# IDOT PCC MIX DESIGN SOFTWARE TUTORIAL

***Version X1.1***

For help, comments, and/or suggestions, please email:

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## 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.

The spreadsheet is organized across a series of tabs. To navigate from one input screen to another, please use the tabs found at the bottom of the Excel screen.

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 password 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 right-hand 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.

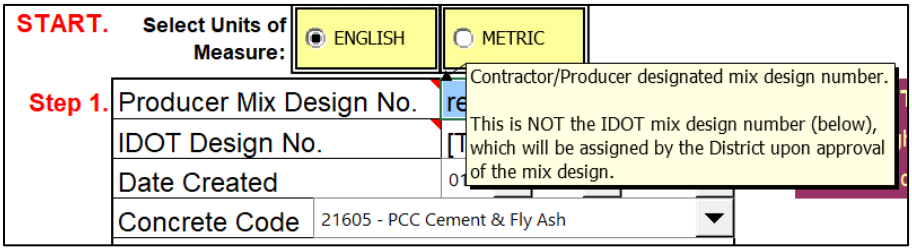


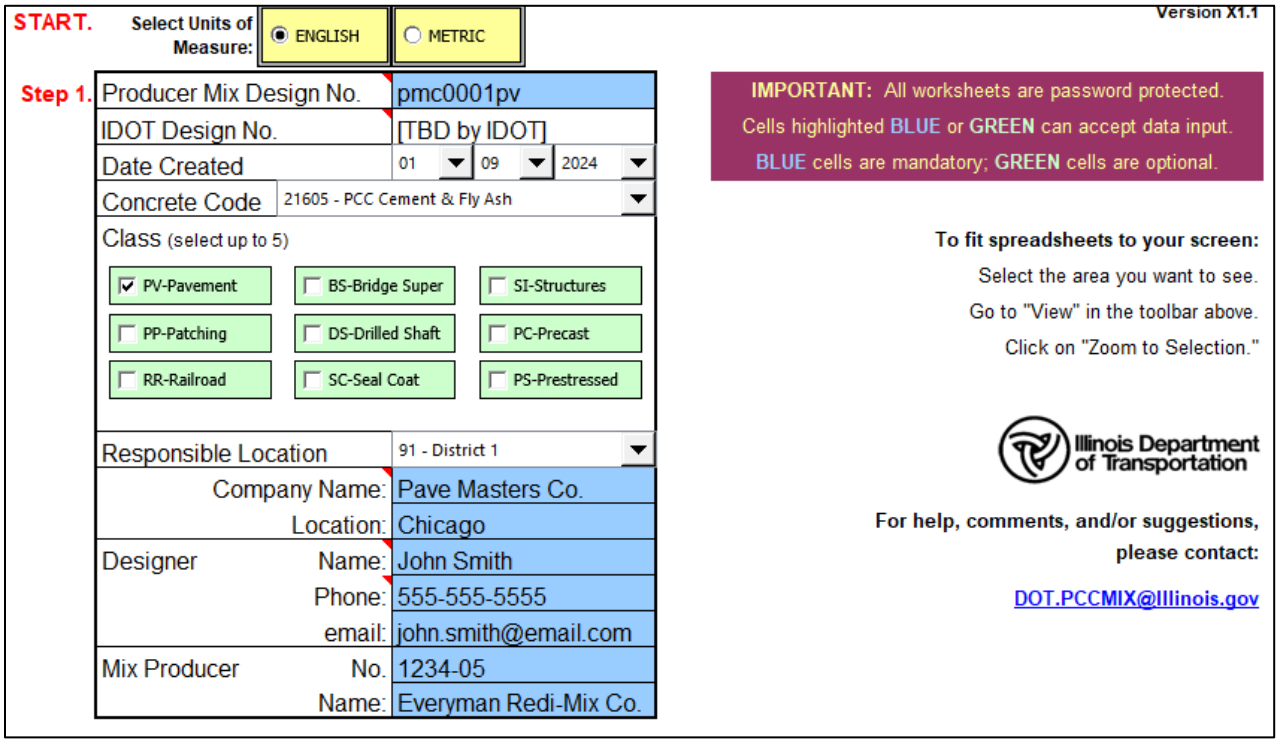

**Figure 1. Example of a comment; note red flag, which indicates the cell has a comment.**

## 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.*




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.<br><br>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 I 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 laboratory responsible for creation and/or testing of mix design.

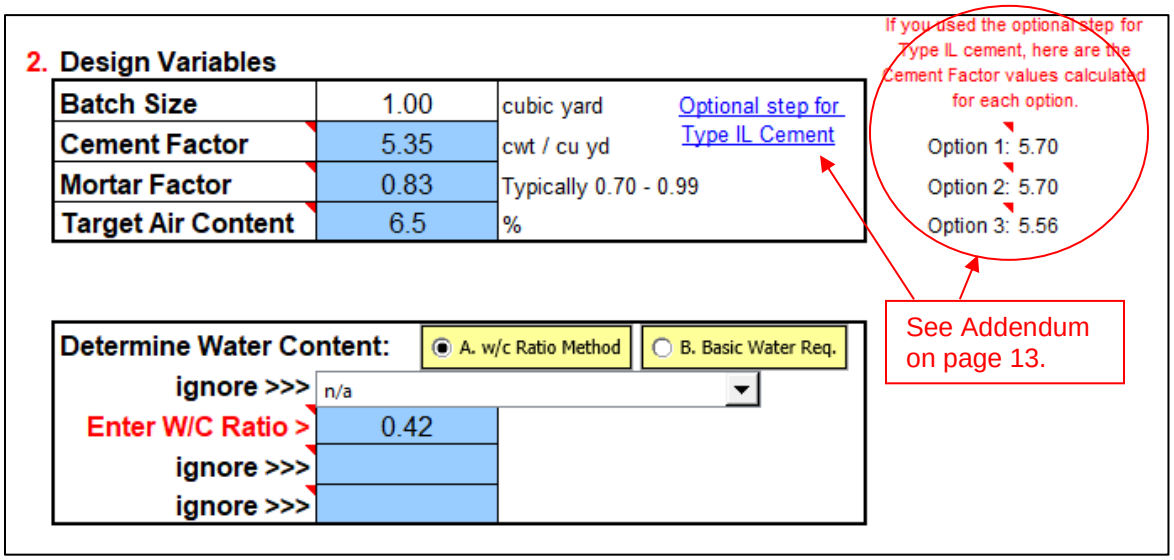
Location: Nearest municipality to Lab/Company.

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

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

**Step 2. Design Variables**

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




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

Cement Factor: 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$^3$**.<br><br>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.<br><br>Thus, the final, adjusted cement factor is reduced to **5.35 cwt/yd$^3$**. |

Mortar Factor: 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.<br><br>Enter **0.83** as a reasonable starting point. |

Target Air Content: 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**

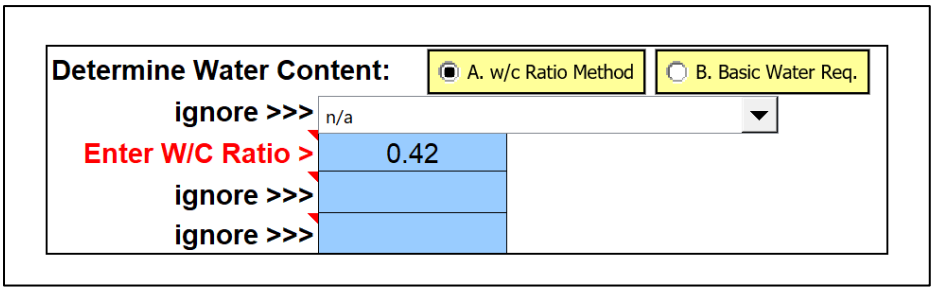
First, using the toggle switch, select either the *w/c Ratio Method* or the *Basic Water Requirement Method* .

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:***

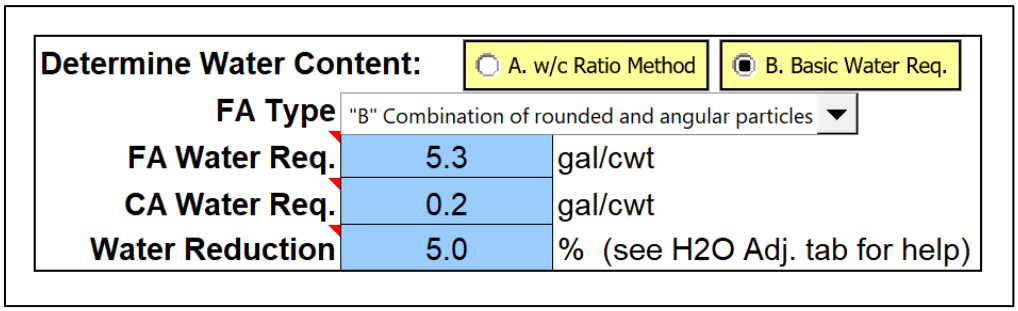



Enter W/C Ratio: When *w/c Ratio Method* is toggled, this field appears. Enter the target w/c ratio that the design water content will be based on; for example, 0.42.

| | |
|---|---|
| **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**. |

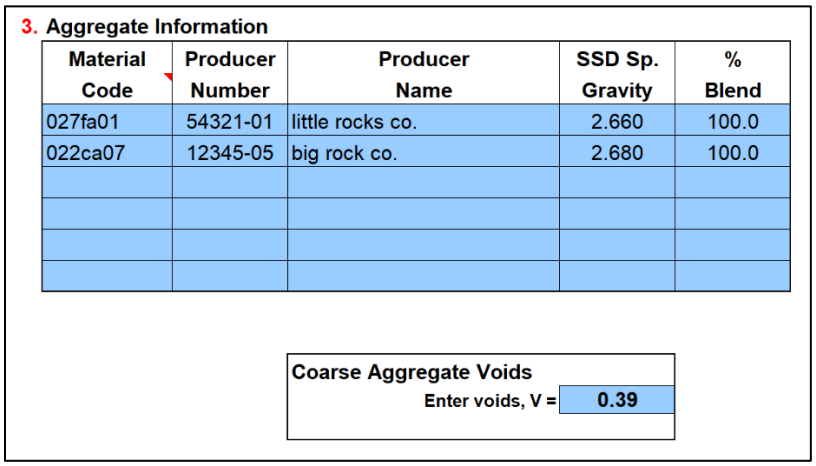
Water Reduction: Percentage of water adjustment (typically a reduction) accounting for various factors, such as admixture use, cement and finely divided mineral content, air content, etc. Note that because this input is referred to as a "reduction," the value entered may seem counter-intuitive; that 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**.<br><br>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.*



3. Aggregate Information

| Material Code | Producer Number | Producer Name | SSD Sp. Gravity | % Blend |
|---|---|---|---|---|
| 027fa01 | 54321-01 | little rocks co. | 2.660 | 100.0 |
| 022ca07 | 12345-05 | big rock co. | 2.680 | 100.0 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Coarse Aggregate Voids
Enter voids, V = 0.39

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**. This material code is for an "A" quality natural sand meeting the gradation criteria for FA 1 per Article 1003.01(c).<br>• Coarse aggregate: Enter **022CA07**. 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 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.

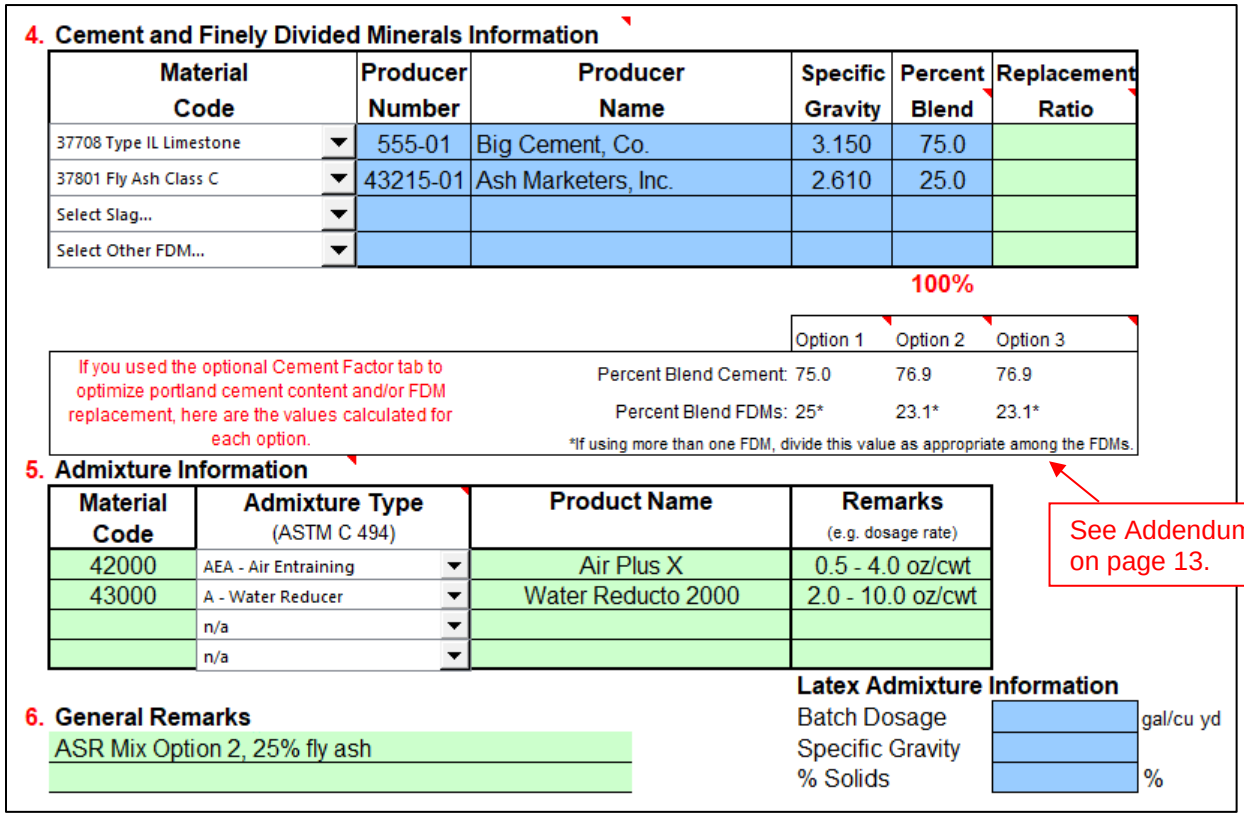
| | |
|---|---|
| **EXAMPLE PROBLEM** | Because this mix is utilizing one coarse aggregate and one fine aggregate (and the mix is not CAM II), enter **100** for coarse aggregate and **100** for fine aggregate, as well. |

Coarse Aggregate Voids: Refer to the District office verifying your mix design for guidance on what value to use. 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.

| | |
|---|---|
| **EXAMPLE PROBLEM** | The example problem 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.).*



**4. Cement and Finely Divided Minerals Information**

| Material Code | Producer Number | Producer Name | Specific Gravity | Percent Blend | Replacement Ratio |
|---|---|---|---|---|---|
| 37708 Type IL Limestone | 555-01 | Big Cement, Co. | 3.150 | 75.0 | |
| 37801 Fly Ash Class C | 43215-01 | Ash Marketers, Inc. | 2.610 | 25.0 | |
| Select Slag... | | | | | |
| Select Other FDM... | | | | | |

100%

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Percent Blend Cement: | 75.0 | 76.9 | 76.9 |
| Percent Blend FDMs: | 25* | 23.1* | 23.1* |

If you used the optional Cement Factor tab to optimize portland cement content and/or FDM replacement, here are the values calculated for each option.

*If using more than one FDM, divide this value as appropriate among the FDMs.

**5. Admixture Information**

| Material Code | Admixture Type (ASTM C 494) | Product Name | Remarks (e.g. dosage rate) |
|---|---|---|---|
| 42000 | AEA - Air Entraining | Air Plus X | 0.5 - 4.0 oz/cwt |
| 43000 | A - Water Reducer | Water Reducto 2000 | 2.0 - 10.0 oz/cwt |
| | n/a | | |
| | n/a | | |

See Addendum on page 13.

**6. General Remarks**

ASR Mix Option 2, 25% fly ash

**Latex Admixture Information**

| | | |
|---|---|---|
| Batch Dosage | | gal/cu yd |
| Specific Gravity | | |
| % Solids | | % |

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.<br><br>• Cement: select **37708 Type IL Limestone** from the drop-down list.<br>• 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**.<br><br>The specific gravity of 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):<br><br>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.<br><br>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**.<br><br>Mix Option 2 requires a minimum 25.0 percent Class C fly ash.<br><br>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.<br><br>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.<br><br>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. Two design reports are generated: one in English units of measure and one in metric (SI).*

**ENGLISH UNITS DESIGN REPORT**

PCC DESIGN MIX

| | | | |
|---|---|---|---|
| IDOT MIX #: | [TBD by IDOT] | CEMENT FACTOR, cwt/yd$^3$: | 5.35 |
| PRODUCER MIX #: | PMC0001PV | MORTAR FACTOR: | 0.83 |
| MATERIAL CODE: | 21605 | CA VOIDS: | 0.39 |
| CLASS(ES): | PV | % AIR: | 6.5 |
| RESP. DISTRICT: | 91 | W/C RATIO: | 0.42 |

| 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 |

PRODUCER NO.: 1234-05

PRODUCER NAME: EVERYMAN REDI-MIX CO.

| | |
|---|---|
| THEO. WATER (gal/cu yd) | 27.2 |

REMARKS: ASR Mix Option 2, 25% fly ash

DESIGNER: JOHN 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 |
| | | | |
| | | | |

**METRIC UNITS DESIGN REPORT**

PCC DESIGN MIX

| | | | |
|---|---|---|---|
| IDOT MIX #: | [TBD by IDOT] | CEMENT FACTOR, kg/m$^3$: | 320 |
| PRODUCER MIX #: | PMC0001PV | MORTAR FACTOR: | 0.83 |
| MATERIAL CODE: | 21605M | CA VOIDS: | 0.39 |
| CLASS(ES): | PV | % AIR: | 6.5 |
| RESP. DISTRICT: | 91 | W/C RATIO: | 0.42 |

| AGGREGATE | Producer No. | Producer Name | Sp. G. | % Blend | Weight (SSD) kg / cu m |
|---|---|---|---|---|---|
| 027FAM01 | 54321-01 | LITTLE ROCKS CO. | 2.66 | 100 | 718 |
| 022CAM07 | 12345-05 | BIG ROCK CO. | 2.68 | 100 | 1135 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| CEMENTITIOUS | Producer No. | Producer Name | Sp. G. | % Blend | kg / cu m |
|---|---|---|---|---|---|
| 37708M | 555-01 | BIG CEMENT, CO. | 3.15 | 75 | 240 |
| 37801M | 43215-01 | ASH MARKETERS, INC. | 2.61 | 25 | 80 |
| | | | | | |
| | | | | | |

| | |
|---|---|
| THEO. WATER (kg/cu m) | 134 |
| TOTAL BATCH WT (kg/cu m) | 2308 |

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

| | |
|---|---|
| THEO. WATER (L/cu m) | 134.4 |

REMARKS: ASR Mix Option 2, 25% fly ash

DESIGNER: JOHN 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 |
| | | | |
| | | | |

Additionally, there is a tab for help determining the percent water adjustment taking into account various factors. However, this table is for informational purposes only. The water adjustment calculated using this table is not referenced by any of the spreadsheet's mix design calculations. To use the water adjustment calculated using this table, **the value *must be entered* on the *Design Variable* tab**.

There are many factors that can be taken into account when determining a mix's water requirement. The table below allows you to estimate the percentage of water adjustment (typically a reduction) based on the mix's constituent materials. **IMPORTANT:** This table is for informational purposes only. The water adjustment calculated here is not referenced by any mix design calculations. **To use the water adjustment calculated here, it must be entered on the Design Variables tab.**

| Water Adjustment | | Suggested Range | Adjustment Percentage |
|---|---|---|---|
| ***Combined aggregate grading:*** | | | |
| | Well-graded | (-10 to 0%) | |
| | Gap-graded | (0 to +10%) | |
| ***Admixture(s):*** | | | |
| Air entraining admixture | 1 to 3% air content | (0%) | |
| Minimum air content specified: | 4 to 5% air content | (-5%) | |
| | 6 to 10% air content | (-10%) | |
| | Normal water-reducing admixture | (-10 to -5%) | |
| | Mid-range water-reducing admixture | (-15 to -8%) | |
| | High range water-reducing admixture (Note 1) | (-30 to -12%) | |
| ***Finely Divided Minerals:*** | | | |
| | Fly Ash (Note 2) | (-10 to 0%) | |
| | Microsilica | (0 to +15%) | |
| | High-Reactivity Metakaolin (HRM) | (-5 to +5%) | |
| | Ground Granulated Blast Furnace (GGBF) Slag | (0%) | |
| ***Other factors:*** | | | |
| | Coarse cement, water/cement ratio > 0.45, and concrete temperature < 60 °F (27 °C) | (-10 to 0%) | |
| | Fine cement, water/cement ratio < 0.40, and concrete temperature > 80 °F (27 °C) | (0 to +10%) | |
| | | Cumulative Adjustment (%) | 0 |
| Reference: Appendix Q, Table 1.2 "Adjustment to Basic Water Requirement" in the PCC Level III Technician Course Manual. | | | **0 %** |

**Note 1:** A polycarboxylate superplasticizer may reduce the water content up to 40%.

**Note 2:** For each 10% of fly ash, it is recommended to allow a water reduction of at least 3%.

## 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:**

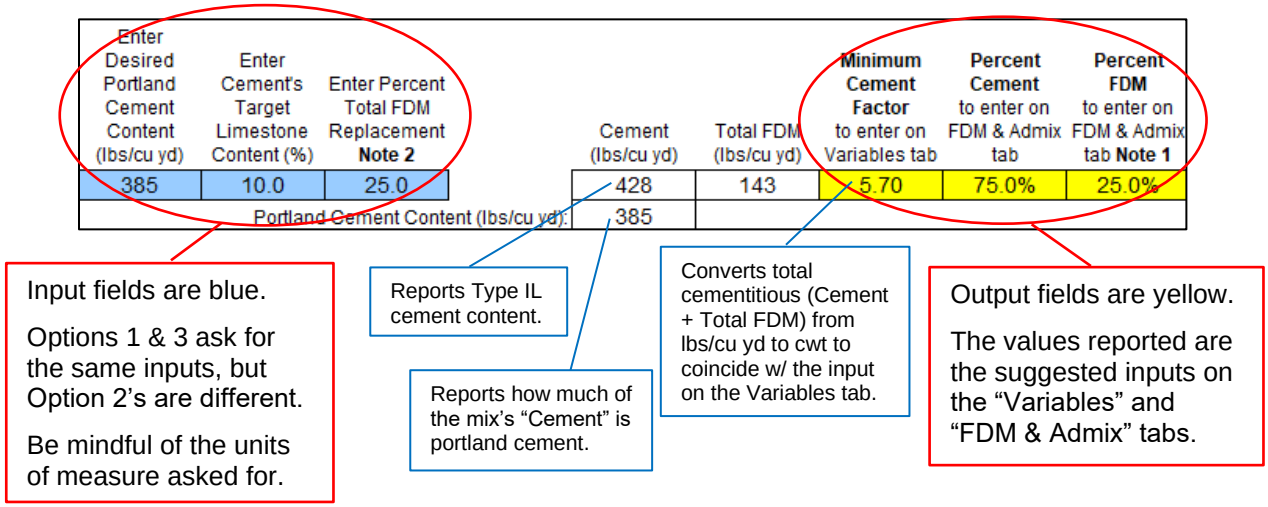
- **Option 1: Ensuring a certain portland cement content is included in your mix.** In this case, you the mix designer want a certain amount of portland cement in your mix, taking into account that not all of a Type IL cement is made up of portland cement. This option may be of interest for lean mixes (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.



## 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/yd$^3$ total cementitious), if using a Type IL(10) cement, the portland cement content is 361 lbs/yd$^3$. However, based on the performance of a number of your designs, you've decided your mixes need at least 385 lbs/yd$^3$ 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/yd$^3$ Type IL(10) cement to obtain 385 lbs/yd$^3$ 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/yd$^3$.

**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/yd$^3$ 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/yd$^3$ of fly ash. This works out to about 10 lbs/yd$^3$ 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/yd$^3$ of GGBF slag, which works out to about 15 lbs/yd$^3$ 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$^3$
$\ell$ 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*, $\ell$, *r*) and only one unknown variable (e.g., *x*).

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

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

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

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 | | | | |