USER'S GUIDE FOR STATISTICAL EXPERIMENTAL DESIGN FOR OPTIMIZING CONCRETE (SEDOC)

Prepared for
National Cooperative Highway Research Program
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INTRODUCTION

This document is a user's guide for the *Statistical Experimental Design for Optimizing Concrete (SEDOC)* computational tool. *SEDOC* is a pair of Microsoft® Excel workbooks and auxiliary "help files" that have been created to support the completion of Steps 1 through 6 in the Methodology laid out in *NCHRP Report 566: Guidelines for Concrete Mixtures Containing Supplementary Cementitious Materials to Enhance Durability of Bridge Decks*. Each workbook (or individual Excel file) is made up of various worksheets, which are the individual pages (denoted by the tabs at the bottom of the screen) that have been created to perform specific tasks in the Methodology. The user of the tool is expected to have reviewed the Guidelines and have a general concept of the Methodology, but electronic versions of much of the Guidelines have been included as linked files, allowing the tool to be used alone.

The tool is divided in two parts: *SEDOC: Setup* and *SEDOC: Analysis. SEDOC: Setup* and *SEDOC: Analysis* are used to complete Steps 1-3 and Steps 5-6, respectively. *SEDOC: Setup* provides guidance and information about appropriate test methods for different service environments and about potential raw materials, and electronic versions of the worksheets from the Guidelines for compiling data and making decisions. Ultimately, *SEDOC: Setup* leads to the selection of factors, factor levels and responses that will be part of the experiment. *SEDOC: Analysis* accepts the selected factors and levels and provides the experimental design, i.e., the list of specific mixtures to be tested to support the statistical analysis. Based on the data generated by the experimental testing program, this workbook performs the conversions to individual desirabilities, the calculation of the overall desirability, the selection of the Best Tested Concrete (BTC), and the modeling and prediction of the Best Predicted Concrete (BPC). There are many pre-formatted plots and tables included in the tool designed to help the user analyze and discover any trends within the data. Finally, *SEDOC: Analysis* includes a worksheet to analyze the confirmation test data and to provide a basis for making final recommendations for the concrete mixture to be used in the application, which is called the Best Concrete (BC) for that experiment.

Resources

For technical assistance with Excel-based problems, please contact Microsoft Corporation. For technical assistance with *SEDOC*, you may contact the program developers via e-mail. The contacts for *SEDOC: Setup* and *SEDOC: Analysis* are John Lawler at Wiss, Janney, Elstner Associates, Northbrook, IL (jlawler@wje.com) and Professor Bruce Ankenman in the Department of Industrial Engineering at Northwestern University, Evanston, IL (ankenman@northwestern.edu), respectively.

Getting Started

The *SEDOC* tool is provided in a single zipped file (SEDOC.ZIP) that must be extracted (unzipped) to create the individual files needed for the tool to function. The zipped file can be extracted by copying the SEDOC folder from the zipped file to a new location using Windows Explorer® in Windows XP® or with a zip-file utility program. (Zip-file utility programs are available as freeware on the internet - a possible choice is ZipGenius, which can be downloaded for free from www.zipgenius.it.) This process will create a folder containing the *SEDOC* workbooks and a subfolder containing the web-browser-accessible background information and help files.

Important Note: Both *SEDOC: Setup* and *SEDOC: Analysis* use *Visual Basic*® macros within the Excel software. Excel has the ability to run macros, but since running some macros can be dangerous to your machine, it also includes security features that may prevent *SEDOC* from running correctly, if those features are not set properly. Macros must be enabled for the *SEDOC* tool to perform as intended. To do this, open Excel before starting the tool and check the macro security settings to ensure that they are adjusted to allow macros to run. The security settings are accessed from the Excel menu bar under Tools >> Macro >> Security. Choose Medium Security and exit from Excel. This will cause a dialog to open whenever a macro is initiated allowing the user to decide whether to allow macros to be enabled. To run the macros in *SEDOC*, select "Enable Macros" in this dialog. Another potential security related issue is related to ActiveX® controls. These may be disabled by Excel automatically if the version of Excel being used does not recognize the controls as "safe for initialization." Consult the Microsoft® website (support.microsoft.com) for help solving this issue.

Steps 1-3 of the Methodology (supported by *SEDOC: Setup*) may lead to the selection of many possible orthogonal experimental designs. At the time of writing of this manual, however, only selected experimental designs are supported by versions of the *SEDOC: Analysis* workbook. While the modeling process outlined in the Guidelines may be applied to analyze data collected based on any orthogonal design, if the user wishes to use the *SEDOC: Analysis* worksheets, the experimental design must be adjusted to exactly match the supported designs so that a *SEDOC: Analysis* workbook will apply. Currently the following designs are supported by the files named below:

- 9-mixtures - 3 three-level factors and 0 two-level factors (SEDOC_Analysis-9_Mix-3_3L-0_2L.xls)
- 9-mixtures - 3 three-level factors and 1 two-level factor (SEDOC_Analysis-9_Mix-3_3L-1_2L.xls)
- 9-mixtures - 4 three-level factors and 0 two-level factors (SEDOC_Analysis-9_Mix-4_3L-0_2L.xls)
- 18-mixtures - 7 three-level factors and 1 two-level factor (SEDOC_Analysis-18_Mix-7_3L-1_2L.xls)
- 18-mixtures - 3 three-level factors and 5 two-level factors (SEDOC_Analysis-18_Mix-3_3L-5_2L.xls)

Note that the folder created during the zip-file extraction will contain blank versions of the *SEDOC: Analysis* workbooks for the supported designs. It will also contain one completed version of a *SEDOC: Analysis* workbook that was completed during the development of the Methodology, as an example of how the files may be used. For the links to the help documentation to function properly, the associated files must be a subfolder of the folder in which the *SEDOC* workbook is located and that subfolder must be named “Background Information”. This folder will be created automatically when the zip-file is extracted.

Conventions

The following are general conventions that apply to both workbooks.

- Gray-shaded cells are for users to fill in. These cells should be completed with information specific to the current application, unless the default information is deemed sufficient. All other cells and plots are protected so that they can not be inadvertently changed.
- All useful information on each worksheet is contained within yellow borders. To see all the features offered on each worksheet, continue to scroll down until the yellow columns to the left and right end. The cells outside the border are used to make supporting calculations for the plots and predictions given within the border, so it is important that they are not altered.
- All the light blue boxes contain directions to help the user perform the task related to that workbook.

OVERVIEW OF EXCEL WORKBOOKS

A brief description of each of the worksheets (pages) that make up the *SEDOC* workbooks is given below. These worksheets and the features presented on each are discussed in detail in the remainder of this user's guide.

Overview of *SEDOC: Setup* Worksheets

SEDOC: Setup is an Excel workbook that includes the following functional worksheets:

1. Task Center - This page is the focal point for the *SEDOC: Setup* workbook. The flowcharts in Step 1 (Performance Definition) and Step 2 (Materials Selection) have been digitized on this page. A list of test methods, selected by the user based on service environment, is generated on this page. This worksheet also includes a place for the users to document each step in the Materials Selection and Experimental Design processes.
2. Desirability Functions - Desirability functions for each of the common test methods are included on this page, so that the user may define a function for each response to be included in the testing program. (These will be later transferred to *SEDOC: Analysis.)*
3. Guideline Worksheets - The worksheets from Step 2, designed to help the user collect data about the available raw materials, and from Step 3, intended to provide a location for

narrowing down the choices of the Factors and Levels for the experimental testing program, make up the remainder of the Workbook.

Overview of *SEDOC: Analysis* Worksheets

SEDOC: Analysis includes the following functional worksheets.

1. Experimental Design Worksheet - The mixtures for testing are selected based on the factors and levels input by the user.
2. Compound Factor Settings Worksheet - If the user chooses to employ Compound Factors, such as the linked SCM Type and Amount Factors used in the example test matrix, the details are specified on this sheet.
3. Response Selection Worksheet - The responses to be included in the analysis are selected on this worksheet. The user may "turn off" certain responses so that the best performers can be selected based on a subset of the test results, if desired. The sheet presents the individual desirabilities for each response for each mixture. It also calculates the overall desirability for each mixture.
4. Data Entry Worksheet - This page is provided for the user to enter all the test data.
5. Desirability Analysis Worksheet - The selection of the BTC and BPC concrete is performed on this page. The selection of the BTC is done automatically from the responses selected on the "Response Selection" sheet. The selection of the BPC is done through a macro that is initiated when the user clicks on a button. The user can input ranges and step sizes for interpolation between the settings of each factor level if it is desired. However, the default optimization (no interpolation) is used if the user does not input ranges and step sizes.
6. Confirmation Analysis Worksheet - This worksheet is used to input the data from the confirmation testing and compare the BTC and BPC for making the final selection of the BC in step 6.
7. Individual Response/Desirability Function Worksheets - Each performance test (response) has its own worksheet. The test data entered on the Data Entry Worksheet is copied from that worksheet and used to determine the desirability for each mixture on these worksheets. A default desirability function is already loaded on this page but the user can modify these if desired. These sheets also contain scatter, trend, and factor effect

plots so that the user can evaluate each individual response and compare the performance of the mixtures one test method at a time.

DESCRIPTION OF INDIVIDUAL WORKSHEETS

Each individual worksheet from the two workbooks is discussed separately in the remainder of this user's guide. For the more complex worksheets, an overview page is provided first, followed by a more in-depth discussion of each of the tables or plots contained on that worksheet. Note that the title of the workbook and a graphic representation of the worksheet tab are given at the top of each page so that it is clear where the worksheet can be found.

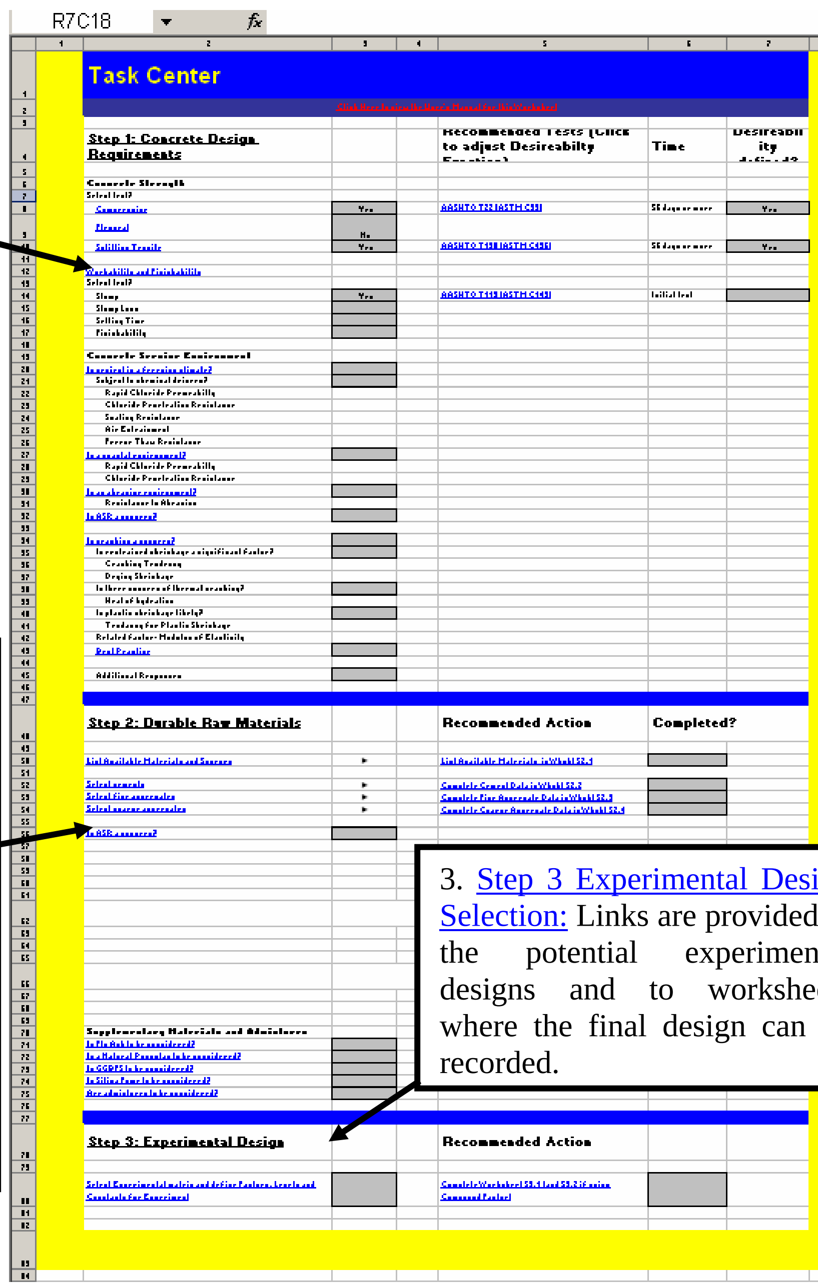
SEDOC: Setup

SEDOC: Setup

Task Center Worksheet: Overview

Purpose: On this worksheet, the decision boxes in the flowcharts that provide the framework for Steps 1 and 2 from *NCHRP Report 566* have been converted to a set of pull down boxes. The recommendations generated by the answers to the questions link either to desirability functions for each test method or to worksheets where the raw materials can be evaluated in comparison to each other.
Note: Gray shaded boxes are used for input; they are the only cells were you, the user, need to type or make selections.

1. Step 1 Flowchart: The left column reviews the possible service environments that are significant to durability of a bridge deck. These questions are to be answered in the column of gray boxes. Based on the answers to these questions, appropriate test methods are recommended. The test title is linked to the desirability function for that response.



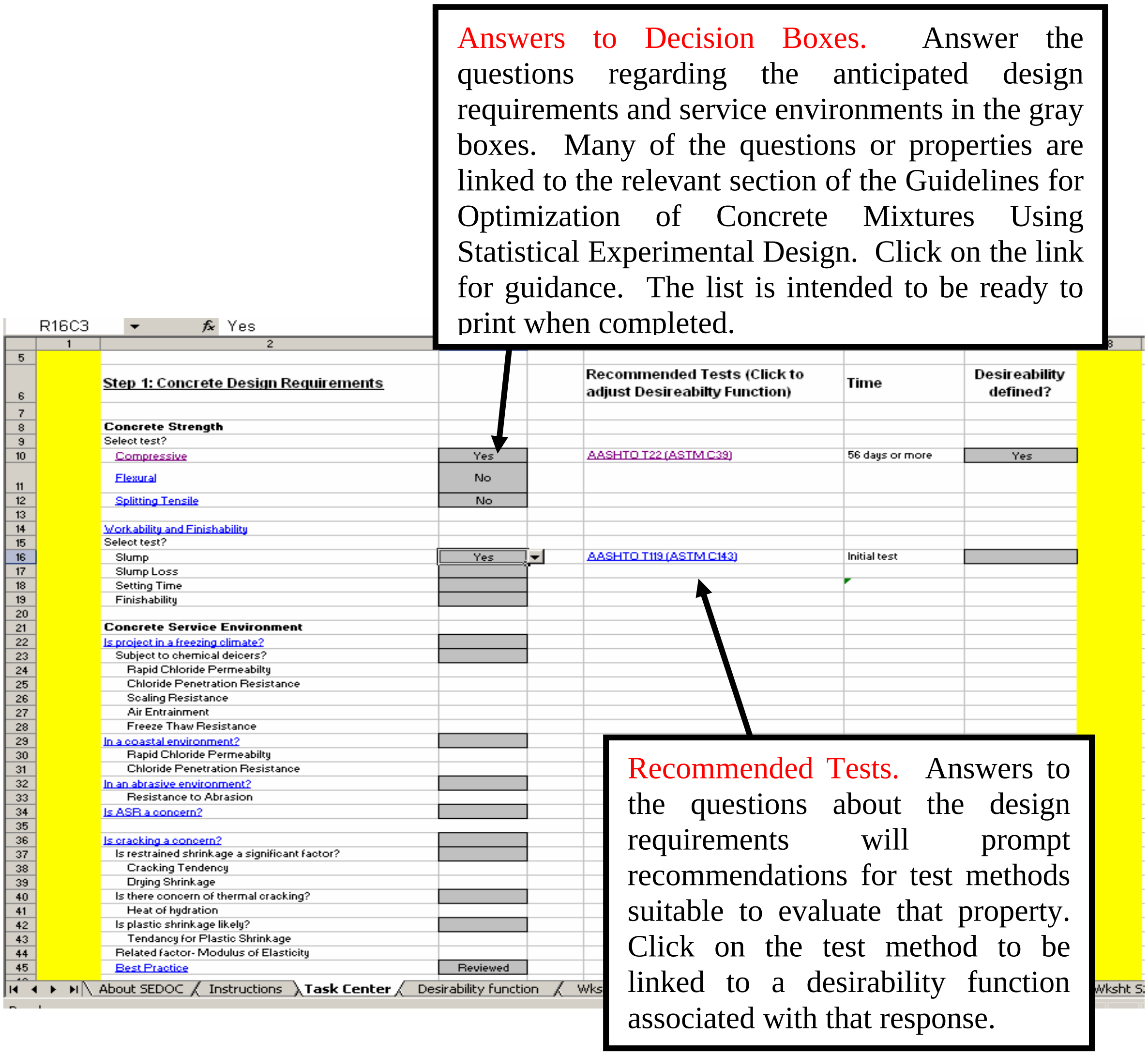
2. Step 2 Flowchart: This list leads the user through the selection of the raw materials, one type of material at a time. This also includes a process for evaluating the ASR-potential for an aggregate source and selecting appropriate mitigation measures, if needed. Links are provided to worksheets where the different types of raw materials can be compared.

3. Step 3 Experimental Design Selection: Links are provided to the potential experimental designs and to worksheets where the final design can be recorded.

SEDOC: Setup

Task Center Worksheet: Step 1 Flowchart

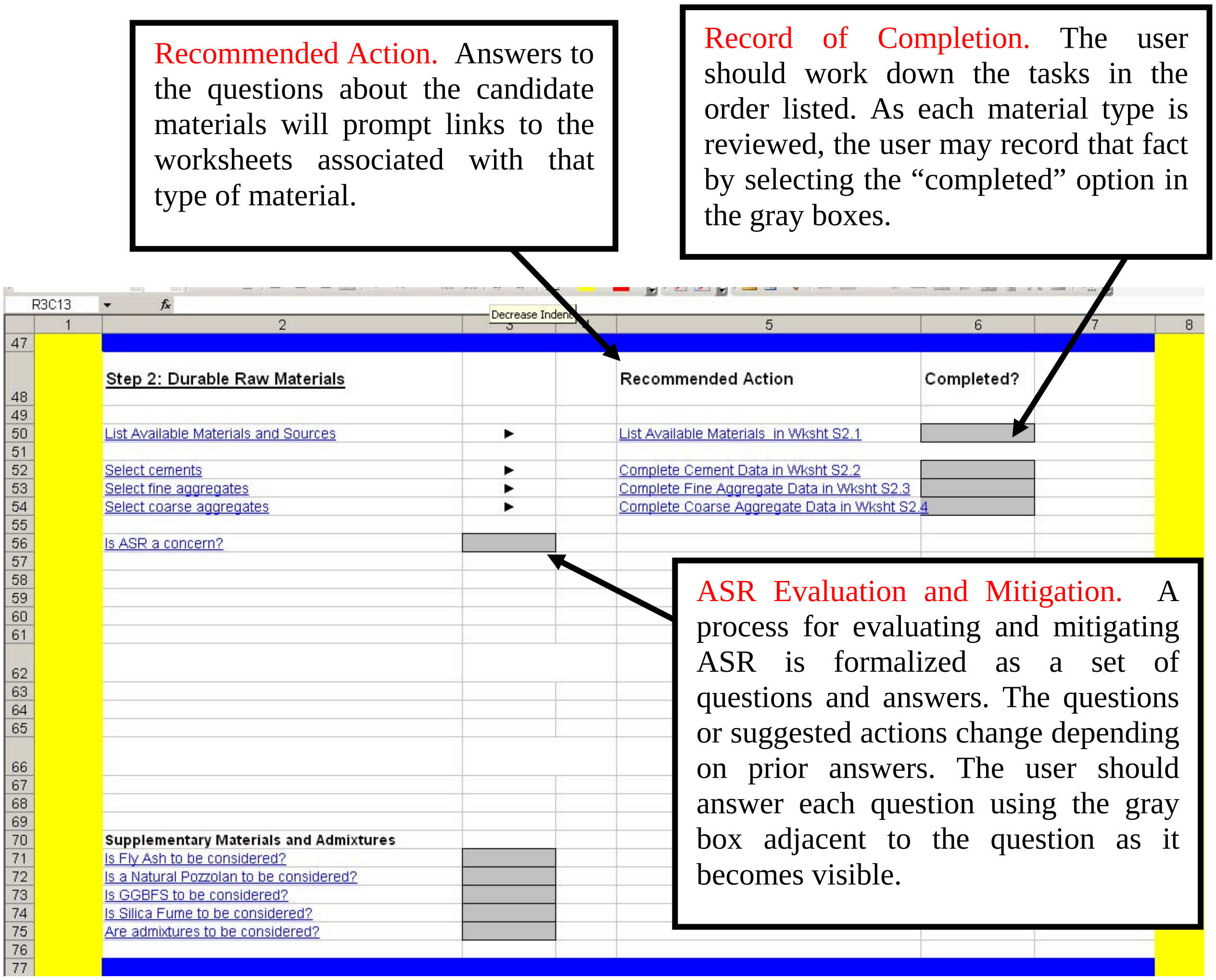
Purpose: The flowchart in Step 1 provides a framework for defining the program of tests for the optimization experiment, based on the anticipated design requirements and service environment.



SEDOC: Setup

Task Center Worksheet: Step 2 Flowchart

Purpose: The flowchart in Step 2 outlines a procedure for selecting the raw materials to be considered for use in the concrete mixtures. The tasks in Step 2 are listed in the column on the left of the page. Each type of material is supported by general guidance that can be accessed with a web browser using the hyperlinks.



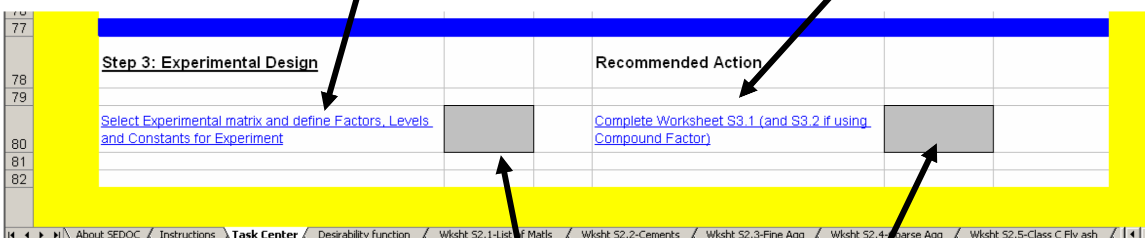
SEDOC: Setup

Task Center Worksheet: Step 3 Experimental Design Selection

Purpose: Step 3 involves selecting the experimental matrix and defining the factors, levels and constants of the experiment. This selection must be done based on an appropriate orthogonal experimental design chosen from the tables provided in the linked document. The size and shape of the design will be governed by the number of mixtures to be tested, so there is expected to be a need for some iterative adjustments between the selected design and the parameters of the experiment.

Selection of Design Matrix. The user should follow the link to background discussion and tables of orthogonal experimental designs that will lend themselves to statistical analysis in the remainder of the experiment.

Recommended Action. A link is provided to Worksheet S3.1 that may be used to define the factors, levels and constants. This worksheet should be printed and will be used as the foundation of the experimental investigation.

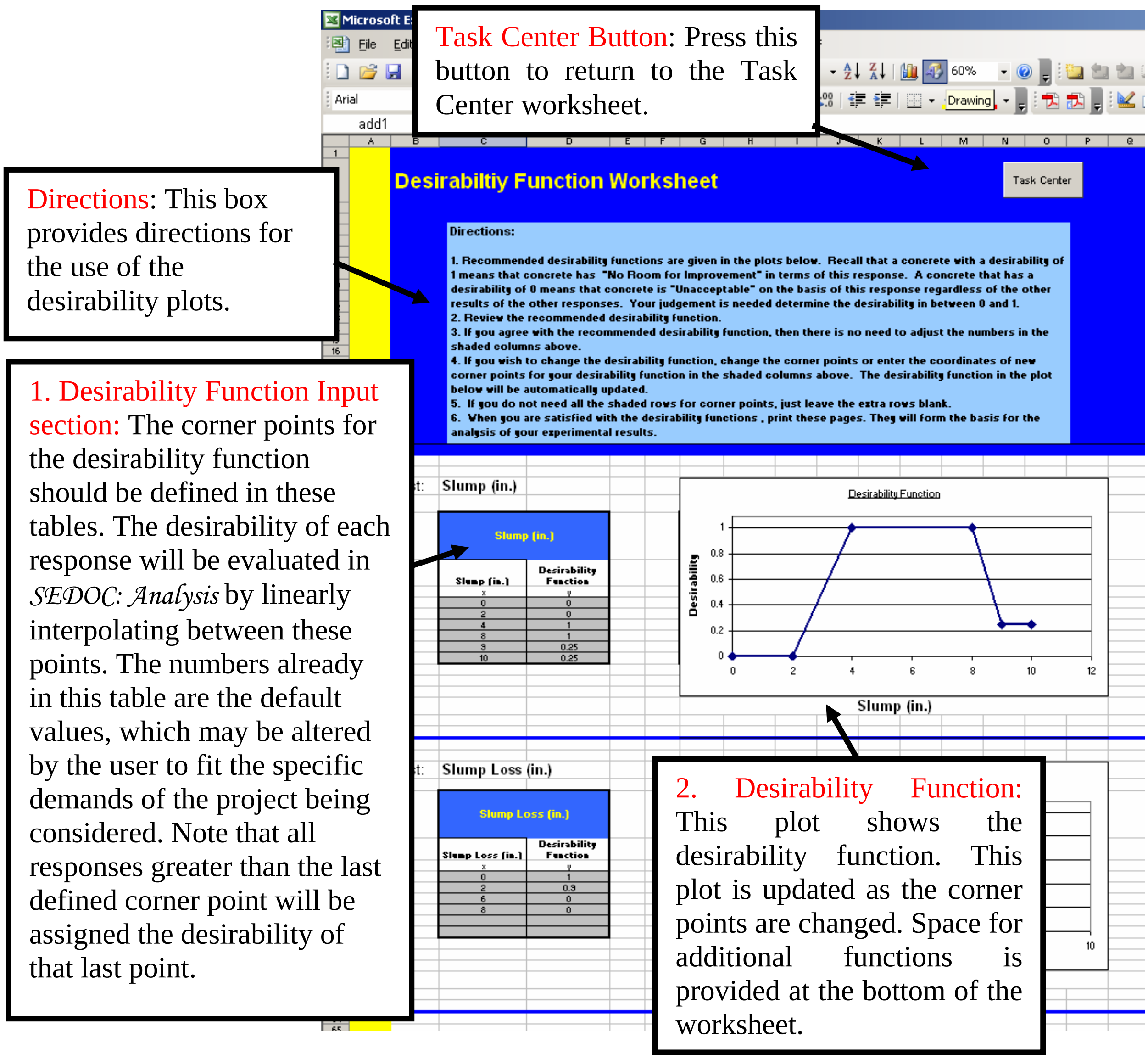


Record of Completion. When the design has been chosen, the user may record that fact by selecting the "completed" option in the gray boxes.

SEDOC: Setup

Desirability Function Worksheet

Purpose: On this worksheet, desirability functions are defined for each of the responses that may be recommended for inclusion in the test program by Step 1. A default function is provided, but you are encouraged to revise this function as you evaluate whether to include this response and consider what is actually measured by the test method. (These desirability functions are not used directly in *SEDOC: Analysis*, but this sheet may be printed so that the values may be transferred to the appropriate worksheet of that workbook.)

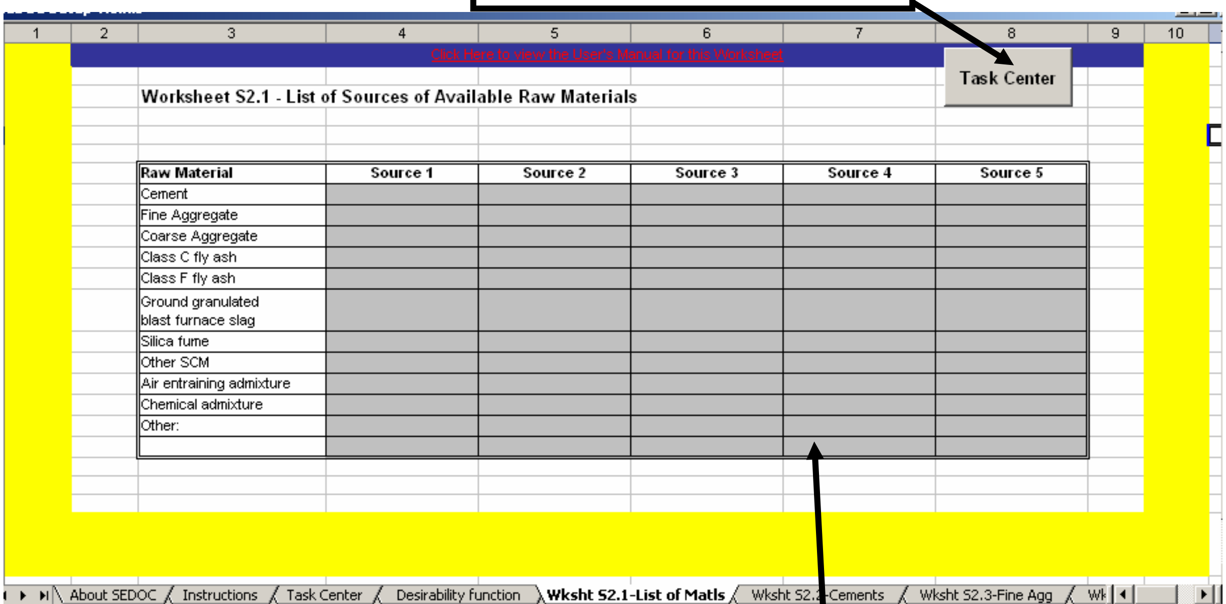


SEDOC: Setup

Step 2 Materials Selection Worksheets

Purpose: On Excel worksheets labeled "Wksht S2.#" in *SEDOC: Setup*, the Step 2 worksheets are presented in electronic form so that you can organize and compare data regarding locally-available source materials. "Wksht S2.1" is for listing the available material sources, while the remaining worksheets are for compiling the reported properties of the raw materials.

Task Center Button: Press this button to return to the Task Center worksheet.

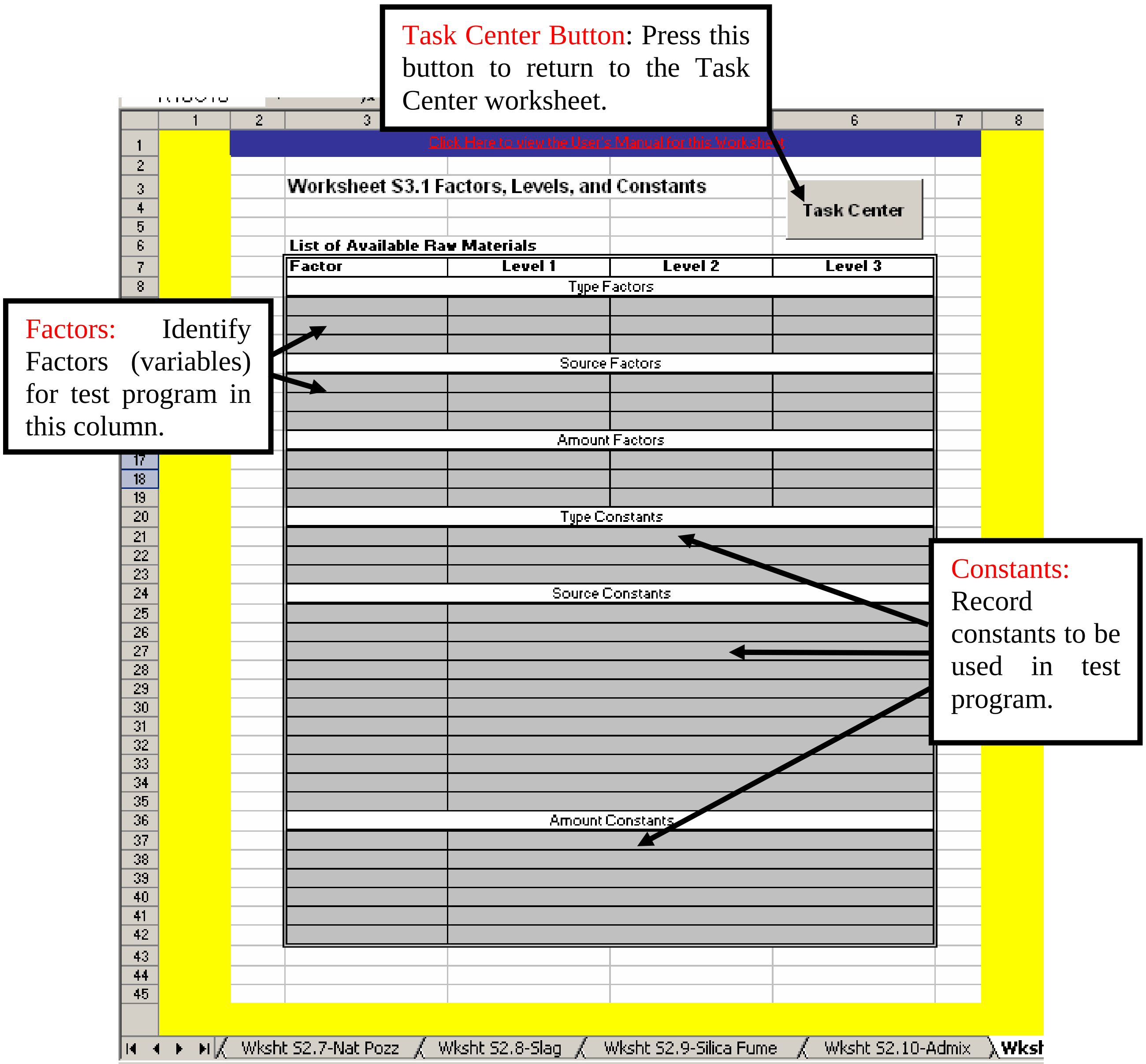


1. Worksheet workspace: This space is provided to help organize the available data regarding candidate raw materials.

SEDOC: Setup

Step 3 Experimental Design Selection Worksheet

Purpose: On Excel worksheets labeled "Wksht S3.1" in *SEDOC: Setup*, the Step 3 worksheet is presented in electronic form so that you can record the factors and levels selected for testing. "Wksht S3.2" is also included if a compound factor is used.



SEDOC: Analysis

SEDOC: Analysis

Experimental Design Worksheet: Overview

Purpose: On this worksheet, enter the factors and their levels chosen in Steps 1-3 into the Factors and Levels Table. The worksheet then automatically generates the design matrix of concrete mixtures to mix and test in the experiment.

Overall Directions: This box provides overall directions for the use of all the worksheets in *SEDOC: Analysis.*

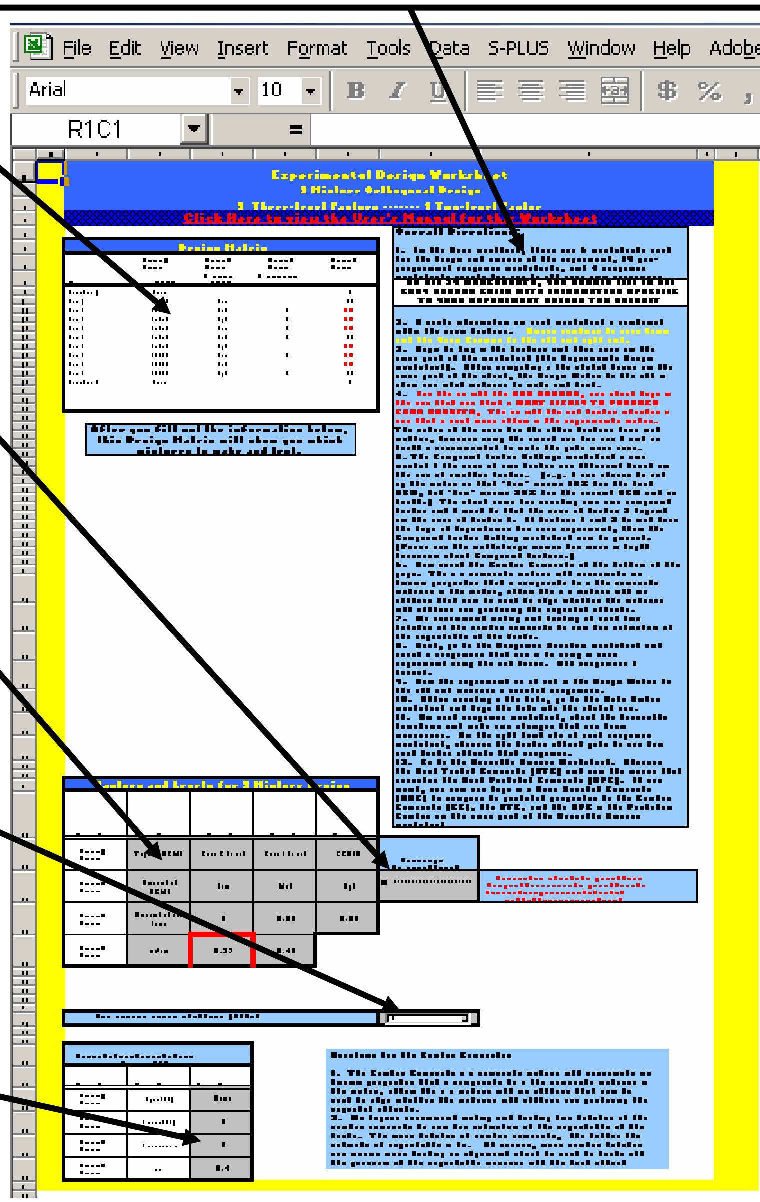
1. The Design Matrix: This matrix identifies the concrete mixtures for testing test in the experiment. The matrix is generated automatically and is based on the factors and levels filled in below.

2. Compound Factor Check Box: Check the box if you are using a compound factor.

3. Factors and Levels Table: In the gray-shaded cells, enter the factor names and levels chosen for each factor.

4. The Number of Control Mixtures: Select the number of control mixtures you are planning to mix and test. These replicates are used to estimate the repeatability of the tests.

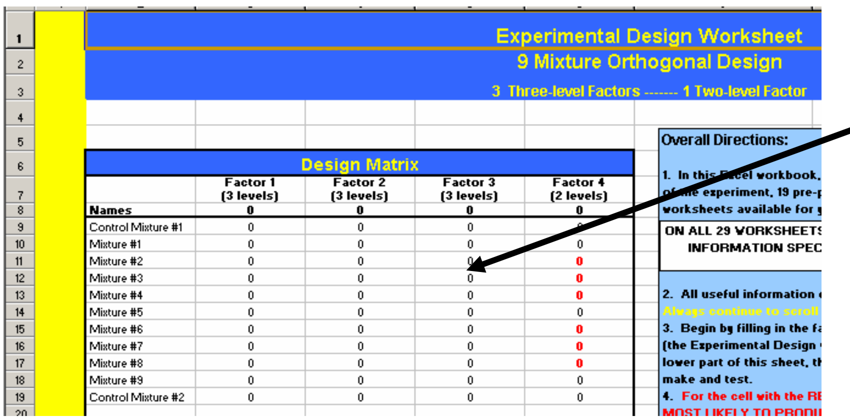
5. The Control Concrete: This is where you enter the levels of each factor for the concrete mixture that you consider to be a control. Often this is a concrete with no additives.



SEDOC: Analysis

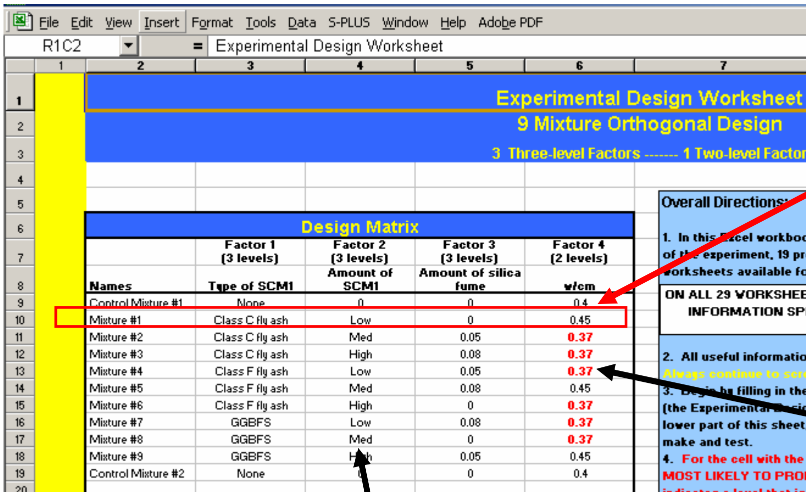
Experimental Design Worksheet: The Design Matrix

Purpose: The design matrix identifies the set of concrete mixtures that are to be mixed and tested. This matrix is an orthogonal experimental design. In this setting, "orthogonal" means that all levels of each factor are used the same number of times with all levels of the other factors. This balance allows for a wide variety of concrete mixtures within the ranges of the factors specified. It also allows for uncorrelated estimates for each factor effect and for clear interpretation of simple trend plots.



A Blank Design Matrix. To get the completed design matrix, you must fill in the Factors and Levels Table lower down on this worksheet. See ***SEDOC: Setup*** for help in choosing the factors and their levels.

After filling in the Factors and Levels Table lower down on this same worksheet, the design matrix will be automatically generated by *SEDOC: Analysis.*



Names	Factor 1 (3 levels) Type of SCM1	Factor 2 (3 levels) Amount of SCM1	Factor 3 (3 levels) Amount of silica fume	Factor 4 (2 levels) w/cm
Control Mixture #1	None	0	0	0.4
Mixture #1	Class C fly ash	Low	0	0.45
Mixture #2	Class C fly ash	Med	0.05	0.37
Mixture #3	Class C fly ash	High	0.08	0.37
Mixture #4	Class F fly ash	Low	0.05	0.37
Mixture #5	Class F fly ash	Med	0.08	0.45
Mixture #6	Class F fly ash	High	0	0.37
Mixture #7	GGBFS	Low	0.08	0.37
Mixture #8	GGBFS	Med	0	0.37
Mixture #9	GGBFS	High	0.05	0.45
Control Mixture #2	None	0	0	0.4

Example: This design matrix shows that for this experiment, mixture 1 should have a Low level of Class C fly ash, no silica fume and a w/cm of 0.45.

A Level in Red: This level appears more often than the other levels and thus it should be chosen to be a level that, in your judgment, has a high likelihood of producing better concrete.

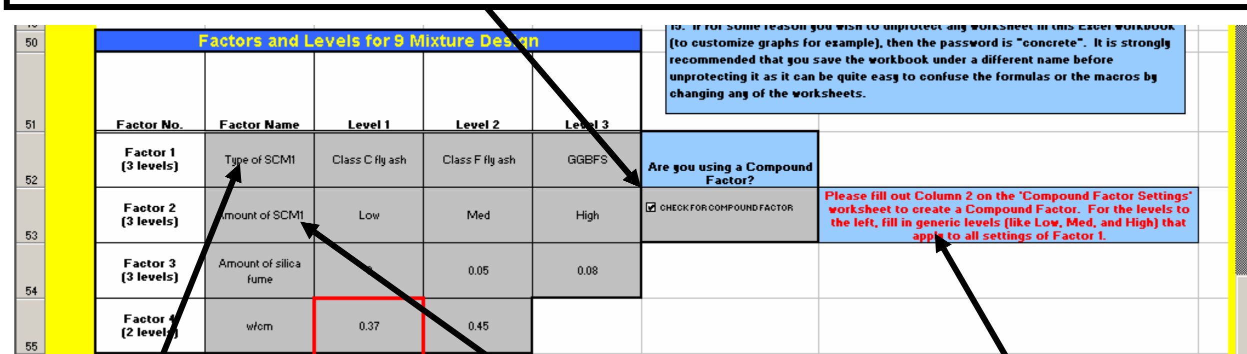
A Completed Design Matrix: This design matrix shows 11 mixtures, 2 of which are control concretes and the other 9 make up the orthogonal experimental design. Notice that in this orthogonal design, each level of each factor appears 3 times (once with each level of the other factors' levels), except for the level in red that appears 6 times (twice with each of the other factors' levels).

SEDOC: Analysis

Experimental Design Worksheet: Compound Factor* Check Box

Purpose: This Check Box modifies the modeling routines to account for the inclusion of a Compound Factor*. Check this box when Factor 2 is an Amount Factor that specifies different amounts for each level of Factor 1, which must be a Type Factor.

Compound Factor Check Box: Check the box if you are using a Compound Factor. Note that only Factor 1 and Factor 2 can be made into a Compound Factor in *SEDOC: Analysis*. If the box is not checked, then Factor 1 and Factor 2 are unrelated and can be any kind of factor (Type Factor or Amount Factor.)



Factor 1. The Type Factor: If you are using a Compound Factor, Factor 1 must be a Type Factor. In the example shown, it is the type of the first SCM. ("First" because this example has 2 SCMs. The second SCM is silica fume and Factor 3 is an amount factor for the amount of silica fume.)

Factor 2. The Amount Factor: If you are using a Compound Factor, Factor 2 must be an amount factor. In the example shown, it is the amount of the first SCM. Notice that the levels of Factor 2 on this page are generic levels like Low, Med, and High. The actual amounts for each type will be specified on the Compound Factor Settings Worksheet.

The Red Warning: If the box is checked, this red warning appears that reminds you that the actual levels of Factor 2 should be typed in on the *Compound Factor Settings Worksheet*.

* Note: A Compound Factor is a pair of variables (factors) that act together to define the type and amount of a certain material so that the amount of each material can be customized for each type. When using a Compound Factor in *SEDOC: Analysis*, Factor 1 must be a type factor and Factor 2 must be the Amount Factor that gives generic amounts for each type. For example: suppose that Factor 1 is a Type Factor for SCM and its levels are Class C fly ash, Class F fly ash, or slag (GGBFS). Let Factor 2 be an Amount Factor whose levels are Low, Med., and High. However, the amounts specified for Low, Med., and High for each type of SCM are different. For example, Low, Med., and High for the fly ashes might be 15%, 25%, and 40%, but Low, Med., and High for slag might be 25%, 35%, and 50%. Thus, the levels of Factor 2 change

(from 15%, 25%, and 40% to 25%, 35%, and 50%) depending on the level of Factor 1 (fly ash or slag).

SEDOC: Analysis

Experimental Design Worksheet: The Factors and Levels Table

Purpose: The Factors and Levels table is where the factors and levels chosen for the experiment by using the *SEDOC: Setup* are input.

Factors and Levels for 9 Mixture Design

Factor No.	Factor Name	Level 1	Level 2	Level 3
Factor 1 (3 levels)	Type of SCM1	Class C fly ash	Class F fly ash	GGBFS
Factor 2 (3 levels)	Amount of SCM1	Low	Med	High
Factor 3 (3 levels)	Amount of silica fume	0	0.05	0.08
Factor 4 (2 levels)	w/cm	0.37	0.45	

Factors Levels: In these rows, type in the levels that you have chosen for each factor. Use *SEDOC: Setup* to help you decide which factors and levels to choose. Notice that levels can be either numerical amounts or types like "Class C fly ash", "Class F fly ash" or slag ("GGBFS"). When a Compound Factor is used, they can also be generic amounts like "High", "Med", and "Low".

Factors Names: In this column, type the names of the factors that you wish to test in your experiment.

A Level in Red. A level that is boxed in red will appear more often than the other levels in the design matrix. Thus, it should be chosen to be a level that, in your judgment, has a high likelihood of producing the best concrete.

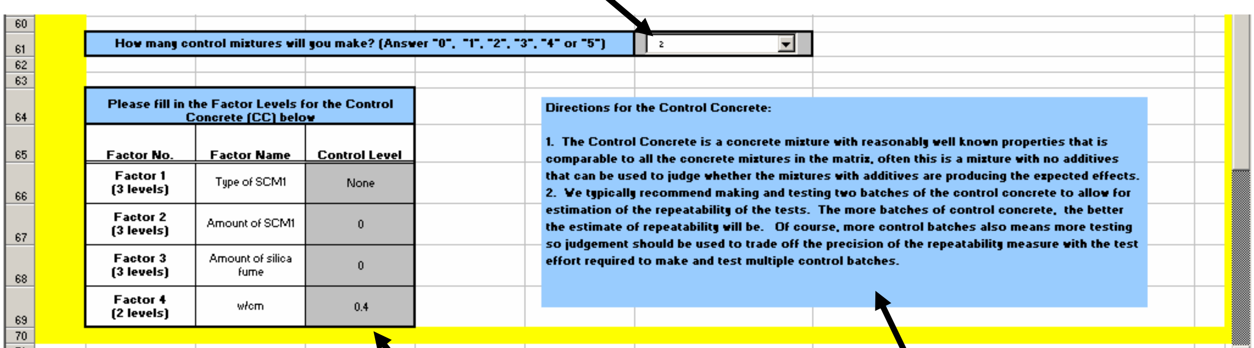
SEDOC: Analysis

Experimental Design Worksheet: The Number and Design of Control Mixtures

Purpose: Use the Control Mixtures Selection Box to choose the number of control mixture batches that you are planning to mix and test. Including a control mixture will allow comparison of the performance of a mixture that does not fit within the range of levels chosen for the design matrix. Testing repeated control mixtures allows for the estimation of the repeatability of the test procedures. This repeatability will be used on the factor effects plots on the individual response worksheets.

The control concrete is used as a standard against which to compare all the mixtures in the design matrix. This may be a mixture for which extensive experience is available or it may be a mixture that contains no SCMs so that the benefits of SCMs can be differentiated from a conventional mixture.

Number of Control Mixtures Selection Box: Choose the number of control mixtures that you plan to make. If control mixes are to be included, we recommend at least 2 control mixtures be tested to allow for an estimate of the test repeatability. However, if a measure of repeatability is already available, making multiple control batches may not be necessary.



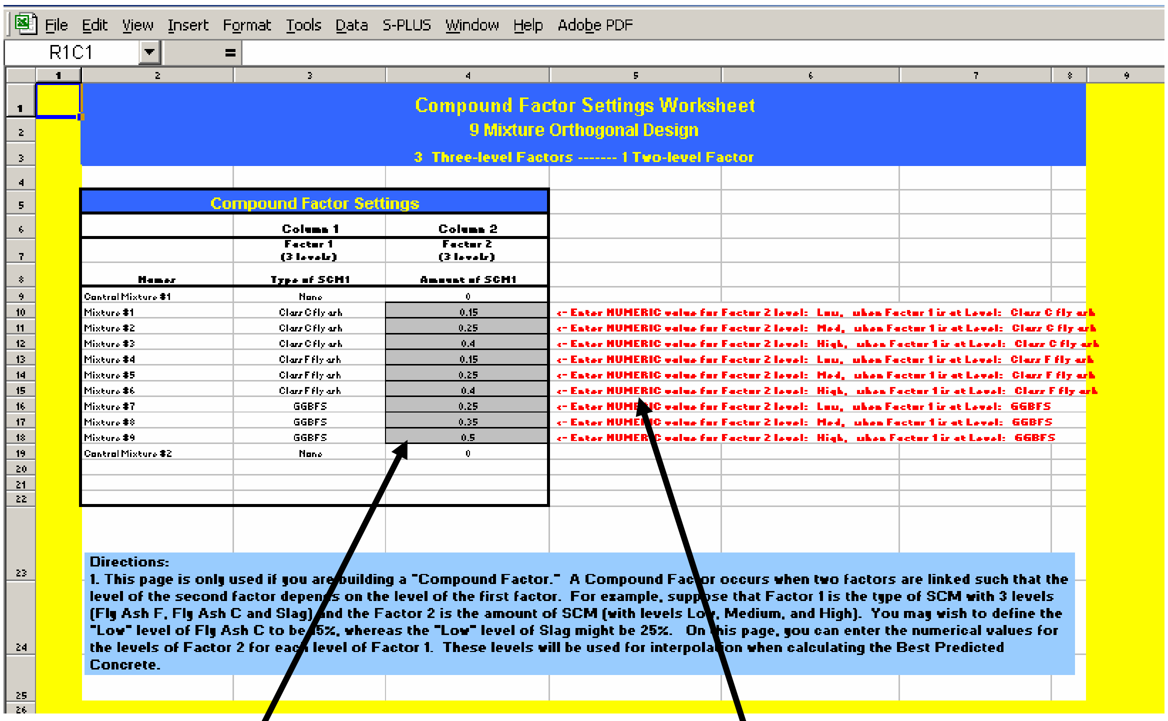
Directions for the Control Concrete: This blue box has directions for using a control concrete.

Control Factor Levels: In these gray-shaded boxes, type in the levels of each factor that are used for the control concrete. These levels are not necessarily levels within the ranges specified in the Factor and Levels Table.

SEDOC: Analysis

Compound Factor* Settings Worksheet

Purpose: If you are using a Compound Factor*, type in the amount levels of Factor 2 for each of the levels of Factor 1 on this sheet. These levels were defined generically on the Experimental Design Worksheet but must be defined specifically on this sheet. This worksheet is only needed if you are using a Compound Factor (i.e., the Compound Factor check box on the experimental design worksheet is checked.) If you are not using a Compound Factor, this sheet is not needed or used. This worksheet is used for input; there is no output on this page.



1. Factor 2 Levels: In the shaded boxes, type in the levels of Factor 2 for each level of Factor 1.

2. Information Requests: These red requests explain exactly what should be entered in each shaded box. They only show up if you have checked the Compound Factor box on the experimental design worksheet and are based on the generic amount descriptions provided there.

* Note: A Compound Factor is a pair of variables (factors) that act together to define the type and amount of a certain material so that the amount of each material can be customized for each type. (See the description of the *Experimental Design Worksheet: Compound Factor** Check Box above or the Guidelines for more information.)

SEDOC: Analysis

Individual Response/Desirability Function Worksheet: Overview

Purpose: There is a worksheet like this one dedicated to each individual performance test (response) that you plan to use. The sheet holds the desirability function for that response and provides several plots that are useful for analyzing the data from that response. The only inputs on these sheets are the corner points for the desirability function and a selection box to allow you to choose the repeatability that best reflects your test repeatability. The worksheet provides a plot of the desirability function, a plot of the scaled factor effects on the response, and individual response vs. factor plots for each factor. There are additional response worksheets at the end of the workbook so that any additional responses that you wish to evaluate can be included.

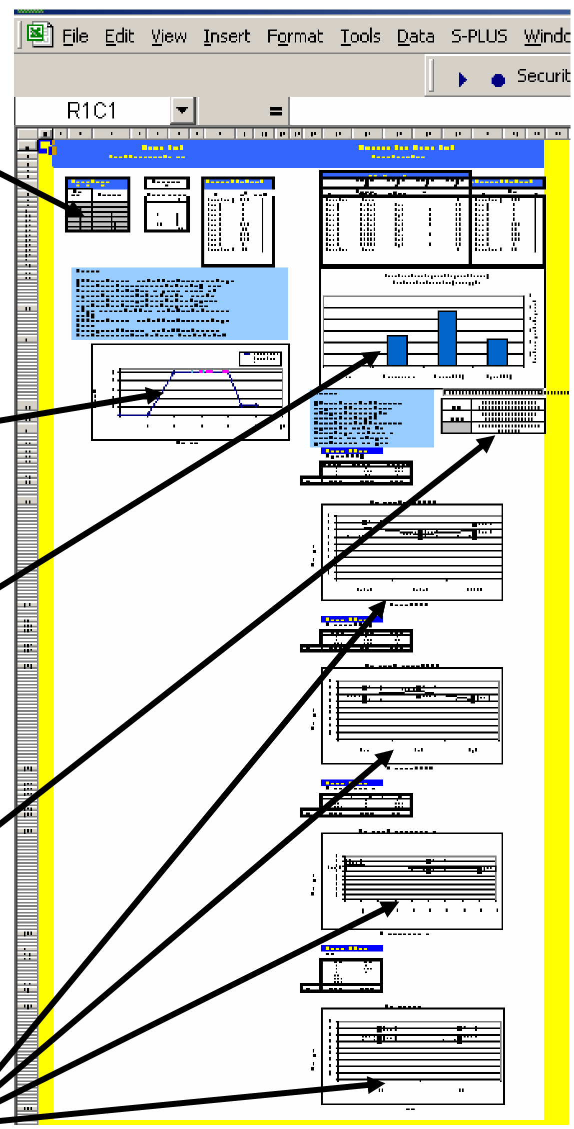
1. Desirability Function Input: For most responses, recommended corner points for the desirability function will already be in this table, however, you can adjust these corner points to reflect the requirements of your application.

2. Desirability Function Plot: This plot shows the desirability function and plots each mixture that was tested on the plot.

3. Factor Effects Plot: This bar chart shows the scaled factor effects with respect to the repeatability of the test. You can also compare them to each other.

4. Repeatability Selection: The selection box allows you to choose a repeatability for this performance test (response).

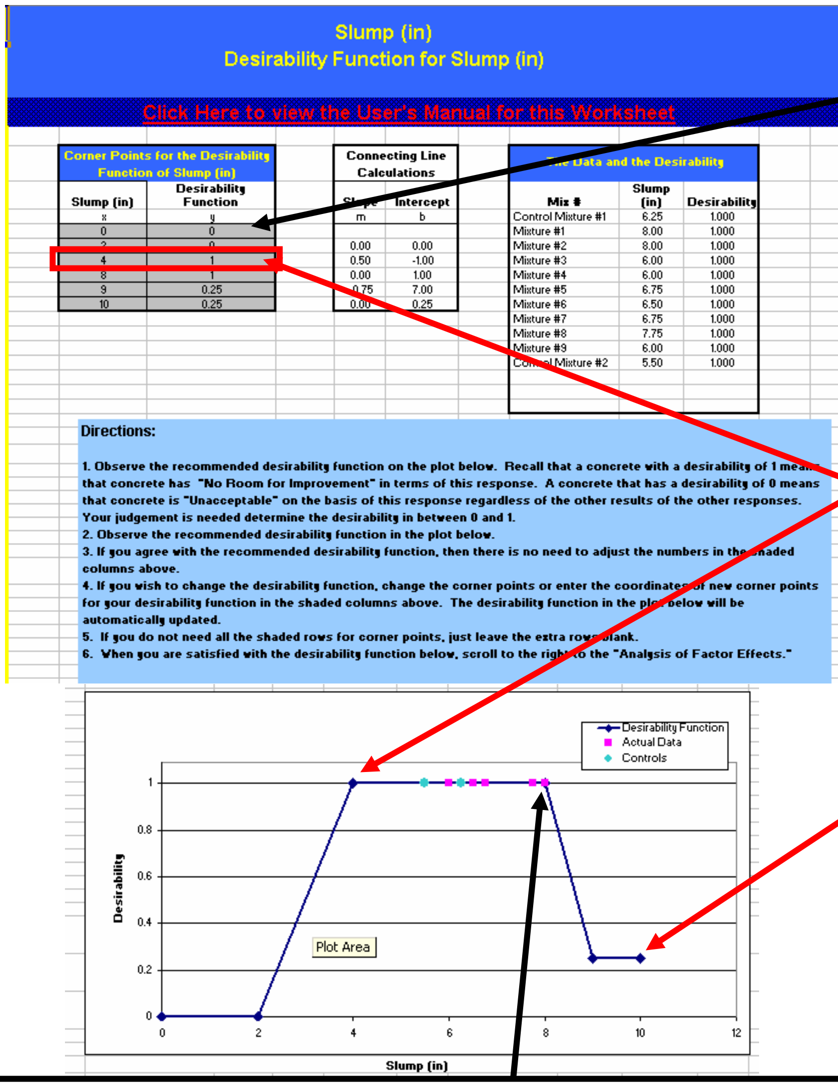
5. Scatter/Trend Plots: These scatter plots of the factor levels versus the response show the relationship (trends) in this particular response with respect to each factor.



SEDOC: Analysis

Individual Response/Desirability Function Worksheet: Desirability Function Input and Plot

Purpose: This section of the worksheet allows you to create the desirability function for the response the individual response. The desirability function maps any test value for this response to an individual desirability, which is a number between 0 and 1 with 0 meaning unacceptable and 1 meaning there is no room for improvement. Controlling this function for each response allows you to specify exactly what type of performance is best for your application. You control this function by typing in the corner points (vertices) of the function and then *SEDOC: Analysis* connects these points with line segments.



Corner Points: The default desirability corner points are already entered here, but you can change these to match your application.

Example: The coordinates for the third corner point are typed in the third row of gray-shaded cells and are (4,1). This is then plotted as the third corner point on the desirability function.

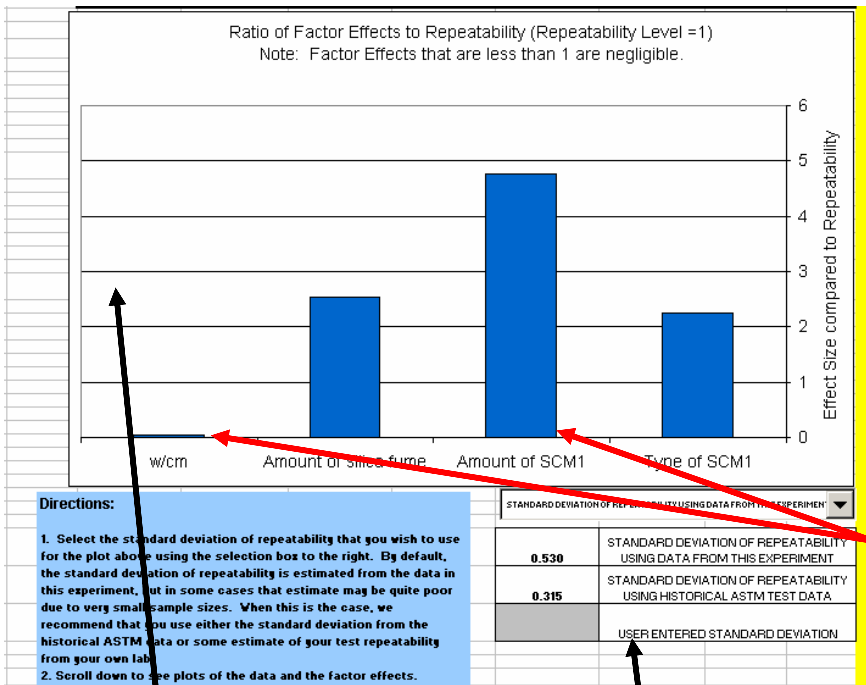
Example: Since this desirability function ends at 0.25 any value of slump above the last corner point will get an individual desirability of 0.25.

The Desirability Function is plotted here with a point for each of the mixtures and the control concrete to show the performance. The point shown here is for mixture # 1, which had slump value of 8 inches and is thus assigned an individual desirability of 1.

SEDOC: Analysis

Individual Response/Desirability Function Worksheet: Factor Effects Plot and Repeatability Selection

Purpose: The factor effects plot shows which factors have the biggest effect on this response. Large bars that are greater than 1 indicate potentially large effects.



Example: The w/cm bar is less than 1 and thus it is clearly not a significant effect on slump. (Slump was determined by admixture dosage.) The other three factor effects are greater than 1 and thus have potentially significant effects. The Amount of SCM is the factor with the strongest effect on Slump. To see how the factors affect the slump, scroll down on this same worksheet to see the scatter/trend plots.

The Factor Effects Plot shows the relative factor effects. The bars show the amount of variability explained by each factor scaled by the variance of the repeatability. If a factor effect bar is less than 1, then that factor effect is less than the estimated repeatability and thus is not large enough to be considered important.

This selection menu allows you to choose different measures of the repeatability for your test. This repeatability is used to scale the bars in the factor effects chart. It is not used in any other place in *SEDOC*. The three choices are as follows:

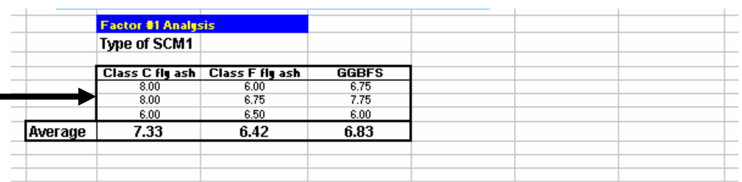
1. Make and test multiple batches of the control or other mixture concrete and use the standard deviation of the test results from this experiment to estimate repeatability.
2. Use the standard deviation or coefficient of variation that is published by ASTM from repeated measurements of the same concrete mixture by various labs that have followed the ASTM standard being used.
3. Use the standard deviation of repeated measurements on the same concrete from your own lab records of the procedure being used. You must enter the standard deviation in the gray shaded cell.

SEDOC: Analysis

Individual Response/Desirability Function Worksheet: Scatter/Trend Plots

Purpose: The Scatter/Trend Plots show how the factors affect the response. All the mixtures are labeled on the scatter plot of factor level versus response and then the trends are shown with line segments. From these plots, it is easy to see which factor level is preferred and how much difference it makes to choose the optimum factor level. It is also a place to check for problems in the data entry or testing issues since many relationships are well known. For example, it is well known that increasing the w/c ratio should decrease the strength of the concrete. If these trends plots do not correspond with well-known relationships, it could indicate data or testing problems. These plots also help to find new unknown trends.

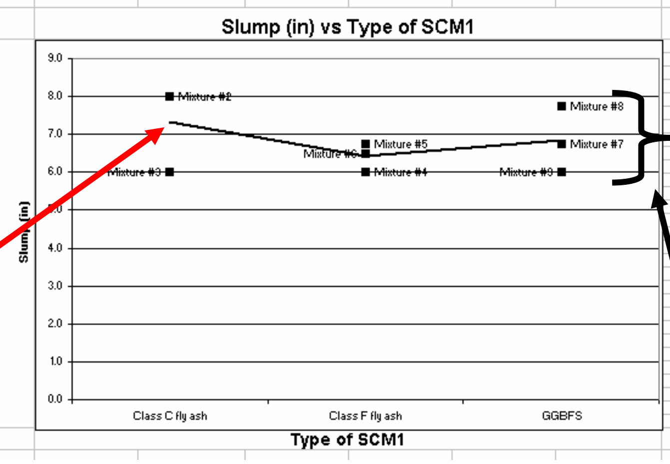
This table shows the data used in the scatter plot and the averages at each factor level that determine the trends.



Factor #1 Analysis

Type of SCM1

	Class C fly ash	Class F fly ash	GGBFS
	8.00	6.00	6.75
	8.00	6.75	7.75
	6.00	6.50	6.00
Average	7.33	6.42	6.83



Example: The trend shows that on average the Class C fly ash has almost an inch more slump than the Class F fly ash and about half an inch more than the slag.

It is expected that there will be a fair amount of spread in the data at each factor level since each of the three points plotted have different levels of the other factors in the experiment (Amount of SCM, silica fume, and w/cm). Thus the trends are often more easily interpreted than the raw plotted data.

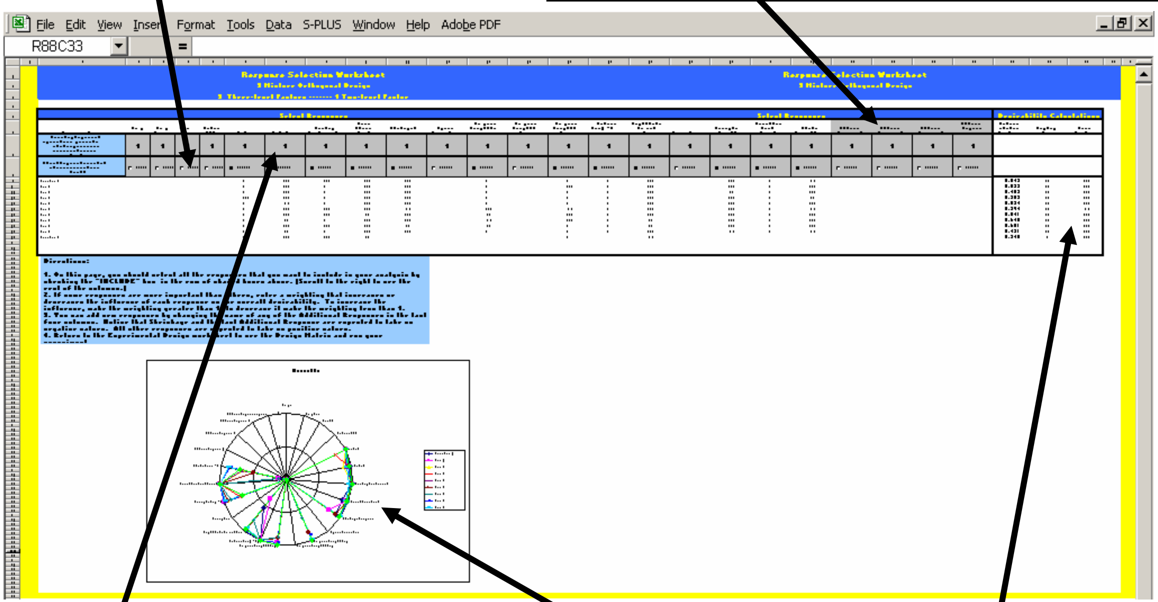
SEDOC: Analysis

Response Selection Worksheet: Overview

Purpose: This worksheet allows you to select and weight the performance tests that are to be run on each of the concrete mixtures in the design matrix.

1. Selection Boxes: This row of check boxes allows you to select the performance tests that will be used in the calculation of the overall desirability.

5. Additional Responses: If you wish to use a performance test that is not included in the spreadsheet, enter the names of the new performance tests in these shaded boxes. The *Individual Response/Desirability Function Worksheet* will also need to be completed.



2. Weights: Typing weights in this shaded row allows you to make certain performance tests more important (in the calculation of the overall desirability) than others by giving them higher weights. The effect the weighting is described on the next page.

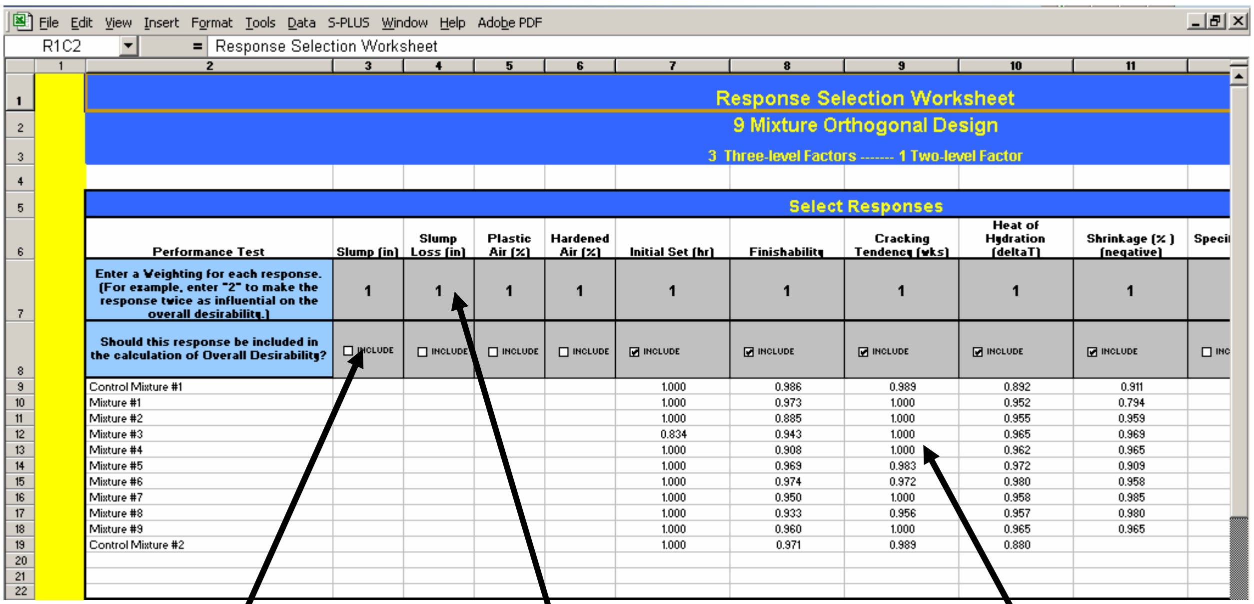
3. Radar Plot: This plot gives a graphical view of the individual desirabilities for each mixture on each response.

4. Calculated Overall Desirability: The overall desirability for each mixture is calculated in the last column.

SEDOC: Analysis

Response Selection Worksheet: Selection Boxes and Weights

Purpose: When the "Include" box is checked for a particular response, then the individual desirability for that response will be included in the overall desirability function with the weight specified in the cell above. The overall desirability is the weighted geometric mean of individual desirabilities for each of the responses. The functional effect of a weight of *n* is that the response is included *n* times during the calculation of that geometric mean. For example, suppose that only 3 responses are selected and the individual desirabilities are 0.98, 0.89, and 0.85 with weights 2, 1, and 1, respectively. The weighted product of the individual desirabilities is $0.98^2 \times 0.89 \times 0.85 = 0.726$. The weighting total is the sum of the included weights. In this example, it is 2+1+1 = 4. The overall desirability is the weighted product raised to the inverse of the weighting total. For the example, the overall desirability is $D = \left(0.98^2 \times 0.89 \times 0.85\right)^{\frac{1}{4}} = \sqrt[4]{0.98^2 \times 0.89 \times 0.85} = 0.923$. Since the individual desirabilities range between 0 and 1, the overall desirability also ranges between 0 and 1 where 0 is unacceptable and 1 is desirable.



Performance Test	Slump (in)	Slump Loss (in)	Plastic Air (%)	Hardened Air (%)	Initial Set (hr)	Finishability	Cracking Tendency (wks)	Heat of Hydration (deltaT)	Shrinkage (%) (negative)	Speci
Enter a Weighting for each response. (For example, enter "2" to make the response twice as influential on the overall desirability.)	1	1	1	1	1	1	1	1	1	
Should this response be included in the calculation of Overall Desirability?	☐ INCLUDE	☐ INCLUDE	☐ INCLUDE	☐ INCLUDE	☑ INCLUDE	☑ INCLUDE	☑ INCLUDE	☑ INCLUDE	☑ INCLUDE	☐ INC
Control Mixture #1					1.000	0.986	0.989	0.892	0.911	
Mixture #1					1.000	0.973	1.000	0.952	0.794	
Mixture #2					1.000	0.885	1.000	0.955	0.959	
Mixture #3					0.834	0.943	1.000	0.965	0.969	
Mixture #4					1.000	0.908	1.000	0.962	0.965	
Mixture #5					1.000	0.969	0.983	0.972	0.909	
Mixture #6					1.000	0.974	0.972	0.980	0.958	
Mixture #7					1.000	0.950	1.000	0.958	0.985	
Mixture #8					1.000	0.933	0.956	0.957	0.980	
Mixture #9					1.000	0.960	1.000	0.965	0.965	
Control Mixture #2					1.000	0.971	0.989	0.880		

Selection Boxes: This row of check boxes allows you to select which performance tests will be included in the calculation of the overall desirability.

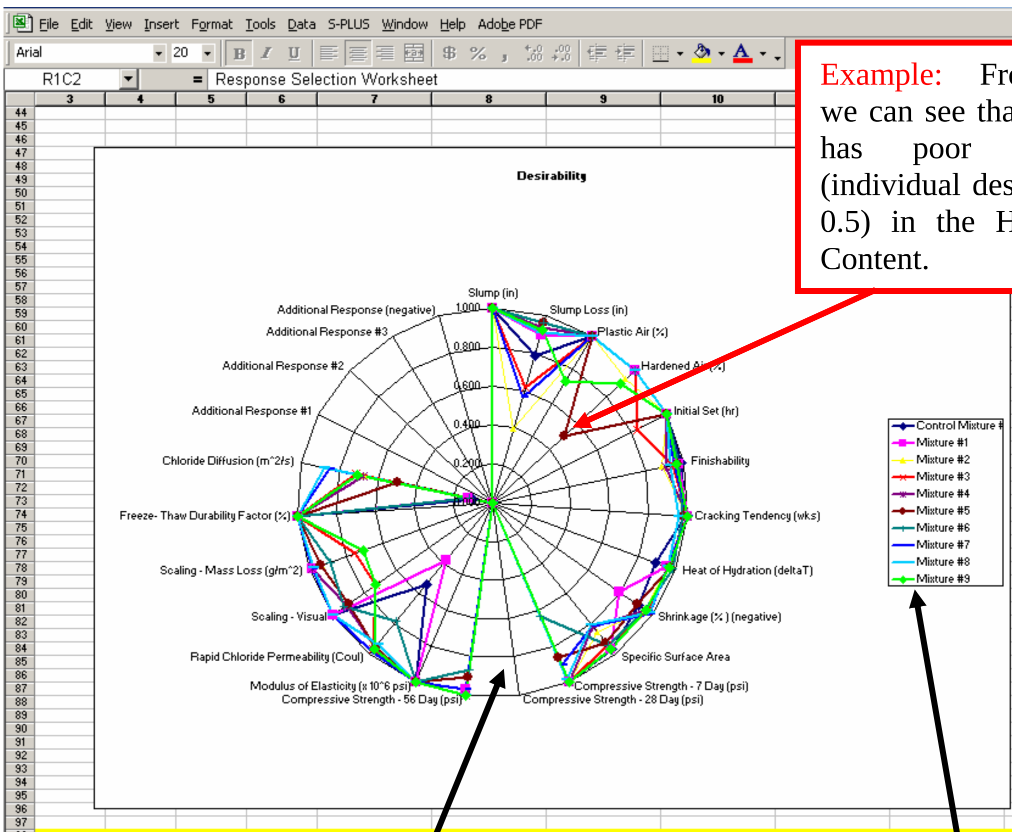
Weights: Entering weights in this shaded row allows you to make certain performance tests more important (in the calculation of the overall desirability) than others by giving them higher weights. By default, all the responses have an equal weighting of 1.

Individual Desirabilities: When the Selection Box is checked, the individual desirabilities are automatically calculated and displayed. The individual desirabilities are calculated from the response data in the *Data Entry Worksheet* and the desirability function on the *Individual Response Worksheet* for each response.

SEDOC: Analysis

Response Selection Worksheet: Radar Plot

Purpose: The radar plot is a graphical view of all the individual desirabilities for each response. Each mixture is shown in a different color with a legend. Since an individual desirability of 0 is at the center of the plot for each response, points that are far from the center of the plot indicate better performance.



Example: From the plot, we can see that Mixture #5 has poor performance (individual desirability near 0.5) in the Hardened Air Content.

Responses Not Included: Responses that are not included (the “Include” box is not checked) are not plotted. In this case, the Compressive Strength at 28 days and the Additional Responses are not included.

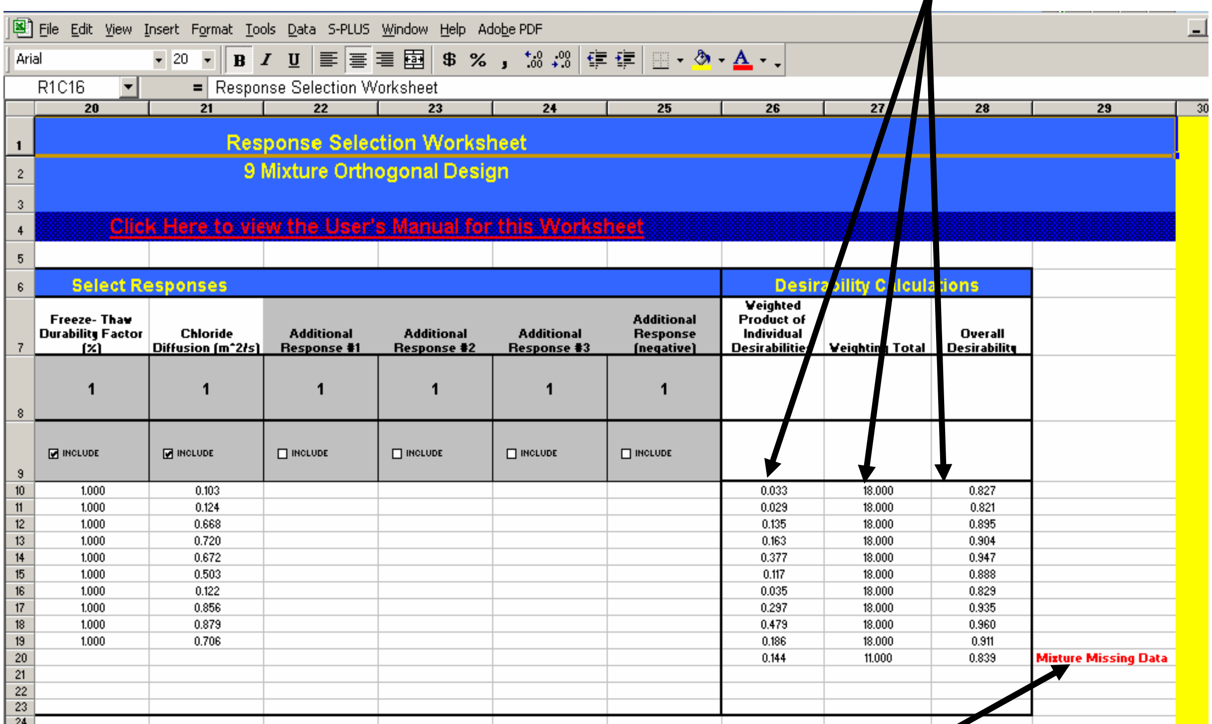
Mixture Legend: This legend shows the symbol and color for plotting each mixture’s individual desirabilities.

SEDOC: Analysis

Response Selection Worksheet: Calculated Overall Desirability

Purpose: The last three columns of this worksheet are used for the calculation of the overall desirability. The first column is the weighted product of each of the individual desirabilities raised to the power of the weight. The overall desirability is the weighted product raised to the inverse of the weighting total. (See the description under *Response Selection Worksheet: Selection Boxes and Weights* for a discussion about how the overall desirability is calculated.)

Columns for calculating the overall desirability



Warning for Missing Data: If a certain mixture does not have data for an included response (i.e., the "Include" box is checked), then fair comparisons of the overall desirability can not be made with the other mixtures since that mixture has a different weighting total. This red warning appears for each mixture that does not have enough data. Whenever this warning appears, this mixture is excluded from consideration for selection as the Best Tested Concrete. (See discussion below of possible alternative strategies for including a mixture in the analysis even if test data is not available for all responses.)

If a mixture is to be considered for the Best Tested Concrete, even though there is no data available for a specific response, then there are two choices:

1. Uncheck the "Include" box for every response with missing data in this row.

2. On the Data Entry Worksheet, enter an estimate for each of the missing data values in this row. Here are three strategies for estimating the missing data values:
    a. Use the best engineering judgment available to estimate the response of that mixture.
    b. Enter the "worst" response from the other mixtures, this will at least make sure that this mixture does not have a higher overall desirability due to missing data. (Worst, in this context, means the response with the lowest individual desirability.)
    c. Use a regression equation with the other mixtures to estimate the response for the mixture with missing data. This prediction is not supported in *SEDOC: Analysis*, but can easily be done with standard Excel Data Analysis Tools or with any standard statistical software package.

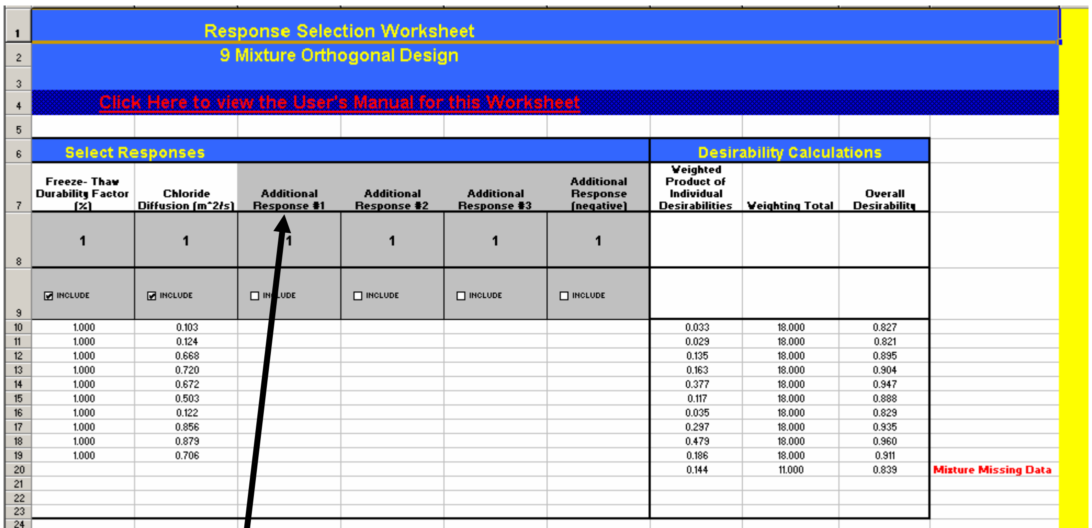
Note: Entering estimates instead of data is dangerous and should not be done lightly. Any conclusions drawn from an analysis of such estimates should not be relied upon for critical application decisions.

SEDOC: Analysis

Response Selection Worksheet: Additional Responses

Purpose: The additional response columns allow performance measures other than the test methods available in *SEDOC: Analysis* to be used. When an additional response is to be included, type in the name of the new performance test (response) in place of one of the Additional Responses in the gray-shaded cells above the column. Since a default desirability function for an unknown response cannot be provided, that function must be defined on the Worksheet for that Additional Response. The Worksheet can be renamed if desired, but this is not done automatically and is also not required. The name typed in to this cell will be used throughout the other worksheets for this new response.

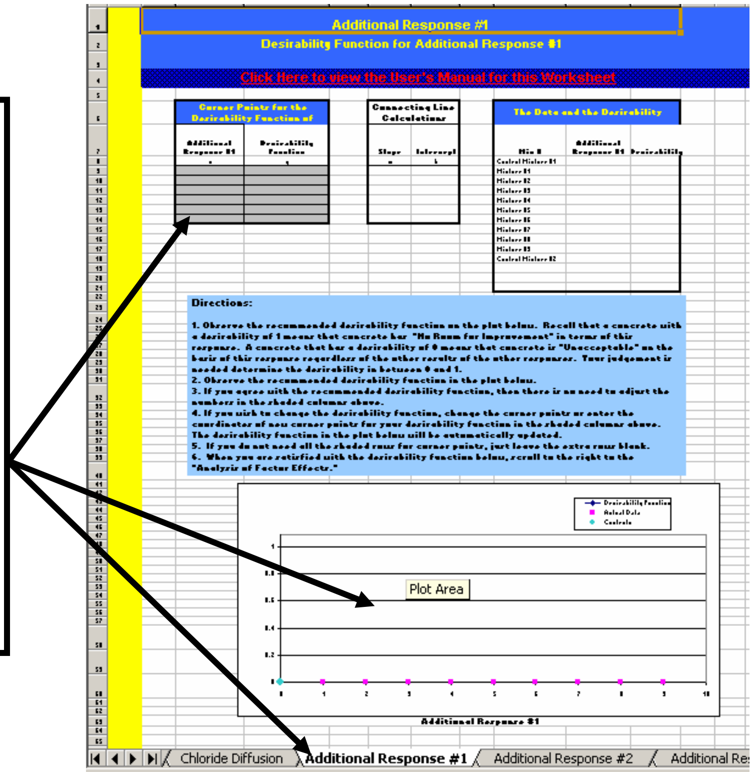
Note: The last column should only be used for a response that will have strictly negative values. (This is significant during modeling calculations.)


Response Selection Worksheet
9 Mixture Orthogonal Design
Click Here to view the User's Manual for this Worksheet

	Select Responses						Desirability Calculations			
7	Freeze- Thaw Durability Factor (%)	Chloride Diffusion (m^2/s)	Additional Response #1	Additional Response #2	Additional Response #3	Additional Response (negative)	Weighted Product of Individual Desirabilities	Weighting Total	Overall Desirability	
8	1	1	1	1	1	1				
9	☑ INCLUDE	☑ INCLUDE	☐ INCLUDE	☐ INCLUDE	☐ INCLUDE	☐ INCLUDE				
10	1.000	0.103					0.033	18.000	0.827	
11	1.000	0.124					0.029	18.000	0.821	
12	1.000	0.668					0.135	18.000	0.895	
13	1.000	0.720					0.163	18.000	0.904	
14	1.000	0.672					0.377	18.000	0.947	
15	1.000	0.503					0.117	18.000	0.888	
16	1.000	0.122					0.035	18.000	0.829	
17	1.000	0.856					0.297	18.000	0.935	
18	1.000	0.879					0.479	18.000	0.960	
19	1.000	0.706					0.186	18.000	0.911	
20							0.144	11.000	0.839	Mixture Missing Data

Additional Responses: To add an additional response, type the name of the response into these gray cells. The first three columns are for responses that take on only positive values, the last response is for a response that takes on negative values.

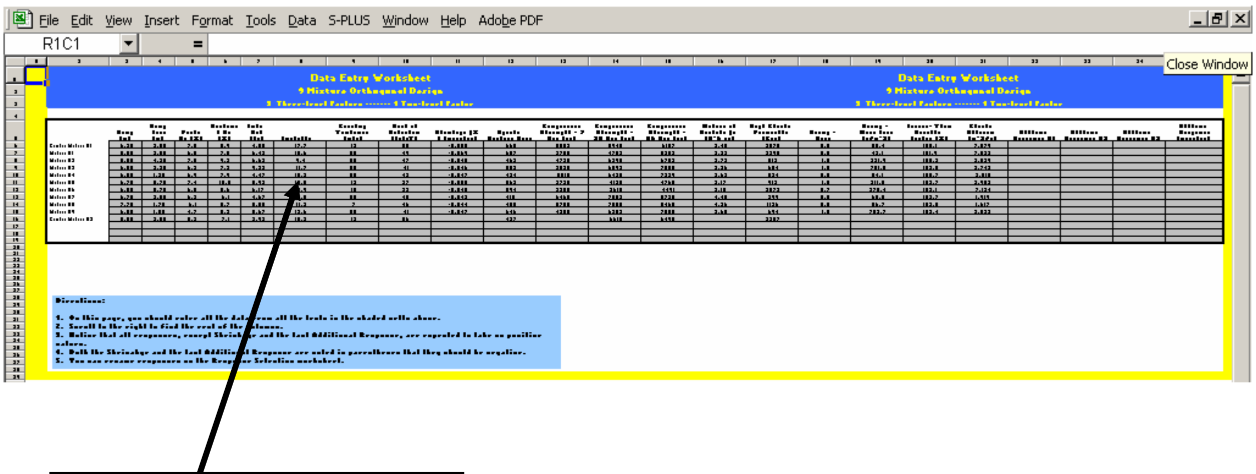
Additional Response Worksheet: To use an additional response, you must provide a desirability function. This is done on the Individual Worksheet for that Additional Response. An example is shown below for Additional Response #1. Type the corner points for your desirability function into the gray shaded cells and the desirability function will be plotted in the plot below.



SEDOC: Analysis

Data Entry Worksheet: Overview

Purpose: This worksheet is for input of the results from the testing program. This sheet is used for input only; there are no calculations or output on this page.

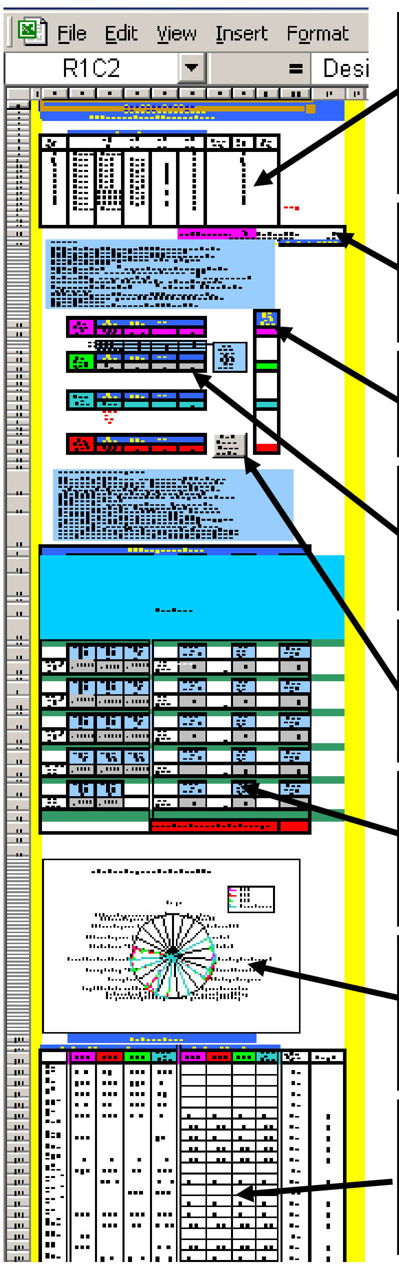


Data Entry Area: Enter the data from each of the performance tests in the gray shaded boxes. If you are not using a particular response, just leave the data blank.

SEDOC: Analysis

Desirability Analysis Worksheet: Overview

Purpose: This worksheet is used to identify the BTC and provides all the statistical modeling and prediction. It controls the execution of the optimization macro that calculates the BPC. The ranges and step sizes for used for that interpolation are defined here. It also provides for the prediction of the performance of a User Selected Concrete (USC), which you, the user, can define to be any mixture within the test space of the experiment.



1. Desirability Calculations: Overall Desirability of each mixture is calculated and the mixtures are ranked. There is also a predicted overall desirability that comes from the regression models.

2. Pseudo R^2: The Pseudo R^2 is an indication of how well the statistical models fit the data. 100% is a perfect fit. A good fit has an R^2 above 85%.

3. The Best Tested Concrete (BTC): The levels and predicted performance of the BTC are given.

4. The User Selected Concrete (USC): These gray-shaded boxes allow the user to type in any set of levels and see the predicted overall desirability for that concrete mixture.

5. The Best Predicted Concrete (BPC): This button starts the macro that calculates the levels for the BPC. The associated levels and a prediction of BPC's overall desirability are listed.

6. Interpolation Control for the BPC calculation: The user can enter ranges and step sizes for interpolation between the specified levels of each factor.

7. Radar Plot: A radar plot compares the individual desirabilities for each response for the BTC, the USC, the BPC and the control concrete.

8. Prediction Center: This table shows the regression model's prediction for each response for the BTC, the USC, the BPC and the control concrete.

SEDOC: Analysis

Desirability Analysis Worksheet: Desirability Calculations

Experimental Design worksheet / Compound Factor Settings / Response Selection / Data Entry / **Desirability Analysis** / Confirmation Analysis / Slump

Purpose: This section of the worksheet shows the design matrix and the overall desirability as calculated from the actual test data. The Best Tested Concrete is the concrete with the highest calculated overall desirability. To assess the accuracy of the prediction models, the predicted overall desirability is also shown for comparison with the calculated overall desirability.

Calculated Overall Desirability: This column gives the overall desirability calculated directly from the test data that is entered on the *Data Entry Worksheet*.

Desirability Rank: The ranking in this column is based on the calculated overall desirability in the column to the left. The highest ranked mixture is declared the Best Tested Concrete (BTC) since it is the best performing concrete that has actual test data.

Predicted Overall Desirability: This column gives a prediction of the overall desirability based on the regression models. If the regression models are working well, these predictions should be very close to the calculated overall desirability.

		Design Matrix								
			Factor 1 (3 levels)	Factor 2 (3 levels)	Factor 3 (3 levels)	Factor 4 (2 levels)				
	Desirability Rank	Names	Type of SCM1	Amount of SCM1	Amount of silica fume	w/cm	Calculated Overall Desirability	Desirability Rank	Predicted Overall Desirability	
9	8	Control Mixture #1	None	0	0	0.4	0.769	8		
10	10	Mixture #1	Class C fly ash	Low	0	0.[illegible]	0.[illegible]53	10	0.753	
11	4	Mixture #2	Class C fly ash	Med	0.05	0.37	0.9[illegible]1	4	0.951	
12	6	Mixture #3	Class C fly ash	High	0.08	0.37	0.92[illegible]	6	0.913	
13	3	Mixture #4	Class F fly ash	Low	0.05	0.37	0.949	3	0.936	
14	7	Mixture #5	Class F fly ash	Med	0.08	0.45	0.903	7	0.903	
15	9	Mixture #6	Class F fly ash	High	0	0.37	0.766	9	0.802	
16	2	Mixture #7	GGBFS	Low	0.08	0.37	0.965	2	0.957	
17	1	Mixture #8	GGBFS	Med	0	0.37	0.965	1	0.965	
18	5	Mixture #9	GGBFS	High	0.05	0.45	0.932	5	0.932	
19		Control Mixture #2	None	0	0	0.4				Mixture Missing Data, Cannot be BTC.
20										
21										
22										
23						Best Tested Concrete=		Mixture #8		Residual SS=
24										Total Corrected SS=

Warning for Missing Data: If a mixture does not have data for an included response (i.e., the "Include" box is checked), then a fair comparison of its desirability with the other mixtures in not possible. Whenever this warning appears, it is because this mixture is missing data and that mixture is eliminated from consideration for selection as the Best Tested Concrete. See *Response Selection Worksheet: Calculated Overall Desirability* for strategies for dealing with this issue, if it is desirable to include that mixture.

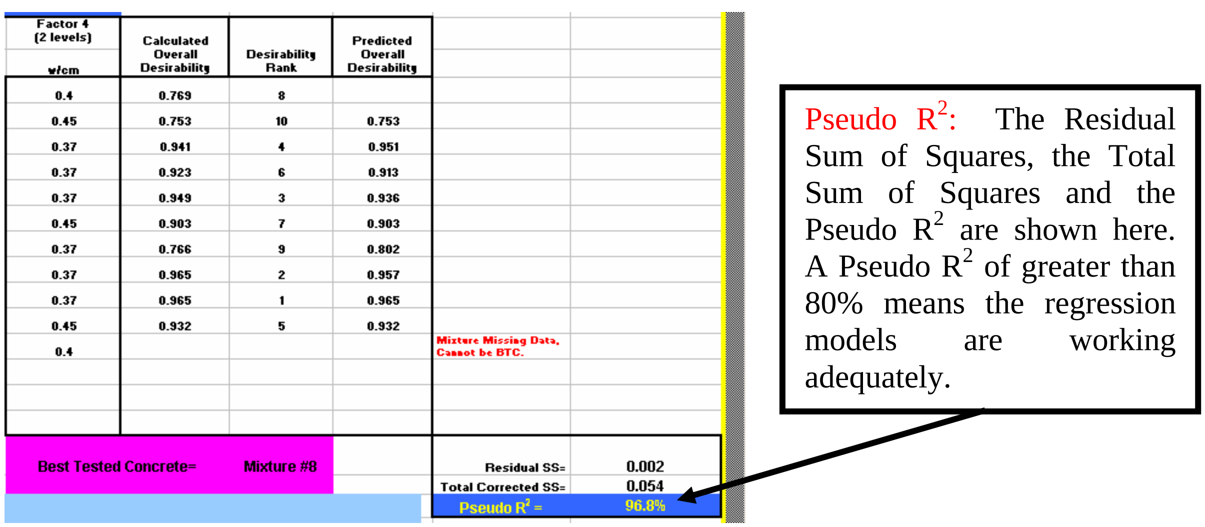
SEDOC: Analysis

Desirability Analysis Worksheet: Pseudo R^2

Purpose: The Pseudo R^2 value is a measure of the accuracy of the prediction models. In standard linear regression, the R^2 value is a value that ranges from 0 to 100%, where 100% means the model fits perfectly and 0% means that the model fits very poorly. The standard R^2 is measured by comparing the Residual SS (the sum of squared differences between the data and the model predictions) with the Total Corrected SS (the sum of squared differences between the data and the data average). The Pseudo R^2 is calculated in exactly the same way, but since the prediction model for the overall desirability is not a standard linear regression, the Pseudo R^2 does not have all the same properties as the standard R^2. This is why we call it Pseudo R^2. However, it can be roughly interpreted in the same way as R^2. Specifically, if the Pseudo R^2 is greater than 80% then the model fits adequately, and if it is above 90%, the model fits very well. The formula for the Pseudo R^2 is:

$$\text{Pseudo R}^2 = \frac{\text{Total Corrected SS-Residual SS}}{\text{Total Corrected SS}}.$$

An example of the calculations for Residual SS and Total Corrected SS is given after the figure that shows where to find the Pseudo R^2 on the worksheet.



Below is an example of the calculation of a Pseudo R^2. The data are the calculated overall desirabilities and the goal is to see how well the regression models are able to predict the overall desirabilities.

Data	Model Prediction	Difference from Predictions	Squared Differences from Predictions	
0.753	0.753	0.000	0.00000	
0.941	0.951	-0.010	0.00009	
0.923	0.913	0.010	0.00011	
0.949	0.936	0.013	0.00017	
0.903	0.903	0.000	0.00000	
0.766	0.802	-0.036	0.00127	
0.965	0.957	0.008	0.00006	
0.965	0.965	0.000	0.00000	
0.932	0.932	0.000	0.00000	
			0.00170	Residual Sum of Squares (SS)

Data	Data Average	Difference from Data Average	Squared Differences from Data Average	
0.753	0.900	-0.146	0.02144	
0.941	0.900	0.042	0.00172	
0.923	0.900	0.023	0.00055	
0.949	0.900	0.049	0.00244	
0.903	0.900	0.003	0.00001	
0.766	0.900	-0.134	0.01786	
0.965	0.900	0.065	0.00421	
0.965	0.900	0.065	0.00424	
0.932	0.900	0.033	0.00107	
			0.05353	Total Corrected Sum of Squares (SS)

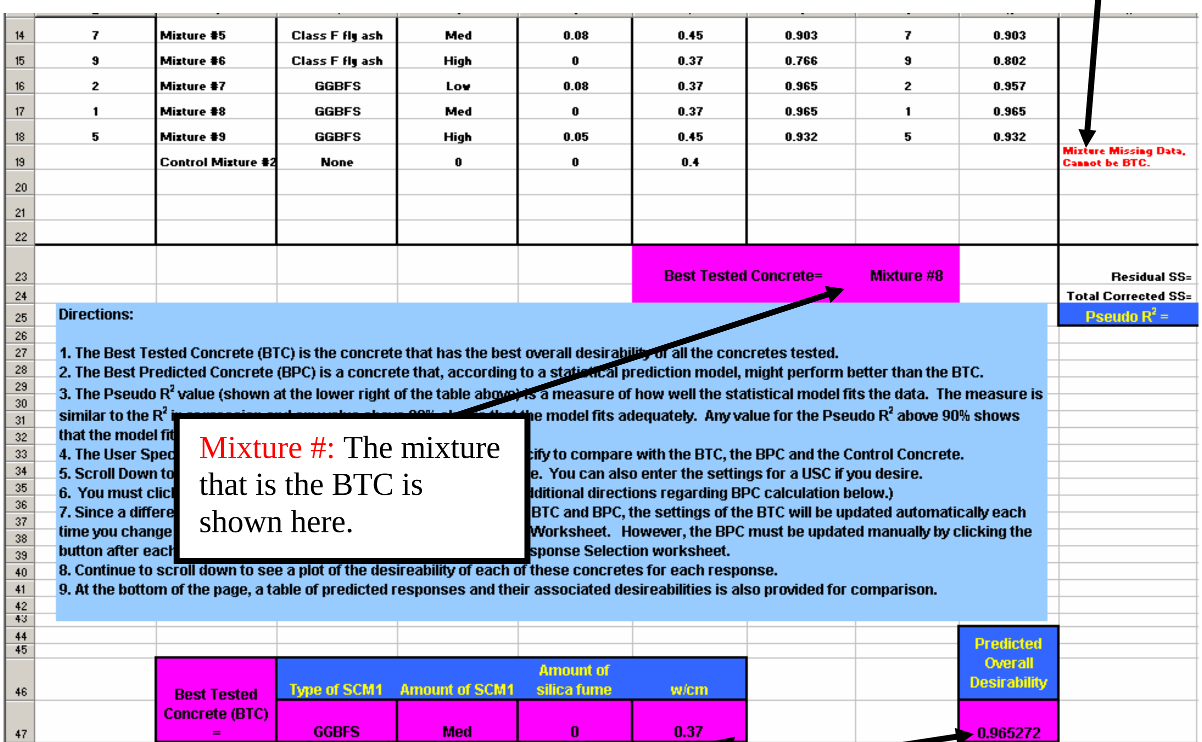
$$\text{Pseudo R}^2 = \frac{\text{Total Corrected SS-Residual SS}}{\text{Total Corrected SS}} = \frac{0.05353 - 0.0017}{0.5353} = 96.8\%$$

SEDOC: Analysis

Desirability Analysis Worksheet: The Best Tested Concrete (BTC)

Purpose: The Best Tested Concrete (BTC) is the concrete mixture that gave the best performance as tested. Best performance simply means that it has the highest calculated overall desirability. Since the overall desirability changes if you change the weights or include different responses on the response selection worksheet, the BTC will be updated anytime a new weight is entered or any of the "Include" boxes are checked or unchecked on the Response Selection Worksheet.

Warning for Missing Data: If a mixture does not have data for an included response (i.e., the "Include" box is checked), then a fair comparison of its desirability with the other mixtures in not possible. Whenever this warning appears, it is because this mixture is missing data and that mixture is eliminated from consideration for selection as the Best Tested Concrete. See *Response Selection Worksheet: Calculated Overall Desirability* for strategies for dealing with this issue, if it is essential to include that mixture.



Mixture #: The mixture that is the BTC is shown here.

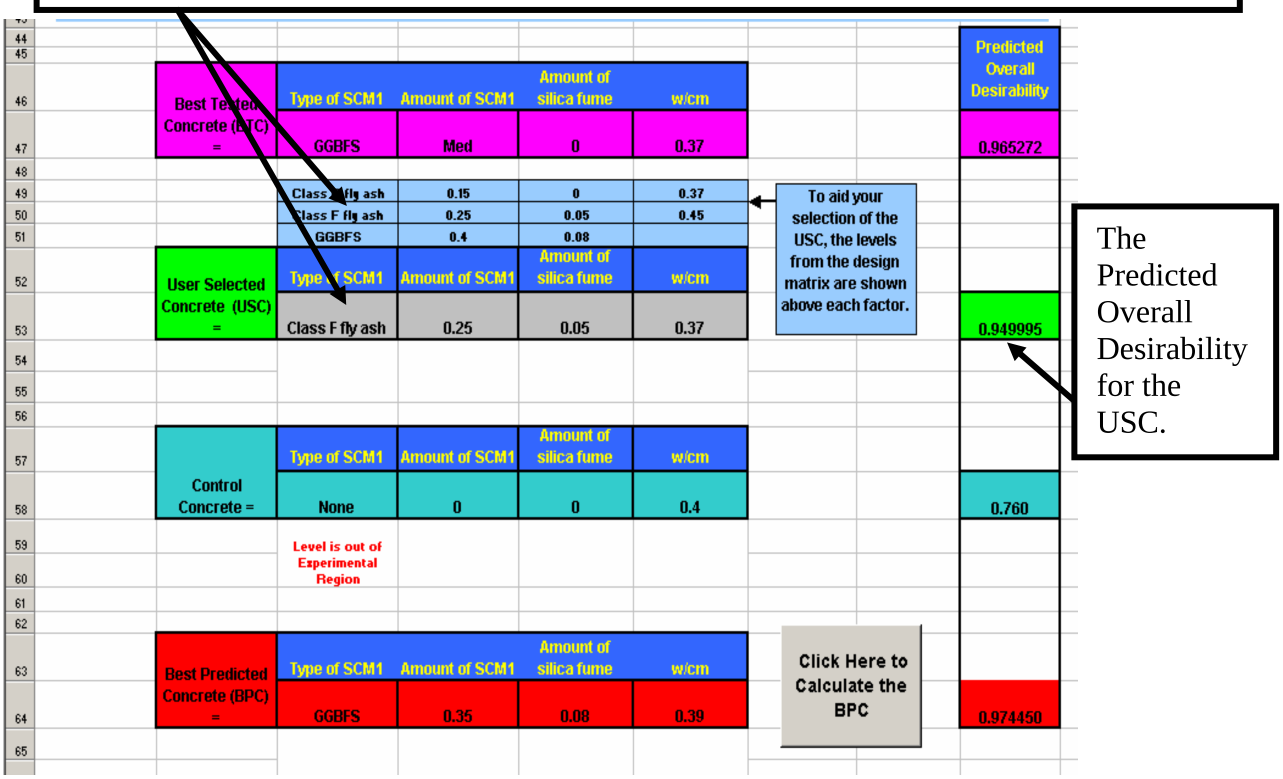
The Best Predicted Concrete: The levels for each of the factors for the BTC are shown here with the overall desirability as predicted by the regression models.

SEDOC: Analysis

Desirability Analysis Worksheet: The User Selected Concrete (USC)

Purpose: The user selected concrete (USC) can be any concrete mixture selected by you, the user, from the experimental test space. The performance of this mixture is modeled and the individual responses and desirabilities and the overall desirability are predicted. The USC is determined by entering levels for each factor in the gray-shaded cells provided. The USC allows the comparison of any mixture with the BTC and BPC. For example, it may be that a certain SCM is very expensive and both the BTC and the BPC call for a high level of that SCM. If you wanted to know how much performance would be lost by lowering the level of that SCM, you could type in a concrete mixture with a lower level of that SCM into the USC and then compare the overall desirability with the overall desirability of the BTC and the BPC. In the Prediction Center at the bottom of this worksheet, the predicted value of each of the individual responses for the USC, the BTC, the BPC, and the Control Concrete can be compared.

The User Selected Concrete (USC): Enter a set of feasible levels for each factor in the gray-shaded cells and this becomes the USC. The light blue table above the factors shows you the levels of the factors that are used in the design matrix. If the factor is a Type Factor, then the USC must use one of the levels of that factor in the table. The syntax of the name of that level must match exactly. However, if the factor levels are numerical, then any reasonable numerical value can be entered.
Note: If you type in a level that is outside the range of the levels in the design matrix, then the models will be extrapolating and may have substantial errors in their prediction of the responses and the desirability. A warning will appear to let you know when the model predictions are outside the experimental region.

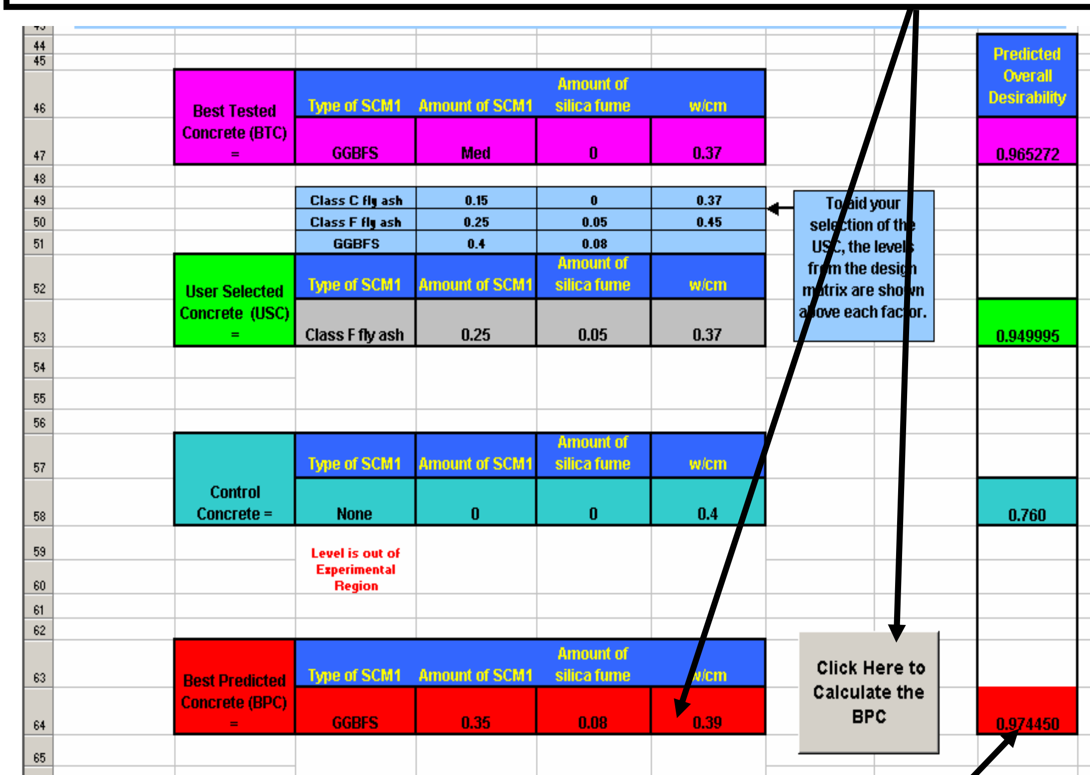


SEDOC: Analysis

Desirability Analysis Worksheet: The Best Predicted Concrete (BPC)

Purpose: The Best Predicted Concrete (BPC) is the concrete mixture that has the highest predicted overall desirability from all the possible combination of levels for all factors for the factor levels in a user-defined grid. It is determined by an Excel macro that cycles through all of the combinations of the levels and saves the combination that resulted in the highest predicted overall desirability. The macro is executed by clicking on the button in the worksheet.

The Best Predicted Concrete: When this "button" is clicked, an Excel macro will execute that will sequentially fill in a large number of factor levels into the red cells for the BPC. As it executes, it will predict the overall desirability for each of these factor level combinations using the regression models. At the completion of the macro, the red cells will contain the combination of factor levels that had the highest predicted overall desirability. (See the *Desirability Analysis Worksheet: Prediction Center* for a discussion about how this prediction is preformed.) This is the BPC. By default, the grid of factor levels is simply all possible combinations of the factor levels that you typed into the "Factor and Levels Table" on the *Experimental Design Worksheet*. However, the grid can be refined by using the "Interpolation Control for the BTC Calculation" that is located lower down on this worksheet.

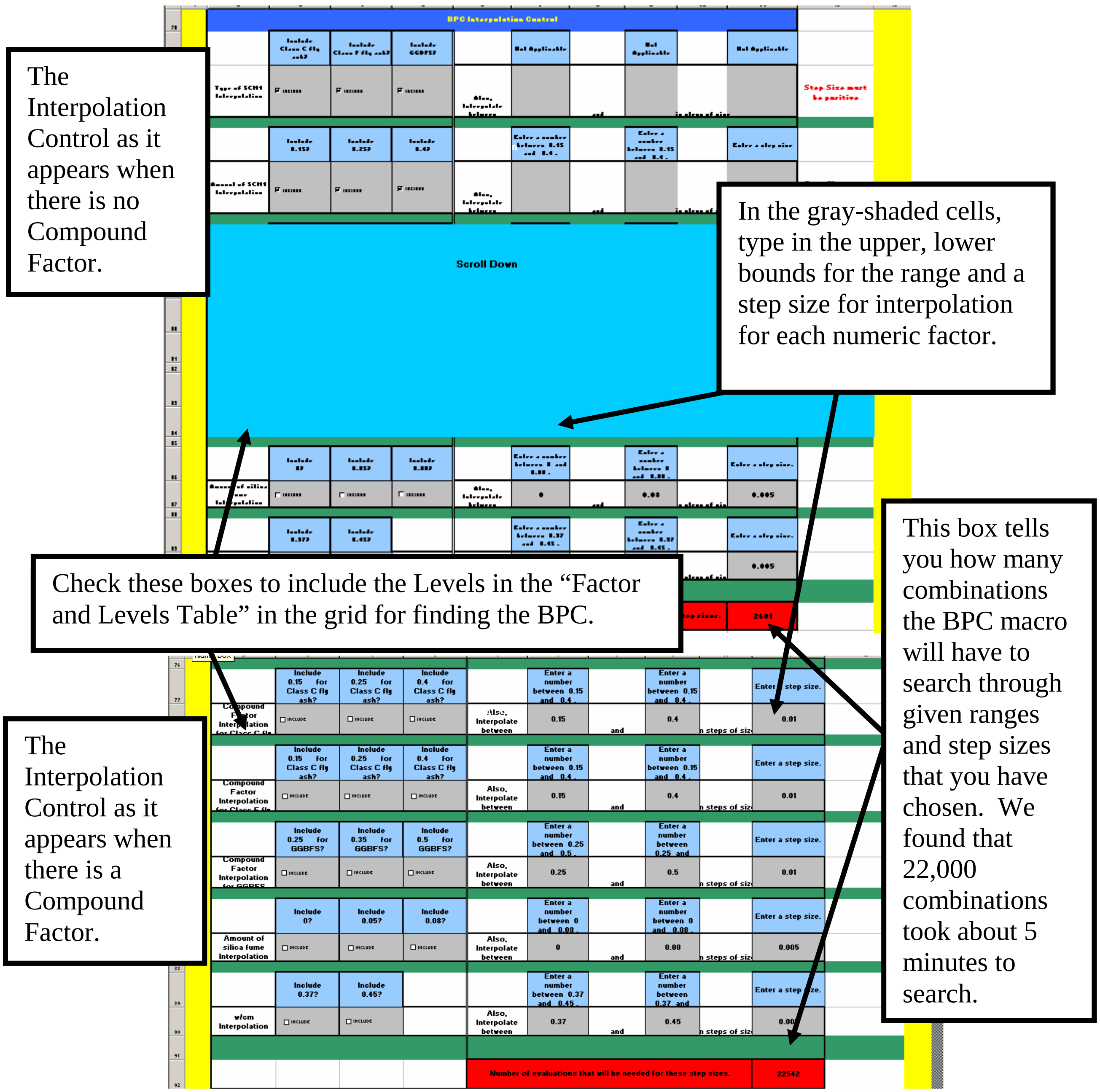


The Predicted Overall Desirability for the BPC.

SEDOC: Analysis

Desirability Analysis Worksheet: Interpolation Control for the BPC

Purpose: This control center allows you to control the grid of factor-level combinations that are checked by the Excel macro that is searching for the BPC. For each factor, you can check a box to include or exclude the levels in the "Factors and Levels Table" on the *Experimental Design Worksheet*. For Amount Factors, an upper and lower bound for a range are required, as well as a step size. The macro will then check all levels of that factor starting at the lower bound and at every step increment until the upper bound is reached. The smaller the step size, the longer the BPC calculation will take to complete.

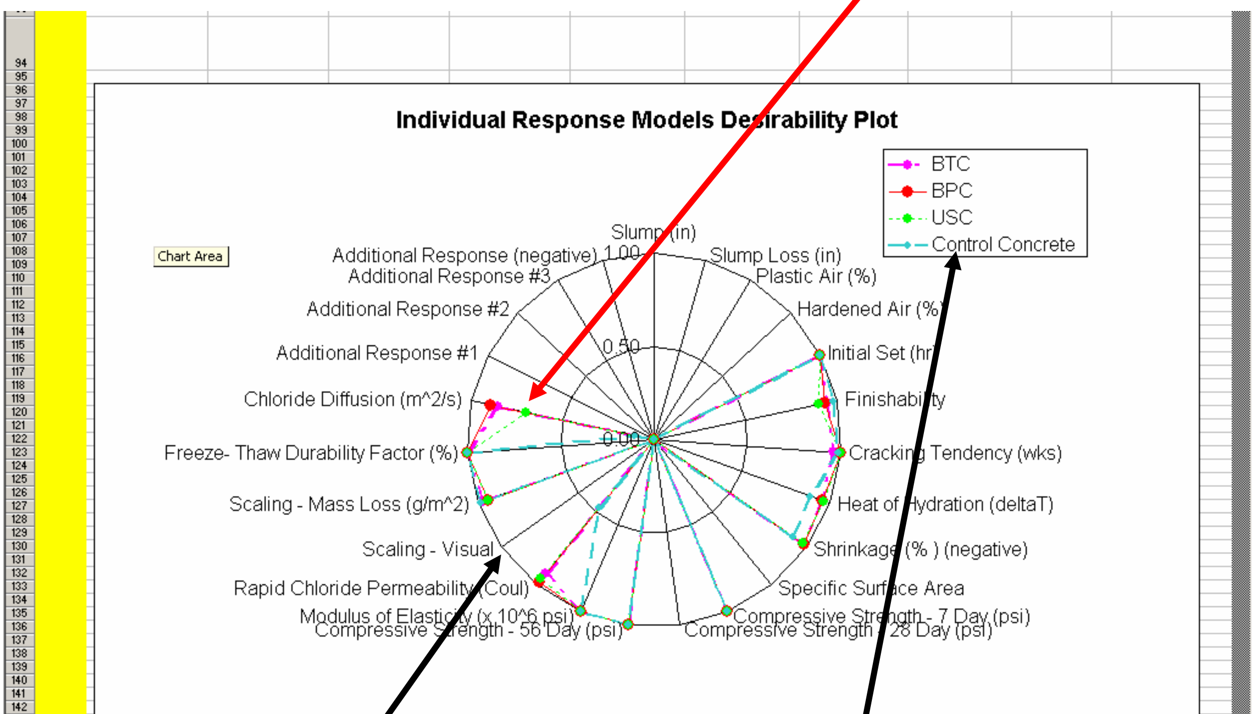


SEDOC: Analysis

Desirability Analysis Worksheet: Radar Plot

Purpose: The radar plot is a graphical view of all the individual desirabilities comparing the BTC, the BPC, the control concrete, and the USC. Since an individual desirability of 0 is at the center of the plot for each response, points that are far from the center of the plot indicate better performance.

Example: From the plot, we can see that the USC has relatively poor predicted performance (individual desirability near 0.7) in the Chloride Diffusion Test.



Responses Not Included: Responses that are not included (the "Include" box is not checked) are not plotted. In this case, the Scaling – Visual Response is one of the responses that is not included.

Mixture Legend: This legend shows the symbol and color for plotting each mixture's individual desirabilities.

SEDOC: Analysis

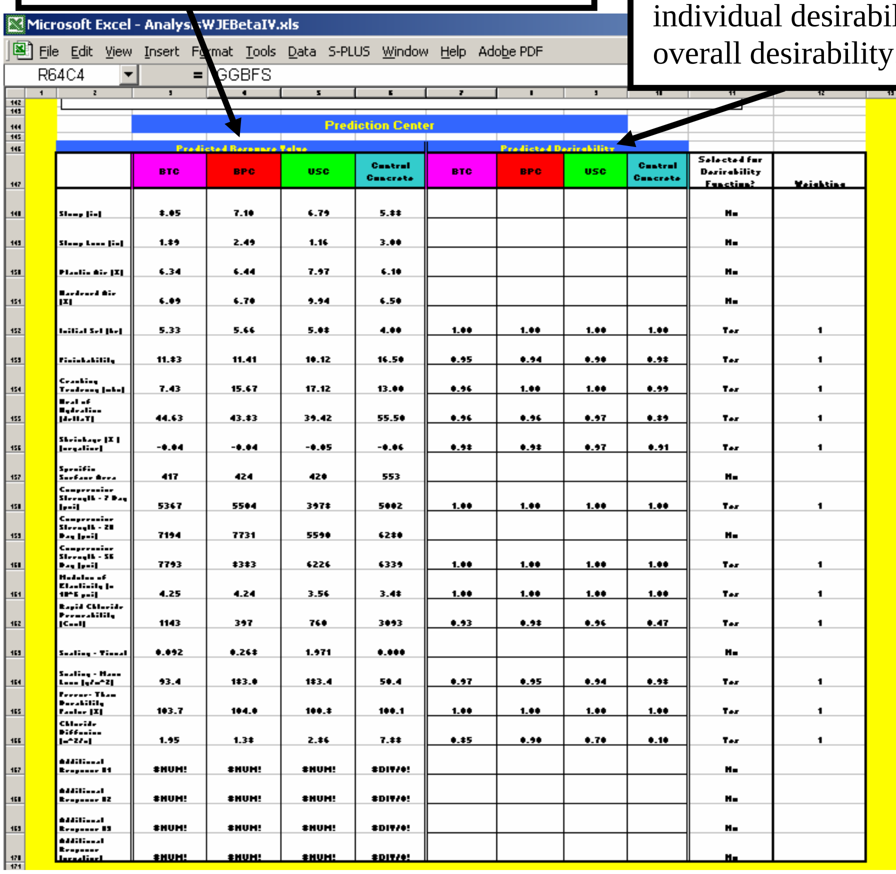
Desirability Analysis Worksheet: Prediction Center

Purpose: The prediction center shows all the predicted responses and associated desirabilities of the statistical models for the USC, the BTC, and the BPC. The prediction center is a place where you can find out in what way the BPC is expected to be better than the BTC. The expected performance of these two mixtures on each response can be compared to determine if the BPC is expected to be a substantial improvement over the BTC.

The predictions are generated using the following procedure: First, each individual response is modeled with a regression model for each factor. These predicted responses are converted to individual desirabilities using the desirability function for each response. These predicted individual desirabilities are then converted into a predicted overall desirability using the weights specified on the Response Selection Worksheet. This is the predicted overall desirability that is displayed above for comparison of the USC, the BTC, and the BPC. Since the control concrete often cannot be predicted with a regression model, because the levels of the control mixture are often outside of the tested ranges, the average of all the control mixtures is shown instead.

This half of the table shows the predictions of the regression models for each of the responses for the BTC, the BPC, and the USC.

This half of the table shows the individual desirabilities of the predicted responses on the other side of the table. The weighted geometric mean of the individual desirabilities is the predicted overall desirability.



Prediction Center

	Predicted Response Value				Predicted Desirability					
	BTC	BPC	USC	Control Concrete	BTC	BPC	USC	Control Concrete	Selected for Desirability Function?	Weighting
Slump [in]	8.05	7.10	6.79	5.88					No	
Slump Loss [in]	1.89	2.49	1.16	3.00					No	
Plastic Air [%]	6.34	6.44	7.97	6.10					No	
Hardened Air [%]	6.09	6.70	9.94	6.50					No	
Initial Set [hr]	5.33	5.66	5.08	4.00	1.00	1.00	1.00	1.00	Yes	1
Finishability	11.83	11.41	10.12	16.50	0.95	0.94	0.90	0.98	Yes	1
Cracking Tendency [mils]	7.43	15.67	17.12	13.00	0.96	1.00	1.00	0.99	Yes	1
Heat of Hydration [deltaT]	44.63	43.83	39.42	55.50	0.96	0.96	0.97	0.89	Yes	1
Shrinkage [%] [negative]	-0.04	-0.04	-0.05	-0.06	0.98	0.98	0.97	0.91	Yes	1
Specific Surface Area	417	424	420	553					No	
Compressive Strength - 7 Day [psi]	5367	5504	3978	5002	1.00	1.00	1.00	1.00	Yes	1
Compressive Strength - 28 Day [psi]	7194	7731	5590	6280					No	
Compressive Strength - 56 Day [psi]	7793	8383	6226	6339	1.00	1.00	1.00	1.00	Yes	1
Modulus of Elasticity [x 10^6 psi]	4.25	4.24	3.56	3.48	1.00	1.00	1.00	1.00	Yes	1
Rapid Chloride Permeability [Coul]	1143	397	760	3093	0.93	0.98	0.96	0.47	Yes	1
Scaling - Visual	0.092	0.268	1.971	0.000					No	
Scaling - Mass Loss [g/m^2]	93.4	183.0	183.4	50.4	0.97	0.95	0.94	0.98	Yes	1
Freeze-Thaw Durability Factor [%]	103.7	104.0	100.8	100.1	1.00	1.00	1.00	1.00	Yes	1
Chloride Diffusion [m^2/s]	1.95	1.38	2.86	7.88	0.85	0.90	0.70	0.10	Yes	1
Additional Response #1	#NUM!	#NUM!	#NUM!	#DIV/0!					No	
Additional Response #2	#NUM!	#NUM!	#NUM!	#DIV/0!					No	
Additional Response #3	#NUM!	#NUM!	#NUM!	#DIV/0!					No	
Additional Response [negative]	#NUM!	#NUM!	#NUM!	#DIV/0!					No	

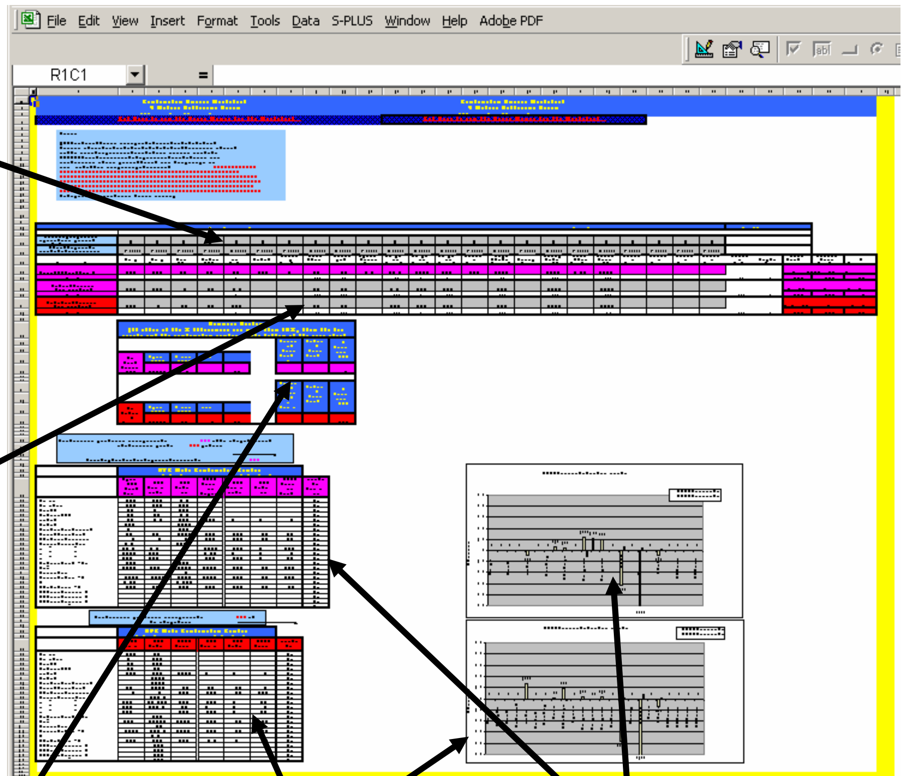
SEDOC: Analysis

Confirmation Analysis Worksheet: Overview

Purpose: This worksheet allows for the selection of the responses to be used for Confirmation Testing, and for the comparison of the BTC and BPC Confirmation testing results. After the confirmation test data is input, this worksheet provides a side-by-side comparison of the two confirmation batches for each response and desirability. A comparison of the model predictions for each response with the actual Confirmation Test results is also provided.

1. Confirmation Response Selection: Use the row of click boxes and weights to choose which performance tests will be run on the confirmation batches of the BTC and BPC.

2. Confirmation Data Entry: Use the row of shaded boxes to enter the data from your confirmation testing.



3. Overall Desirability Comparison: The overall desirability of the BTC and BPC Confirmation batches is provided and compared to the predicted overall desirability.

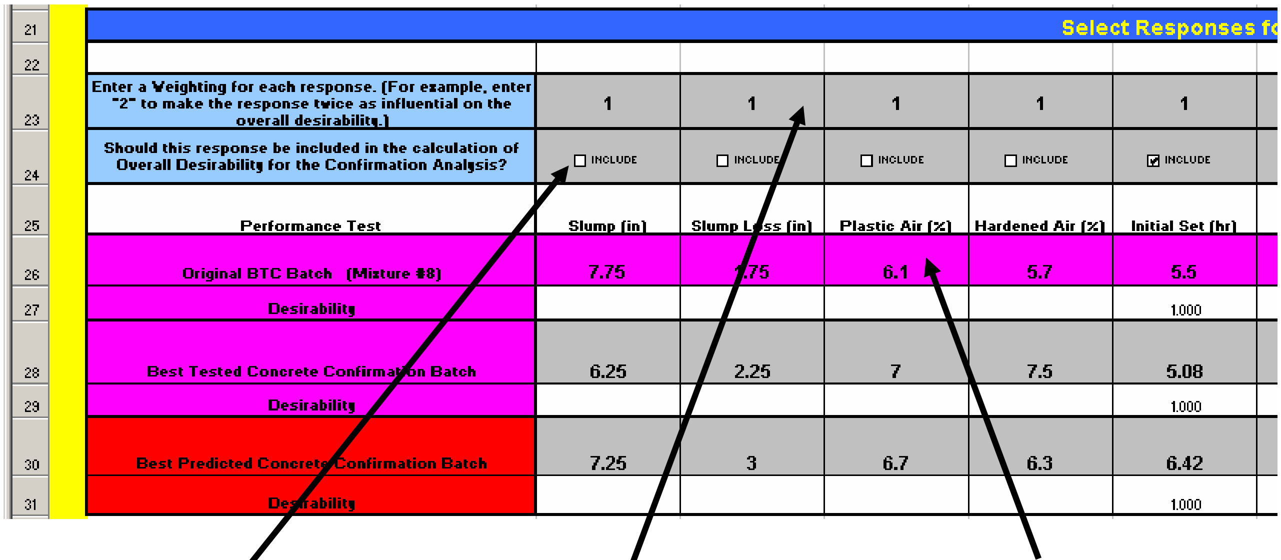
4. BPC Model Evaluation: A bar graph and a table compare the predictions of the statistical model with the actual results of the BPC Confirmation batch.

5. BTC Model Evaluation: A bar graph and a table compare the predictions of the statistical model with the actual results of the BTC Confirmation batch.

SEDOC: Analysis

Confirmation Analysis Worksheet: Confirmation Response Selection

Purpose: This section of the worksheet is for the selection and weighting of the responses that are used for Confirmation Testing. The overall desirability of the original batch of BTC using only these weights and responses is also provided for reference.



Selection Boxes: Use the row of click boxes to choose which performance will be run on the Confirmation batches of the BTC and BPC.

Weights: In the gray-shaded cells, type in the weights for the responses for comparing the BTC to the BPC.

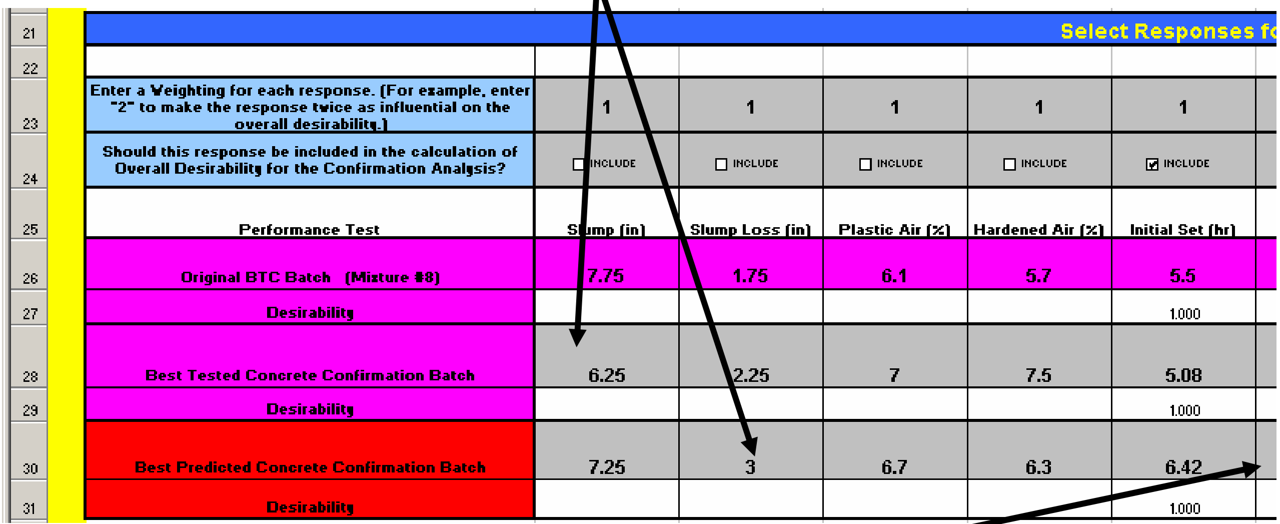
Results from the original BTC batch: For reference, the pink row shows the results from the original BTC batch.

SEDOC: Analysis

Confirmation Analysis Worksheet: Confirmation Data Entry

Purpose: This area of the worksheet is used to enter and analyze the data from the confirmation batches of BTC and BPC.

Data entry: Type in data in these rows of gray-shaded cells.



21						Select Responses fo
22						
23	Enter a Weighting for each response. (For example, enter "2" to make the response twice as influential on the overall desirability.)	1	1	1	1	1
24	Should this response be included in the calculation of Overall Desirability for the Confirmation Analysis?	☐ INCLUDE	☐ INCLUDE	☐ INCLUDE	☐ INCLUDE	☑ INCLUDE
25	Performance Test	Slump (in)	Slump Loss (in)	Plastic Air (%)	Hardened Air (%)	Initial Set (hr)
26	Original BTC Batch (Mixture #8)	7.75	1.75	6.1	5.7	5.5
27	Desirability					1.000
28	Best Tested Concrete Confirmation Batch	6.25	2.25	7	7.5	5.08
29	Desirability					1.000
30	Best Predicted Concrete Confirmation Batch	7.25	3	6.7	6.3	6.42
31	Desirability					1.000

Missing Data: If an important performance test cannot be run on one or both of the confirmation batches, then an estimate of the performance can be used but only with great caution. See *Response Selection Worksheet: Calculated Overall Desirability* for strategies for dealing with this issue, if it is essential to include that mixture.
Note: Entering estimates instead of data is dangerous and should not be done lightly. Any conclusions drawn from an analysis of such estimates should not be relied upon for critical application decisions.

SEDOC: Analysis

Confirmation Analysis Worksheet: Overall Desirability Comparison

Experimental Design worksheet / Compound Factor Settings / Response Selection / Data Entry / Desirability Analysis / Confirmation Analysis / Slump /

Purpose: The overall desirability of the two confirmation batches are compared with each other and with the predictions from the regression models in this section of the worksheet.

Summary Section
(If either of the % differences are more than 10%, then the bar graphs and the confirmation center at the bottom of this page should be consulted to see which responses have not been predicted well.)

	Type of SCM1	Amount of SCM1	Amount of silica fume	w/cm		Calculated Overall Desirability of Confirmation Mixture	Predicted Overall Desirability	% Difference for BTC
Best Tested Concrete (BTC) =	GGBFS	Med	0	0.37		0.964446	0.964489	0.00%

	Type of SCM1	Amount of SCM1	Amount of silica fume	w/cm		Calculated Overall Desirability of Confirmation Mixture	Predicted Overall Desirability	% Difference for BPC
Best Predicted Concrete (BPC) =	GGBFS	0.35	0.08	0.39		0.975415	0.973285	0.22%

Overall Desirability Comparison: The overall desirability of the BTC and BPC confirmation batches is shown and the percent difference from the predictions is calculated. If the percent difference is greater than 10%, some investigation should be done to determine if there is a data entry error. If no error can be found, then the regression models are unable to accurately predict and should not be trusted.

SEDOC: Analysis

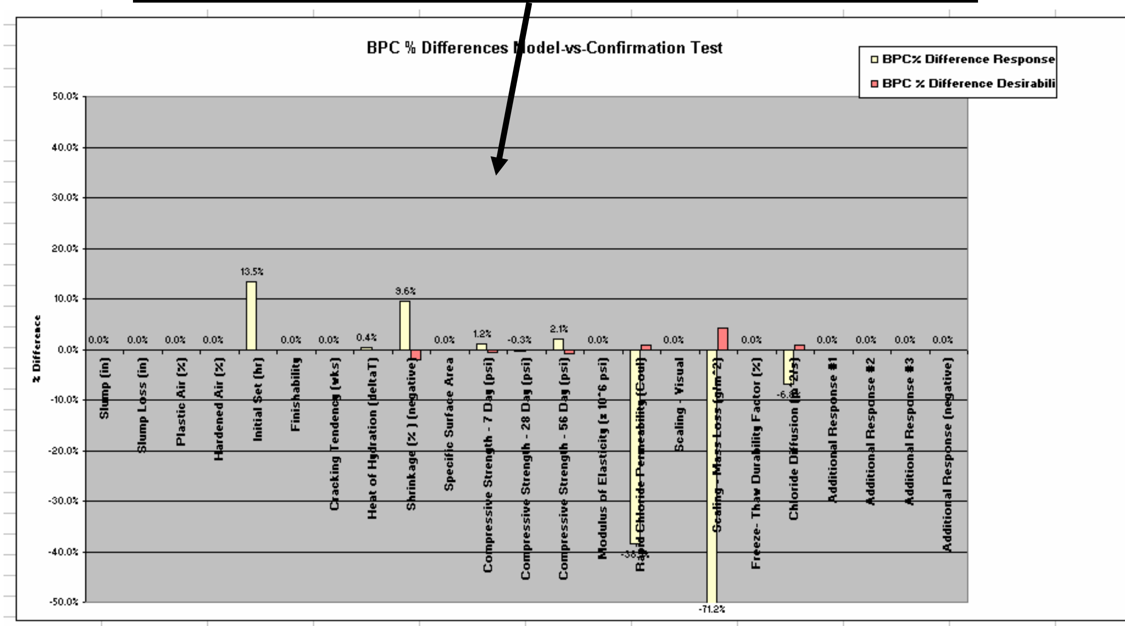
Confirmation Analysis Worksheet: BPC Model Evaluation

Purpose: This part of the worksheet provides a comparison of the BPC model predictions for each response with the actual test results.

	BPC Model Confirmation Center Individual Responses			Individual Desirabilities			
	BPC Confirmation Test	BPC Prediction	BPC% Difference Response	BPC Confirmation Test	BPC Prediction	BPC % Difference Desirability	Included in Confirmation Test?
Slump (in)	7.25	7.10					No
Slump Loss (in)	3.00	2.49					No
Plastic Air (%)	6.70	6.44					No
Hardened Air (%)	6.30	6.70					No
Initial Set (hr)	6.42	5.66	13.5%	1.000	1.00	0.0%	Yes
Finishability		11.41					No
Cracking Tendency (wks)		15.67					No
Heat of Hydration (deltaT)	44.00	43.83	0.4%	0.960	0.96	0.0%	Yes
Shrinkage (%) (negative)	-0.05	-0.04	9.6%	0.962	0.98	-2.1%	Yes
Specific Surface Area		424.06					No
Compressive Strength - 7 Day (psi)	5570.00	5503.86	1.2%	0.993	1.00	-0.7%	Yes
Compressive Strength - 28 Day (psi)	7710.00	7730.90	-0.3%	1.000	1.00	0.0%	Yes
Compressive Strength - 56 Day (psi)	8560.00	8383.16	2.1%	0.992	1.00	-0.8%	Yes
Modulus of Elasticity (x 10^6 psi)		4.24					No
Rapid Chloride Permeability (Coul)	244.00	396.63	-38.5%	0.988	0.98	0.8%	Yes
Scaling - Visual	0.00	0.27					No
Scaling - Mass Loss (g/m^2)	52.78	183.02	-71.2%	0.98[illegible]	0.95	4.1%	Yes
Freeze- Thaw Durability Factor (%)		10[illegible].00					No
Chloride Diffusion (m^2/s)	1.28	1.38	-6.8%	0.9[illegible]4	0.90	0.8%	Yes
Additional Response #1		#NUM!					No
Additional Response #2		#NUM!					No
Additional Response #3		#NUM!					No
Additional Response (negative)		#NUM!					No

Results from the confirmation BPC batch.

A bar chart shows the percent difference of the confirmation batch from the prediction for each response.



SEDOC: Analysis

Confirmation Analysis Worksheet: BTC Model Evaluation

Purpose: This part of the worksheet provides a comparison of the BTC model predictions for each response with the actual confirmation test results.

	BTC Model Confirmation Center							
	Individual Responses				Individual Desirabilities			
	Original BTC Batch (Mixture #8)	BTC Confirmation Test	BTC Prediction	BTC % Difference Response	BTC Confirmation Test	BTC Prediction	BTC % Difference Desirability	Included in Confirmation Test?
Slump (in)	7.75	6.25	8.05					No
Slump Loss (in)	1.75	2.25	1.89					No
Plastic Air (%)	6.10	7.00	6.34					No
Hardened Air (%)	5.70	7.50	6.09					No
Initial Set (hr)	5.50	5.08	5.33	-4.8%	1.000	1.00	0.0%	Yes
Finishability	11.30		11.83					No
Cracking Tendency (wks)	7.00		7.43					No
Heat of Hydration (deltaT)	46.00	46.00	44.63	3.1%	0.957	0.96	-0.2%	Yes
Shrinkage (%) (negative)	-0.04	-0.05	-0.04	1.7%	0.974	0.98	-0.4%	Yes
Specific Surface Area	408.00		417.00					No
Compressive Strength - 7 Day (psi)	5705.00	6020.00	5366.96	12.2%	0.948	1.00	-5.2%	Yes
Compressive Strength - 28 Day (psi)	7888.00	7970.00	7193.67	10.8%	1.000	1.00	0.0%	Yes
Compressive Strength - 56 Day (psi)	8460.00	8520.00	7792.61	9.3%	0.997	1.00	-0.3%	Yes
Modulus of Elasticity (x 10^6 psi)	4.26		4.25					No
Rapid Chloride Permeability (Coul)	1136.00	778.00	1142.70	-31.9%	0.961	0.93	3.5%	Yes
Scaling - Visual	0.00	0.00	[illegible].09					No
Scaling - Mass Loss (g/m^2)	86.72	24.99	93.4[illegible]	-73.3%	0.993	0.97	2.1%	Yes
Freeze- Thaw Durability Factor (%)	103.80		103.73					No
Chloride Diffusion (m^2/s)	1.62	1.88	1.95	-3.8%	0.859	0.85	0.7%	Yes
Additional Response #1								No
Additional Response #2								No
Additional Response #3								No
Additional Response (negative)								No

Results from the original BTC batch.

Results from the confirmation BTC batch.

A bar chart shows the percent difference of the confirmation batch from the prediction for each response.