GEORGIA DEPARTMENT OF TRANSPORTATION
STUDY GUIDE FOR CONCRETE TECHNICIANS

I. Procedure for Selecting Proportions

A. Establishing Limiting Criteria

Before starting to establish mix proportions, information must be assembled on the characteristics of Department approved materials and the requirements of the concrete. Information on materials should include:

1. Relationships of strength to water/cement ratio for available combinations of materials, including cement.
2. Specific gravities and absorptions of fine and coarse aggregates.
3. Gradings of fine and coarse aggregates.
4. Effects of any admixtures to be used, and addition rates.

B. The job Specification, or other sources of information should be examined in detail to ascertain requirements for:

1. Maximum water/cement ratio
2. Minimum cement factor
3. Air content
4. Slump
5. Maximum size of aggregate and limitations or grading
6. Strength
7. Required admixtures

C. In the case of Department of Transportation work, the second list of criteria will govern. This information can be found on the chart containing uses of concrete in the Standard Specifications.

II. Definition of Terms

Before you begin proportioning, it would be helpful to review the terms and definitions as follows:

1. Specific Gravity. The specific gravity of a material is expressed as a ratio of its weight to the weight of the same volume of water.

   Specific gravity of water is equal to one.

   The specific gravity of cement is equal to 3.14; or we could say (cement is 3.14 times as dense as water).

2. "Solid" weight per cubic foot. The solid weight per cubic foot of a material is expressed as the product of the materials specific gravity times the weight of one cubic foot of water (62.4 lbs).

   The solid weight per cubic foot of cement is equal to:

   $3.14 \times 62.4 \text{lbs} = 195.94 \text{ lbs/ft}^3$

3. Absolute Volume. The absolute volume of a material is the volume exclusive of the void spaces between particles. It is expressed as the ratio of the loose materials weight to the solid weight per cubic foot of the same material.

   One sack of cement (94 lbs) occupies approximately one cubic foot of bulk volume, but the absolute volume of the solid cement particles is only about 0.48 ft^3.

$$\frac{94\,lbs}{195.94\,lbs/ft^3} = 0.48\ ft^3$$

III. Determining Proportions

Determination of proportions can best be done by establishing a list of requirements needed in finding proportions and then fulfilling these requirements according to the Specifications.

1. Selection of Cement Factor

   The Department of Transportation has already established a minimum cement factor for all classes of concrete. This factor can be obtained from the Specifications.

2. Determining Mix Water Requirement

   The Department of Transportation has established a maximum amount of water for a given amount of cement. Actual mixing water required to produce the desired slump will be somewhat less than the maximum. Even though tables have been established which can aid in determining the actual amount of mixing water needed for certain size and shape aggregates and corresponding slump values, we must rely largely on experience. Therefore, a concrete technician who works with a given combination of materials daily should be familiar enough with his materials to determine the actual mixing water required.

3. Specific Gravities

   Specific gravities can be obtained from the List of Approved Aggregate Sources (QPL 1 & 2) published by the Department.

4. Determination of Aggregate Volume

   In determining the ratio of fine aggregate volume to coarse aggregate volume, we must again rely on experience or other acceptable published design procedures. This should be easy enough for a concrete technician who is familiar with the characteristics of the material he is using.

5. Allowance for Volume of Air

   The Specification establishes the design air content and a range of air contents for all Classes of concrete used by the Department. These volumes of air should be taken into consideration in your design.

IV. Example Problems

Example 1: Establish the proportions for a Class "A" mix using the following materials:

Materials	Sp. Gr.	Absorption	Solid Wt./ft^3
Medusa Cement	3.14		$3.14 \times 62.4 = 195.94$
Howard Sand	2.61	0.43	$2.61 \times 62.4 = 162.86$
Dalton Rock	2.74	0.62	$2.74 \times 62.4 = 170.98$

			Volumes	
Cement	611		3.12	ft^3
Sand	1168		7.17	ft^3
Stone	1918		11.22	ft^3
Water	33.0	gals.	4.41	ft^3
Air	4 %		1.08	ft^3
	Total Volume =		27.00	ft^3

$$\text{Absolute Vol.} = \frac{\text{Weight}}{\text{Solid Wt./ft}^3}$$

$$\text{Absolute Vol. Cement} = \frac{611\,\text{lbs}}{195.94\,\text{lbs/ft}^3} = 3.12\,\text{ft}^3$$

$$\text{Absolute Vol. Water} = \frac{33.0\,\text{gals} \times 8.33\,\text{lbs/gal}}{62.4} = 4.41\,\text{ft}^3$$

$$\text{Absolute Vol. Air} = 27.00 \times 0.04 = 1.08\,\text{ft}^3$$

Total Vol. of Cement, Water, Air = 8.61 ft^3

$$\text{Total Vol. Aggregate} = 27.00 - 8.61 = 18.39\,\text{ft}^3$$

$$\text{Volume of Sand} = 18.39 \times 0.39 = 7.17\,\text{ft}^3$$

$$\text{Volume of Stone} = 18.39 - 7.17 = 11.22\,\text{ft}^3$$

$$\text{Batch Weights} = \text{Absolute Volume} \times \text{Solid Wt./ft}^3$$

$$\text{Batch Wt. Sand} = 7.17 \times 162.86 = 1168\,\text{lbs}$$

$$\text{Batch Wt. Stone} = 11.22 \times 170.98 = 1918\,\text{lbs}$$

Example 2: Listed below are the one cubic yard proportions for a Class A concrete mix. It has been determined that this mix produces concrete that has excessive slump (6.0"). Reduce the water by 2.0 gallons per cubic yard and make the necessary adjustment in the sand so as to keep the same volume of concrete. Remember, in general, one gallon of water per cubic yard will change slump measurements approximately 1.0 inch.

Materials	Proportions (lbs)	Sp. Gr.	Adj. Abs. Vol. (ft^3)	Adjusted Proportions
Cement	611	3.14	3.12	611 lbs
Sand	1155	2.63	7.09	1164 lbs
Stone	1899	2.66	11.44	1899 lbs
Water (gals)	(34.0) 32.0		4.27	32.0 gals
Air	4 %		1.08	

$$\text{Reduce water by 2 gallons} = 34.0 - 2.0 = 32.0$$

$$\text{Absolute Vol. Cement} = \frac{611\,\text{lbs}}{195.94\,\text{lbs}/\text{ft}^3} = 3.12\ \text{ft}^3$$

$$\text{Absolute Vol. Water} = \frac{32.0\,\text{gals} \times 8.33\,\text{lbs}/\text{gal}}{62.4\,\text{lbs}/\text{ft}^3} = 4.27\ \text{ft}^3$$

$$\text{Absolute Vol. Stone} = \frac{1899\,\text{lbs}}{165.98\,\text{lbs}/\text{ft}^3} = 11.44\ \text{ft}^3$$

$$\text{Absolute Vol. Air} = 27.00 \times 0.04 = 1.08\ \text{ft}^3$$

Total Volume of Cement, Water, Stone, Air = 19.91 ft^3

$$\text{Volume of Sand} = 27.00 - 19.91 = 7.09\ \text{ft}^3$$

Adjusted Proportions

$$\text{Cement} = 3.12 \times 195.94 = 611\,\text{lbs}$$

$$\text{Sand} = 7.09 \times 164.11 = 1164\,\text{lbs}$$

$$\text{Stone} = 11.44 \times 165.98 = 1899\,\text{lbs}$$

Example 3: Listed below are the proportions for a Class B concrete mix. It has been determined that the mix will not produce workable concrete because of a lack of sand. Increase the sand by 110 pounds per cubic yard and make no changes in the cement, water, and air. Retain the same volume of concrete which is one cubic yard.

Materials	Proportions (lbs)	Sp. Gr.	Absolute Vol. (ft^3)	Adjusted Proportions
Cement	470	3.14	2.40	470 lbs
Sand	1063	2.63	7.15	1173 lbs
Stone	2075	2.66	11.83	1964 lbs
Water	34.0 gals		4.54	34.0 gals
Air	4 %		1.08	4 %

$$\text{Add } 110 \text{ lbs to sand weight} = 1063 \text{ lbs} + 110 \text{ lbs} = 1173 \text{ lbs}$$

$$\text{Absolute Vol. Sand} = \frac{1173 \text{ lbs}}{164.11 \text{ lbs/ft}^3} = 7.15 \text{ ft}^3$$

$$\text{Absolute Vol. Cement} = \frac{470 \text{ lbs}}{195.94 \text{ lbs/ft}^3} = 2.40 \text{ ft}^3$$

$$\text{Absolute Vol. Water} = \frac{34.0 \text{ gals} \times 8.33 \text{ lbs/gal}}{62.4 \text{ lbs/ft}^3} = 4.54 \text{ ft}^3$$

$$\text{Absolute Vol. Air} = 27.00 \times 0.04 = 1.08 \text{ ft}^3$$

Total Volume of Sand, Cement, Water, Air = 15.17 ft^3

$$\text{Absolute Volume of Stone} = 27.00 - 15.17 = 11.83 \text{ ft}^3$$

Adjusted Proportions

$$\text{Stone} = 11.83 \times 165.98 = 1964 \text{ lbs}$$

Example 4: The one cubic yard mix proportions listed below will not produce concrete of the desired consistency on the job. Increase the water by 1.5 gallons per yard and keep the same coarse to fine aggregate ratio.

Materials	Proportions (lbs)	Sp. Gr.	Absolute Vol. (ft^3)	Adjusted Weights
Cement	611	3.14	3.12	611 lbs
Sand	1193	2.66	7.09	1177 lbs
Stone	1894	2.71	11.10	1877 lbs
Water (gals)	33.0 gals		4.61	34.5 gals
Air	4 %		1.08	4 %

Determine coarse to fine aggregate ratio by volume.

$$\text{Sand} = \frac{1193 \text{ lbs}}{165.98 \text{ lbs/ft}^3} = 7.19 \text{ ft}^3$$

$$\text{Stone} = \frac{1894 \text{ lbs}}{169.10 \text{ lbs/ft}^3} = 11.20 \text{ ft}^3$$

$$\%\text{ fine aggregate to coarse} = \frac{7.19 \text{ ft}^3}{18.39 \text{ ft}^3} = 0.39 \times 100 = 39\%$$

$$\text{Increase water } 1.5 \text{ gallons} = 33.0 + 1.5 = 34.5 \text{ gallons}$$

$$\text{Absolute Vol. Water} = \frac{34.5 \text{ gals} \times 8.33 \text{ lbs/gal}}{62.4 \text{ lbs/ft}^3} = 4.61 \text{ ft}^3$$

$$\text{Absolute Vol. Cement} = \frac{611\,\text{lbs}}{195.94\,\text{lbs}/\text{ft}^3} = 3.12\ \text{ft}^3$$

$$\text{Absolute Vol. Air} = 27.00 \times 0.04 = 1.08\ \text{ft}^3$$

Total Absolute Vol. of Cement, Water, Air = 8.81 ft^3

$$\text{Total Absolute Volume of Aggregate} = 27.00 - 8.81 = 18.19\ \text{ft}^3$$

$$\text{Absolute Vol. of fine aggregate} = 18.19\ \text{ft}^3 \times 0.39 = 7.09\ \text{ft}^3$$

$$\text{Absolute Vol. of coarsee aggregate} = 18.19\ \text{ft}^3 - 7.09\ \text{ft}^3 = 11.10\ \text{ft}^3$$

Adjusted Weights

$\text{Cement} = 3.12 \times 195.94 = 611\,\text{lbs}$

$\text{Sand} = 7.09 \times 165.98 = 1177\,\text{lbs}$

$\text{Stone} = 11.10 \times 169.10 = 1877\,\text{lbs}$

Water = 34.5 gallons

Air = 4.0 %

Example 5: Listed below are the proportions for a Class A concrete mix. The contractor has elected to use a fly ash mix with a 15% cement reduction and a 1.25 lbs. to 1.0 lb. replacement factor. Make this adjustment and maintain the same stone, water, and air volume.

Materials	Proportions (lbs)	Sp. Gr.	Absolute Vol. (ft^3)	Adjusted Weights
Cement	611	3.14	2.65	519 lbs
Fly Ash	0	2.40	0.77	115 lbs
Sand	1193	2.66	6.89	1144 lbs
Stone	1894	2.71	11.20	1894 lbs
Water (gals)	33.0 gals		4.61	33.0 gals
Air	4 %		1.08	4 %

Determine the amount of cement and fly ash required.

$$\text{Cement} = 611 \times 0.15 = 92.0\,\text{lbs}$$

$$611 - 92.0 = 519\,\text{lbs}$$

$$\text{Fly Ash} = 92 \times 1.25 = 115\,\text{lbs}$$

$$\text{Absolute Vol. Cement} = \frac{519\,\text{lbs}}{195.94\,\text{lbs}/\text{ft}^3} = 2.65\ \text{ft}^3$$

$$\text{Absolute Vol. Fly Ash} = \frac{115\,\text{lbs}}{149.76\ \text{lbs}/\text{ft}^3} = 0.77\ \text{ft}^3$$

$$\text{Absolute Vol. Stone} = \frac{1894\ \text{lbs}}{169.10\ \text{lbs}/\text{ft}^3} = 11.20\ \text{ft}^3$$

$$\text{Absolute Vol. Water} = \frac{33.0\ \text{gals} \times 8.33\ \text{lbs}/\text{gal}}{62.4\ \text{lbs}/\text{ft}^3} = 4.41\ \text{ft}^3$$

$$\text{Absolute Vol. Air} = 27.00 \times 0.04 = 1.08\ \text{ft}^3$$

Total Absolute Vol. of Cement, Fly Ash, Stone, Water, Air = 20.11 ft^3

$$\text{Absolute Volume of Sand} = 27.00 - 20.11 = 6.89\ \text{ft}^3$$

Adjusted Batch Weights

$$\text{Cement} = 2.65 \times 195.94 = 519\ \text{lbs}$$

$$\text{Fly Ash} = 0.77 \times 149.76 = 115\ \text{lbs}$$

$$\text{Sand} = 6.89 \times 165.98 = 1144\ \text{lbs}$$

$$\text{Stone} = 11.20 \times 169.10 = 1894\ \text{lbs}$$

Water = 33.0 gallons

Air = 4.0 %

V. Test Procedures

The Technician Examination will also contain questions related to accepted methods of testing fresh Portland cement concrete.