5.18 MIX DESIGN METHODS

5.18.01 CONCRETE MIX DESIGN

(a) Scope.

This method covers the procedure for designing concrete mixes and is based on the absolute volumes of the various components of the mix, i.e.: the absolute volumes of cement (plain, blended or fly ash modified), aggregate, water and air in one cubic yard of concrete.

(b) Procedure.

(1) Specifications: Specifications govern the following elements of concrete mixtures:

a. Minimum Cement Content or "Cement Factor" (CF) expressed as pounds per cubic yard of concrete.

b. Maximum allowable water content or water-cement ratio (W/C) expressed as pounds of water per pound of cement.

c. When air entrained concrete is specified, the air content is expressed as percent of the volume of the concrete.

NOTE: When air entrained concrete is not specified, a percentage of entrapped air is used during design. Experience has shown that the entrapped air is usually between 2% and 4%.

Since the quantities of cement, water and air are limited by specifications, the volumes occupied by each of these elements are calculated. Calculations are then made to determine the quantity of aggregate required, when added to the combined volumes of other ingredients, to result in a cubic yard of mixed concrete.

(2) Calculations.

a. Secure one or more copies of **KDOT Form No. 694**, WORK SHEET - CONCRETE MIX DESIGN. (See Example.)

b. Complete Part I of the form. This includes the class of concrete, the water-cement ratio, specified minimum cement factor, percent air, and the specific gravity (Bulk, Saturated Surface Dry Basis) of each aggregate.

The specific gravity is determined by tests conducted on samples obtained from project stockpiles. Due to differences in processing and gradation, there may be an appreciable difference between the specific gravity of the aggregate submitted to the Laboratory and the specific gravity of the aggregate in the project stockpiles.

When designing concrete mixes composed of sweetened mixed aggregate, the percentage of each aggregate may be determined by specification requirements,

or the contractor may elect to use certain aggregate combinations to produce the required gradation.

When designing a "coarse-fine" mix, equal parts of coarse aggregate and fine aggregate are normally used. This portion has proven to be satisfactory and should be changed only to improve the characteristics of the mix and not as a convenience to the producer or contractor. Deviation from these proportions shall not be made without prior approval from the District Materials Engineer.

c. Complete Part II of the form by calculating the volume, in cubic feet, occupied by the cement, water and air in a cubic yard of the mixture. Then subtract the sum of these values from 27 to determine the volume of aggregate that must be added to produce a cubic yard of concrete.

NOTE: If the specific gravity of Type II cement is not known, a value of 3.20 will be assumed. For Type I cement use a value of 3.15.

d. Complete Part III as follows:

1. Calculate the volume occupied by 100 lbs. of combined aggregate.

2. Using simple proportioning, calculate the number of pounds of combined aggregate required to produce the volume of aggregate determined in Part II.

NOTE: The basic formula in Parts II and III is:

$$\textit{Absolute volume (cu. ft.)} = \frac{\textit{Weight (lbs.)}}{\textit{spec. grav. x 62.4}}$$

e. Complete Part IV to determine the weight in pounds of each ingredient in one cubic yard of concrete.

Calculate the saturated, surface dry weight of each individual aggregate in the batch by multiplying the total weight of aggregate as determined in Part III by the design percentage for each aggregate.

f. If the aggregate contains free moisture, as determined by **KT-24**, the initial batch weight is multiplied by the percent of free moisture in the aggregate and this quantity is added to the initial batch weight. An equivalent amount must then be deducted from the pounds of water computed under Part IV. If the aggregate is absorptive, as determined by **KT-24**, the aggregate weight must be reduced by the percent of absorption and the computed water requirement must be increased by a like amount. Since moisture conditions of aggregates may change throughout a given pour, the initial moisture conditions will govern only as long as the moisture content remains the same.
The batch weights thus determined can easily be converted from pounds per cubic yard to pounds per sack or any other convenient unit required for the batching operation.

g. At the option of the contractor, fly ash from an approved source and meeting the specified requirements may be used as a partial replacement for Portland Cement. Calculations for fly ash substitution are to be made on the back of **KDOT Form No. 694** as revised May 1987.

KANSAS DEPARTMENT OF TRANSPORTATION
WORK SHEET - CONCRETE MIX DESIGN
(Absolute Volume Method Designed for One Cubic Yard)

DESIGNED BY:_____ DATE:_____ Mix Design No. K32-1
Class Concrete A (AE) PROJECT:_____
W/C: Max. 0.49 Design CF 620 Aggregate Type MA-1
Specified Min. CF 620 Design CF 620 Agg. No. 1 Sp. Gr. 70 % 2.60
Designed for 6 % Air Agg. No. 2 Sp. Gr. 30 % 2.58
Admixture PRO-AIRE Agg. No. 3 Sp. Gr. _____ % _____

Vol. Cement $= \frac{\text{Design CF}}{\text{Sp. Gr.} * 62.4} = \frac{620}{3.20 * 62.4}$ = 3.105 Cu. Ft.

Vol. Water $= \frac{\text{Design CF} * \text{Design W / C}}{62.4} = \frac{620 * 0.47}{62.4}$ = 4.670 Cu. Ft.

Vol. Air (Entrained and Entrapped) $= \frac{6}{100} * 27$ = 1.620 Cu. Ft.

Volume Cement, Water, and Air = 9.395 Cu. Ft.
Vol. occupied by Aggregates = 27 - Vol. Cement, Water, and Air
27 - 9.395 = 17.605 Cu. Ft.

DETERMINE ABSOLUTE VOLUME OCCUPIED BY 100 LBS. COMBINED AGGREGATE

$\frac{\text{\%Agg. No. 1} * 100 \text{ lbs.}}{\text{Sp. Gr. Agg. No. 1} * 62.4 * 100} = \frac{70 * 100 \text{ lbs}}{2.60 * 62.4 * 100}$ = 0.431 Cu. Ft.

$\frac{\text{\% Agg. No. 2} * 100 \text{ lbs}}{\text{Sp. Gr. Agg. No. 2} * 62.4 * 100} = \frac{30 * 100 \text{ lbs}}{2.58 * 62.4 * 100}$ = 0.186 Cu. Ft.

$\frac{\text{\% Agg. No. 3} * 100 \text{ lbs}}{\text{Sp. Gr. Agg. No. 3} * 62.4 * 100} = \frac{\text{lbs.}}{* 62.4 * 100}$ = _____ Cu. Ft.

Absolute Volume 100 lbs combined Aggregate = 0.617 Cu. Ft.
Total Weight Combined Aggregate:
$\frac{100 * \text{Vol. occupied by Aggregates}}{\text{Abs. Vol. 100 lbs Combined Agg.}} = \frac{100 * 17.605}{0.617}$ = 2853 lbs.

BATCH WEIGHT CALCULATIONS

Cement - Design CF = 620 lbs.

Water = Design CF x Design W/C = 620 x 0.47 = 291 lbs.

Agg. No. 1 = lbs. Comb. Agg. $\frac{\text{x \% Agg.}}{100}$ No. 2 = 2853 x $\frac{70}{100}$ = 1997 lbs.*
Agg. No. 2 = lbs. Comb. Agg. $\frac{\text{x \% Agg.}}{100}$ No. 2 = 2853 x $\frac{30}{100}$ = 856 lbs.*
Agg. No. 3 = lbs. Comb. Agg. $\frac{\text{x \% Agg.}}{100}$ No. 3 = _____ x $\frac{\_\_\_}{100}$ = _____ lbs.*

WEIGHT FOR ONE CUBIC YARD = _____ lbs.

* Saturated Surface Dry

Cement Source ASH GROVE TYPE II Water Source _____

Aggregate No. 1 Type Basic Sand , Source _____

Aggregate No. 2 Type C A - 6 , Source _____

Aggregate No. 3 Type _____ , Source _____

Weight per Cu. Ft. Fresh Concrete - Design 139.41 lbs.

Weight per Cu. Ft. Fresh Concrete - Air Free 148.31 lbs.

Calculated By _____ Checked _____ Approved _____ Date _____

Rev. 5-87 (For Fly Ash Mixes Continue on Back Sheet) D.O.T. Form No. 694

Revision Sheet for Fly Ash in Concrete Mix No. K 32 - 1 - FA

Source of Fly Ash:_____ (Distributor)

Power Plant Location:_____Class:_____

Test Report or Certification Identification:_____87-0001_____

specific Gravity of Fly Ash, $Sp.Gr._{fa}$ 2.55 substitution rate 1.0

a. Percent cement to be replaced = 15 %

b. Weight of cement being replaced = cf x a. = 620 x 15 = 93 lbs.

c. Weight of cement remaining = CF - b. = 620 - 93 = 527 lbs.

d. Volume of cement remaining = $\frac{c.}{Sp.Gr._c \times 62.4}$ = $\frac{527}{3.20 \times 62.4}$ = 2.639 Cu. Ft.

e. Weight of Fly Ash = b. x substitution rate = 93 x 1.0 = 93 lbs.

f. Volume of Fly Ash = $\frac{e.}{Sp.Gr._{fa} \times 62.4}$ = $\frac{93}{255 \times 62.4}$ = 0.584 Cu. Ft.

g. Volume of cement plus Fly Ash = d. + f. = 2.639 + 0.584 = 3.223 Cu. Ft.

h. Volume gain due to Fly Ash = g. - original cement volume = 3.223 - 3.105 = 0.118 Cu. Ft.

I. Revised volume of Fine Agg. (No. 1) = $\frac{\text{orig. wt. agg. No. 1}}{Sp.Gr. \times 62.4}$ - h. = 19.97 - 0.118 = 12.191 Cu. Ft.

j. New weight of Agg. No.1 per Cu. Yd. = I. x Sp.Gr. x 62.4 = 12.191 x 2.60 x 62.4 = 1978 Cu.Ft.

k. Compute revised batch weights.

(c.) Cement (revised) ---------- 527 lbs.

(e.) Fly Ash ---------- 93 lbs.

Water---------- 291 lbs.

(j.) Agg. No. 1 (Fine Agg. - revised)---------- 1978 lbs.

Agg. No. 2---------- 856 lbs.

Agg. No. 3---------- ---------- 0 lbs.

m. Revised Weight for one cubic yard 3745 lbs.

n. Revised lbs./Cu.Ft.; Design air content $\frac{m.}{27}$ = 138.70 lbs./Cu.Ft.

o. Revised lbs./Cu.Ft.: Air Free $\frac{m.}{27.000 - \text{vol. air}}$ = $\frac{3745}{27.00 - 1.620}$ = 147.56 lbs./Cu.Ft.

Calculated By_____ Checked_____ Approved _____ Date _____

(c) CMS - Concrete Mix design

The Concrete Mix Design program (Hot Key Path MDB) in CMS does the mix design calculations once the base information required has been input into the program. The base information **required** is as follows:

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DTMTB252                          PCC DESIGN MIX                CREATE    MATERIAL

PC Mix#:                 Matl Code:                 Name:                    W/C Max:
Spec Min CF:             Design CF:          % Air:      Design Slump:          Design:
Water Source:                                Eff. Date          Term Date:
  Material                 Name              Prod #        Prod Name            spg     %Blend


  Cement                   Name              Prod #        Prod Name            spg     %Blend


Kg Per Cubic Meter                           Material      Name                 Prod #    L/m3
Agg1=        Water=        AEA
Agg2=        Cmnt1:        ADMIX1
Agg3=        Cmnt2:        ADMIX2
Agg4=        Cmnt3:        ADMIX3
Total:       Conc unit wt:                 Air Free Unit Wt:                 # Mixes to Create:
                                                                             W/C Increment:
Remarks:

F1=HELP          F3=EXIT          F5=RFRSH          F9=CNCL          F10=CMMT
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(1) CMS Input Fields

a. PC Mix # - This number identifies a particular mix design to the CMS system and is composed of the "District Number" followed by the letter "P" which the system requires to access a PCC mix. Then following are five spaces which are free form entry, most of the districts have a specific numbering sequence for this location. The last space in the Mix Design # is system generated at the time of creation but must be input to view a specific mix design when in the "read" mode.

b. Matl Code - This number identifies the type of concrete being produced by this particular design.

c. W/C Max - The water/cement ratio as specified in the Standard Specifications or Special Provision.

d. Spec Min CF - The minimum kilograms (pounds) of cement per cubic meter (cubic yard) of concrete as specified in the Standard Specification or Special Provision for the PCC type being produced.

e. Design CF - The kilograms (pounds) of cement per cubic meter (cubic yard) of concrete actually targeted for used in this particular mix design.

f. % Air - The target air content for this mix design and should be within the specified limits of Section 402.

g. Design Slump - The target slump for this mix design and should be within the limits specified for the type of construction for which the mix is being produced.

h. Design - This is the target water/cement ratio for this particular mix design and should be equal to or less than the "W/C Max" value which appears in the line above this entry.

i. Water Source - Enter the source of water

j. Eff Date - The date on which this mix design becomes usable to the CMS system. Attempts to use this mix design prior to the "Eff Date" will be denied by the system.

k. Term Date - The date on which this mix design is no longer usable by the CMS system. Attempts to use this mix design after the "Term Date" will be rejected by the system.

l. Material, Prod #, spg & % Blend - The numbers which identify the aggregate, the aggregate producer, aggregate specific gravity and percent of this aggregate in the total blend are entered at this location. At least one aggregate entry is required and the total of the "% Blend" column for the aggregates entered must = 100%.

m. The cements is entered after all of the aggregate entries are complete. At least one cement entry is required and the total of the “% Blend” column for the cements must =100%.

n. Admix and AEA - The material code, producer code and the quantity, L/cubic meter (oz/cu yd), to be used is entered if admixtures are being used.

o. # Mixes to Create and W/C Increment - The final information input for the mix designs optional entry for the user. The system automatically enters a default value of “1” in each of these entry fields. These default values can be over written if you desire. These entries inform the system how many mix designs to create (4 in the example) and at what increments of the W/C (0.02 in the example).

Starting with the design W/C (0.49 from the example), the system will create the number of mixes indicated at the W/C increments indicated. Each mix design created in this manner will have the same number but will have a sequential letter for the last character (a, b, etc.).

The values under the heading "Kilograms Per Cubic Meter" (Lbs Per Cubic Yard) are calculated by the system at the time of creation of the mix design.