.49 lb water per lb Cement. (Table II-17)
Nominal maximum size aggregate: 1 in (Table II-17)
Air Content: 6% ± 2% (Table II-17)
Slump: 1 – 5 in (Table II-17)
Sp. Gr. of Slag: 2.90 (Specific gravity of slag will vary; therefore, the most current gravity should be obtained from the District Materials Section)

Fineness Modulus of Sand: 2.70 (fine aggr. data sheet)
Sp. Gr. of Fine Aggregate: 2.66 (fine aggr. data sheet)
Sp. Gr. of Coarse Aggregate: 2.61 (coarse aggr. data sheet)
Dry rodded unit weight of C.A.: 104 lb/ft³ (Lab Results)
Sp. Gr. of Cement: 3.15 (from supplier)

Let us now solve for the absolute volume of each material, remembering the total must be 1 yd³ (27.00 ft³) for all materials.

The minimum cement content is 588 lbs.; however, a portion of the cement will be replaced with slag. We need to refer to Section 217.02(a) Table 1 of the Specifications. The alkali content of the cement is 0.82%; therefore, 50% of the cement will be replaced by slag.

1. **Cement:** 294 lbs. (this is equal to 50% of 588 lbs., which is the design weight for cement on Class A3 General Use mixes.)

   \[
   \frac{294 \text{ lbs.}}{3.15 \text{ (sp.gr. of port. cem.)} \times 62.4 \text{ (weight of 1 ft³ of water)}}
   \]

   To find absolute volume:

   \[
   \frac{294}{3.15 \times 62.4} = 1.50 \text{ ft}³ \text{ (absolute volume)}
   \]

2. **Slag:** 294 lbs. (this is equal to 50% of 588 lbs., which is design weight for cement on Class A3 General use mixes.)

   To find absolute volume:

   \[
   \frac{294 \text{ lbs.}}{2.90 \text{ (sp.gr. for this slag)} \times 62.4 \text{ (weight of 1 ft³ of water)}} = 1.62 \text{ ft}³
   \]
3. **Water**: By specifications, the maximum water is 0.49 lb water per lb. cementitious material. For this mix, you would consider the cementitious weight to be: 294 lbs. Cement + 294 lbs. Slag = 588 lbs.

588 x 0.49 = 288 lbs.

To find absolute volume:

\[
\frac{288}{1.00 \times 62.4} = 4.62 \text{ ft}^3 = \text{Absolute Volume}
\]

4.62 ft³ x 7.5 (gallons of water in 1 ft³) = 34.6 gallons

4. **Air**: The target air content is 6%. To find the absolute volume of air:

\[
0.06 \times 27 \text{ ft}^3 = 1.62 \text{ ft}^3 = \text{Absolute Volume}
\]

As air will not weigh anything, it will not have a specific gravity, so we have solved for the 6% volume displaced by the air in a cubic yard.

5. **Coarse Aggregate**: A factor of 0.68 is obtained from Table A1.5.3.6 of ACI by using the Fineness Modulus of the sand and the nominal maximum size of the coarse aggregate in the method described on Page 3-10. To convert this to volume, we say 0.68 x 27 ft³ = 18.36 ft³ (this volume is dry rodded). With the dry rodded unit weight given as 104 lb/ft³, determine the weight of coarse aggregate going into the mix by the following:

18.36 ft³ x 104 lb/ft³ = 1909 lbs. (design wt. of C.A.)

The specific gravity of the coarse aggregate was 2.61. The absolute volume is determined by the following:

\[
\frac{1909 \text{ lbs.}}{2.61 \times 62.4 \text{ (wt. of ft}^3 \text{ of water)}} = 11.72 \text{ ft}^3 = \text{Absolute Volume}
\]

6. **Fine Aggregate**: To solve for the amount of fine aggregate, work the problem in reverse as compared to the other materials. First, total the absolute volume of the other five materials:

<table>
<thead>
<tr>
<th>Material</th>
<th>Design Quantity</th>
<th>Absolute Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>294 lbs.</td>
<td>1.50 ft³</td>
</tr>
<tr>
<td>Slag</td>
<td>294 lbs.</td>
<td>1.62 ft³</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>4.62 ft³</td>
</tr>
<tr>
<td>Air</td>
<td>6 %</td>
<td>1.62 ft³</td>
</tr>
<tr>
<td>Coarse Aggr.</td>
<td>1909 lbs.</td>
<td>11.72 ft³</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>21.08 ft³</td>
</tr>
</tbody>
</table>
If the five materials total 21.08 ft³, it is proper to assume that the fine aggregate will fill the remaining volume of a cubic yard. To find the volume the fine aggregate will occupy, solve the following:

\[ 27.00 \text{ ft}^3 - 21.08 \text{ ft}^3 = 5.92 \text{ ft}^3 \]

Now, multiply the volume of fine aggregate times the specific gravity of fine aggregate times 62.4 (unit weight of water):

\[ 5.92 \text{ ft}^3 \times 2.66 \times 62.4 = 983 \text{ lbs. (design weight of fine aggregate)} \]

The Class A3 general use concrete mix utilizing slag will be shown on the TL-27 as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>294 lbs.</td>
</tr>
<tr>
<td>Slag</td>
<td>294 lbs.</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
</tr>
<tr>
<td>Air</td>
<td>6 %</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>1909 lbs.</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>983 lbs.</td>
</tr>
</tbody>
</table>
ACI WORKSHEET

CLASS A3 General MIX DESIGN

MODIFIED WITH 50% blast furnace slag

FINE AGGREGATE

F.M. 2.70

SP. GR. 2.66

NOMINAL MAX. SIZE C.A. 1”

COARSE AGGREGATE

DRY RODDED UNIT WT. 104 lb/ft³

SP. GR. 2.61

TABLE 5.3.6 FACTOR 0.68

OTHER DATA NEEDED FOR SPECIAL DESIGNS Sp.Gr. of Blast Furnace Slag = 2.90

QUANTITY OF COARSE AGGREGATE

TABLE 5.3.6 0.68 X 27 ft³ X UNIT WT. 104 = 1909 lbs.

ABSOLUTE VOLUMES

FORTLAND CEMENT

0.50 x 588 = 294 lbs. = 1.50 ft³

3.15 x 62.4

WATER

0.49 x 588 = 288 lbs. = 4.62 ft³

1.00 x 62.4

AIR

6 % x 27 = 1.62 ft³

100

C. AGGR.

1909 lbs. = 11.72 ft³

SP. GR. 2.61 X 62.4

ADDITIONAL MATERIALS

slag

588 - 294 = 294 lbs. = 1.62 ft³

2.90 x 62.4

TOTAL = 21.08 ft³

27.00 ft³

21.08 ft³

F.A. 5.92 ft³ X 2.66 SP.GR. X 62.4 = 983 lbs.

SUGGESTED QUANTITIES

CEMENT 294 lbs.

±5% TOLERANCE

WATER 288 lbs. or 34.6 gals.

AIR 6 %

C. AGGR. 1909 lbs. - [_______] + [_______]

F. AGGR. 983 lbs. - [_______] + [_______]

ADDL. MATLS. slag = 294 lbs.

= 2014 v1.0  3-17
FLY ASH

Production:

Waste product of coal fired electrical utility

Specifications:

Must meet ASTM C618 Class F with maximum loss on ignition of 6%
Replaces up to 30% of the cement

Reaction:

Reacts with the free lime (calcium hydroxide) given off by cement during hydration, and water to produce cementitious material.

Advantages:

Utilization of a waste product
Reduces energy for production of cement
Reduces heat of hydration
Improves workability
Improves sulfate resistance
Reduces alkali-silica aggregate reaction
Costs less than cement

Disadvantages:

Another admixture
Scaling and drying shrinkage may be increased
Slower strength gain
Air content difficult to control
1. Finer than cement
2. Unburned carbon
**ACI Concrete Mix Design Utilizing Fly Ash**

When fly ash is utilized as an additive in concrete, it must conform to the requirements of ASTM C618 Class F or Class C, except that the Loss on Ignition shall be limited to a maximum of 6%. Class F, fly ash shall replace 20 to 30% by weight of the design cement depending on the alkali content of the cement used. The minimum total cementitious materials are specified in Table II-17. The method of design is very similar to that used in the previous mix designs in this chapter.

EXAMPLE: Using the ACI worksheet provided, let us design a VDOT Class A3 General mix using fly ash.

Conditions:
- Minimum Cement Content: 588 lbs. (Table II-17)
- Alkali Content of Cement: 0.65% (from supplier)
- Maximum Water-Cement ratio: 0.49 lbs. water per lb. cement (Table II-17)
- Nominal Maximum Size Aggregate: 1 in (Table II-17)
- Air Content: 6% ± 2% (Table II-17)
- Slump: 1 - 5” (Table II-17)
- Sp. Gr. of fly ash: 2.25 (Specific gravity of fly ash will vary. The most current gravity from the manufacturer/supplier should be used).
- Fineness Modulus of Sand: 2.70 (fine aggr. data sheet)
- Sp. Gr. of Fine Aggregate: 2.66 (fine aggr. data sheet)
- Sp. Gr. of Coarse Aggregate: 2.61 (coarse aggr. data sheet)
- Dry-rodded Unit Weight of C.A.: 104 lb/ft³ (lab results)
- Sp.Gr. of Cement: 3.15 (from supplier)

Let us now solve the absolute volume of each material, remembering the total must be 27.00 ft³ for all materials.

The minimum cement content is 588 lbs.; however, a portion of the cement will be replaced with fly ash. We need to refer to Section 217.02(a) Table 1 of the Specifications. The alkali content of the cement is 0.65%; therefore, 20% of the cement will be replaced by fly ash.

1. **Cement:** 470 lbs. (this is equal to 80% of 588 lbs., which is the design wt. of cement of a Class A3 General Mix).

   \[
   \frac{470 \text{ lbs.}}{3.15 \text{ (sp.gr. of cement)} \times 62.4 \text{(weight of 1 ft³ of water)}} = 2.39 \text{ ft}^3 \text{ Absolute volume}
   \]

2. **Fly ash:** 118 lbs. (this is equal to 20% of 588 lbs., which is design wt. for cement of a Class A3 General use mix).

   To find absolute volume:

   \[
   \frac{118 \text{ lbs.}}{2.25 \text{(sp.gr. for this fly ash)} \times 62.4 \text{(weight of 1 ft³ of water)}} = 0.84 \text{ ft}^3
   \]
3. **Water**: By specification, the maximum water is 0.49 lbs. water per lb. cementitious material. For this mix, you would consider the cementitious weight to be 588 lbs. Cement + Fly Ash (470 lbs. + 118 lbs.).

\[
588 \times 0.49 = 288 \text{ lbs.}
\]

To find absolute volume:

\[
\frac{288}{1.00 \times 62.4} = 4.62 \text{ ft}^3 = \text{Absolute volume}
\]

4.62 ft\(^3\) \times 7.5 \text{ (gallons of water in 1 ft}^3\text{)} = 34.6 \text{ gallons}

4. **Air**: The target air content is 6%. To find the absolute volume of air:

\[
0.06 \times 27.00 \text{ ft}^3 = 1.62 \text{ ft}^3 = \text{Absolute Volume}
\]

As air will not weigh anything, it will not have a specific gravity, so we have solved for the 6% volume displaced by the air a cubic yard.

5. **Coarse Aggregate**: A factor of 0.68 is obtained from Table A1.5.3.6 of ACI by using the Fineness Modulus of the sand and the nominal maximum size of the coarse aggregate as described on Page 3-10. To convert this to volume, \(0.68 \times 27.00 \text{ ft}^3 = 18.36 \text{ ft}^3\) (this volume is dry rodded). With the dry rodded unit weight given as 104 lb/ft\(^3\), determine the weight of coarse aggregate going into the mix by the following:

\[
18.36 \text{ ft}^3 \times 104 \text{ lb/ft}^3 = 1909 \text{ lbs. (this is the design mass of C.A.)}
\]

The specific gravity of the coarse aggregate was 2.61. The absolute volume is determined by the following:

\[
\frac{1909}{2.61 \times 62.4 \text{ (wt. of ft}^3\text{ of water)}} = 11.72 \text{ ft}^3 = \text{Absolute Volume}
\]

6. **Fine Aggregate**: To solve for the amount of fine aggregate, we will work the problem in reverse as compared to the other materials. First, we must total the absolute volume of the other five materials:

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>Absolute Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>470 lbs.</td>
<td>2.39 ft(^3)</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>118 lbs.</td>
<td>0.84 ft(^3)</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>4.62 ft(^3)</td>
</tr>
<tr>
<td>Air</td>
<td>6 %</td>
<td>1.62 ft(^3)</td>
</tr>
<tr>
<td>Coarse Aggr.</td>
<td>1909 lbs.</td>
<td>11.72 ft(^3)</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>21.19 ft(^3)</td>
</tr>
</tbody>
</table>
If the five materials total 21.19 ft\(^3\), it is proper to assume that the fine aggregate will fill the remaining volume of a cubic yard. To find the volume the fine aggregate will occupy, solve the following:

\[27.00 \text{ ft}^3 - 21.19 \text{ ft}^3 = 5.81 \text{ ft}^3\]

Now, multiply the volume of fine aggregate times the specific gravity of fine aggregate times 62.4 (unit weight of water):

\[5.81 \text{ ft}^3 \times 2.66 \times 62.4 = 964 \text{ lbs.} \text{ (design mass of fine aggregate)}\]

The Class A3 general use concrete mix utilizing fly ash will be shown on the TL-27 as follows:

- Cement: 470 lbs.
- Fly Ash: 118 lbs.
- Water: 288 lbs.
- Air: 6 %
- Coarse Aggregate: 1909 lbs.
- Fine Aggregate: 964 lbs.
ACI WORKSHEET
CLASS A3 General MIX DESIGN

MODIFIED WITH 20% Fly Ash

FINE AGGREGATE
F.M. 2.70
SP. GR. 2.66
NOMINAL MAX. SIZE C.A. 1 inch

COARSE AGGREGATE
DRY RODDED UNIT WT. 104 lb/ft^3
SP. GR. 2.61

OTHER DATA NEEDED FOR SPECIAL DESIGNS
Sp.Gr. of Fly Ash = 2.25

TABLE 5.3.6 FACTOR 0.68
QUANTITY OF COARSE AGGREGATE

TABLE 5.3.6 0.68 X 27 ft^3 X UNIT WT. 104 lb/ft^3 = 1909 lbs.

ABSOLUTE VOLUMES
PORTLAND CEMENT
\[
\frac{588 \times 0.80 = 470}{3.15 \times 62.4} \quad \text{lbs.} = \quad 2.39 \text{ ft}^3
\]
WATER \(470 + 118 = 588\)
\[
\frac{588 \times 0.49 = 288}{1.00 \times 62.4} \quad \text{lbs.} = \quad 4.62 \text{ ft}^3
\]
AIR
\[
\frac{6}{100} \% \times 27 = \quad 1.62 \text{ ft}^3
\]
C. AGGR.
\[
\frac{1909}{\text{SP. GR. 2.61} \times 62.4} \quad \text{lbs.} = \quad 11.72 \text{ ft}^3
\]

ADDITIONAL MATERIALS
fly ash
\[
\frac{588 \times 0.20 = 118}{2.25 \times 62.4} \quad \text{lbs.} = \quad 0.84 \text{ ft}^3
\]
TOTAL
\[
27.00 \text{ ft}^3
\]
- 21.19 ft^3

F.A. 5.81 ft^3 X 2.66 SP.GR. X 62.4 = 964 lbs.

SUGGESTED QUANTITIES ±5% TOLERANCE
CEMENT ________ 470 ________ lbs.
WATER ________ 288 ________ lbs. or 34.6 gal.
AIR ________ 6 %
C.A. AGGR. ________ 1909 ________ lbs. - [_______] + [_______]
F. AGGR. ________ 964 ________ lbs. - [_______] + [_______]
ADDL. MATLS. Flyash = 118 lbs.

=
ACI Design Example Problem No. 1

Design a Class A4 Post and Rail concrete mix with slag to be used in footing, using coarse and fine aggregate from Lone Star Industries, Dock Street. Dry rodded unit weight of coarse aggregate is 101 lb/ft\(^3\). Alkali Content of Cement is 0.67%. Specific gravity of slag is 2.94. Use data sheets page 3-32 and 3-33.

CLASS A4 Post & Rail MIX DESIGN MODIFIED WITH Slag

FINE AGGREGATE
F.M. 2.80
SP. GR. 2.64
NOMINAL MAX. SIZE C.A. 1/2
OTHER DATA NEEDED FOR SPECIAL DESIGNS Slag 40%

COARSE AGGREGATE
DRY RODDED UNIT WT. 101 lb/ft\(^3\)
SP. GR. 2.63

TABLE A1.5.3.6 FACTOR 0.55

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 0.55 X 27 ft\(^3\) X UNIT WT. 101 = 1500 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT (0.40) (635)=254

\[
\frac{635 - 254}{3.15 \times 62.4} = 1.94 \text{ ft}^3
\]

WATER

\[
\frac{.45 \times 635}{1.00 \times 62.4} = 4.58 \text{ ft}^3
\]

AIR

\[
\frac{7.0 \% \times 27}{100} = 1.89 \text{ ft}^3
\]

C. AGGR.

\[
\frac{1500}{2.63} \times 62.4 = 9.14 \text{ ft}^3
\]

ADDITIONAL MATERIALS

\[
\frac{.40 \times 635}{2.94 \times 62.4} = 1.38 \text{ ft}^3
\]

TOTAL = 18.93 \text{ ft}^3

27.00 \text{ ft}^3
- 18.93 \text{ ft}^3

F.A. 8.07 \text{ ft}^3 X 2.64 SP.GR. X 62.4 = 1329 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 381 lbs.
WATER 286 lbs. or 34.3 gals.
AIR 7.0 %
C. AGGR. 1500 lbs. - [_______] + [_______]
F. AGGR. 1329 lbs. - [_______] + [_______]
ADDL. MATLS. Slag = 254 lbs.
ACI Design Example Problem No.2

Design a Class A4 General Use mix to be used in a bridge deck. Coarse and fine aggregate will be obtained from Sadler Materials, Richmond, Va. Make no adjustments for retarder. Dry rodded unit weight of the coarse aggregate is 102 lb/ft³. Alkali content of the cement is 0.72%. Fly ash can be obtained from JTM Industries with a Specific Gravity of 2.35. Use aggregate data sheets page 3-32 and 3-33.

CLASS A4 General MIX DESIGN MODIFIED WITH Fly Ash

FINE AGGREGATE
F.M. 3.00
SP. GR. 2.64
NOMINAL MAX. SIZE C.A. 1"
OTHER DATA NEEDED FOR SPECIAL DESIGNS Fly Ash 20% Replacement

COARSE AGGREGATE
DRY RODDED UNIT WT. 102 lb/ft³
SP. GR. 2.62
TABLE A1.5.3.6 FACTOR 0.65

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 0.65 X 27 ft³ X UNIT WT. 102 = 1790 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT (.20)(635)=127

635 - 127 = 508 lbs. = 2.58 ft³
3.15 x 62.4

WATER
.45 x 635 = 286 lbs. = 4.58 ft³
1.00 x 62.4

AIR
6.5 % x 27 = 1.76 ft³
100

C. AGGR.
1790 lbs. = 10.95 ft³
SP.GR. 2.62 X 62.4

ADDITIONAL MATERIALS
.20 x 635 = 127
2.35 x 62.4

TOTAL = 20.74 ft³

27.00 ft³
- 20.74 ft³
F.A. 6.26 ft³ X 2.64 SP.GR. X 62.4 = 1031 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE
CEMENT 508 lbs.
WATER 286 lbs. or 34.3 gals.
AIR 6.5 %
C. AGGR. 1790 lbs. - [ ] + [ ]
F. AGGR. 1031 lbs. - [ ] + [ ]
ADDL. MATLS. Fly Ash = 127 lbs.
ACI Design Example Problem No. 3

Design a Class A4 Post and Rail Concrete modified with slag. Fine aggregate will come from Chickahominy, Inc., Charles City, VA, and coarse aggregate will come from Virginia Traprock, Inc., Leesburg, VA. Dry rodded unit weight of the coarse aggregate is 100 lb/ft³. Alkali content of the cement is 0.85%. Specific gravity of slag is 2.94. Use aggregate data sheets on page 3-32 and 3-33.

CLASS A4 Post and Rail MIX DESIGN

MODIFIED WITH 50% Slag

FINE AGGREGATE

F.M. 2.70

SP. GR. 2.62

SP. GR. 3.04

DRIED RODDED UNIT WT. 100 lb/ft³

SP. GR. 3.04

NOMINAL MAX. SIZE C.A. 1/2” TABLE A1.5.3.6 FACTOR .56

OTHER DATA NEEDED FOR SPECIAL DESIGNS 50% Slag (Sp. Gr. = 2.94)

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 .56 x 27 ft³ x UNIT WT. 100 = 1512 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT ( .50 (635)=318) 635 - 318 = 317 lbs. = 1.61 ft³

45 x 635 = 286 lbs. = 4.58 ft³

AIR

7 % x 27 = 1.89 ft³

100 C. AGGR. 1512 lbs. = 7.97 ft³

SP.GR. 3.04 x 62.4

ADDITIONAL MATERIALS .50 x 635 = 318

2.94 x 62.4

TOTAL

17.78 ft³

27.00 ft³

- 17.78 ft³

F.A. 9.22 ft³ x 2.62 SP.GR. x 62.4 = 1507 lbs.

SUGGESTED QUANTITIES

CEMENT 317 lbs. ± 5% TOLERANCE

WATER 286 lbs. or 34.3 gals.

AIR 7 %

C. AGGR. 1512 lbs. - [ ] + [ ]

F. AGGR. 1507 lbs. - [ ] + [ ]

ADDL. MATLs. 50% Slag = 318 lbs.
ACI Design Example Problem No. 4

Design a Class A4 General Use mix to be used in a box culvert using fine and coarse aggregate from West Sand and Gravel, Richmond, Va. Alkali content of the Type I cement is 0.59%. Dry rodded unit weight of the coarse aggregate is 104 lb/ft^3. Fly Ash is available from Monex with a specific gravity of 2.25. Use aggregate data sheets on page 3-32 and 3-33.

<table>
<thead>
<tr>
<th>CLASS</th>
<th>A4 General</th>
<th>MIX DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIFIED WITH</td>
<td>Fly Ash</td>
<td></td>
</tr>
</tbody>
</table>

| FINE AGGREGATE | 2.70 |
| SP. GR. | 2.64 |

| COARSE AGGREGATE | DRY RODDED UNIT WT. | 104 lb/ft^3 |
| SP. GR. | 2.60 |
| NOMINAL MAX. SIZE C.A. | 1" |
| TABLE AL.5.3.6 FACTOR | 0.68 |

OTHER DATA NEEDED FOR SPECIAL DESIGNS:
- Fly Ash 20% Replacement
- Sp. Gravity 2.25

QUANTITY OF COARSE AGGREGATE
- TABLE AL.5.3.6 0.68 X 27 ft^3 X UNIT WT. 104 = 1909 lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT (0.20)(635)=127

\[
\frac{0.20 \times 635 = 127}{3.15 \times 62.4} = 2.58 \text{ ft}^3
\]

WATER

\[
\frac{0.45 \times 635 = 286}{1.00 \times 62.4} = 4.58 \text{ ft}^3
\]

AIR

\[
\frac{6.5 \% \times 27}{100} = 1.76 \text{ ft}^3
\]

C. AGGR.

\[
\frac{1909 \text{ lbs.}}{2.60 \times 62.4} = 11.77 \text{ ft}^3
\]

ADDITIONAL MATERIALS

\[
\frac{20 \times 635 = 127}{2.25 \times 62.4} = 0.90 \text{ ft}^3
\]

TOTAL = 21.59 ft^3

- 21.59 ft^3

F.A. 5.41 ft^3 X 2.64 SP.GR. X 62.4 = 891 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

| CEMENT | 508 lbs. |
| WATER | 286 lbs. or 34.3 gals. |
| AIR | 6.5 % |
| C. AGGR. | 1909 lbs. - [_____] + [_____] |
| F. AGGR. | 891 lbs. - [_____] + [_____] |
| ADDL. MATLS. Fly Ash | = 127 lbs. |
Allowable Field Adjustments

If the quantities calculated by ACI absolute volume method do not give the required workability and consistency in the field, the mix can be adjusted by an allowable interchange of coarse aggregate and fine aggregate. The interchange of coarse aggregate and fine aggregate may vary up to 5 percent (by weight), but neither may be changed more than 5 percent. When an interchange of aggregate is needed, the fine aggregate, normally being of less weight than coarse aggregate, is increased or decreased 5 percent and then the coarse aggregate is changed by an equal volume so the design will be 27 ft$^3$.

For example, when the first load of concrete using the Class A3 general use design (as shown below) arrived on the project, the slump was 2 inches. The contractor desired a higher slump. In order to accomplish this, the surface areas of the aggregate must be decreased as much as is allowable, which will make the mix as coarse as possible and remain within the specification requirements.

**Class A3 General Mix Design:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP Cement</td>
<td>588 lbs.</td>
<td>Sp. gr. F.A. = 2.67</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>Sp. gr. C.A. = 2.61</td>
</tr>
<tr>
<td>Air</td>
<td>6%</td>
<td>F.M. of F.A. = 2.70</td>
</tr>
<tr>
<td>#57</td>
<td>1965 lbs.</td>
<td>Unit wt. of C.A. = 107 lbs/ft$^3$</td>
</tr>
<tr>
<td>F.A.</td>
<td>930 lbs.</td>
<td>Sp. gr. Cement = 3.03</td>
</tr>
</tbody>
</table>

The F.A., being of less weight than the C.A., will be decreased by 5% as follows:

\[ \text{F.A.} = 930 \times 0.05 = 47 \text{ lbs.} \]

\[ \text{Original Wt. of F.A.} = 930 \text{ lbs.} \]
\[ \text{Less 5\%} = -47 \text{ lbs.} \]
\[ \text{New Wt. of F.A.} = 883 \text{ lbs.} \]

The C.A. must then be increased the same volume that the F.A. is decreased so the design will remain 27 ft$^3$. This is accomplished as follows:

\[ 47 \text{ lbs. F.A.}/[2.67(\text{F.A. Sp. Gr.}) \times 62.4] = 0.28 \text{ ft}^3 \]
\[ 0.28 \times [2.61 (\text{C.A. Sp. Gr.}) \times 62.4] = 46 \text{ lbs. of C.A. to be added} \]

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original wt. of C.A. #57</td>
<td>1965 lbs.</td>
</tr>
<tr>
<td>Plus wt. C.A. to be increased</td>
<td>$\pm 46$ lbs.</td>
</tr>
<tr>
<td>Net wt. of C.A.</td>
<td>2011 lbs.</td>
</tr>
</tbody>
</table>
The adjusted design quantities are:

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>588 lbs.</td>
</tr>
<tr>
<td>Air</td>
<td>6 %</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
</tr>
<tr>
<td>#57</td>
<td>2011 lbs.</td>
</tr>
<tr>
<td>F.A.</td>
<td>883 lbs.</td>
</tr>
</tbody>
</table>

After these adjustments are made, the design should be checked to make sure it yields 27.00 ft$^3$

### Absolute Volume (ft$^3$)

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Volume Calculation</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP Cement</td>
<td>588 lbs.</td>
<td>$\frac{588}{3.03 \times 62.4}$</td>
<td>3.11 ft$^3$</td>
</tr>
<tr>
<td>Air</td>
<td>6%</td>
<td>$0.06 \times 27$</td>
<td>1.62 ft$^3$</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>$\frac{288}{1.00 \times 62.4}$</td>
<td>4.62 ft$^3$</td>
</tr>
<tr>
<td>C. A. - #57</td>
<td>2011 lbs.</td>
<td>$\frac{2011}{2.61 \times 62.4}$</td>
<td>12.35 ft$^3$</td>
</tr>
<tr>
<td>F. A. - 883</td>
<td>883 lbs.</td>
<td>$\frac{883}{2.67 \times 62.4}$</td>
<td>5.30 ft$^3$</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>27.00 ft$^3$</td>
</tr>
</tbody>
</table>
Allowable Field Adjustment Example Problem No. 1

The following Class A3 General mix design produced a harsh mix. The contractor desires to reduce the harshness. Show the aggregate adjustments that may be made within the specification requirements.

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP Cement</td>
<td>588 lbs.</td>
<td>3.03</td>
</tr>
<tr>
<td>Air</td>
<td>6.0%</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>2.62</td>
</tr>
<tr>
<td>F. A.</td>
<td>998 lbs.</td>
<td></td>
</tr>
<tr>
<td>C. A. No. 57</td>
<td>1895 lbs.</td>
<td></td>
</tr>
</tbody>
</table>

SOLUTION:

998 x 0.05 = 50 lbs. (This weight must be added to the weight of sand)

998 + 50 = 1048 lbs. (Total weight of sand)

\[
\frac{50}{2.64 \times 62.4} = 0.30 \text{ ft}^3 \\
0.30 \times 2.62 \times 62.4 = 49 \text{ lbs.}
\]

(The weight of C.A. must be decreased by this amount)

1895 - 49 = 1846 lbs. (Total weight of C.A. due to increase in the sand)

ADJUSTED MIX DESIGN

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>588 lbs.</td>
</tr>
<tr>
<td>Air</td>
<td>6.0%</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
</tr>
<tr>
<td>F. A.</td>
<td>1048 lbs.</td>
</tr>
<tr>
<td>C. A. No. 57</td>
<td>1846 lbs.</td>
</tr>
</tbody>
</table>
Allowable Field Adjustment Example Problem No. 2

The following Class A3 General mix design produced a slump of 3 inches. The contractor desires a 4” slump. Show the aggregate adjustments that may be made within the specification requirements.

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight</th>
<th>Sp. Gr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>470 lbs.</td>
<td>2.62</td>
</tr>
<tr>
<td>Air</td>
<td>6%</td>
<td>2.70</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>3.04</td>
</tr>
<tr>
<td>F. A.</td>
<td>1189 lbs.</td>
<td>106 lb/ft³</td>
</tr>
<tr>
<td>C. A. No. 57</td>
<td>1946 lbs.</td>
<td>0.65%</td>
</tr>
<tr>
<td>Flyash</td>
<td>118 lbs.</td>
<td>2.25</td>
</tr>
</tbody>
</table>

SOLUTION:

1189 X 0.05 = 59 lbs. (This weight must be subtracted from the weight of sand)

1189 - 59 = 1130 lbs. (Total weight of sand)

\[
\frac{59}{2.62 \times 3.04 \times 62.4} = \text{0.36 ft}^3
\]

0.36 X 3.04 X 62.4 = 68 lbs. (This weight must be added to C.A. weight)

1946 + 68 = 2014 lbs. (Total weight of C. A.)

ADJUSTED MIX DESIGN

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>470 lbs.</td>
</tr>
<tr>
<td>Air</td>
<td>6%</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
</tr>
<tr>
<td>F. A.</td>
<td>1130 lbs.</td>
</tr>
<tr>
<td>C. A. - No. 57</td>
<td>2014 lbs.</td>
</tr>
<tr>
<td>Flyash</td>
<td>118 lbs.</td>
</tr>
</tbody>
</table>
Allowable Field Adjustment Example Problem No. 3

The following Class A4 General mix design produced a harsh mix. The contractor desires to reduce the harshness. Show the aggregate adjustments that may be made within the specification requirements.

Cement - 381 lbs.  
Air - 6.5%  
Water - 286 lbs.  
F. A. - 1063 lbs.  
C. A. No. 57 - 1798 lbs.  
Slag - 254 lbs.  
F. A. Sp. Gr. - 2.60  
F. A. F. M. - 2.93  
C. A. Sp. Gr. - 2.67  
C. A. Unit Wt. - 96.5 lbs/ft³  
Cement Alkali Content - 0.70%

SOLUTION:

1063 X 0.05 = 53 lbs.  (This weight must be added to the weight of sand)

1063 + 53 = 1116 lbs.  (Total weight of sand)

\[
\frac{53}{2.60 \times 62.4} = 0.33 \text{ ft}^3 \quad 0.33 \times 2.67 \times 62.4 = 55.0 \text{ lbs.}
\]

(The weight of C. A. must be decreased by this amount)

1798 - 55 = 1743 lbs.  (Total weight of C. A. due to increase in the sand)

ADJUSTED MIX DESIGN

Cement - 381 lbs.  
Air - 6.5%  
Water - 286 lbs.  
F. A. - 1116 lbs.  
C. A. - No. 57 - 1743 lbs.  
Slag - 254 lbs.
VIRGINIA DEPARTMENT OF TRANSPORTATION
RESULTS OF QUALITY TEST ON
COMMERCIALY PRODUCED
COARSE AGGREGATES

(THE VALUES THAT FOLLOW ARE TO BE USED FOR TRAINING PURPOSES ONLY. FOR ACTUAL VALUES, REFER TO THE LATEST PUBLISHED LIST.)

<table>
<thead>
<tr>
<th>PRODUCER AND LOCATION</th>
<th>SP. GR.</th>
<th>ABS.(%)</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sadler Materials, Richmond, VA</td>
<td>2.62</td>
<td>0.9</td>
<td>37.6</td>
<td>38.0</td>
<td>----</td>
</tr>
<tr>
<td>Lone Star Industries, Dock St., Richmond, VA</td>
<td>2.63</td>
<td>0.8</td>
<td>39.2</td>
<td>38.0</td>
<td>34.0</td>
</tr>
<tr>
<td>Fredericksburg Sand &amp; Gravel, Fredericksburg, VA</td>
<td>2.64</td>
<td>0.3</td>
<td>37.5</td>
<td>35.5</td>
<td>----</td>
</tr>
<tr>
<td>Virginia Traprock, Inc., Leesburg, VA</td>
<td>3.04</td>
<td>0.4</td>
<td>----</td>
<td>19.1</td>
<td>26.7</td>
</tr>
<tr>
<td>West Sand and Gravel, Richmond, VA</td>
<td>2.60</td>
<td>1.0</td>
<td>----</td>
<td>39.3</td>
<td>37.1</td>
</tr>
<tr>
<td>Bull Run Stone Co., Manassas, VA</td>
<td>2.67</td>
<td>1.5</td>
<td>----</td>
<td>14.3</td>
<td>----</td>
</tr>
<tr>
<td>Dillon, E &amp; Co., Swords Creek, VA</td>
<td>2.83</td>
<td>0.4</td>
<td>23.1</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Lone Jack, Glasgow, A</td>
<td>2.81</td>
<td>0.3</td>
<td>----</td>
<td>18.9</td>
<td>21.8</td>
</tr>
<tr>
<td>Shenandoah Asphalt, Vesuvius, VA</td>
<td>2.59</td>
<td>1.0</td>
<td>----</td>
<td>30.3</td>
<td>39.3</td>
</tr>
</tbody>
</table>
## VIRGINIA DEPARTMENT OF TRANSPORTATION

**FINE AGGREGATE DATA**

(The values that follow are to be used for training purposes only. For actual values, refer to the latest published list.)

<table>
<thead>
<tr>
<th>PRODUCER AND LOCATION</th>
<th>SP. GR.</th>
<th>ABS.(%)</th>
<th>F.M.</th>
<th>LOSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickahominy, Inc.</td>
<td>2.62</td>
<td>1.0</td>
<td>2.7</td>
<td>7.9</td>
</tr>
<tr>
<td>Charles City, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sadler Materials</td>
<td>2.64</td>
<td>0.5</td>
<td>3.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Richmond, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fredericksburg Sand &amp; Gravel</td>
<td>2.62</td>
<td>0.8</td>
<td>2.7</td>
<td>11.9</td>
</tr>
<tr>
<td>Fredericksburg, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lone Star Industries</td>
<td>2.64</td>
<td>0.6</td>
<td>2.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Dock St., Richmond, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Sand and Gravel</td>
<td>2.64</td>
<td>0.9</td>
<td>2.7</td>
<td>6.7</td>
</tr>
<tr>
<td>Richmond, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aylett Sand &amp; Gravel</td>
<td>2.62</td>
<td>0.2</td>
<td>2.9</td>
<td>4.6</td>
</tr>
<tr>
<td>Aylett, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dillon E. &amp; Co.</td>
<td>2.80</td>
<td>1.1</td>
<td>3.1</td>
<td>13.8</td>
</tr>
<tr>
<td>Swords Creek, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stuart M. Perry, Inc.</td>
<td>2.67</td>
<td>1.0</td>
<td>2.8</td>
<td>9.1</td>
</tr>
<tr>
<td>Winchester, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilson Quarries</td>
<td>2.83</td>
<td>0.5</td>
<td>2.8</td>
<td>6.8</td>
</tr>
<tr>
<td>Horsepasture, VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 3
Study Problems

ACI Mix Design Problem No. 1

Design a Class A4 general mix using a Type II cement from Giant Cement Co. with an alkali content of 0.19. Fly Ash, Specific Gravity of 2.35, is available if necessary from Monex Resources, Inc. Coarse aggregate will come from Lone Star Industries, Richmond, VA. Dry rodded unit weight of coarse aggregate is 103 lb/ft³. Fine aggregate will come from West Sand and Gravel, Richmond, VA. Use aggregate data sheets found on page 3-32 and 3-33.

<table>
<thead>
<tr>
<th>CLASS MODIFIED WITH</th>
<th>MIX DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINE AGGREGATE</td>
<td>COARSE AGGREGATE</td>
</tr>
<tr>
<td>SP. GR.</td>
<td>DRY RODDED UNIT WT.</td>
</tr>
</tbody>
</table>

NOMINAL MAX. SIZE C.A. | TABLE A1.5.3.6 FACTOR

OTHER DATA NEEDED FOR SPECIAL DESIGNS | quantum of coarse aggregate | TABLE A1.5.3.6 | x 27 | ft³ | x unit wt. | = | lbs.

### ABSOLUTE VOLUMES

<table>
<thead>
<tr>
<th>PORTLAND CEMENT</th>
<th>lbs. =</th>
<th>ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.15 x 62.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WATER</th>
<th>lbs. =</th>
<th>ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00 x 62.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AIR</th>
<th>% x 27 =</th>
<th>ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. AGGR.</th>
<th>Lbs. =</th>
<th>ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF.GR.</td>
<td>x 62.4</td>
<td></td>
</tr>
</tbody>
</table>

### ADDITIONAL MATERIALS

<table>
<thead>
<tr>
<th>=</th>
<th>ft³</th>
</tr>
</thead>
</table>

| TOTAL | = | ft³ |
|-------|-----|
| 27.00 | |

<table>
<thead>
<tr>
<th>-</th>
<th>ft³</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>F.A.</th>
<th>ft³ x SP.GR.</th>
<th>62.4</th>
<th>=</th>
<th>lbs.</th>
</tr>
</thead>
</table>

### SUGGESTED QUANTITIES

<table>
<thead>
<tr>
<th>± 5% TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEMENT</td>
</tr>
<tr>
<td>WATER</td>
</tr>
<tr>
<td>AIR</td>
</tr>
<tr>
<td>C. AGGR.</td>
</tr>
<tr>
<td>F. AGGR.</td>
</tr>
<tr>
<td>ADDL. MATLS.</td>
</tr>
</tbody>
</table>

3-34
ACI Mix Design Problem No. 2

Design a Class A4 general use mix using IP cement from Roanoke. Coarse aggregate will come from Dillon Company, Swords Creek, VA. Fine aggregate will come from Sadler Materials, Richmond, VA. Dry rodded unit weight of the coarse aggregate is 105 lb/ft³. Specific gravity of the IP cement from Roanoke is 3.02. Use aggregate data sheets found on page 3-32 and 3-33.

CLASS MIX DESIGN
MODIFIED WITH COARSE AGGREGATE
FINE AGGREGATE
F.M. ______________
SP. GR. ______________
NOMINAL MAX. SIZE C.A. ______
OTHER DATA NEEDED FOR SPECIAL DESIGNS

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 __________ X 27 ft³ X UNIT WT. __________ = __________ lbs.

ABSOLUTE VOLUMES
PORTLAND CEMENT
3.15 x 62.4 lbs. = __________ ft³

WATER
1.00 x 62.4 lbs. = __________ ft³

AIR
% x 27 = __________ ft³

C. AGGR.
SP.GR. __________ X 62.4 Lbs. = __________ ft³

ADDITIONAL MATERIALS
= __________ ft³

27.00 ft³
- __________ ft³

F.A. __________ ft³ X __________ SP.GR. X 62.4 = __________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE
CEMENT ______________ lbs.
WATER ________ lbs. or ________ gals.
AIR ______________ %
C. AGGR. ______________ Lbs. - [_________] + [_________]
F. AGGR. ______________ Lbs. - [_________] + [_________]
ADDL. MATLS. __________ = __________ =
ACI Mix Design Problem No. 3

Design a Class A4 Post and rail concrete mix using a Type II cement from Lehigh Cement Co. with an alkali content of 0.57. Design the mix with a water cement ratio of 0.43 and the minimum amount of slag required. Coarse aggregate will come from Sadler Materials, Richmond, VA. Dry rodded unit weight of coarse aggregate is 101 lb/ft³. Fine aggregate will come from Chickahominy Inc., Charles City, VA. Specific gravity of the slag is 2.94. Use aggregate data sheets found on page 3-32 and 3-33.

<table>
<thead>
<tr>
<th>CLASS MIX DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINE AGGREGATE</td>
</tr>
<tr>
<td>DRY RODDED UNIT WT.</td>
</tr>
<tr>
<td>COARSE AGGREGATE</td>
</tr>
<tr>
<td>SP. GR.</td>
</tr>
<tr>
<td>SP. GR.</td>
</tr>
<tr>
<td>NOMINAL MAX. SIZE C.A.</td>
</tr>
<tr>
<td>TABLE A1.5.3.6 FACTOR</td>
</tr>
<tr>
<td>OTHER DATA NEEDED FOR SPECIAL DESIGNS</td>
</tr>
</tbody>
</table>

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 _______ X 27 ft³ X UNIT WT. _______ = _______ lbs.

### ABSOLUTE VOLUMES

- **PORTLAND CEMENT**
  - 3.15 x 62.4 lbs. = _______ ft³
- **WATER**
  - 1.00 x 62.4 lbs. = _______ ft³
- **AIR**
  - _______ % x 27 = _______ ft³
- **C. AGGR.**
  - SP.GR. _______ X 62.4 Lbs. = _______ ft³
- **ADDITIONAL MATERIALS**
  - _______ = _______ ft³
  - _______ = _______ ft³
  - _______ = _______ ft³
  - **TOTAL** = _______ ft³
- **F.A.** _______ ft³ X _______ SP.GR. X 62.4 = _______ lbs.

### SUGGESTED QUANTITIES ± 5% TOLERANCE

- **CEMENT** _______ lbs.
- **WATER** _______ lbs. or _______ gals.
- **AIR** _______ %
- **C. AGGR.** _______ Lbs. - [_______] + [_______]
- **F. AGGR.** _______ Lbs. - [_______] + [_______]
- **ADDL. MATLS.** _______ = _______
ACI Mix Design Problem No. 4

Design a Class A4 general concrete mix using Type I cement from Blue Circle Atlantic with an alkali content of 0.32. Fly ash with a specific gravity of 2.35 is available from Monex Resources, Inc. Coarse aggregate will come from Virginia Traprock, Inc. Dry rodded unit weight of the coarse aggregate is 105 lb/ft³. Fine aggregate will come from Sadler Materials. Use aggregate data sheets found on page 3-32 and 3-33.

<table>
<thead>
<tr>
<th>CLASS MODIFIED WITH</th>
<th>MIX DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINE AGGREGATE</td>
<td>COARSE AGGREGATE</td>
</tr>
<tr>
<td>F.M.</td>
<td>DRY RODDED UNIT WT.</td>
</tr>
<tr>
<td>SP. GR.</td>
<td>SP. GR.</td>
</tr>
<tr>
<td>NOMINAL MAX. SIZE C.A.</td>
<td>TABLE A1.5.3.6 FACTOR</td>
</tr>
</tbody>
</table>

OTHER DATA NEEDED FOR SPECIAL DESIGNS

<table>
<thead>
<tr>
<th>QUANTITY OF COARSE AGGREGATE</th>
<th>TABLE A1.5.3.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>X 27 ft³ X UNIT WT.</td>
<td>= __________ lbs.</td>
</tr>
</tbody>
</table>

**ABSOLUTE VOLUMES**

<table>
<thead>
<tr>
<th>PORTLAND CEMENT</th>
<th>lbs. = __________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.15 x 62.4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WATER</th>
<th>lbs. = ______________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00 x 62.4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AIR</th>
<th>% x 27 = ______________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. AGGR.</th>
<th>Lbs. = ______________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP.GR. x 62.4</td>
<td></td>
</tr>
</tbody>
</table>

**ADDITIONAL MATERIALS**

<table>
<thead>
<tr>
<th>= ______________ ft³</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>= __________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.00</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F.A.</th>
<th>______________ ft³ X ______________ SP.GR. X 62.4 = ______________ lbs.</th>
</tr>
</thead>
</table>

**SUGGESTED QUANTITIES** ± 5% TOLERANCE

<table>
<thead>
<tr>
<th>CEMENT</th>
<th>lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WATER</td>
<td>lbs. or gals.</td>
</tr>
<tr>
<td>AIR</td>
<td>%</td>
</tr>
<tr>
<td>C. AGGR.</td>
<td>Lbs. - [<em><strong><strong><strong>] + [</strong></strong></strong></em>]</td>
</tr>
<tr>
<td>F. AGGR.</td>
<td>Lbs. - [<em><strong><strong><strong>] + [</strong></strong></strong></em>]</td>
</tr>
<tr>
<td>ADDL. MATLS.</td>
<td>= __________</td>
</tr>
</tbody>
</table>

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ACI Mix Design Problem No. 5

Design a Class A4 General mix using Type IS cement from Roanoke with a specific gravity of 3.05. Coarse aggregate will come from Virginia Traprock, Leesburg, VA and fine aggregate will come from Lone Star Industries, Dock St., Richmond, VA. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 100 lb/ft³. Use aggregate data sheets found on page 3-32 and 3-33.

<table>
<thead>
<tr>
<th>CLASS MIX DESIGN MODIFIED WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINE AGGREGATE F.M.</td>
</tr>
<tr>
<td>SP. GR.</td>
</tr>
<tr>
<td>NOMINAL MAX. SIZE C.A.</td>
</tr>
<tr>
<td>OTHER DATA NEEDED FOR SPECIAL DESIGNS</td>
</tr>
</tbody>
</table>

**QUANTITY OF COARSE AGGREGATE**
TABLE A1.5.3.6 _______ X 27 ft³ X UNIT WT. _______ = _______  lbs.

**ABSOLUTE VOLUMES**

- **PORTLAND CEMENT** 3.15 x 62.4 lbs. = _______ ft³
- **WATER** 1.00 x 62.4 lbs. = _______ ft³
- **AIR** 100 % x 27 = _______ ft³

- **C. AGGR.** Lbs. = _______ ft³
- **SP.GR.** _______ x 62.4

**ADDITIONAL MATERIALS** = _______ ft³

**TOTAL** = _______ ft³

27.00 ft³
- _______ ft³

F.A. _______ ft³ X _______ SP.GR. X 62.4 = _______ lbs.

**SUGGESTED QUANTITIES** ± 5% TOLERANCE

- **CEMENT** _______ lbs.
- **WATER** _______ Lbs. or _______ gals.
- **AIR** _______ %
- **C. AGGR.** _______ Lbs. - [_______] + [_______]
- **F. AGGR.** _______ Lbs. - [_______] + [_______]
- **ADDL. MATLS.** _______ =
ACI Mix Design Problem No. 6

Design a slag modified Class A3 General use mix. Coarse and fine aggregate will come from Sadler Materials, Richmond, Va. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 99 lb/ft^3. Alkali content of the Type II cement is 0.28%. Specific gravity of the slag is 2.94. Use aggregate data sheets found on page 3-32 and 3-33.

CLASS MIX DESIGN
MODIFIED WITH

FINE AGGREGATE
F.M. 
SP. GR. 
NOMINAL MAX. SIZE C.A. 
OTHER DATA NEEDED FOR SPECIAL DESIGNS 

COARSE AGGREGATE
DRY RODDED UNIT WT. 
SP. GR. 
TABLE A1.5.3.6 FACTOR 

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 ________ X 27 ft^3 X UNIT WT. ________ = ________ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT 
3.15 x 62.4 lbs. = ________ ft^3

WATER 
1.0 x 62.4 lbs. = ________ ft^3

AIR 
% x 27 = ________ ft^3

C. AGGR. 
SP.GR. X 62.4 Lbs. = ________ ft^3

ADDITIONAL MATERIALS 
= ________ ft^3

TOTAL 
= ________ ft^3

27.00 ft^3

- ________ ft^3

F.A. ________ ft^3 X ________ SP.GR. X 62.4 = ________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 

WATER 

AIR 

C. AGGR. Lbs. - [_______] + [_______]

F. AGGR. Lbs. - [_______] + [_______]

ADDL. MATLS. ________ = ________

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ACI Mix Design Problem No. 7

Design a Class A3 Paving mix, modified with slag. Coarse and fine aggregate will come from West Sand and Gravel, Richmond, Va. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 104 lb/ft³. Specific Gravity of slag is 2.94. Alkali content of the cement is 0.81%. Use aggregate data sheets found on page 3-32 and 3-33.

CLASS MIX DESIGN
MODIFIED WITH
FINE AGGREGATE
F.M.                COARSE AGGREGATE
SP. GR.              DRY RODDED UNIT WT.
NOMINAL MAX. SIZE C.A. TABLE A1.5.3.6 FACTOR
OTHER DATA NEEDED FOR SPECIAL DESIGNS

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 ______ X 27 ft³ X UNIT WT. __________ = __________ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT
3.15 x 62.4 lbs. = __________ ft³

WATER
1.00 x 62.4 lbs. = __________ ft³

AIR
100 % x 27 = __________ ft³

C. AGGR.
SP.GR. ______ X 62.4 Lbs. = __________ ft³

ADDITIONAL MATERIALS
= __________ ft³

TOTAL = __________ ft³

27.00 ft³

- _________ ft³

F.A. _________ ft³ X _________ SP.GR. X 62.4 = __________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT ______________ lbs.
WATER _________ lbs. or _________ gals.
AIR ______________ %
C. AGGR. _________ Lbs. - [_______] + [_______]
F. AGGR. ______________ Lbs. - [_______] + [_______]
ADDL. MATLS. _________ =

=
ACI Mix Design Problem No. 8 – Modified With Fly Ash

Design a fly ash modified Class A3 General Use mix. Coarse and fine aggregate will come from Lone Star Industries, Dock St., Richmond, VA. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 105 lb/ft³. Specific gravity of fly ash is 2.22. Alkali content of the cement is 0.65%. Use aggregate data sheets found on page 3-32 and 3-33.

CLASS _____________ MIX DESIGN ______________
MODIFIED WITH _______________

FINE AGGREGATE

F.M. _______________ DRY RODDED UNIT WT. _______________
SP. GR. _______________ SP. GR. _______________

COARSE AGGREGATE

NOMINAL MAX. SIZE C.A. _________ TABLE A1.5.3.6 FACTOR ___________

OTHER DATA NEEDED FOR SPECIAL DESIGNS _______________

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 _________ X 27 ft³ X UNIT WT. _________ = ___________ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT

___________ lbs. = _______________ ft³

3.15 x 62.4

WATER

___________ lbs. = _______________ ft³

1.00 x 62.4

AIR

___________ % x 27 = _______________ ft³

100

C. AGGR.

___________ Lbs. = _______________ ft³

SP.GR. _________ X 62.4

ADDITIONAL MATERIALS

___________ = _______________ ft³

___________ = _______________ ft³

TOTAL = _______________ ft³

27.00 ft³

- __________ ft³

F.A._________ ft³ X __________ SP.GR. X 62.4 = _______________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT _______________ lbs.

WATER __________ lbs. or _______ gals.

AIR _______________

C. AGGR. _______________ Lbs. - [_______] + [_______]

F. AGGR. _______________ Lbs. - [_______] + [_______]

ADDL. MATLS. _________ = _________

___________ = _________
ACI Mix Design Problem No. 9 - Modified With Fly Ash

Design a fly ash modified Class A4 General Use mix. Coarse and fine aggregate will come from Sadler Materials, Richmond, VA. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 98 lb/ft³. Fly ash has a specific gravity of 2.30. Alkali content of the cement is 0.76%. Use aggregate data sheets found on page 3-32 and 3-33.

CLASS MIX DESIGN
FINE AGGREGATE MODIFIED WITH COARSE AGGREGATE
F.M. DRY RODDED UNIT WT.
SP. GR. SP. GR.
NOMINAL MAX. SIZE C.A. TABLE A1.5.3.6 FACTOR
OTHER DATA NEEDED FOR SPECIAL DESIGNS

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 _____ X 27 ft³ X UNIT WT. = _________ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT

3.15 x 62.4 lbs. = _________ ft³

WATER

1.00 x 62.4 lbs. = _________ ft³

AIR

% x 27 = _________ ft³

100

C. AGGR.

SP.GR. X 62.4 lbs. = _________ ft³

ADDITIONAL MATERIALS

= _________ ft³

TOTAL = _________ ft³

27.00 ft³

- _________ ft³

F.A. _____ ft³ X _________ SP.GR. X 62.4 = _________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT _________ lbs.

WATER _________ lbs. or _________ gals.

AIR _________ %

C. AGGR. _________ Lbs. - [_______] + [_______]

F. AGGR. _________ Lbs. - [_______] + [_______]

ADDL. MATLS. _________ = _________
ACI Mix Design Problem No. 10 - Modified With Slag

Design a slag modified Class A4 Post & Rail mix. Coarse aggregate will come from Lone Jack, Glasgow, and fine aggregate will come from Wilson Quarries, Horsepasture. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 102 lb/ft³. Specific Gravity of the Slag is 2.85. Alkali content of the cement is 0.95%. Use aggregate data sheets found on page 3-32 and 3-33.

<table>
<thead>
<tr>
<th>CLASS</th>
<th>MIX DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINE AGGREGATE</td>
<td></td>
</tr>
<tr>
<td>MODIFIED WITH</td>
<td></td>
</tr>
<tr>
<td>DRY RODDED UNIT WT.</td>
<td></td>
</tr>
<tr>
<td>SP. GR.</td>
<td></td>
</tr>
<tr>
<td>NOMINAL MAX. SIZE C.A.</td>
<td></td>
</tr>
<tr>
<td>TABLE A1.5.3.6 FACTOR</td>
<td></td>
</tr>
<tr>
<td>OTHER DATA NEEDED FOR SPECIAL DESIGNS</td>
<td></td>
</tr>
<tr>
<td>QUANTITY OF COARSE AGGREGATE</td>
<td></td>
</tr>
<tr>
<td>TABLE A1.5.3.6 _____ X 27 ft³ X UNIT WT. _____ = _____ lbs.</td>
<td></td>
</tr>
</tbody>
</table>

### ABSOLUTE VOLUMES

<table>
<thead>
<tr>
<th>PORTLAND CEMENT</th>
<th>___________ lbs. = ___________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.15 x 62.4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WATER</th>
<th>___________ lbs. = ___________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00 x 62.4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AIR</th>
<th>___________ % x 27 = ___________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. AGGR.</th>
<th>___________ Lbs. = ___________ ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP.GR. _____ X 62.4</td>
<td></td>
</tr>
</tbody>
</table>

### ADDITIONAL MATERIALS

<table>
<thead>
<tr>
<th>___________</th>
<th>___________ ft³</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>___________</th>
<th>___________ ft³</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>___________ ft³</th>
</tr>
</thead>
</table>

| 27.00 ft³                  |                |
| -                          | ___________ ft³ |

F.A. _____ ft³ X SP.GR. _____ X 62.4 = ___________ lbs.

### SUGGESTED QUANTITIES ± 5% TOLERANCE

<table>
<thead>
<tr>
<th>CEMENT</th>
<th>___________ lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WATER</td>
<td>___________ lbs. or ___________ gals.</td>
</tr>
<tr>
<td>AIR</td>
<td>___________ %</td>
</tr>
<tr>
<td>C. AGGR.</td>
<td>___________ Lbs. - [<em><strong><strong><strong><strong>] + [</strong></strong></strong></strong></em>]</td>
</tr>
<tr>
<td>F. AGGR.</td>
<td>___________ Lbs. - [<em><strong><strong><strong><strong>] + [</strong></strong></strong></strong></em>]</td>
</tr>
<tr>
<td>ADDL. MATLS.</td>
<td>___________ = ___________</td>
</tr>
</tbody>
</table>

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ACI Mix Design Adjustment Problem No. 1

The following Class A4 General Use mix design produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One yd³.

Based on SSD Condition

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP Cement</td>
<td>635 lbs.</td>
<td>Sand - F. M.</td>
<td>2.80</td>
</tr>
<tr>
<td>Sand</td>
<td>1150 lbs.</td>
<td>Sand - Sp. Gr.</td>
<td>2.64</td>
</tr>
<tr>
<td>No. 57</td>
<td>1954 lbs.</td>
<td>CA - Sp. Gr.</td>
<td>3.04</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>CA - Unit Weight</td>
<td>108 lb/ft³</td>
</tr>
<tr>
<td>Air</td>
<td>6.5 %</td>
<td>IP Cement - Sp. Gr.</td>
<td>3.05</td>
</tr>
</tbody>
</table>

**ANSWER**

Cement _____________ lbs.

Sand _____________ lbs.

No. 57 _____________ lbs.

Water _____________ lbs.

Air _____________ %
ACI Mix Design Adjustment Problem No. 2

The following Class A3 General Use mix design produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One yd³.

Based on SSD Condition

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount</th>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS Cement</td>
<td>588 lbs.</td>
<td>Sand - F. M.</td>
<td>2.70</td>
</tr>
<tr>
<td>Sand</td>
<td>983 lbs.</td>
<td>Sand - Sp. Gr.</td>
<td>2.66</td>
</tr>
<tr>
<td>No. 57</td>
<td>1909 lbs.</td>
<td>CA - Sp. Gr.</td>
<td>2.61</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>CA - Unit Weight</td>
<td>104 lb/ft³</td>
</tr>
<tr>
<td>Air</td>
<td>6.0 %</td>
<td>IS Cement - Sp. Gr.</td>
<td>3.02</td>
</tr>
</tbody>
</table>

**ANSWER**

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>_______ lbs.</td>
</tr>
<tr>
<td>Sand</td>
<td>_______ lbs.</td>
</tr>
<tr>
<td>No. 57</td>
<td>_______ lbs.</td>
</tr>
<tr>
<td>Water</td>
<td>_______ lbs.</td>
</tr>
<tr>
<td>Air</td>
<td>_______ %</td>
</tr>
</tbody>
</table>
ACI Mix Design Adjustment Problem No. 3

The following Class A4 General Use mix design modified with 40% slag produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One yd³.

Based on SSD Condition

<table>
<thead>
<tr>
<th>Material</th>
<th>lb.</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>381</td>
<td>Sand - F. M.</td>
<td>2.70</td>
</tr>
<tr>
<td>Sand</td>
<td>1285</td>
<td>Sand - Sp. Gr.</td>
<td>2.62</td>
</tr>
<tr>
<td>No. 57</td>
<td>1799</td>
<td>CA - Sp. Gr.</td>
<td>3.04</td>
</tr>
<tr>
<td>Water</td>
<td>286</td>
<td>CA - Unit Weight, 98 lb/ft³</td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td>6.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slag</td>
<td>254</td>
<td>Slag - Sp. Gr.</td>
<td>2.95</td>
</tr>
</tbody>
</table>

ANSWER

<table>
<thead>
<tr>
<th>Material</th>
<th>lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>No. 57</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td></td>
</tr>
<tr>
<td>Slag</td>
<td></td>
</tr>
</tbody>
</table>
ACI Mix Design Adjustment Problem No. 4

The following Class A3 General Use Mix Design produced a 2 inch slump. The contractor wants a 3 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design - One yd³

Based on SSD Condition

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight (lbs)</th>
<th>Particle Size</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP Cement</td>
<td>588</td>
<td></td>
<td>2.80</td>
</tr>
<tr>
<td>Sand</td>
<td>1107</td>
<td></td>
<td>2.64</td>
</tr>
<tr>
<td>No. 57</td>
<td>1934</td>
<td></td>
<td>2.83</td>
</tr>
<tr>
<td>Water</td>
<td>288</td>
<td></td>
<td>106.9 lb/ft³</td>
</tr>
<tr>
<td>Air</td>
<td>6.0 %</td>
<td></td>
<td>3.05</td>
</tr>
</tbody>
</table>

ANSWER

Cement _________ lbs.

Sand _________ lbs.

No. 57 _________ lbs.

Water _________ lbs.

Air _________ %
ACI Mix Design Adjustment Problem No. 5

The following Class A3 General Use Mix Design modified with 20% flyash produced a 3 inch slump. The contractor wants a 4 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design – One yd$^3$

Based on SSD Condition

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>470 lbs.</td>
<td>Sand – F. M.</td>
<td>2.80</td>
</tr>
<tr>
<td>Sand</td>
<td>1120 lbs.</td>
<td>Sand – Sp. Gr.</td>
<td>2.83</td>
</tr>
<tr>
<td>No. 57</td>
<td>1863 lbs.</td>
<td>CA – Sp. Gr.</td>
<td>2.62</td>
</tr>
<tr>
<td>Water</td>
<td>288 lbs.</td>
<td>CA – Unit Weight</td>
<td>103 lb/ft$^3$</td>
</tr>
<tr>
<td>Air</td>
<td>6.5 %</td>
<td>Flyash – Sp. Gr.</td>
<td>3.00</td>
</tr>
<tr>
<td>Flyash</td>
<td>118 lbs.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ANSWER**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>_________ lbs.</td>
</tr>
<tr>
<td>Sand</td>
<td>_________ lbs.</td>
</tr>
<tr>
<td>No. 57</td>
<td>_________ lbs.</td>
</tr>
<tr>
<td>Water</td>
<td>_________ lbs.</td>
</tr>
<tr>
<td>Air</td>
<td>_________ %</td>
</tr>
<tr>
<td>Flyash</td>
<td>_________ lbs.</td>
</tr>
</tbody>
</table>
ACI Mix Design Adjustment Problem No. 6

The following Class A4 General Use Mix Design produced a 2 inch slump. The contractor wants a 3 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design - One yd^3

Based on SSD Condition

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount</th>
<th>Description</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS Cement</td>
<td>635 lbs.</td>
<td>Sand - F. M.</td>
<td>2.90</td>
</tr>
<tr>
<td>Sand</td>
<td>1094 lbs.</td>
<td>Sand - Sp. Gr.</td>
<td>2.62</td>
</tr>
<tr>
<td>No. 57</td>
<td>1871 lbs.</td>
<td>CA - Sp. Gr.</td>
<td>2.83</td>
</tr>
<tr>
<td>Water</td>
<td>286 lbs.</td>
<td>CA - Unit Weight</td>
<td>105 lb/ft^3</td>
</tr>
<tr>
<td>Air</td>
<td>6.5 %</td>
<td>IS Cement - Sp. Gr.</td>
<td>3.02</td>
</tr>
</tbody>
</table>

ANSWER

Cement ________ lbs.

Sand ________ lbs.

No. 57 ________ lbs.

Water ________ lbs.

Air ________ %
ACI WORKSHEET

CLASS ___________ MIX DESIGN

MODIFIED WITH ___________

FINE AGGREGATE
F.M. ___________
SP. GR. ___________
NOMINAL MAX. SIZE C.A. ___________

COARSE AGGREGATE
DRY RODDED UNIT WT. ___________
SP. GR. ___________
TABLE A1.5.3.6 FACTOR ___________
OTHER DATA NEEDED FOR SPECIAL DESIGNS ___________

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 ________ X 27 ft³ X UNIT WT. ________ = ________ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT
3.15 x 62.4 lbs. = ________ ft³

WATER
1.00 x 62.4 lbs. = ________ ft³

AIR
% x 27 = ________ ft³

C. AGGR.
SP.GR. ________ x 62.4 Lbs. = ________ ft³

ADDITIONAL MATERIALS
= ________ ft³

TOTAL = ________ ft³

27.00 ft³

- ________ ft³

F.A. ________ ft³ X SP.GR. X 62.4 = ________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT ______________________ lbs.
WATER ________ lbs. or _____ gals.
AIR ______________________ %
C. AGGR. ______________________ Lbs. - [_______] + [_______]
F. AGGR. ______________________ Lbs. - [_______] + [_______]
ADDL. MATLS. ________ =

_______ =

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ACI WORKSHEET

CLASS _____________ MIX DESIGN

MODIFIED WITH _____________

FINE AGGREGATE
F.M. _____________ DRY RODDED UNIT WT. _____________
SP. GR. _____________ SP. GR. _____________
NOMINAL MAX. SIZE C.A. _____________ TABLE A1.5.3.6 FACTOR _____________
OTHER DATA NEEDED FOR SPECIAL DESIGNS _____________

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 _____________ x 27 ft$^3$ x UNIT WT. _________ = _________ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT
3.15 x 62.4 lbs. = _____________ ft$^3$

WATER
1.00 x 62.4 lbs. = _____________ ft$^3$

AIR
% x 27 = _____________ ft$^3$

C. AGGR. SP.GR. _________ x 62.4 Lbs. = _____________ ft$^3$

ADDITIONAL MATERIALS = _____________ ft$^3$

TOTAL = _____________ ft$^3$

27.00 ft$^3$

- _________ ft$^3$

F.A. _________ ft$^3$ x _________ SP.GR. x 62.4 = _________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT _____________ lbs.
WATER _________ lbs. or ______ gals.
AIR _________ %
C. AGGR. _________ Lbs. - [_______] + [_______]
F. AGGR. _________ Lbs. - [_______] + [_______]
ADDL. MATLS. _________ = _________ =

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ACI WORKSHEET

CLASS ______________ MIX DESIGN
MODIFIED WITH __________________

FINE AGGREGATE COARSE AGGREGATE
F.M. ______________ DRY RODDED UNIT WT. ___________
SP. GR. ______________ SP. GR. ______________________
NOMINAL MAX. SIZE C.A. _______ TABLE A1.5.3.6 FACTOR _________
OTHER DATA NEEDED FOR SPECIAL DESIGNS _______________________

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 _________ x 27 ft³ x UNIT WT. _________ = _______ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT
3.15 x 62.4 lbs. = __________ ft³

WATER
1.00 x 62.4 lbs. = __________ ft³

AIR
100  % x 27 = __________ ft³

C. AGGR.
SP. GR. _______ Lbs. x 62.4 = __________ ft³

ADDITIONAL MATERIALS

TOTAL = __________ ft³

27.00 ft³
- __________ ft³
F.A. _______ ft³ x _______ SP. GR. x 62.4 = __________ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT ______________ lbs.
WATER _______ lbs. or _____ gals.
AIR ______________ %
C. AGGR. ______________ Lbs. - [_______] + [_______]
F. AGGR. ______________ Lbs. - [_______] + [_______]
ADDL. MATLS. _________ =
_________ =

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