PCC MIX DESIGN SOFTWARE TUTORIAL **Version 2.6**	For help, comments, and/or suggestions, please email: DOT.PCCMIX@illinois.gov

!!! IMPORTANT !!! This spreadsheet utilizes macros.
For a version without macros, please use Version X1.1.

General

This spreadsheet is designed to calculate and report PCC mix designs for submittal to IDOT. The spreadsheet is comprised of data inputs based on the mix design methodology provided in the PCC Level III Technician course manual.

Buttons are provided for ease of navigation, and their use is recommended as they ensure proper operation throughout the design process. Using the worksheet tabs, found at the bottom of the Excel screen, will also work.

The blue-shaded areas are cells which require data input, green-shaded areas are optional (unless required by your District), and white cells are calculation fields, which are protected from accidental overwriting.

Throughout the spreadsheet, comments have been interspersed to offer hints on where to find relevant information. To view comments, hold the cursor over the red tags found in the upper righthand corner of commented cells, as shown below. These comments generally refer to sections of the Course Manual; however, it should be noted that the Department's Standard Specifications and Special Provisions take precedence.

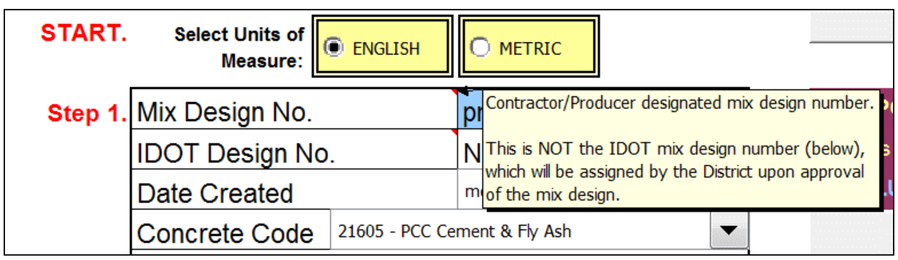


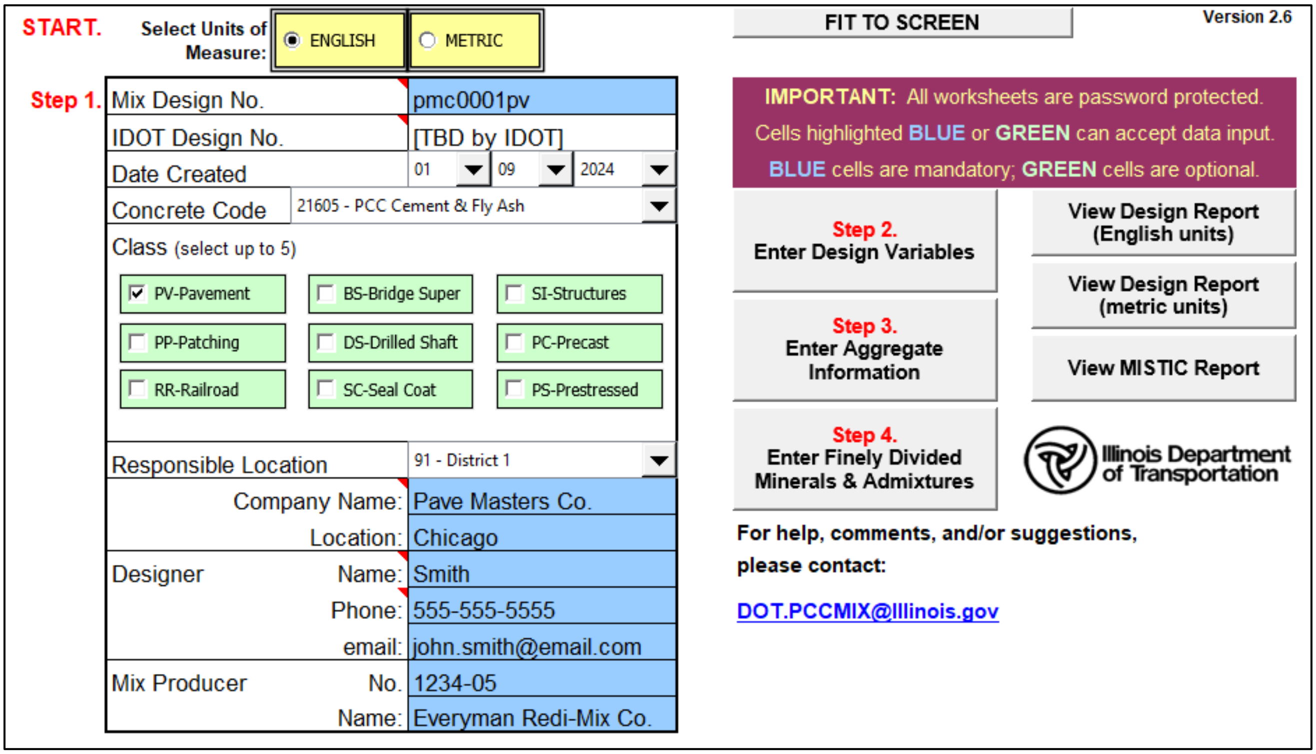
Figure 1. Example of a comment; note red flag, which indicates the cell has a comment.

Tutorial Mix Design

This tutorial also includes notes for how to input the example mix design discussed in Section 2.8 of the Course Manual. If you follow the notes in order as they are presented herein, you should successfully create a basic PCC paving mix design while also being introduced to all of the spreadsheet's functions and capabilities.

Step 1. Design Information

The Design Information page is important to establish the who-what-where of the mix design. This is where the designer decides in which units of measure the mix will be designed, what type of concrete it is, for what Classes of concrete it is valid, and those responsible for the mix design.



Fit to Screen [button]: Click this button to optimize each page of the mix design spreadsheet for viewing on your screen.

English/Metric [toggle]: Toggle button for selecting the units of measure for the mix design's inputs. All data inputs will have to be entered in the chosen units of measure. However, the design will be reported in **both** units of measure on the different final mix design reports generated.

EXAMPLE PROBLEM	Assuming most of us are more comfortable using English units of measure (lbs, yd^3, etc.), the example mix design will be designed using English units. Click on the **ENGLISH** toggle button.

Mix Design No.: Alphanumeric designation (up to nine characters in length). This is the Producer's or Contractor's self-designated mix design number; this is not the mix design number assigned by IDOT, see "IDOT Mix Design No." below.

EXAMPLE PROBLEM	Because this is the Producer's or Contractor's mix design number, any reasonably succinct and unique identifier can be used here. For this example, we will use **PMC0001PV** (i.e., Pave Masters Co. paving mix #1).

IDOT Mix Design No.: Alphanumeric mix design number reported to the Department's CMMS database. This number will be assigned by your District to an approved mix design.

EXAMPLE PROBLEM	Because this mix design number is assigned by the District upon approval, this cell reads **[TBD by IDOT]**.

Date Created: The date the mix design was created.

Step 1. Design Information (continued)

Concrete Code: Select the appropriate material code. This code is used by the Department's CMMS database to designate the type of concrete.

EXAMPLE PROBLEM	Because this mix will utilize Type IL portland cement and Class C fly ash, the appropriate Concrete Code to select from the drop-down list is **21605**.

Class: Select up to five Classes of concrete.

EXAMPLE PROBLEM	Because this mix will be used for a continuously reinforced portland cement concrete pavement, the appropriate Class to select is **PV**.

Responsible Location: District responsible for mix design's use; for example, "91" for District 1.

EXAMPLE PROBLEM	Select one of the nine IDOT Districts with which you typically work; for example, select **91** if you often work with District 1 in the Chicago area.

Company Name: Name of producer/contractor/consultant responsible for creating the mix design.

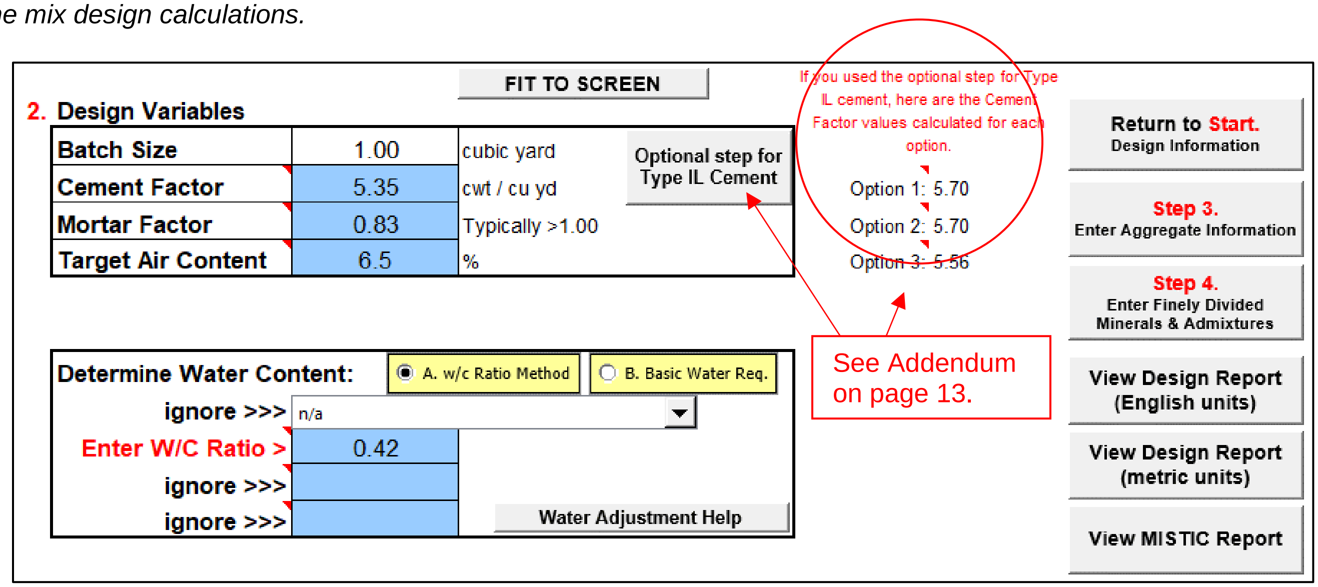
Location: Nearest municipality to Company.

Designer: Name, phone number, and email of person that created the design.

Mix Producer: IDOT-assigned producer number and name of producer.

Step 2. <u>Design Variables</u>

The Design Variables page is were the designer first begins to determine the mix design's parameters that factor into the mix design calculations.



<u>Batch Size:</u> Batch size in cubic yards (cubic meters). All mix designs are created per 1 yd^3 (1 m^3).

<u>Cement Factor</u>: Cement quantity in hundredweight per cubic yard (kilograms per cubic meter).

EXAMPLE PROBLEM	From Table 2.2.1 in the Course Manual, the cement factor for Class PV concrete from a central mixed plant is **5.65 cwt/yd^3**. Also, from Section 2.2.2, a cement factor reduction of **0.30 cwt/yd^3** can be applied because a water-reducing admixture will be used. Thus, the final, adjusted cement factor is reduced to **5.35 cwt/yd^3**.

<u>Mortar Factor:</u> Refer to Table 2.7.2.2 *Design Mortar Factor* in the Course Manual.

EXAMPLE PROBLEM	From Table 2.7.2.2 in the Course Manual, a mortar factor can be selected for Class PV concrete. Enter **0.83** as a reasonable starting point.

<u>Target Air Content:</u> Percentage of entrained air in the concrete to improve durability. Refer to Table 2.6 *Air Content* in the Course Manual.

EXAMPLE PROBLEM	From Table 2.6 in the Course Manual, the midpoint of the air content range for Class PV concrete is **6.5%**.

Step 2. **Design Variables** (continued)

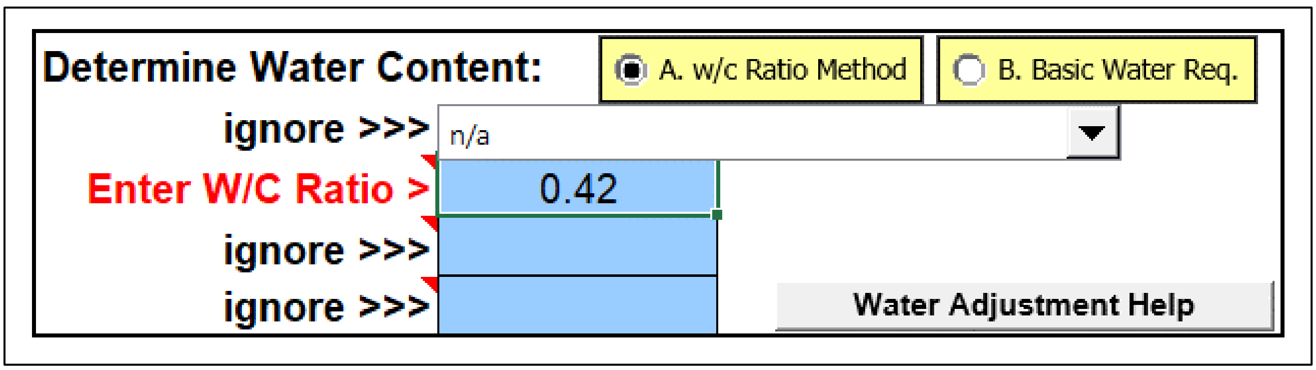
Determine Water Content
First, using the toggle switch, select either the *w/c Ratio Method* or the *Basic Water Requirement Method*.

The *w/c Ratio Method* will determine water content based on the w/c ratio entered and the total content of cement and finely divided minerals. No water adjustment needs to be entered as it will be back-calculated based on the w/c ratio and assumed aggregate water requirements (see Note).

> **Note:** If the "w/c Ratio Method" is selected, the spreadsheet will assume a Type B fine aggregate with basic water requirement of 5.3 gal/cwt (0.44 L/kg).

Alternatively, the *Basic Water Requirement* method requires the fine and coarse aggregate water requirements, as well as percent water reduction. Refer to Appendix Q *Basic and Adjusted Water Requirement Method* in the Course Manual for more information. **See next page for when using the *Basic Water Requirement* method.**

If the* W/C Ratio Method *has been selected:

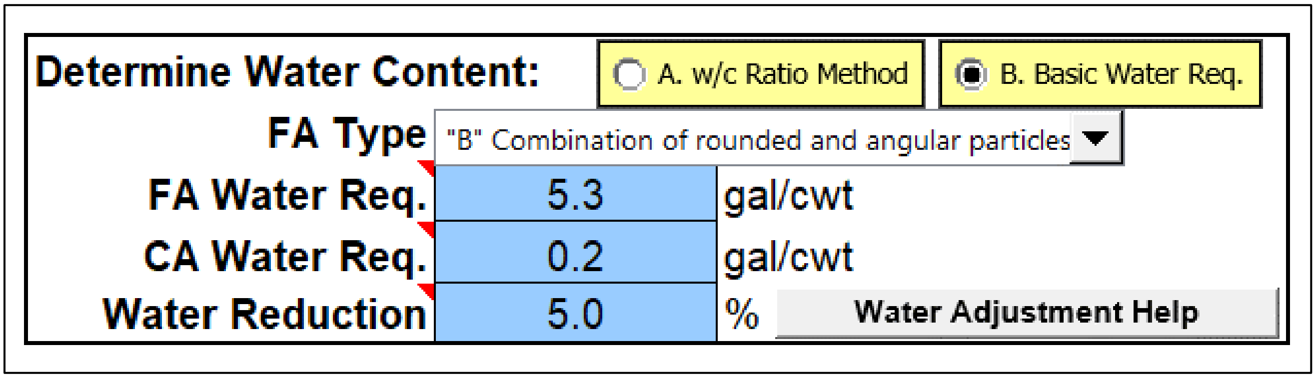


Enter W/C Ratio: When *w/c Ratio Method* is toggled, this field appears. Enter the target w/c ratio that the design water content will be based on; for example, 0.42.

EXAMPLE PROBLEM	In this example, per **Table 2.5** in the Course Manual, the maximum w/c for Class PV concrete is **0.42**.

Step 2. **Design Variables** (continued)

If the* Basic Water Requirement Method *has been selected:



FA Type: Select fine aggregate type.

EXAMPLE PROBLEM	Assume this mix will utilize a Type "B" fine aggregate, select **B** from the drop-down list.

FA Water Req.: Water requirement for fine aggregate in gallons per hundredweight (liters per kilogram) of cement and finely divided minerals. This value is based on the type of fine aggregate.

EXAMPLE PROBLEM	Assuming this mix will utilize a Type "B" fine aggregate, enter **5.3 gal/cwt**.

CA Water Req.: Water requirement for coarse aggregate in gallons per hundredweight (liters per kilogram) of cement and finely divided minerals material. This value is based on the type of coarse aggregate.

EXAMPLE PROBLEM	Because this mix will utilize a crushed stone, enter **0.2 gal/cwt**.

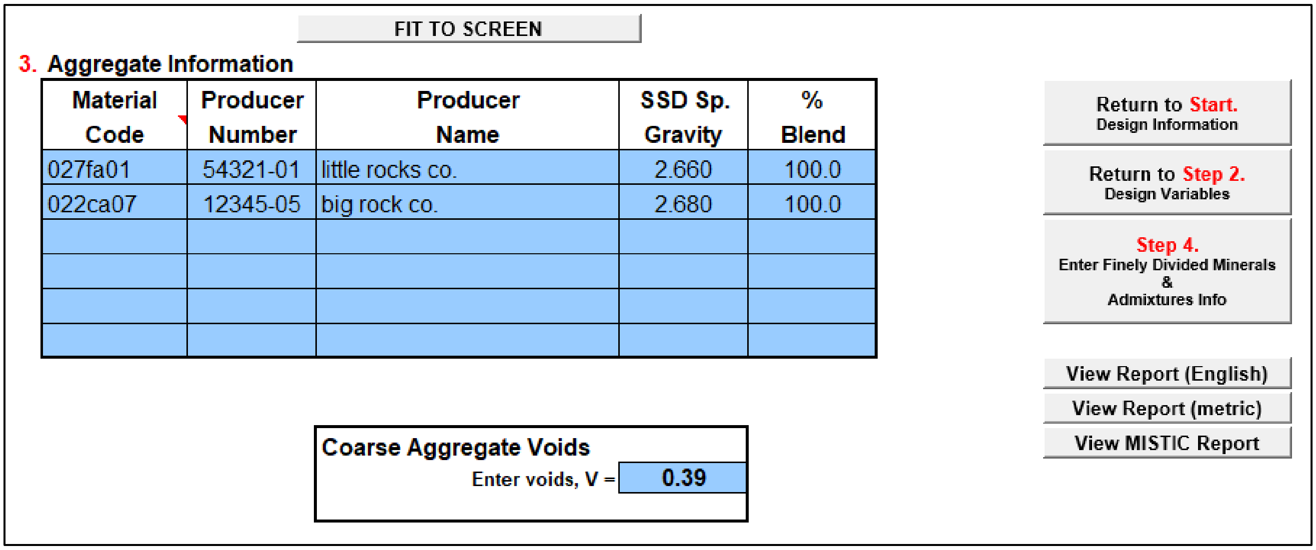
Water Reduction: Percentage of water adjustment (typically a reduction) accounting for various factors, such as admixture use, cement and finely divided mineral content, air content, etc. Note that because this input is referred to as a "reduction," the value entered may seem counter-intuitive; that is, a water reduction should be entered as a positive value, while a water addition should be entered as a negative value. For example, enter "10.0" for a 10 percent water reduction, and enter "-10.0" for a 10 percent water addition.

For help determining a reasonable water adjustment, refer to Appendix Q *Basic and Adjusted Water Requirement Method* in the Course Manual.

EXAMPLE PROBLEM	Because this mix will utilize a water-reducing admixture to provide a target water reduction of 10%, enter **10.0**. Note: If for some reason this mix needed a 10 percent water addition, you would have entered -10.0.

Step 3. Aggregate Information

The Aggregate Information worksheet is where the designer enters all fine and coarse aggregate information.



Material: Aggregate material codes. Coarse and fine aggregates may be entered in any order, except as required by your District.

EXAMPLE PROBLEM	• Fine aggregate: Enter **027FA01** as given in the Course Manual. This material code is for an “A” quality natural sand meeting the gradation criteria for FA 1 per Article 1003.01(c). • Coarse aggregate: Enter **022CA07** as given in the Course Manual. This material code is for an “A” quality crushed stone meeting the gradation criteria for CA 7 per Article 1004.01(c).

Producer Number: Aggregate producer number. This field is required for all aggregate components.

Producer Name: Aggregate producer name.

Specific Gravity: Saturated Surface Dry (SSD) specific gravity of each aggregate.

EXAMPLE PROBLEM	The example problem as given in the Course Manual indicates that the saturated surface-dry specific gravities for the fine and coarse aggregate components are **2.66** and **2.68**, respectively.

% Blend: Percent blend for aggregate components. If only using one coarse aggregate and one fine aggregate material, enter “100” for each. On the other hand, if blending coarse aggregate materials, say, CA 11 and CA 16 at 75 and 25 percent, respectively, enter a "75" for the CA 11 and a "25" for the CA 16. Similarly, if blending fine aggregate materials. Do not blend coarse and fine aggregate, except as noted below for CAM II:

Note for CAM II designs *only*—Recommended % Blend of coarse-to-fine aggregate: 50-50 when using CA 7, CA 9, or CA 11; 75-25 when using CA 6; and 100-0 (i.e., no fine aggregate) when using CA 10. For example, when using CA 6 and FA 1, enter “75” for the CA 6 and “25” for the FA 1.

EXAMPLE PROBLEM	Because this mix is utilizing one coarse aggregate component and one fine aggregate component (and the mix is not CAM II), enter **100** for coarse aggregate and **100** for fine aggregate.

Step 3. Aggregate Information (continued)

Coarse Aggregate Voids

Refer to the District office verifying your mix design for guidance on what value to use for Voids. For example, some Districts may provide a value for general aggregate types, such as "0.36" for gravels, or one value for all aggregates.

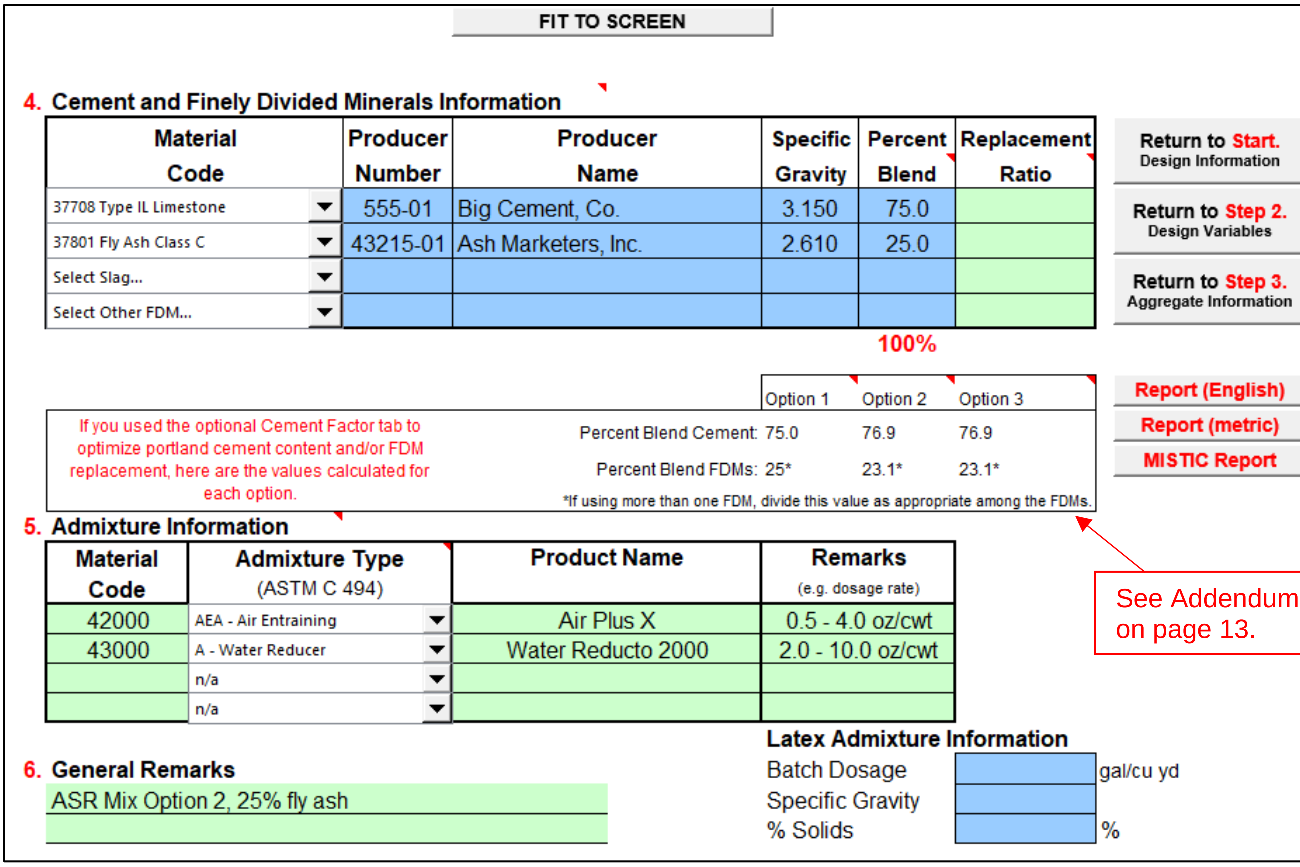
Important: *Enter* "1.00" *for any mix design that does not contain coarse aggregate.*

Coarse Aggregate Voids	
Enter voids, V =	0.39

EXAMPLE PROBLEM	The example problem as given in the Course Manual notes that the Voids for the coarse aggregate is **0.39**.

Step 4. Finely Divided Minerals & Admixtures Information

This worksheet is where the designer enters all information pertaining to cement and finely divided minerals, as well as chemical admixtures (e.g., air-entraining water-reducing admixtures, etc.).



See Addendum on page 13.

Material: Cement and finely divided mineral (FDM) material codes. Each line is dedicated to a specific material: Line 1 for cement, Line 2 for fly ash, Line 3 for GGBF slag, and Line 4 for miscellaneous (e.g., microsilica, high-reactivity metakaolin, etc.).

EXAMPLE PROBLEM	Because this mix will utilize a Type IL cement and Class C fly ash, Lines 1 and 2 will be used. • Cement: select **37708 Type IL, Limestone** from the drop-down list. • Fly ash: select **37801 Fly Ash Class C** from the drop-down list.

Producer Number: Material producer number. This field is required for all finely divided minerals.

Producer Name: Material producer name.

Specific Gravity: Specific gravity of each material. The specific gravity of cement is normally assumed to be 3.15 for ordinary portland cement or portland-limestone cement. However, for portland-pozzolan or portland-slag cements, this value should be verified with the District. Specific gravity values for finely divided minerals can be obtained from the Qualified Producer List of Finely Divided Minerals.

EXAMPLE PROBLEM	The example problem as given in the Course Manual notes that the specific gravity for the fly ash component is **2.61**. The specific gravity of portland-limestone cement is assumed to be **3.15**.

Step 4. Finely Divided Minerals & Admixtures Information (continued)

Percent Blend: The blend percentage must be entered for each material, totaling 100. For example, when blending fly ash and cement at 20 and 80 percent, respectively, enter "20" for the fly ash and "80" for the cement.

EXAMPLE PROBLEM	First, we have to determine if we need to mitigate for alkali-silica reaction (ASR): From Section 2.4.3 in the Course Manual, it is determined that the component aggregates are **Group II** (fine aggregate expansion in the **>0.16% - 0.27%** range and coarse aggregate expansion **≤0.16%**). Thus, we are required to use Mix Option 1, 2, 3, 4, or 5. Because the example problem as given notes that the mix will utilize a cement with alkali content >0.60% and a Class C fly ash, we will use **Mix Option 2**. Mix Option 2 requires a minimum 25.0 percent Class C fly ash. Furthermore, from Section 2.4.1.1 in the Course Manual, the Class C fly ash component can replace up to 30 percent of the cement. Thus, it is decided to use **25 percent** fly ash. Because the total Percent Blend must equal 100, enter **75.0** for the cement and **25.0** for the fly ash.

Replacement Ratio: (Optional) Enter the replacement ratio for each finely divided mineral, if applicable. If left blank, the default value of “1.00” will be used.

Step 5. Admixtures Information

Material Code: Enter admixture material codes here. The 5-digit material code for admixtures can be found on the Approved/Qualified Product List of Concrete Admixtures.

Admixture Type: Choose admixture type.

Product Name: Enter admixture product’s name.

Remarks: Enter key information regarding proposed dosage rates, dosing procedures, etc.

Step 6. General Mixture Remarks

Remarks: Enter any pertinent information not already covered. When required to mitigate for alkali-silica reaction (ASR), indicate the mixture option selected.

EXAMPLE PROBLEM	Because we are required to mitigate for alkali-silica reaction, we must indicate the mixture option selected. Enter **ASR Mix Option 2, 25% fly ash**.

Latex Admixture Information (only required for mix designs using a latex admixture)

Batch Dosage:	Enter latex admixture dosage in terms of gallons per cubic yard (liters per cubic meter).
Specific Gravity:	Enter manufacturer’s specific gravity for the latex admixture.
% Solids:	Enter manufacturer’s percent solids for the latex admixture.

Design Report

Given the inputs, the mix design proportions are calculated and reported. Three design reports are generated: one in English units of measure, one in metric (SI), and one formatted for Departmental prior to submittal to CMMS.

ENGLISH UNITS DESIGN REPORT

PCC MIX DESIGN — Version 2.6

IDOT MIX #: **Not Assigned** MATERIAL: **21605** CONCRETE PC FLYASH EFFECTIVE:

CONTR MIX #: **PMC0001PV** CLASS: **PV**

RESP: **91** DISTRICT 1 REVIEWED BY:

BATCH CU YD	ADX	H2O% RED	FINE MOD	% AIR	VOIDS	(Z) CEMENT	MORTAR FACTOR	{TYPE} ASH	{TYPE} FA	{GAL/CWT} FA	{GAL/CWT} CA	{ABS. VOL} CA,B	{ABS. VOL} FA,A
1.00	**--**	**5.0**	**--**	**6.5**	**.39**	**5.35**	**0.83**	**C**	**B**	**5.30**	**0.00**	0.4236	0.2690

MATERIAL	PROD NO	PROD NAME	SP G	% BLEND	%MOIST / REPL	[LBS / CU YD] SSD	[LBS / CU YD] ADJ	[KG / CU M] ADJ
027FA01	**54321-01**	LITTLE ROCKS CO.	**2.660**	**100.0**	**--**	1205	1205	718
022CA07	**12345-05**	BIG ROCK CO.	**2.680**	**100.0**	**--**	1912	1912	1135
37708	**555-01**	BIG CEMENT, CO.	**3.150**	**75.0**	**1.00**	405	405	240
37801	**43215-01**	ASH MARKETERS, INC.	**2.610**	**25.0**	**1.00**	135	135	80
					ADJ. H2O (gal : lbs)	27.3	227	135
					TOTAL BATCH WT (lbs)		3884	2308

{FA + CA} MIX-H2O: 5.30 W/C RATIO: 0.42

TOTAL CEMENTITIOUS MATL: 5.40 THEO. H2O (gal : lbs) 27.2 227

PRODUCER: **1234-05** PROD NAME: **EVERYMAN REDI-MIX CO.**

REMARKS: ASR Mix Option 2, 25% fly ash

REMARKS:

ADDITIONAL INFORMATION: Lab: PAVE MASTERS CO. Location: CHICAGO

Designer: SMITH Created: 01/09/24

Adx(s):

Matl Code	Type	Product Name	Remarks
42000	AEA	AIR PLUS X	0.5 - 4.0 oz/cwt
43000	A	WATER REDUCTO 2000	2.0 - 10.0 oz/cwt

Designer Phone: 555-555-5555

Designer email: john.smith@email.com

Printed 4/11/2024

METRIC UNITS DESIGN REPORT

PCC MIX DESIGN — Version 2.6

IDOT MIX #: **Not Assigned** MATERIAL: **21605M** CONCRETE PC FLYASH EFFECTIVE:

CONTR MIX #: **PMC0001PV** CLASS: **PV**

RESP: **91** DISTRICT 1 REVIEWED BY:

BATCH CU M	ADX	H2O% RED	FINE MOD	% AIR	VOIDS	(Z) CEMENT	MORTAR FACTOR	{TYPE} ASH	{TYPE} FA	{L / KG} FA	{L / KG} CA	{ABS. VOL} CA,B	{ABS. VOL} FA,A
1.00	**--**	**5.0**	**--**	**6.5**	**.39**	**320**	**0.83**	**C**	**B**	**0.4420**	**0.0000**	0.4236	0.2700

MATERIAL	PROD NO	PROD NAME	SP G	% BLEND	%MOIST / REPL	[KG / CU M] SSD	[KG / CU M] ADJ	[LBS / CU YD] ADJ
027FAM01	**54321-01**	LITTLE ROCKS CO.	**2.660**	**100.0**	**--**	718	718	1205
022CAM07	**12345-05**	BIG ROCK CO.	**2.680**	**100.0**	**--**	1135	1135	1912
37708M	**555-01**	BIG CEMENT, CO.	**3.150**	**75.0**	**1.00**	240	240	405
37801M	**43215-01**	ASH MARKETERS, INC.	**2.610**	**25.0**	**1.00**	80	80	135
					ADJ. H2O (L : kg)	134.4	134	226
					TOTAL BATCH WT (kg)		2308	3883

{FA + CA} MIX-H2O: 0.4420 W/C RATIO: 0.42

TOTAL CEMENTITIOUS MATL: 320 THEO. H2O (kg : lbs) 134.4 226

PRODUCER: **1234-05** PROD NAME: **EVERYMAN REDI-MIX CO.**

REMARKS: ASR Mix Option 2, 25% fly ash

REMARKS:

ADDITIONAL INFORMATION: Lab: PAVE MASTERS CO. Location: CHICAGO

Designer: SMITH Created: 01/09/24

Adx(s):

Matl Code	Type	Product Name	Remarks
42000	AEA	AIR PLUS X	0.5 - 4.0 oz/cwt
43000	A	WATER REDUCTO 2000	2.0 - 10.0 oz/cwt

Designer Phone: 555-555-5555

Designer email: john.smith@email.com

Printed 4/11/2024

CMMS DESIGN REPORT

IDOT Acceptance Info

Reviewer (first & last name):	John Jones
IDOT PCC Mix No.:	91pccXX555
Approval Date (m/d/yyyy):	1/30/2024
Effective Date (m/d/yyyy):	2/1/2024

For IDOT Use Only
Submit to CMMS

PCC DESIGN MIX

IDOT MIX #: 91PCCXX555
PRODUCER MIX #: PMC0001PV
MATERIAL CODE: 21605
CLASS(ES): PV
RESP. DISTRICT: 91
REVIEWED BY: JOHN JONES

CEMENT FACTOR, cwt/yd^3: 5.35
MORTAR FACTOR: 0.83
CA VOIDS: 0.39
% AIR: 6.5
W/C RATIO: 0.42

PRODUCER NO.: 1234-05
PRODUCER NAME: EVERYMAN REDI-MIX CO.

EFFECTIVE DATE: 2/1/2024

AGGREGATE	Producer No.	Producer Name	Sp. G.	% Blend	Weight (SSD) lbs / cu yd
027FA01	54321-01	LITTLE ROCKS CO.	2.66	100	1205
022CA07	12345-05	BIG ROCK CO.	2.68	100	1912

CEMENTITIOUS	Producer No.	Producer Name	Sp. G.	% Blend	lbs / cu yd
37708	555-01	BIG CEMENT, CO.	3.15	75	405
37801	43215-01	ASH MARKETERS, INC.	2.61	25	135

THEO. WATER (lbs/cu yd): 227
TOTAL BATCH WT (lbs/cu yd): 3884

	Code	Dosage	
LATEX:	43700		gal/cu yd

THEO. WATER (gal/cu yd): 27.2

REMARKS: ASR Mix Option 2, 25% fly ash

DESIGNER SMITH
PHONE: 555-555-5555
EMAIL: john.smith@email.com

ADMIXTURES:

Code	Type	Name	Remarks
42000	AEA	AIR PLUS X	0.5 - 4.0 oz/cwt
43000	A	WATER REDUCTO 2000	2.0 - 10.0 oz/cwt

Note for IDOT Users: The CMMS Report has four input fields ***to be completed by the District when approving a mix design***. Once a mix design is approved, click the “Submit to CMMS” button to export the file to CMMS.

ADDENDUM
Optional Step when using Type IL Cement

On the Design Variables tab/page, you will now find a link/button to a new tab, “Cement Factor (Optional).” This new, optional step has been added for the mix designer’s consideration in light of experiences some producers have had since transitioning to Type IL portland-limestone cement.

The options provided should not be used for non-blended cements (e.g., Type I/II, III).

Three options are provided that the mix designer may find useful:

- **Option 1: Ensuring a certain portland cement content is included in your mix.** In this case, you the mix designer want a certain amount of portland cement in your mix, taking into account that not all of a Type IL cement is made up of portland cement. This option may be of interest for lean mixes (i.e., low total cementitious content), particularly those that include finely divided minerals (e.g., fly ash, slag). For ‘straight cement’ mixes, IDOT’s current minimum cement factors ought to have no problem ensuring sufficient portland cement is included in the mix. For example., even the leanest 535-lbs/yd^3 mix using a Type IL(15) cement would have about 455 lbs/yd^3 portland cement; historically, the least amount of portland cement in a conventional IDOT PCC design was about 400 lbs/yd^3.

  Please note that the premise of this option is not intended to imply that the Department believes there is indeed a minimum portland cement content necessary to achieve certain desired performance results. Nor is it intended to imply that to have performance equivalent to a mix previously designed with Type I/II cement, you should factor out any of the added limestone. This option is purely intended to provide a simple, consistent means to calculate the amount of Type IL cement necessary to ensure a designer-specified amount of portland cement is included in a mix. This option (and similarly, option 3) is provided to acknowledge that some mix designers may have found in their experience that there is a minimum portland cement content they need due to different cement sources, types of mixes and applications, plant configurations, etc.

- **Option 2: Wanting to minimize FDM replacement when using a blended cement.** In this case, you the mix designer wish the FDM replacement to be based only on the portland cement portion of the Type IL cement.

  For example, you have a 605 lbs/yd^3 Class BS mix using Type IL(10) cement and 25% GGBF slag. Previously, when calculating the replacement of a Type I/II cement, it was simply 25% of 605, resulting in approximately 150 lbs/yd^3 slag and about 455 lbs/yd^3 of cement. However, if trying to base the replacement on only the portland cement portion of a Type IL cement, the calculation is more complicated (see Note 1). Using the spreadsheet for this example, you will find that your mix can offset the slag replacement, thereby increasing the cement content, by about 10 lbs/yd^3.

- **Option 3: Combining options 1 and 2.** This case simply allows you the mix designer to both specify a certain portland cement content is included in your mix as well as minimize any FDM replacement by calculating it based only on your specified portland cement content.

Enter Desired Portland Cement Content (lbs/cu yd)	Enter Cement's Target Limestone Content (%)	Enter Percent Total FDM Replacement **Note 2**		Cement (lbs/cu yd)	Total FDM (lbs/cu yd)	**Minimum Cement Factor** to enter on Variables tab	**Percent Cement** to enter on FDM & Admix tab	**Percent FDM** to enter on FDM & Admix tab **Note 1**
385	10.0	25.0		428	143	5.70	75.0%	25.0%
Portland Cement Content (lbs/cu yd):				385				

Input fields are blue.

Options 1 & 3 ask for the same inputs, but Option 2’s are different.

Be mindful of the units of measure asked for.

Reports Type IL cement content.

Reports how much of the mix’s “Cement” is portland cement.

Converts total cementitious (Cement + Total FDM) from lbs/cu yd to cwt to coincide w/ the input on the Variables tab.

Output fields are yellow.

The values reported are the suggested inputs on the “Variables” and “FDM & Admix” tabs.

CASE STUDY EXAMPLES

OPTION 1 CASE STUDY

Say you typically mitigate for ASR using 25% GGBF slag. For the leanest of your central-mixed paving designs (i.e., 535 lbs/yd³ total cementitious), if using a Type IL(10) cement, the portland cement content is 361 lbs/yd³. However, based on the performance of a number of your designs, you've decided your mixes need at least 385 lbs/yd³ portland cement to perform to your expectations (e.g., rate of early and/or ultimate strength gain, time to set, time to saw joints, etc.).

After entering the necessary inputs into the spreadsheet, you see that you'll need 428 lbs/yd³ Type IL(10) cement to obtain 385 lbs/yd³ portland cement. And because the cement portion of your total cementitious has increased, the amount of slag needed has also increased to maintain the 25% FDM replacement, resulting in a total cementitious of 570 lbs/yd³.

1) If wanting a minimum portland cement content:
In this case, you are wanting to ensure a certain minimum amount of portland cement is included in your mix, i.e., taking into account that not all of a blended cement is made up of portland cement.

Enter Desired Portland Cement Content (lbs/cu yd)	Enter Cement's Target Limestone Content (%)	Enter Percent Total FDM Replacement **Note 2**	Cement (lbs/cu yd)	Total FDM (lbs/cu yd)	**Minimum Cement Factor** to enter on Variables tab	**Percent Cement** to enter on FDM & Admix tab	**Percent FDM** to enter on FDM & Admix tab **Note 1**
385	10.0	25.0	428	143	5.70	75.0%	25.0%
		Portland Cement Content (lbs/cu yd):	385				

OPTION 2 CASE STUDY

Say your typical Class SI concrete design is 570 lbs/yd³ total cementitious with 25% Class F fly ash replacement to mitigate for ASR. In an effort to manage your fly ash demand due a run of shortages and restrictions, you've decided to base the percent replacement on only the portland cement portion of your Type IL(10).

After entering the necessary inputs into the spreadsheet, you see that you'll now need about 132 lbs/yd³ of fly ash. This works out to about 10 lbs/yd³ less than before (an 8% reduction).

2) If wanting to minimize FDM replacement:
In this case, you are wanting to calculate FDM replacement based only on the amount of portland cement in your mix. With respect to ASR mitigation, this will still meet the intent of Mixture Option 2 (Article 1020.05(d)(2)b of the Standard Specifications) as long as the "Percent Total FDM Replacement" entered meets the minimums specified (e.g., 25.0% if using fly ash, GGBF slag, or a combination thereof).

Enter Percent Total FDM Replacement **Note 2**	Enter Cement's Target Limestone Content (%)	Enter Desired Cement Factor (cwt)	Cement (lbs/cu yd)	Total FDM (lbs/cu yd)	**Minimum Cement Factor** to enter on Variables tab	**Percent Cement** to enter on FDM & Admix tab	**Percent FDM** to enter on FDM & Admix tab **Note 1**
25.0	10.0	5.70	438	132	5.70	76.9%	23.1%
		Portland Cement Content (lbs/cu yd):	395				

OPTION 3 CASE STUDY

Extending the case given for Option 1 above: say that because of a breakdown at the processing plant your slag supply is restricted, you've decided you minimize replacement while still meeting the 25% minimum required for ASR mitigation.

After entering the necessary inputs into the spreadsheet, you see that you'll now need about 128 lbs/yd³ of GGBF slag, which works out to about 15 lbs/yd³ less than before (a 10% reduction).

3) If wanting to do both 1 and 2:

Enter Desired Portland Cement Content (lbs/cu yd)	Enter Cement's Target Limestone Content (%)	Enter Percent Total FDM Replacement **Note 2**	Cement (lbs/cu yd)	Total FDM (lbs/cu yd)	**Minimum Cement Factor** to enter on Variables tab	**Percent Cement** to enter on FDM & Admix tab	**Percent FDM** to enter on FDM & Admix tab **Note 1**
385	10.0	25.0	428	128	5.56	76.9%	23.1%
		Portland Cement Content (lbs/cu yd):	385				

Note 1: **Derivation of formula to calculate FDM replacement based only on the portland cement content of a Type IL cement.**

Variables:
Z is Cement Factor (i.e., total cementitious) in cwt/yd^3
z is total cementitious content in lbs/yd^3
x is Type IL cement content in lbs/yd^3
y is FDM content in lbs/yd^3
p is portland cement content in lbs/yd^3
L is limestone content in lbs/yd^3
ℓ is nominal percent (%) limestone in the Type IL cement
r is replacement rate in percent (%)

Known:

$$z = Z \times 100 = x + y$$
$$x = p + L$$
$$L = x\left(\frac{l}{100}\right)$$
$$\frac{r}{100} = \frac{y}{p+y}$$

Derivation: Simplify and rearrange the above equations to be in terms of known variables (i.e., *z*, ℓ, *r*) and only one unknown variable (e.g., *x*).

$$x = p + L$$
$$p = x - L$$

Because $L = x\left(\frac{l}{100}\right)$, then $p = x - x\left(\frac{l}{100}\right) = x\left(1 - \frac{l}{100}\right) = x\left(\frac{100-l}{100}\right)$

$$\boxed{1 - \frac{n}{100} = \frac{100}{100} - \frac{n}{100} = \frac{100-n}{100}}$$

$$\frac{r}{100} = \frac{y}{p+y}$$
$$y = \frac{r}{100}(p+y) = \frac{yr}{100} + \frac{pr}{100}$$
$$\frac{pr}{100} = y - \frac{yr}{100} = y\left(1 - \frac{r}{100}\right) = y\left(\frac{100-r}{100}\right)$$
$$y = \frac{pr}{100}\Big/\left(\frac{100-r}{100}\right) = \frac{pr}{100}\left(\frac{100}{100-r}\right) = \frac{pr}{100-r}$$

Because $p = x\left(\frac{100-l}{100}\right)$, then $y = x\left(\frac{100-l}{100}\right)\left(\frac{r}{100-r}\right) = x\left(\frac{r}{100}\right)\left(\frac{100-l}{100-r}\right)$

$$z = x + y$$
$$z = x + x\left(\frac{r}{100}\right)\left(\frac{100-l}{100-r}\right) = x\left[1 + \frac{r}{100}\left(\frac{100-l}{100-r}\right)\right]$$
$$x = z \div \left[1 + \frac{r}{100}\left(\frac{100-l}{100-r}\right)\right]$$

OR $x = Z \times 100 \div \left[1 + \frac{r}{100}\left(\frac{100-l}{100-r}\right)\right]$

2) If wanting to minimize FDM replacement:

In this case, you are wanting to calculate FDM replacement based only on the amount of portland cement in your mix. With respect to ASR mitigation, this will still meet the intent of Mixture Option 2 (Article 1020.05(d)(2)b of the Standard Specifications) as long as the "Percent Total FDM Replacement" entered meets the minimums specified (e.g., 25.0% if using fly ash, GGBF slag, or a combination thereof).

Enter Percent Total FDM Replacement **Note 2**	Enter Cement's Target Limestone Content (%)	Enter Desired Cement Factor (cwt)	Cement (lbs/cu yd)	Total FDM (lbs/cu yd)	**Minimum Cement Factor** to enter on Variables tab	**Percent Cement** to enter on FDM & Admix tab	**Percent FDM** to enter on FDM & Admix tab **Note 1**
25.0	10.0	5.70	438	132	5.70	76.9%	23.1%
		Portland Cement Content (lbs/cu yd):	395				