3 ACI Concrete Mix Design and Allowable Field Adjustments

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/ft^3 of water = 196.56 lb/ft^3

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. _____

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 ft^3 X UNIT WT._____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____% x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =
_____ =

Student Notes:

Student Notes:

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

[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)

Nominal Maximum size of Aggregate		Volume of dry-rodded coarse aggregate * per unit volume of concrete for different fineness moduli** of fine aggregate						
Metric	English	2.40	2.50	2.60	2.70	2.80	2.90	3.00
9.5 mm	3/8	0.50	0.49	0.48	0.47	0.46	0.45	0.44
12.5 mm	½	0.59	0.58	0.57	0.56	0.55	0.54	0.53
19.0 mm	¾	0.66	0.65	0.64	0.63	0.62	0.61	0.60
25.0 mm	1	0.71	0.70	0.69	0.68	0.67	0.66	0.65
37.5 mm	1 ½	0.75	0.74	0.73	0.72	0.71	0.70	0.69
50 mm	2	0.78	0.77	0.76	0.75	0.74	0.73	0.72
75 mm	3	0.82	0.81	0.80	0.79	0.78	0.77	0.76
150 mm	6	0.87	0.86	0.85	0.84	0.83	0.82	0.81

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

** See ASTM Method 136 for calculation of fineness modulus

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	588 / 3.05 x 62.4	= 3.09	ft^3
WATER	588 x 0.49 = 288 lbs. / 1.00 x 62.4	= 4.62	ft^3
AIR	6 / 100 % x 27	= 1.62	ft^3
C. AGGR.	1909 lbs. / SP. GR. 2.61 X 62.4	= 11.72	ft^3
ADDITIONAL MATERIALS		=	ft^3
		=	ft^3
	TOTAL	= 21.05	ft^3

27.00 ft^3

- 21.05 ft^3

F.A. 5.95 ft^3 X 2.66 SP.GR. X 62.4 = 988 lbs.

SUGGESTED QUANTITIES _____ ± 5% TOLERANCE

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/ft^3 (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 yd^3 (27.00 ft^3) 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.)

   $$\frac{294 \text{ lbs.}}{3.15 \text{ (sp.gr. of port. cem.)} \times 62.4 \text{ (weight of 1 ft}^3\text{ of water)}}$$

   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:

   $$\frac{294 \text{ lbs.}}{2.90\text{(sp.gr. for this slag)} \times 62.4 \text{ (weight of 1 ft}^3\text{ of water)}} = 1.62 \text{ ft}^3$$

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 ft^3 x 7.5 (gallons of water in 1 ft^3) = 34.6 gallons

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

   0.06 x 27 ft^3 = 1.62 ft^3 = 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 ft^3 = 18.36 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 ft^3 x 104 lb/ft^3 = 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:

	Design	Absolute Volume
Cement	294 lbs.	1.50 ft^3
Slag	294 lbs.	1.62 ft^3
Water	288 lbs.	4.62 ft^3
Air	6 %	1.62 ft^3
Coarse Aggr.	1909 lbs.	11.72 ft^3
TOTAL		21.08 ft^3

   If the five materials total 21.08 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 ft^3 – 21.08 ft^3 = 5.92 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 ft^3 x 2.66 x 62.4 = 983 lbs. (design weight of fine aggregate)

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

Cement	-	294 lbs.
Slag	-	294 lbs.
Water	-	288 lbs.
Air	-	6 %
Coarse Aggregate	-	1909 lbs.
Fine Aggregate	-	983 lbs.

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/ft^3

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 ft^3 X UNIT WT. 104 = 1909 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT $\frac{.50 \times 588 = 294 \text{ lbs.}}{3.15 \times 62.4}$ = 1.50 ft^3

WATER $\frac{.49 \times 588 = 288 \text{ lbs.}}{1.00 \times 62.4}$ = 4.62 ft^3

AIR $\frac{6}{100}$ % x 27 = 1.62 ft^3

C. AGGR. $\frac{1909 \text{ lbs.}}{\text{SP. GR. } 2.61 \times 62.4}$ = 11.72 ft^3

ADDITIONAL MATERIALS slag = _____ ft^3

588 - 294 = 294 lbs. = 1.62 ft^3

2.90 x 62.4

TOTAL = 21.08 ft^3

27.00 ft^3

- 21.08 ft^3

F.A. 5.92 ft^3 X 2.66 SP.GR. X 62.4 = 983 lbs.

SUGGESTED QUANTITIES ±5% TOLERANCE

CEMENT 294 lbs.

WATER 288 lbs. or 34.6 gals.

AIR 6 %

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

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

ADDL. MATLS. slag = 294 lbs.

_____ =

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/ft^3 (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 ft^3 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).

   $$\frac{470 \text{ lbs. (this is design weight for 1 yd}^3\text{)}}{3.15 \text{ (sp.gr. of cement) X } 62.4 \text{(weight of 1 ft}^3 \text{ of water)}}$$

   $$\frac{470 \text{ lbs.}}{3.15 \text{ X } 62.4} = 2.39 \text{ ft}^3 \text{ Absolute volume}$$

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:

   $$\frac{118 \text{ lbs.}}{2.25 \text{(sp.gr.for this fly ash)X } 62.4 \text{(weight of 1 ft}^3 \text{ of water)}} = 0.84 \text{ ft}^3$$

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 x 0.49 = 288 lbs.

   To find absolute volume:

   $$\frac{288}{1.00 \text{ x } 62.4} = 4.62 \text{ ft}^3 = \text{Absolute volume}$$

   4.62 ft^3 x 7.5 (gallons of water in 1 ft^3) = 34.6 gallons

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

   0.06 x 27.00 ft^3 = 1.62 ft^3 = 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 x 27.00 ft^3 = 18.36 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 ft^3 x 104 lb/ft^3 = 1909 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:

	Design	Absolute Volume
Cement	470 lbs.	2.39 ft^3
Fly Ash	118 lbs.	0.84 ft^3
Water	288 lbs.	4.62 ft^3
Air	6 %	1.62 ft^3
Coarse Aggr.	1909 lbs.	11.72 ft^3
TOTAL		21.19 ft^3

   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 ft^3 – 21.19 ft^3 = 5.81 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 ft^3 x 2.66 x 62.4 = 964 lbs. (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

COARSE AGGREGATE

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

NOMINAL MAX. SIZE C.A. 1 inch

TABLE 5.3.6 FACTOR 0.68

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

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 $\frac{588 \times .80 = 470}{3.15 \times 62.4}$ lbs. = 2.39 ft^3

WATER {470 + 118 =588} $\frac{588 \times 0.49 = 288}{1.00 \times 62.4}$ lbs. = 4.62 ft^3

AIR $\frac{6}{100}$ % x 27 = 1.62 ft^3

C. AGGR. $\frac{1909}{\text{SP. GR. } 2.61 \text{ X } 62.4}$ lbs. = 11.72 ft^3

ADDITIONAL MATERIALS fly ash = _____ ft^3

$\frac{588 \times 0.20 = 118}{2.25 \times 62.4}$ lbs. = 0.84 ft^3

TOTAL = 21.19 ft^3

27.00 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 gals.

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

COARSE AGGREGATE

DRY RODDED UNIT WT. 101 lb/ft^3

SP. GR. 2.63

TABLE A1.5.3.6 FACTOR 0.55

OTHER DATA NEEDED FOR SPECIAL DESIGNS Slag 40%
Sp. Gravity 2.94

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 {(.40)(635)=254} $\frac{635 - 254 = 381}{3.15 \times 62.4}$ lbs. = 1.94 ft^3

WATER $\frac{.45 \times 635 = 286}{1.00 \times 62.4}$ bs. = 4.58 ft^3

AIR $\frac{7.0}{100}$ % x 27 = 1.89 ft^3

C. AGGR. $\frac{1500}{\text{SP.GR. } 2.63 \times 62.4}$ lbs. = 9.14 ft^3

ADDITIONAL MATERIALS $\frac{.40 \times 635 = 254}{2.94 \times 62.4}$ = 1.38 ft^3

_____ = _____ ft^3

TOTAL = 18.93 ft^3

27.00 ft^3

\- 18.93 ft^3

F.A. 8.07 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/ft^3. 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	COARSE AGGREGATE
F.M. 3.00	DRY RODDED UNIT WT. 102 lb/ft^3
SP. GR. 2.64	SP. GR. 2.62
NOMINAL MAX. SIZE C.A. 1"	TABLE A1.5.3.6 FACTOR 0.65

OTHER DATA NEEDED FOR SPECIAL DESIGNS Fly Ash 20% Replacement
Sp. Gravity 2.35

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 0.65 X 27 ft^3 X UNIT WT. 102 = 1790 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT {(.20)(635)=127} $\frac{635 - 127 = 508 \text{ lbs.}}{3.15 \times 62.4}$ = 2.58 ft^3

WATER $\frac{.45 \times 635 = 286 \text{ lbs.}}{1.00 \times 62.4}$ = 4.58 ft^3

AIR $\frac{6.5}{100}$ % x 27 = 1.76 ft^3

C. AGGR. $\frac{1790 \text{ lbs.}}{\text{SP.GR. } 2.62 \times 62.4}$ = 10.95 ft^3

ADDITIONAL MATERIALS $\frac{.20 \times 635 = 127}{2.35 \times 62.4}$ = 0.87 ft^3

_____ = _____ ft^3

TOTAL = 20.74 ft^3

27.00 ft^3

− 20.74 ft^3

F.A. 6.26 ft^3 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/ft^3. 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	COARSE AGGREGATE
F.M. 2.70	DRY RODDED UNIT WT. 100 lb/ft^3
SP. GR. 2.62	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 ft^3 X UNIT WT. 100 = 1512 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT {(.50)(635)=318}	$\frac{635 - 318 = 317}{3.15 \times 62.4}$ lbs.	= 1.61	ft^3
WATER	$\frac{.45 \times 635 = 286}{1.00 \times 62.4}$ lbs.	= 4.58	ft^3
AIR	$\frac{7}{100}$ % x 27	= 1.89	ft^3
C. AGGR.	$\frac{1512}{\text{SP.GR. } 3.04 \times 62.4}$ lbs.	= 7.97	ft^3
ADDITIONAL MATERIALS	$\frac{.50 \times 635 = 318}{2.94 \times 62.4}$	= 1.73	ft^3
		=	ft^3
	TOTAL	= 17.78	ft^3

27.00 ft^3

− 17.78 ft^3

F.A. 9.22 ft^3 X 2.62 SP.GR. X 62.4 = 1507 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 317 lbs.

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.

CLASS A4 General MIX DESIGN
MODIFIED WITH Fly Ash

FINE AGGREGATE
F.M. 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 A1.5.3.6 FACTOR 0.68

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

QUANTITY OF COARSE AGGREGATE
TABLE A1.5.3.6 0.68 X 27 ft^3 X UNIT WT. 104 = 1909 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT {(.20)(635)=127 $\frac{635 - 127 = 508}{3.15 \times 62.4}$ lbs. = 2.58 ft^3

WATER $\frac{.45 \times 635 = 286}{1.00 \times 62.4}$ lbs. = 4.58 ft^3

AIR $\frac{6.5}{100}$ % x 27 = 1.76 ft^3

C. AGGR. $\frac{1909}{\text{SP.GR. } 2.60 \times 62.4}$ lbs. = 11.77 ft^3

ADDITIONAL MATERIALS $\frac{.20 \times 635 = 127}{2.25 \times 62.4}$ = 0.90 ft^3

= _____ ft^3

TOTAL = 21.59 ft^3

27.00 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:

IP Cement	- 588 lbs.	Sp. gr. F.A. = 2.67
Water	- 288 lbs.	Sp. gr. C.A. = 2.61
Air	- 6 %	F.M. of F.A. = 2.70
#57	- 1965 lbs.	Unit wt. of C.A. = 107 lbs/ft^3
F.A.	- 930 lbs.	Sp. gr. Cement = 3.03

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

F.A. = 930 x 0.05 = 47 lbs.

Original Wt. of F.A. =	930 lbs.
Less 5% =	- 47 lbs.
New Wt. of F.A.	883 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 lbs. F.A./[2.67(F.A. Sp. Gr.) X 62.4] = 0.28 ft^3

0.28 X [2.61 (C.A. Sp. Gr.) X 62.4] = 46 lbs. of C.A. to be added

Original wt. of C.A. #57	1965 lbs.
Plus wt. C.A. to be increased	+ 46 lbs.
Net wt. of C.A.	2011 lbs.

The adjusted design quantities are:

Cement	588 lbs.
Air	6 %
Water	288 lbs.
#57	2011 lbs.
F.A.	883 lbs.

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

		Absolute Volume (ft^3)
IP Cement - 588 lbs.	$\frac{588}{3.03 \times 62.4}$	= 3.11
Air - 6%	0.06 X 27	= 1.62
Water – 288 lbs.	$\frac{288}{1.00 \times 62.4}$	= 4.62
C. A. - #57 = 2011 lbs.	$\frac{2011}{2.61 \times 62.4}$	= 12.35
F. A. - 883 lbs.	$\frac{883}{2.67 \times 62.4}$	= 5.30
TOTAL		27.00

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.

IP Cement	- 588 lbs.	F. A. Sp. Gr.	- 2.64
Air	- 6.0%	F. A. F. M.	- 3.00
Water	- 288 lbs.	C. A. Sp. Gr.	- 2.62
F. A.	- 998 lbs.	C. A. Unit Wt.	- 108 lb/ft^3
C. A. No. 57	- 1895 lbs.	Cement Sp. Gr.	- 3.03

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 ft^3 0.30 X 2.62 X 62.4 = 49 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

Cement	- 588 lbs.
Air	- 6.0%
Water	- 288 lbs.
F. A.	- 1048 lbs.
C. A. - No. 57	- 1846 lbs.

Student Notes:

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.

Cement	- 470 lbs.	F. A. Sp. Gr.	- 2.62
Air	- 6%	F. A. F. M.	- 2.70
Water	- 288 lbs.	C. A. Sp. Gr.	- 3.04
F. A.	- 1189 lbs.	C. A. Unit Wt.	- 106 lb/ft^3
C. A. No. 57	- 1946 lbs.	Cement Alkali Content	- 0.65%
Flyash	- 118 lbs.	Flyash Sp. Gr.	- 2.25

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)

$\frac{59}{2.62 \times 62.4}$ = 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

Cement	- 470 lbs.
Air	- 6%
Water	- 288 lbs.
F. A.	- 1130 lbs.
C. A. - No. 57	- 2014 lbs.
Flyash	- 118 lbs.

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.	F. A. Sp. Gr.	-	2.60
Air	-	6.5%	F. A. F. M.	-	2.93
Water	-	286 lbs.	C. A. Sp. Gr.	-	2.67
F. A.	-	1063 lbs.	C. A. Unit Wt.	-	96.5 lbs/ft^3
C. A. No. 57	-	1798 lbs.	Cement Alkali Content - 0.70%		
Slag	-	254 lbs.			

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 ft^3 0.33 X 2.67 X 62.4 = 55.0 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

COMMERCIALLY PRODUCED

COARSE AGGREGATES

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

			L. A. ABRASION LOSS		
PRODUCER AND LOCATION	SP. GR.	ABS.(%)	A	B	C
Sadler Materials Richmond, VA	2.62	0.9	37.6	38.0	----
Lone Star Industries Dock St., Richmond, VA	2.63	0.8	39.2	38.0	34.0
Fredericksburg Sand & Gravel Fredericksburg, VA	2.64	0.3	37.5	35.5	----
Virginia Traprock, Inc. Leesburg, VA	3.04	0.4	----	19.1	26.7
West Sand and Gravel Richmond, VA	2.60	1.0	----	39.3	37.1
Bull Run Stone Co. Manassas, VA	2.67	1.5	----	14.3	----
Dillon, E & Co. Swords Creek, VA	2.83	0.4	23.1	----	----
Lone Jack Glasgow, A	2.81	0.3	----	18.9	21.8

Shenandoah Asphalt Vesuvius, VA	2.59	1.0	----	30.3	39.3

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.)

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

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/ft^3. Fine aggregate will come from West Sand and Gravel, Richmond, VA. 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. _____

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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. _____ =

_____ =

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/ft^3. 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

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =
_____ =

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/ft^3. 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.

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =
_____ =

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/ft^3. Fine aggregate will come from Sadler Materials. Use aggregate data sheets found on page 3-32 and 3-33.

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =
_____ =

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/ft^3. 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. _____

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 ft^3 X UNIT WT. _____ = _____lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =
_____ =

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	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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.0 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =
_____ =

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/ft^3. 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. _____

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =
_____ =

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/ft^3. 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	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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT	_____ lbs. / 3.15 x 62.4	=	_____ ft^3
WATER	_____ lbs. / 1.00 x 62.4	=	_____ ft^3
AIR	_____ % x 27 / 100	=	_____ ft^3
C. AGGR.	_____ Lbs. / SP.GR._____ X 62.4	=	_____ ft^3
ADDITIONAL MATERIALS	_____	=	_____ ft^3
	_____	=	_____ 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._____ =
_____ =

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/ft^3. 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
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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT	_____ lbs. / 3.15 x 62.4	=	_____ ft^3
WATER	_____ lbs. / 1.00 x 62.4	=	_____ ft^3
AIR	_____ % x 27 / 100	=	_____ ft^3
C. AGGR.	_____ Lbs. / SP.GR._____ X 62.4	=	_____ ft^3
ADDITIONAL MATERIALS	_____	=	_____ ft^3
	_____	=	_____ 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._____ =
_____ =

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/ft^3. 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.

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =
_____ =

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 yd^3.

Based on SSD Condition

IP Cement	635 lbs.	Sand – F. M.	2.80
Sand	1150 lbs.	Sand – Sp. Gr.	2.64
No. 57	1954 lbs.	CA – Sp. Gr.	3.04
Water	288 lbs.	CA – Unit Weight	108 lb/ft^3
Air	6.5 %	IP Cement – Sp. Gr.	3.05

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 yd^3.

Based on SSD Condition

IS Cement	588 lbs.	Sand – F. M.	2.70
Sand	983 lbs.	Sand – Sp. Gr.	2.66
No. 57	1909 lbs.	CA – Sp. Gr.	2.61
Water	288 lbs.	CA – Unit Weight	104 lb/ft^3
Air	6.0 %	IS Cement – Sp. Gr.	3.02

ANSWER

Cement_____ lbs.

Sand _____ lbs.

No. 57_____ lbs.

Water_____ lbs.

Air _____%

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 yd^3.

Based on SSD Condition

Cement	381 lbs.	Sand - F. M.	2.70
Sand	1285 lbs.	Sand - Sp. Gr.	2.62
No. 57	1799 lbs.	CA - Sp. Gr.	3.04
Water	286 lbs.	CA - Unit Weight	98 lb/ft^3
Air	6.5 %		
Slag	254 lbs.	Slag - Sp. Gr. -	2.95

ANSWER

Cement_____ lbs.

Sand _____ lbs.

No. 57_____ lbs.

Water_____ lbs.

Air _____%

Slag _____ lbs.

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 yd^3

Based on SSD Condition

IP Cement	588 lbs.	Sand – F. M.	2.80
Sand	1107 lbs.	Sand – Sp. Gr.	2.64
No. 57	1934 lbs.	CA – Sp. Gr.	2.83
Water	288 lbs.	CA – Unit Weight	106.9 lb/ft^3
Air	6.0 %	IP Cement – Sp. Gr.	3.05

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

Cement	470 lbs.	Sand - F. M.	2.80
Sand	1120 lbs.	Sand - Sp. Gr.	2.83
No. 57	1863 lbs.	CA - Sp. Gr.	2.62
Water	288 lbs.	CA - Unit Weight	103 lb/ft^3
Air	6.5 %	Flyash - Sp. Gr.	3.00
Flyash	118 lbs.		

ANSWER

Cement_____ lbs.

Sand _____ lbs.

No. 57_____ lbs.

Water _____ lbs.

Air _____%

Flyash _____ lbs.

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

IS Cement	635 lbs.	Sand – F. M.	2.90
Sand	1094 lbs.	Sand – Sp. Gr.	2.62
No. 57	1871 lbs.	CA – Sp. Gr.	2.83
Water	286 lbs.	CA – Unit Weight	105 lb/ft^3
Air	6.5 %	IS Cement – Sp. Gr.	3.02

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =

_____ =

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =

_____ =

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 ft^3 X UNIT WT. _____ = _____ lbs.

ABSOLUTE VOLUMES

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

WATER _____ lbs. = _____ ft^3
1.00 x 62.4

AIR _____ % x 27 = _____ ft^3
100

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

ADDITIONAL MATERIALS _____ = _____ ft^3

_____ = _____ 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._____ =

_____ =

Student Notes: