

CHAPTER 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.

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

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 $3.15 \times 62.4 \text{ lb/ft}^3$ 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	COARSE AGGREGATE
F.M. _____	DRY RODDED UNIT WT. _____
SP. GR. _____	SP. GR. _____
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.	=	_____ 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. _____ =

_____ =

TABLE II-17 Requirements for Hydraulic Cement Concrete

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

Footnotes

- ¹When a high-range water reducer is used, the target air content shall be increased 1% and the slump shall not exceed 7 inches.
- ²When 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 $5\frac{1}{2}\pm 1\frac{1}{2}\%$.
- ³The latex modifier content shall be 3.5 gallons per bag of cement. Slump shall be measured approximately 4½ minutes after discharge from the mixer.
- ⁴Silica 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.
- ⁵The 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.
- ⁶The 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)**

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	1/2	0.59	0.58	0.57	0.56	0.55	0.54	0.53
19.0 mm	3/4	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 1/2	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

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: Calendar Year _____ Mix Design No. _____

Producer _____ Plant Location _____ Phone _____
 Type of Mix: Ready Mix _____ Job Mix _____ Date _____

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

Class of Concrete _____ (E) Slump/ _____ In. _____ mm Air Content _____ %
 _____ (M) Flow

Material	Type	Quantities		Source		Plant/Quarry Location
		lbs.	kg.	Code	Name	
Cement		_____	_____	_____	_____	_____
Min. Admix. 1		_____	_____	_____	_____	_____
Min. Admix. 2		_____	_____	_____	_____	_____
Sand ⁽¹⁾		_____	_____	_____	_____	_____
No. _____	Stone ⁽¹⁾	_____	_____	_____	_____	_____
Gr./No. _____	Aggr. ⁽¹⁾	_____	_____	_____	_____	_____
Water ⁽²⁾	_____ lbs.	_____ gal.	_____ L.	_____	_____	_____
Admixture (AE) ⁽³⁾		_____ oz.	_____ ml.	_____	_____	_____
Admixture (Retarder) ⁽³⁾		_____ oz.	_____ ml.	_____	_____	_____
Admixture (Other) ⁽³⁾		_____ oz.	_____ ml.	_____	_____	_____

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 II-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.

Mineral Admixture #1 - sp.gr. _____
 Mineral Admixture #2 - sp.gr. _____
 Sand - Abs. _____
 Sand - F.M. _____
 Sand - sp.gr. _____

C.A. #1 - Abs. _____
 C.A. #1 - sp.gr. _____
 C.A. #1 Unit mass _____ / _____
Lbs./C.F. kg/C.M.

Aggr. #2 - Abs. _____
 Aggr. #2 - sp.gr. _____
 2nd F.A./C.A.-F.M./u.wt. _____ / _____
E M

Design W/C Ratio _____

Contractor _____
(Name of Company)

By _____
(Certified Technician Preparing Form)

Producer Technician's Expiration Date _____
(Do Not Use Social Security Number)

FOR DEPARTMENT USE ONLY

Remarks: _____

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

Checked by _____

Approved by _____

District Materials Engineer

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

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.

	Total Alkalies of Cement less than or equal to 0.75%	Total Alkalies of Cement greater than 0.75% and less than or equal to 1%
Class F Flyash	20%	25%
GGBF Slag	40%	50%
Silica Fume	7%	10%
Metakaolin	7%	10%

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 yd³. 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)

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/ft³ (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 ft³).

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 yd³ 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 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:

$$\frac{0.68 \text{ (dry-rodded condition of the coarse aggregate)}}{\times 27.0 \text{ ft}^3 \text{ (volume)}} = 18.36 \text{ ft}^3 = \text{dry-rodded volume}$$

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

$$\frac{18.36 \text{ ft}^3 \text{ (dry rodded unit weight)}}{\times 104 \text{ lb/ft}^3 \text{ (dry-rodded volume)}} = 1909 \text{ lbs.} = \text{design weight of coarse aggregate}$$

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.

	<u>Design</u>	<u>Absolute Volume</u>
Cement	588 lbs.	3.09 ft ³
Water	288 lbs.	4.62 ft ³
Air	6%	1.62 ft ³
Coarse Aggregate	1909 lbs.	<u>11.72 ft³</u>
TOTAL		21.05 ft ³

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

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 ft³ X UNIT WT. 104 lb/ft³ = 1909 lbs.

ABSOLUTE VOLUMES

PORTLAND IS CEMENT $\frac{588}{3.05 \times 62.4} = 3.09$ ft³

WATER $\frac{588 \times 0.49}{1.00 \times 62.4} = 4.62$ ft³

AIR $\frac{6}{100} \% \times 27 = 1.62$ ft³

C. AGGR. $\frac{1909}{\text{SP. GR. } 2.61 \times 62.4} = 11.72$ ft³

ADDITIONAL MATERIALS _____ = _____ ft³

_____ = _____ ft³

TOTAL = 21.05 ft³

27.00 ft³

- 21.05 ft³

F.A. 5.95 ft³ 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)

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.)

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

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.

$$588 \times 0.49 = 288 \text{ lbs.}$$

To find absolute volume:

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

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

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 maximum size of the coarse aggregate in the method described on Page 3-10. To convert this to volume, we say $0.68 \times 27 \text{ ft}^3 = 18.36 \text{ ft}^3$ (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:

$$18.36 \text{ ft}^3 \times 104 \text{ lb/ft}^3 = 1909 \text{ lbs. (design wt. of C.A.)}$$

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:

	<u>Design</u>	<u>Absolute Volume</u>
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 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:

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

COARSE AGGREGATE

F.M. 2.70

DRY RODDED UNIT WT. 104 lb/ft³

SP. GR. 2.66

SP. GR. 2.61

MAX. SIZE C.A. 1"

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

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

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

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

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

ADDITIONAL MATERIALS $\frac{\text{slag}}{588 - 294 = 294 \text{ lbs.}} = 1.62 \text{ ft}^3$
 $\frac{294}{2.90 \times 62.4}$

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

±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)

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).

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

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

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:

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

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.).

$$588 \times 0.49 = 288 \text{ lbs.}$$

To find absolute volume:

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

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

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 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:

	<u>Design</u>	<u>Absolute Volume</u>
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.	<u>11.72 ft³</u>
TOTAL		21.19 ft ³

If the five materials total 21.19 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:

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

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

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

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

COARSE AGGREGATE

F.M. 2.70
 SP. GR. 2.66

DRY RODDED UNIT WT. 104 lb/ft³
 SP. GR. 2.61

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 ft³ X UNIT WT. 104 lb/ft³ = 1909 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT $\frac{588 \times .80 = 470}{3.15 \times 62.4}$ lbs. = 2.39 ft³

WATER {470 + 118 = 588} $\frac{588 \times 0.49 = 288}{1.00 \times 62.4}$ lbs. = 4.62 ft³

AIR $\frac{6}{100} \% \times 27 =$ 1.62 ft³

C. AGGR. $\frac{1909}{\text{SP. GR. } 2.61 \times 62.4}$ lbs. = 11.72 ft³

ADDITIONAL MATERIALS $\frac{\text{fly ash}}{2.25 \times 62.4} =$ 0.84 ft³

TOTAL = 21.19 ft³

27.00 ft³
 - 21.19 ft³

F.A. 5.81 ft³ 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/ft³. 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	COARSE AGGREGATE
F.M. <u>2.80</u>	DRY RODDED UNIT WT. <u>101 lb/ft³</u>
SP. GR. <u>2.64</u>	SP. GR. <u>2.63</u>
MAX. SIZE C.A. <u>1/2</u>	TABLE A1.5.3.6 FACTOR <u>0.55</u>
OTHER DATA NEEDED FOR SPECIAL DESIGNS <u>Slag 40%</u>	
<u>Sp. Gravity 2.94</u>	

QUANTITY OF COARSE AGGREGATE
 TABLE A1.5.3.6 0.55 X 27 ft³ X UNIT WT. 101 = 1500 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT {(.40)(635)=254}	<u>635 - 254 = 381</u> lbs.	= <u>1.94</u> ft ³	
	<u>3.15 x 62.4</u>		
WATER	<u>.45 x 635 = 286</u> bs.	= <u>4.58</u> ft ³	
	<u>1.00 x 62.4</u>		
AIR	<u>7.0</u> % x 27	= <u>1.89</u> ft ³	
	<u>100</u>		
C. AGGR.	<u>1500</u> lbs.	= <u>9.14</u> ft ³	
	<u>SP.GR. 2.63</u> X 62.4		
ADDITIONAL MATERIALS	<u>.40 x 635 = 254</u>	= <u>1.38</u> ft ³	
	<u>2.94 x 62.4</u>		
		= _____ ft ³	
	TOTAL	= <u>18.93</u> ft ³	

	27.00	ft ³			
-	<u>18.93</u>	ft ³			
F.A.	<u>8.07</u>	ft ³	X	<u>2.64</u>	SP.GR. X 62.4 = <u>1329</u> 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

COARSE AGGREGATE

F.M. 3.00

DRY RODDED UNIT WT. 102 lb/ft³

SP. GR. 2.64

SP. GR. 2.62

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 ft³ X UNIT WT. 102 = 1790 lbs.

ABSOLUTE VOLUMES

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

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

AIR $\frac{6.5}{100} \% \times 27 = \underline{1.76} \text{ ft}^3$

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

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

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 <u>50% Slag</u>
FINE AGGREGATE	COARSE AGGREGATE
F.M. <u>2.70</u>	DRY RODDED UNIT WT. <u>100 lb/ft³</u>
SP. GR. <u>2.62</u>	SP. GR. <u>3.04</u>
MAX. SIZE C.A. <u>1/2"</u>	TABLE A1.5.3.6 FACTOR <u>.56</u>
OTHER DATA NEEDED FOR SPECIAL DESIGNS	<u>50% Slag (Sp. Gr. = 2.94)</u>

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

27.00 ft³

- 17.78 ft³

F.A. 9.22 ft³ 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/ft³. 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

COARSE AGGREGATE
 DRY RODDED UNIT WT. 104 lb/ft³

SP. GR. 2.64 SP. GR. 2.60

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 ft³ X UNIT WT. 104 = 1909 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT {(.20)(635)=127	$\frac{635 - 127 = 508}{3.15 \times 62.4}$	lbs.	=	<u>2.58</u>	ft ³	
WATER	$\frac{.45 \times 635 = 286}{1.00 \times 62.4}$	lbs.	=	<u>4.58</u>	ft ³	
AIR	$\frac{6.5}{100}$	%	x 27	=	<u>1.76</u>	ft ³
C. AGGR.	$\frac{1909}{2.60}$	lbs.	X 62.4	=	<u>11.77</u>	ft ³
ADDITIONAL MATERIALS	$\frac{.20 \times 635 = 127}{2.25 \times 62.4}$			=	<u>0.90</u>	ft ³
				=		ft ³
	TOTAL			=	<u>21.59</u>	ft ³
27.00	ft ³					
- <u>21.59</u>	ft ³					
F.A. <u>5.41</u>	ft ³	X	<u>2.64</u>	SP.GR. X	62.4	= <u>891</u> 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 ft³.

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:

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

Original Wt. of F.A. =	930 lbs.
Less 5% =	- <u>47</u> 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 ft³. This is accomplished as follows:

$$47 \text{ lbs. F.A.} / [2.67(\text{F.A. Sp. Gr.}) \times 62.4] = 0.28 \text{ ft}^3$$

$$0.28 \times [2.61 (\text{C.A. Sp. Gr.}) \times 62.4] = 46 \text{ lbs. of C.A. to be added}$$

Original wt. of C.A. #57	1965 lbs.
Plus wt. C.A. to be increased	<u>+ 46</u> 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 ft³

		Absolute Volume (ft ³)
IP Cement - 588 lbs.	$\frac{588}{3.03 \times 62.4}$	= 3.11
Air - 6%	0.06×27	= 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		<u>27.00</u>

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:

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

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

$\frac{50}{2.64 \times 62.4} = 0.30$ ft³ $0.30 \times 2.62 \times 62.4 = 49$ 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.

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:

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

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

$\frac{59}{2.62 \times 62.4} = 0.36$ ft³ $0.36 \times 3.04 \times 62.4 = 68$ 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:

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

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

$\frac{53}{2.60 \times 62.4} = 0.33$ ft³ $0.33 \times 2.67 \times 62.4 = 55.0$ 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
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.)

PRODUCER AND LOCATION	SP. GR.	ABS.(%)	L. A. ABRASION LOSS		
			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/ft³. 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 _____ COARSE AGGREGATE _____
F.M. _____ DRY RODDED UNIT WT. _____

SP. GR. _____ SP. GR. _____

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.	=	_____ 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 _____	=	_____ lbs.
	SP.GR. X 62.4		

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/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 _____

FINE AGGREGATE _____ COARSE AGGREGATE _____

F.M. _____ DRY RODDED UNIT WT. _____

SP. GR. _____ SP. GR. _____

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.	=	_____ 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/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.

CLASS _____ MIX DESIGN
MODIFIED WITH _____

FINE AGGREGATE _____ COARSE AGGREGATE _____

F.M. _____ DRY RODDED UNIT WT. _____

SP. GR. _____ SP. GR. _____

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.	=	_____ 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/ft³. 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. _____

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.	=	_____ 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/ft³. 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. _____

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.	=	_____ 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 _____	=	_____ lbs.	
	SP.GR. X 62.4			

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/ft³. 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. _____
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.	=	_____ 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 _____	=	_____ lbs.
	SP.GR. X 62.4		

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/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 _____ COARSE AGGREGATE _____

F.M. _____ DRY RODDED UNIT WT. _____

SP. GR. _____ SP. GR. _____

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.	=	_____	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/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 _____ COARSE AGGREGATE _____

F.M. _____ DRY RODDED UNIT WT. _____

SP. GR. _____ SP. GR. _____

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.	=	_____ 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. 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
MODIFIED WITH _____

FINE AGGREGATE _____ COARSE AGGREGATE _____

F.M. _____ DRY RODDED UNIT WT. _____

SP. GR. _____ SP. GR. _____

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.	=	_____ 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. 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.

	CLASS _____ MIX DESIGN	
	MODIFIED WITH _____	
FINE AGGREGATE		COARSE AGGREGATE
F.M. _____		DRY RODDED UNIT WT. _____
SP. GR. _____		SP. GR. _____
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 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

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 yd³.

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 yd³.

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 yd³

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 yd³

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 yd³

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 _____ COARSE AGGREGATE _____
 F.M. _____ DRY RODDED UNIT WT. _____
 SP. GR. _____ SP. GR. _____
 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 WORKSHEET

CLASS _____ MIX DESIGN

MODIFIED WITH _____

FINE AGGREGATE	COARSE AGGREGATE
F.M. _____	DRY RODDED UNIT WT. _____
SP. GR. _____	SP. GR. _____
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.	= _____ 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 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 WORKSHEET

CLASS _____ MIX DESIGN

MODIFIED WITH _____

FINE AGGREGATE _____ COARSE AGGREGATE _____
 F.M. _____ DRY RODDED UNIT WT. _____
 SP. GR. _____ SP. GR. _____
 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. _____ =

_____ =