

COMPASS USER'S GUIDE

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1. INTRODUCTION

COMPASS stands for Concrete Mixture Performance Analysis System. COMPASS is a windows-based application system that can be used to optimize the materials selection and proportions of paving concrete based on job-specific conditions. To achieve this, COMPASS provides the following capabilities:

- Identify relevant performance criteria that are a function of job-specific inputs such as the importance of the project, type of pavement, climatic conditions, construction constraints, and environmental exposures.
- Identify applicable mixture performance criteria and recommended test methods.
- Assess the impact that changes in materials or proportions, environmental conditions, and construction procedures have on portland cement concrete (PCC) constructability and performance.
- Provide analysis tools for aggregate blending.
- Recommend initial mixture proportions.
- Optimize mixture proportions based on multiple job-specific criteria such as strength, cost, and permeability.

1.1 *Hardware Requirements*

The minimum system required for proper operation of COMPASS is a computer with 128 megabytes (MB) of memory and a processor of at least 500 MHz. The recommended system is a computer with 256 MB of memory and a processor of at least 1 GHz. COMPASS is designed for a screen resolution of 1024 by 768.

1.2 *Operating System Requirements*

COMPASS requires Windows 2000 SP1 or Windows XP Professional.

1.3 *Initiating the Program*

When COMPASS is first opened, the screen shows a menu for File, Edit, and Help (Figure 1). These menus are used to work with project files, modify project options and access help features.

A random "tip of the day" appears each time COMPASS is started. The tip of the day offers useful facts about concrete.

Along the left side of the screen there is a menu with the four computer modules that can be accessed. The computer modules are where the user defines their job-specific inputs and concrete mixture criteria. Each module has the ability to be used independently as a stand-alone tool, or the user can perform a comprehensive analysis using all four modules. Each module builds upon one another's consecutive module's analysis. The computer modules are:

1. Mix Expert,
2. Gradation,
3. Proportioning, and
4. Optimization.

Under each module, a list of most recently used (MRU) files is displayed.

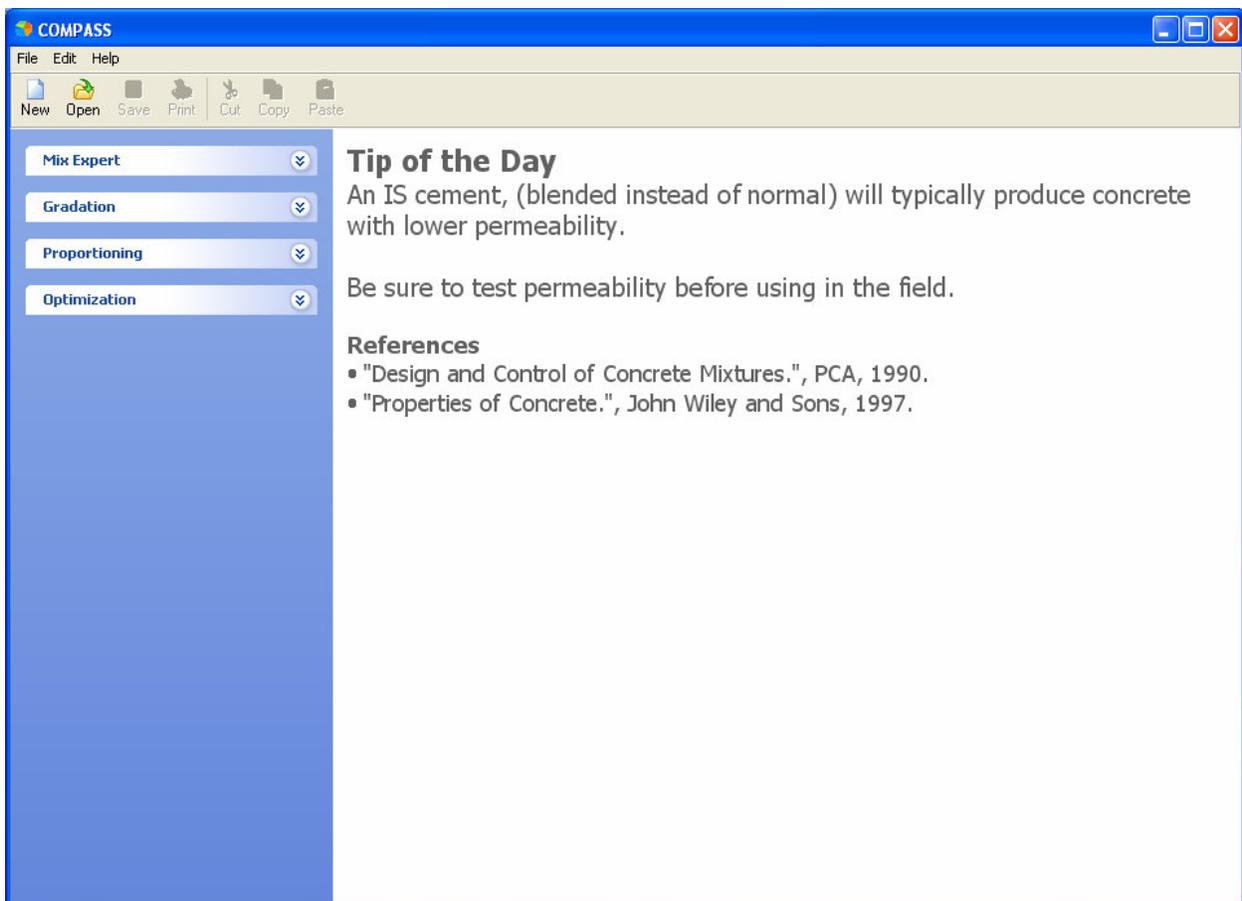


Figure 1: COMPASS Starting Screen

If the user decides to run a comprehensive analysis, the following sequence occurs:

- Identify the performance criteria relative (or important) to job and site-specific conditions. (Module 1 - Mix Expert - Performance Criteria)
- Select materials that best suit the conditions. (Module 1 – Mix Expert - Materials Selection)

- Determine optimal aggregate gradations for maximum packing density and optimal workability (Module 2 - Gradation)
- Determine preliminary mixture proportions. (Module 3 – Proportioning based on ACI 211)
- Optimize the concrete mixture proportions based on job-specific criteria. (Module 4 - Optimization)

The inputs to the first module are cross-referenced with the information in the COMPASS Knowledge Base to help guide the user in identifying the mixture performance criteria and selecting the materials to meet these criteria to optimize the paving mixture for the environment in which their pavement project will be constructed and expected to perform. Modules 2 to 4 include analytical subroutines to optimize materials proportions based on job-specific criteria. The following paragraphs provide a more detailed description of each module.

2. MIX EXPERT

This module consists of a two-stage analysis where mixture performance criteria based on site-specific conditions are identified first and then the user selected materials are evaluated in terms of their effect on the mixture performance criteria of interest.

In the Performance Criteria Analysis, users can select their own mixture design criteria and/or obtain recommendations on design criteria from COMPASS through the knowledge base as a function of site-specific conditions.

Recommended optimization criteria include:

- Slump,
- Set Time,
- Air Content,
- Strength,
- Heat of Hydration
- Temperature of Concrete
- Coefficient of Thermal Expansion
- Shrinkage
- Permeability
- Freeze-Thaw Resistance
- Alkali-Silica Reaction (ASR) Resistance
- Sulfate Resistance
- Corrosion Resistance
- Abrasion Resistance

2.1 General Project Information

To begin the analysis, the general project information can be entered into the program. This is a screen where the user can identify the project and enter specific notes about the project.

2.2 Job-Specific Info

The next screen is the Job-Specific Info screen (Figure 2). This screen includes general job-specific information including:

- **New Construction:** Performance criteria and materials recommendations are provided for concrete to be used in new concrete pavement construction.
- **Patch or Repair:** Additional recommendations specific of patch or repair concrete mixtures are provided.
- **Overlay:** Additional recommendations specific to concrete mixtures used for concrete overlays are provided.
- **Project importance:**
 - **High:** applies to high volume traffic or Interstate highways. For this level in-depth testing with the most sophisticated laboratory equipment and testing procedures is anticipated.
 - **Medium:** corresponds to medium volume traffic or State highways. For this level, less sophisticated laboratory equipment and testing procedures than those used for high importance are recommended.
 - **Low:** applies for low volume traffic/ low priority roads with limited testing budget.
- **Steel Reinforced Pavement:** Applies for presence of any steel in the pavement: This conditions triggers the need to look at designing concrete resistant to corrosion.
- **Construction**
 - **Early Opening:** Refers to the need to open the concrete pavement to traffic soon after construction. This condition triggers the need to look at concrete mixtures that develop higher early-age strengths. A drop down for the Early Opening time provides recommendations on typical mixtures used for different early-opening times. This last option is not currently enabled in this version of the software.
 - **Placement Method**
 - **Slip-form:** When using slip-formed construction, a low slump concrete mixture is recommended to prevent pavement edge slump.
 - **Fixed forms:** A slump of 25-100 mm is recommended for concrete mixtures where fixed forms are used.

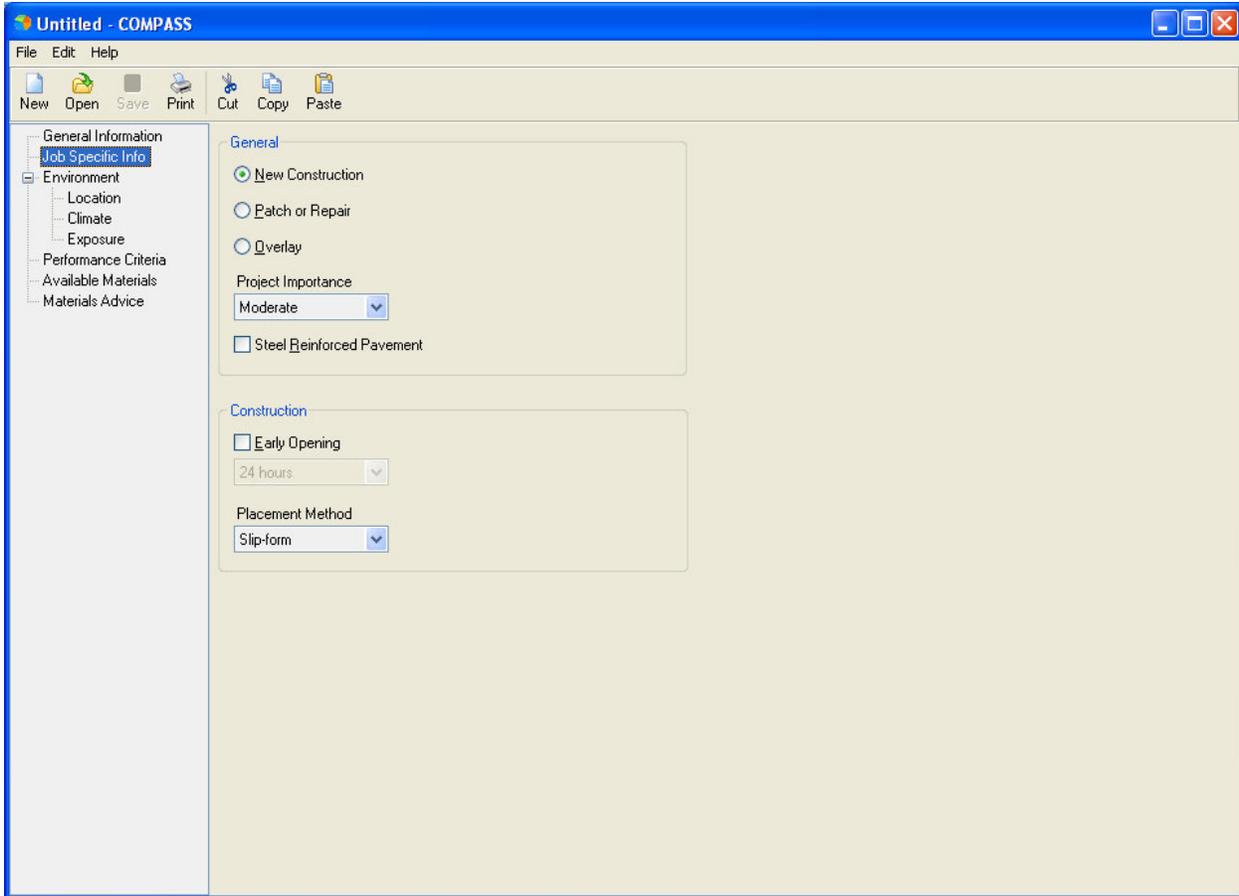


Figure 2: Job Specific Information Input Screen

2.3 Environmental Criteria

After entering the pavement design information, the environmental factors are considered. There are three input screens under environment: location, climate and exposure.

2.3.1. Location

In the Location input screen, the user is able to assess local weather by pin-pointing the location of paving (Figure 3). Location of the project allows extracting historical climatic data for the site where the concrete mixture will be constructed. The climatic weather data is taken from the National Oceanic and Atmospheric Administration (NOAA) weather database. When the project location is selected in COMPASS, the environmental database is queried for weather data from weather stations near the specified location. Using an intelligent algorithm, the most relevant weather stations are selected, and the weather information for the specified location is calculated based on a weighted interpolation scheme. The weather database contains mean hourly readings for the entire year (based on 30 years of historical data) for a number of weather stations distributed nationwide. In other words, the weather data is not current or forecast but historical and the reported information is based on averages of historical data over 30 years for the selected location.

The user can use the navigational arrows and zoom control along the top left corner of the map to locate the project. Once the project site is visually identified, the user can click on the specific location in the map with the mouse. This allows the program to pin-point the location of the project and to attach local weather patterns to the analysis.

Alternatively, the user can enter the latitude and longitude of the paving project under the 'Selected Location' section. The user must click 'Set Location' to lock in that latitude and longitude.

Next to the latitude and longitude boxes, COMPASS shows a dialogue box for the location and weight (%) for the three weather stations that are closest to the paving project. In order to gain accurate weather data, COMPASS considers the three closest weather stations to the paving project and shows the weighted average distribution of those weather stations.

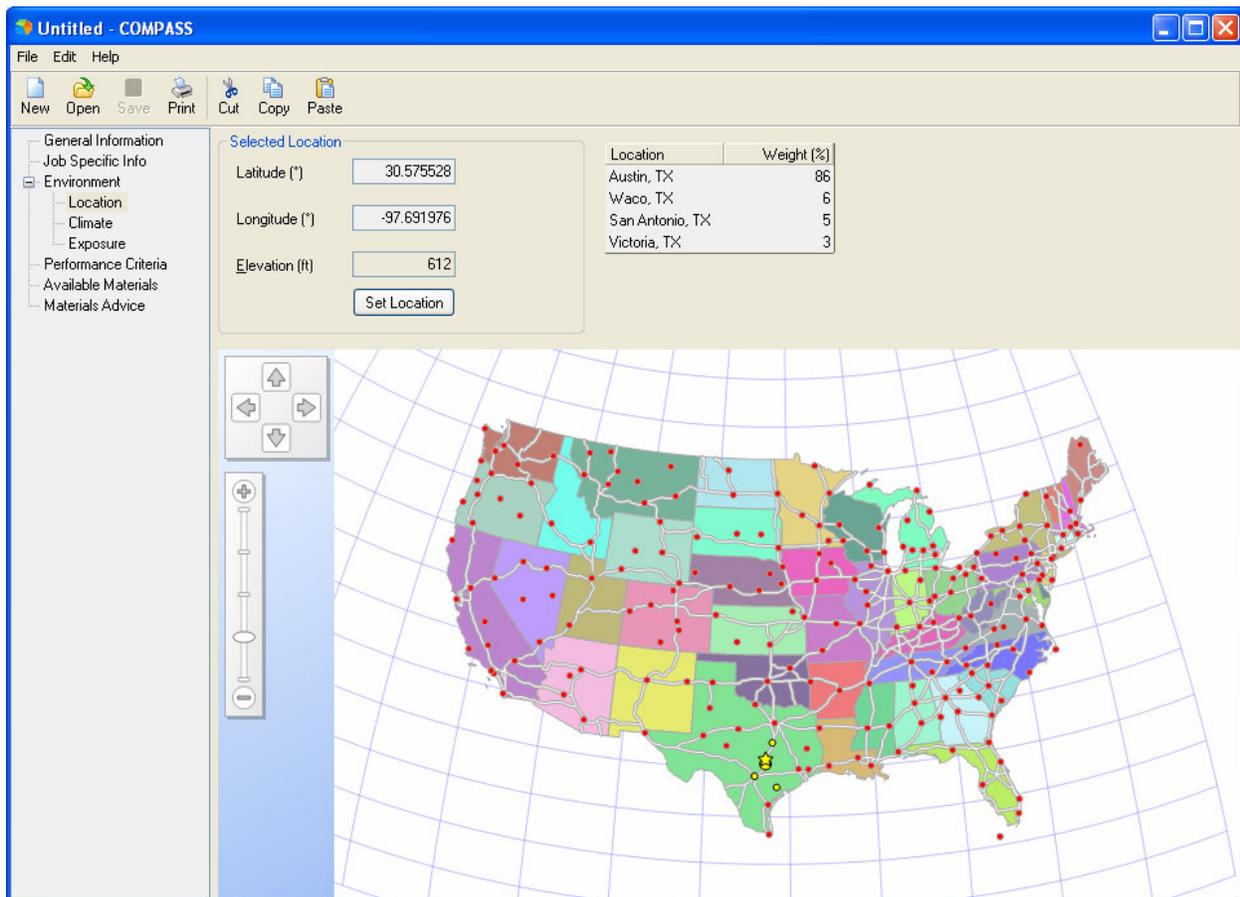


Figure 3: Location Input Screen

2.3.2. Climatic Considerations

Once the Location input screen is completed, the user can move to the Climate input screen. The user is able to select the dates of construction and the time of day

that the paving will take place. With this information, the historical climatic database is queried for the climatic conditions during paving and the following climatic information is evaluated:

- Temperature (Low and High)
- Wind Speed
- Humidity

The user may fine tune the weather data and specifically narrow down the local weather patterns for the construction time. If there is more accurate temperature data, the user is able to adjust those values. The wind speed and humidity (%) is listed alongside the temperature ranges and the user is able to change those values either by entering the values in the input boxes or by dragging the minimum and maximum temperatures in the slider control.

2.3.3. Exposure

After considering the local weather patterns, the user is able to assess the type of exposure the pavement will be subject to, such as an abrasive environment or freeze/thaw environments. There are also considerations for sulfate exposure in coastal regions. The user is able to select the box and click to select which type of exposure is being considered. For sulfate exposure, there is a drop down menu in order to assess the amount of exposure, from negligible to very severe.

- Abrasive Environment: This indicates whether the pavement is subjected to an abrasive environment such as heavy traffic, use of studded tires, or a project where the concrete mixture is required to possess abrasion resistance characteristics.
- Freezing and Thawing: Corresponds to concrete exposed to freezing and thawing cycles in a moist condition or concrete exposed to deicing salts.
- Salt water, brackish water or seawater: Corresponds to concrete exposed to chlorides from deicing salts, salt water, brackish water, seawater, or spray from these sources that require concrete resistant to corrosion when embedded steel is present.
- Sulfate exposure: Recommendations on sulfate resistance of the concrete mixture and recommended cement types are provided based on the level of sulfate exposure. The sulfate exposure levels are defined according to Portland Cement Association (PCA).¹
 - Negligible: corresponds to less than 0.10% by mass of water-soluble S04 in soil or less than 150 ppm S04 in water.
 - Moderate: corresponds to 0.10% to 0.20% by mass of water-soluble S04 in soil or 150 to 1500 ppm S04 in water.
 - Severe: corresponds to 0.20% to 2.0% by mass of water-soluble S04 in soil or 1500 to 10000 ppm S04 in water.
 - Very Severe: corresponds to more than 2.0% by mass of water-soluble S04 in soil or more than 10000 ppm S04 in water.

2.4 Analysis

In using the COMPASS software, the user provides key information that identifies important criteria that the user should consider based on site-specific conditions such as structural design, environmental conditions, and construction constraints. The result from the performance criteria analysis is a list of recommended criteria that the user should consider when selecting materials and proportions to achieve an optimum mixture that meet these criteria.

2.4.1. Performance Criteria Analysis

After entering all the project background data and establishing the weather data, the user is now ready to consider what characteristics are specific to their paving project. The list of performance criteria can be seen across the top of the Performance Criteria screen.

The output screen for the performance criteria analysis is shown in Figure 4. The relevant PCC properties identified appear as tabs across the top of the screen. Clicking on the tab of interest accesses the property specific information: suggested test methods for the project's level of importance, general construction methods to be aware of, and suggested materials and proportions. When clicking on 'Read More' a link to the specific PCC property section in the FHWA's Integrated Materials and Construction Practices for Concrete Pavement is provided for the user to research more detailed information on the selected property.

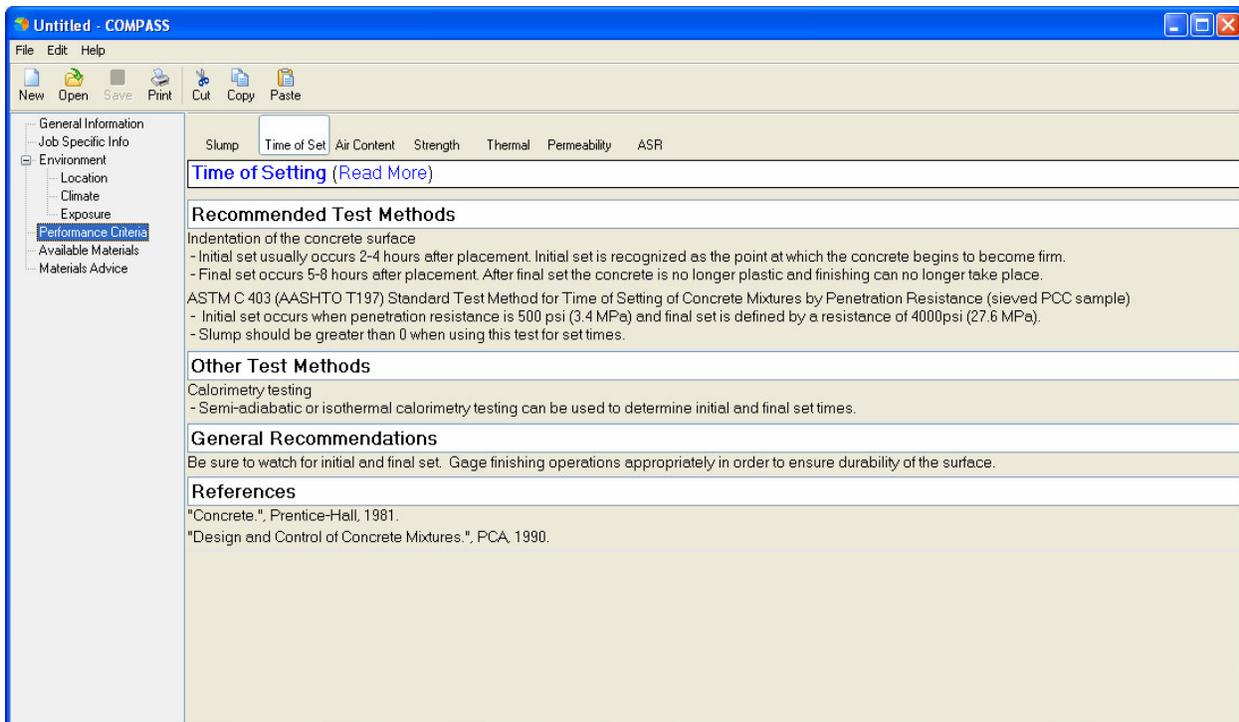


Figure 4: Performance Criteria Analysis window

2.4.2. Materials Selection Analysis Figure

The second analysis stage of this module refers to the Materials Selection Analysis. In this analysis, inputs for selected material constituents in the 'Available Materials' screen (Figure 5) trigger Knowledge Base recommendations and warnings based on ways to optimize the identified, relevant mixture performance criteria.

Available materials inputs that the user can select include:

- Water Type
- Cement Type
- Fine Aggregate Type
- Coarse Aggregate
 - Geological Type
 - Shape
 - Elongated Particles
 - Texture
 - Maximum Size
 - Gradation
 - Los Angeles Abrasion
 - Absorption
 - Marginal Aggregate
 - Recycled Aggregate
 - Potential Impurities
- Admixtures
 - Air Entraining Admixtures
 - Chemical Admixtures
 - Fiber Type
- Supplementary Cementitious Materials (SCM)
 - Fly Ash Class
 - GGBF Slag or Slag Cement
 - Metakaolin: Not enabled in this version
 - Natural Pozzolans
 - Silica Fume: Not enabled in this version

Figure 5: Available Materials Input Screen

Figure 6 shows the output window of this module. On this analysis window, icons of material constituents line the top of the screen. By clicking on the icon of interest, information on recommended materials as well as warnings on selected materials that may compromise a given PCC property are displayed. The user can see additional information on any given entry by clicking on the 'Show Details' button including the information source.

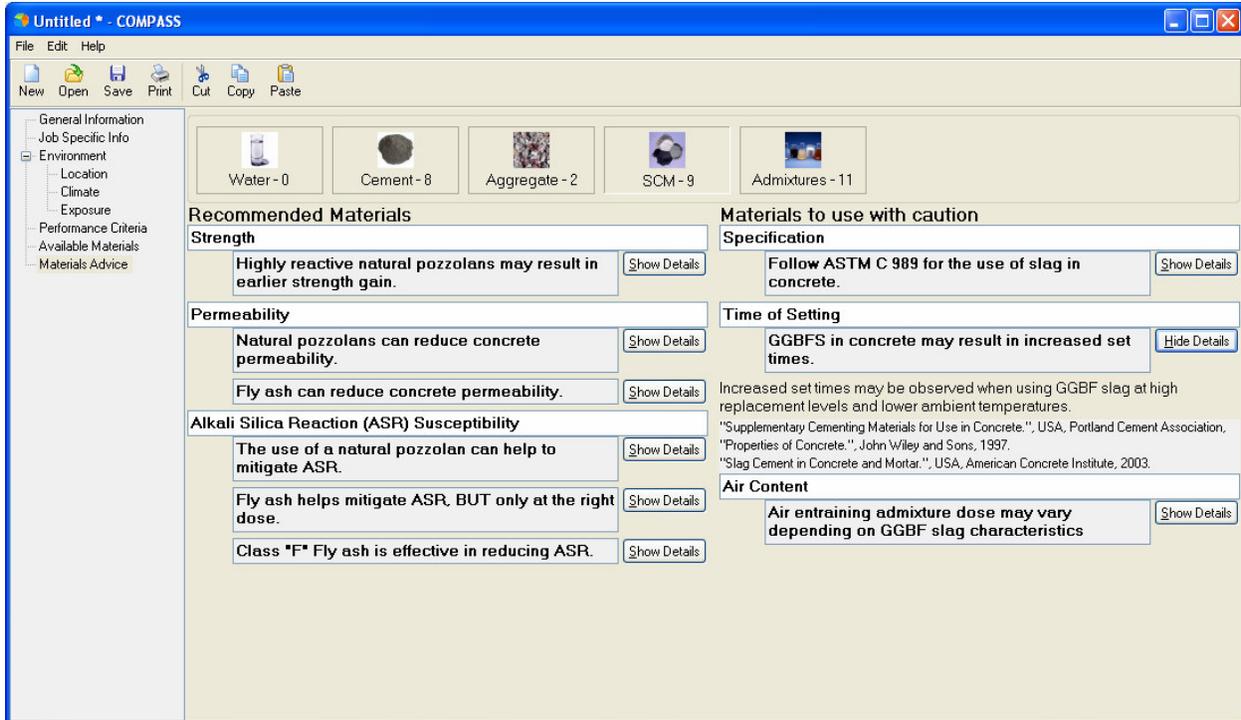


Figure 6: Performance Criteria Output window

3. GRADATION MODULE

Figure 7 shows the Aggregate Gradation Module. The gradation module is used to evaluate properties such as aggregate packing density and workability as a function of user-defined or model recommended aggregate blends. When first starting the gradation module, a general information input screen is shown first where the user can enter the details about the project and specific notes about the analysis being performed.

3.1 Entering Aggregate Blends

Under the 'Aggregates' input screen, the user enters information on each of the aggregates available.

This screen presents the available aggregates on the top half of the screen and the aggregate general information, physical properties and sieve analysis (gradation) on the bottom half of the screen under each of the respective tabs. The inputs entered under each of these tabs correspond to the aggregate selected on the top half of the screen.

The Add, Copy and Remove buttons on the top right corner are used to add new aggregates, create a copy the inputs of an existing aggregate into a new aggregate, and remove available aggregates from the Gradation project file. The Copy and Remove buttons are applied to the highlighted aggregate in the list of aggregates.

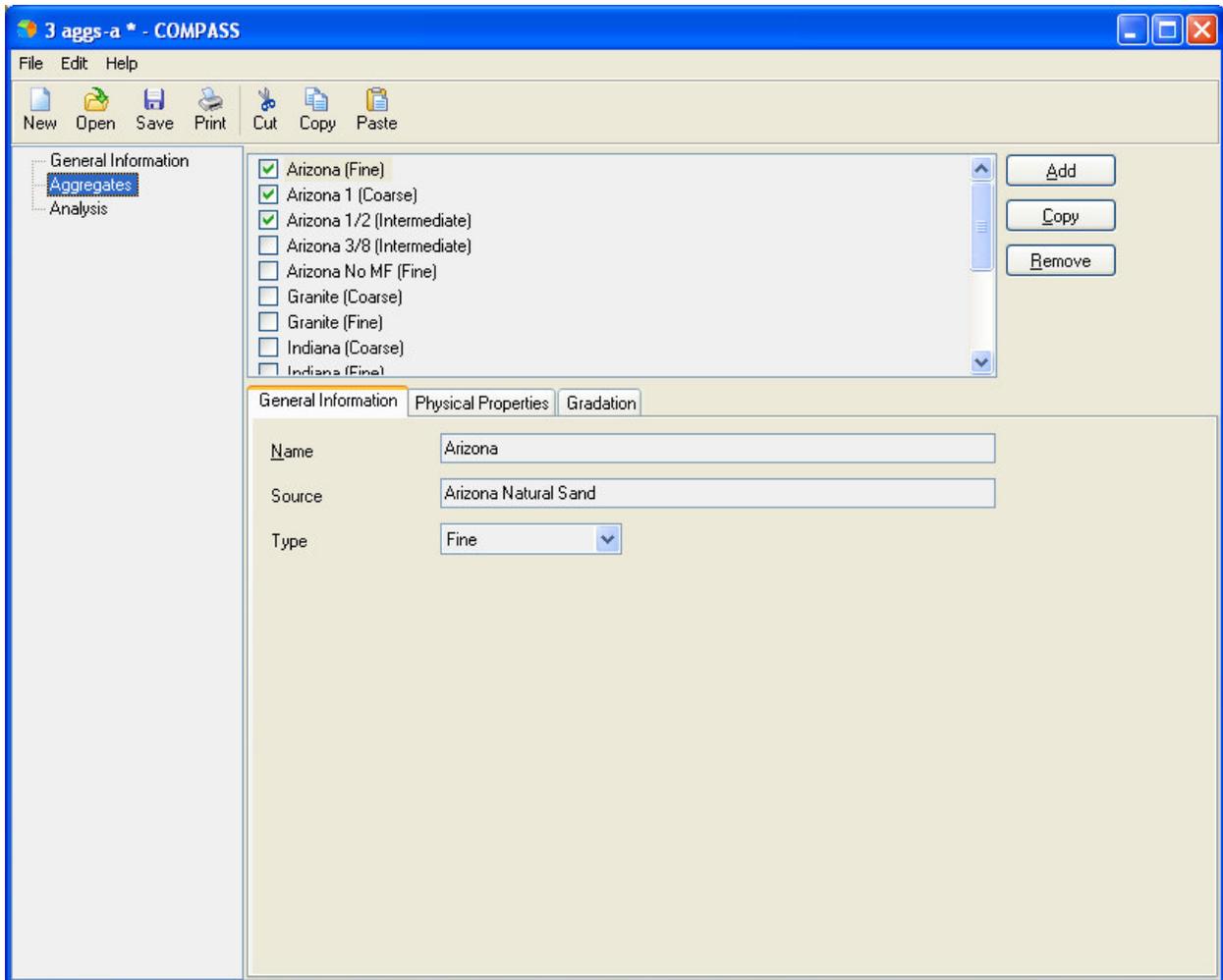


Figure 7: Aggregate Gradation Module Input Screen

Once an aggregate is added its properties need to be established. Select that aggregate by clicking on its name and it will become highlighted. From here, the 'General Information' tab in the middle of the screen is used to re-name and identify the general information about that aggregate. Under the 'Physical Properties' tab, the user can identify values for specific gravity, compacted unit weight, and other parameters explicit to that aggregate. A brief description of each of these tabs follows:

General Information includes:

- Aggregate name (Type a descriptive identification of the aggregate)
- Aggregate source (Type in the name of aggregate source or quarry)
- aggregate type
 - Fine: typically for aggregates with maximum size of aggregate in the No. 4 sieve below,
 - Coarse: typically for aggregates with sieve sizes between 1 ½" to No. 8, and
 - Intermediate: Typically for aggregates with sieve sizes between ½" to No. 16)

Physical Properties include:

- Aggregate shape: subjective assessment of the aggregate shape (e.g. round, semiangular, angular).
- Specific gravity: Obtained through AASHTO T084 (ASTM C 128) for fine aggregate or AASHTO T085 (ASTM C 127) for intermediate and coarse aggregate.
- Compacted (rodded) and Loose Unit weight (density): Obtained through AASHTO T19 (ASTM C 29).
- Packing Characteristics
 - Packing Density: Used in De Larrard compressible packing model and Toufar model. May be determined as the compacted unit weight divided by the product of the specific gravity and water density. Not necessary for user-defined blends.
 - Voids Ratio: Used in Dewar model. May be determined as the product of the specific gravity and water density divided by the loose unit weight. Not necessary for user-defined blends.

Gradation: Under the 'Gradation' tab (Figure 8), the user may enter or modify the sieve analysis for each selected aggregate, which will be used to create a combined gradation later. To set the gradation specific to each aggregate, it must be highlighted by clicking on the name in the list above. The user can select to use percent passing or percent retained for analysis. Depending on which is selected, the user can enter the laboratory analysis in the respective column. The program provides a default set of sieves, but the user has the option of entering additional sieve sizes in the 'Add Sieve' section. Selected sieve sizes can be removed with the 'Remove selected sieve' button. NOTE: The sieve must be highlighted before clicking remove. If an accidental deletion of a sieve size occurs, simply click default sizes and COMPASS will restore the original sieve sizes. By clicking on the 'Revert to default sieves' any user-defined sieves are deleted and the software reverts to the default set of sieves. The graph at the bottom of this screen shows the percent passing and retained under each sieve size for the selected aggregate on the top half of the screen.

This method is repeated for each aggregate individually, until all are entered.

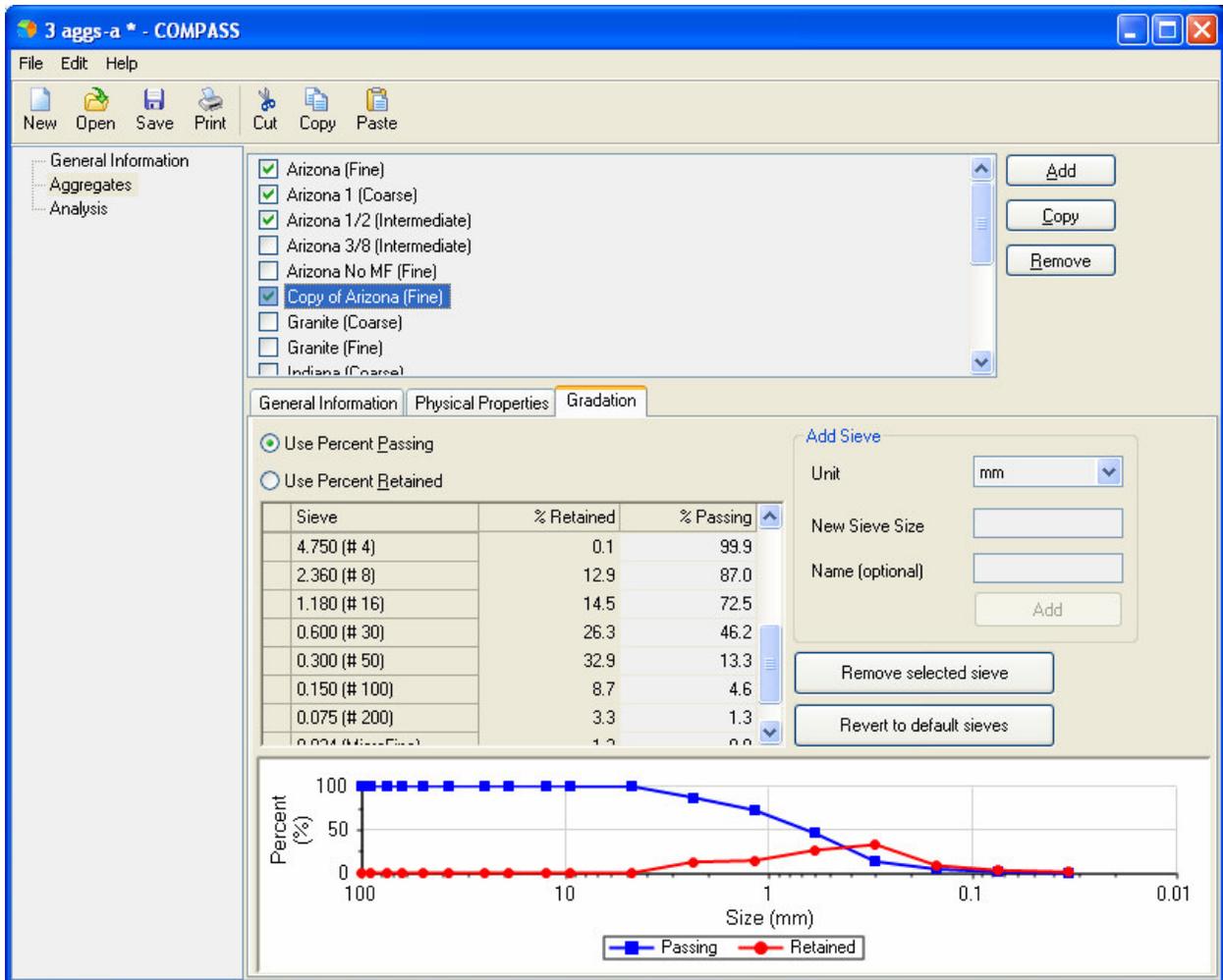


Figure 8: Aggregate Gradation Input Screen

3.2 Analysis

Before proceeding to the analysis window, select the aggregates to use in the analysis by clicking in the box next to each of them in the list of aggregates in the 'Aggregates' input screen. A green check mark should appear for each aggregate selected. This tells COMPASS which aggregates to include into the combined gradation. After checking the desired boxes, proceed to the analysis input screen (Figure 9). The user is then able to perform aggregate blending for multiple aggregates.

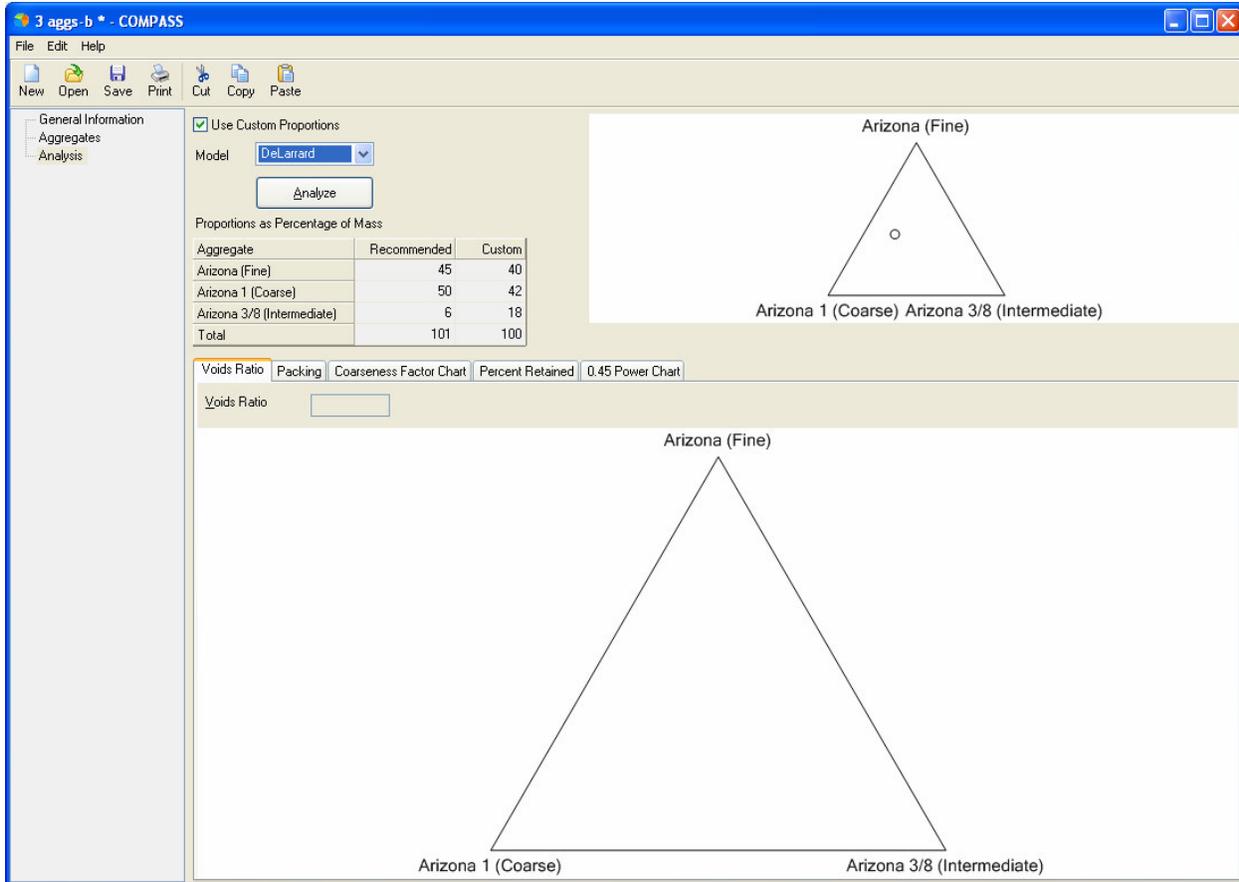


Figure 9: Gradation Analysis window

In the analysis screen, there are two ways of blending the selected aggregate:

1. Using Custom Proportions: The user checks the 'Use Custom Proportions' check box and enters the proportions for each aggregate in the 'Custom' column under the 'Proportions as Percentage of Mass' Table.

Alternatively for custom proportions, a control appears to select the custom blend when blending two or three aggregates.

- a. When two aggregates are blended, a sliding control appears to select the custom blend. The blend is selected by dragging the slider between 0 and 100%.
- b. When three aggregates are blended, a ternary blend control appears to select the custom blend. The ternary blend control has the property that any point selected in it yields a combination of the three aggregates that add up to a 100%. When the point is at any given vertex, the blend equals 100% of the aggregate represented by that vertex and 0% of the other two aggregates. When the point is half way between one vertex and the adjacent one, the blend equals 50% of the aggregate represented by the first vertex and 50% of the aggregate represented by the adjacent vertex and 0% of the third vertex. In the example in Figure 10 below, the selected

point yields a combination of 70% aggregate 1 (X_1), 10% of aggregate 2 (X_2) and 20% of aggregate 3 (X_3).

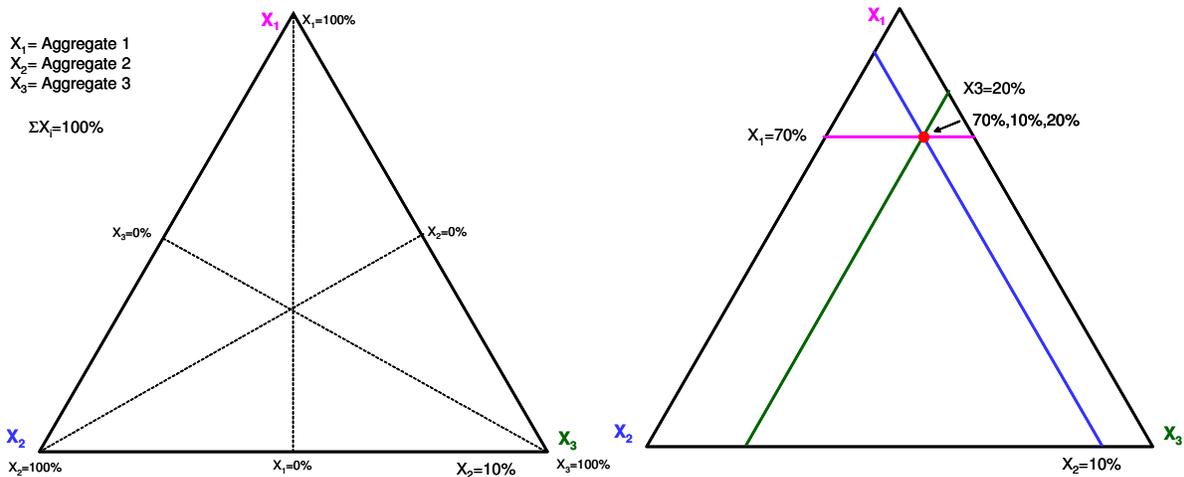


Figure 10: Ternary Blend Control

- c. For more than three aggregates, the custom blend has to be entered in the 'Custom' column.
2. Model: This option is used to analyze the model recommended blends. Uncheck 'Use Custom Proportions' and select either of Toufar, Dewar, or De Larrard models under the 'Model' drop down menu. The proportions for each aggregate appears in the 'Recommended' column under the 'Proportions as Percentage of Mass' Table. The model option can be used for blending up to three aggregates.

To evaluate the user-defined or model recommended blend click 'Analyze'. This creates a series of five graph tabs, shown across the bottom of the screen as Void Ratio, Packing, Coarseness Factor Chart, Percent Retained, and the 0.45 Power Chart. Clicking on different tabs will show different graphs. Figure 11 is a screenshot of a typical 0.45 power curve analysis window for the gradation module.

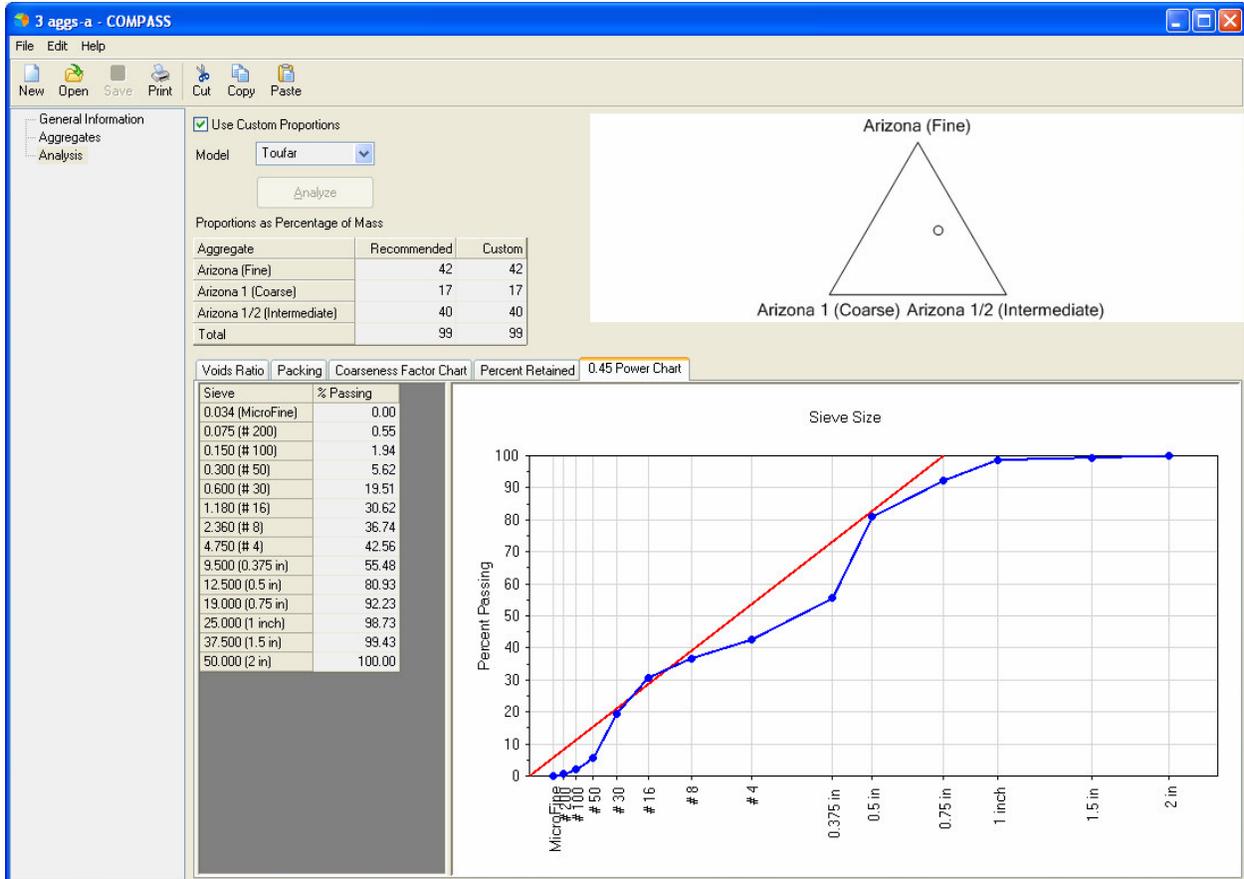


Figure 11: 0.45 Power Curve Analysis window

If the user is not satisfied with the created gradation, they can elect to use different custom proportions. In order to do this, check the box near the top of the screen that reads, 'Use Custom Proportions', and enter the desired values in the 'Custom' column next to the recommend values. Then click analyze again, to re-analyze the new proportions.

4. PROPORTIONING MODULE

This module produces mixture proportions based on ACI 211/Portland Cement Association (PCA) proportioning guidelines to obtain preliminary mixture proportions.^{1,2} The user can obtain mixture proportions with a minimum number of inputs. A general information input screen is shown first where the user can enter the details about the project and specific notes about the mixture proportioning being performed.

4.1 Mixture Design Criteria

In this input screen, the user can define what the specifications for the mixture are, such as slump, 28 day compressive strength, and air content.

The user may select 28-day specified compressive strength (f'_{cr}) and COMPASS computes the required (design) average compressive strength using the method when data are not available to establish a standard deviation (ACI 318). Alternatively, if the user has field strength data, the user can enter the 28-day average compressive strength and the producer's standard deviation. For this method, the following requirements must be met:

“The statistical data should essentially represent the same materials, proportions, and concreting conditions to be used in the new project. The data used for proportioning should also be from a concrete with an f'_{cr} that is within 7 MPa (1000 psi) of the strength required for the proposed work. Also, the data should represent at least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests (one test is the average strength of two cylinders from the same sample).”

If the mixture contains entrained air, the user should check the box next to the 'Entrained Air', in order for COMPASS to consider it during analysis. There is also an option to assess an air content estimate from the amount of exposure the pavement will experience. From there, a drop down menu allows the user to select the degree of exposure as defined by ACI 211.1.

4.2 Materials

The materials input category the user can input the types and properties of aggregate and cementitious materials to use in the mixture proportioning.

4.2.1. Aggregates

Under this input screen, the user is able to select the number of aggregates to be used in the mixture proportioning from a drop down menu, located on the top of the screen. If two aggregates are selected, COMPASS uses the ACI 211.1 method for estimating the bulk volume of coarse aggregate increased by 10% for concrete pavement construction.

If the user created a custom blend for the aggregates, then the Custom Blending box must be checked in order for COMPASS to consider it during analysis. For three and four aggregates, the custom blend check box is selected by default.

From there, the user can enter the coarse aggregate maximum size, along with other aggregate parameters, such as, coarse aggregate oven dry unit weight (to estimate coarse aggregate content using ACI 211.1 method) and fine aggregate fineness modulus.

There is also a table shown to the user that lists the specific gravity, moisture content (%) and absorption (%) of each aggregate. These values can be adjusted by clicking on the desired box within the table and entering the required value. The name of each aggregate can also be edited here.

4.2.2. Cementitious

After the aggregate properties are entered, the cementitious properties must be considered. These values are entered under the cementitious input screen. The cement specific gravity is entered. If there is a SCM being used in the mixture, the SCM content be entered. There is a drop-down menu provided with options to change the SCM content units from percent of cementitious by volume to percent by weight, or they can be defined in English or SI units. For COMPASS to consider the SCM, the user must enable that SCM check box next to the Enabled label. From there, the user can identify the SCM name, content and specific gravity. If there is a second SCM being used, the program provides a second area to enter the second SCM name and properties.

4.3 Analysis

After the materials are entered, it is time for COMPASS to compute the mixture proportions.

4.3.1. Initial Mix Proportions

In this analysis screen, COMPASS displays the initial mixture proportions it created, based on user inputs. These values cannot be directly changed, they are only shown for the user to review. The user can make adjustments under the following two input screens.

4.3.2. Water Adjustments

Under the water adjustments screen, the user can assign factors for water demand adjustment, based on aggregate angularity and gradation, admixtures, SCM's, and other factors, such as environmental. Rough water demand adjustment guidelines are given based on These values can be adjusted by using the slider bars, shown on the right of the screen. Under the admixtures list, the user can select which type of water reducer (normal, mid-range, or high range) is being used by checking the box next to the name. Once the water adjustments are finalized, the suggested maximum water demand adjustment (%) appears at the bottom of the screen. A maximum adjustment of 30% is recommended. However, the user can elect to use the cumulative adjustment instead of the suggested maximum adjustment.

4.3.3. Refined Mix Proportions

After completing the water demand adjustments, the refined mix proportions are shown under the respective tab. Figure 12 is a screenshot of the refined Mix Proportions Analysis window. From this screen, additional mixture adjustments can still be made. On the right hand side, there is a box that is titled Account for Moisture. This box must be checked for COMPASS to compute the aggregate moisture and absorption corrections based on the aggregate moisture and absorption inputs. The moisture corrected proportions are displayed when this box is checked.

The user can also change the batch size. Additional mix adjustments can be made to account for a maximum or minimum water to cementitious ratio, and cement

content. The type of adjustment can be selected from a drop-down menu that includes options for water to cementitious ratio, cement or none. If a cement adjustment is selected, the box for cement will highlight and the corrected value can be entered. After making adjustments, the user will see the new mix proportions. If they do not like the new adjustments and wish to start over, clicking the reset button will restore the initial values.

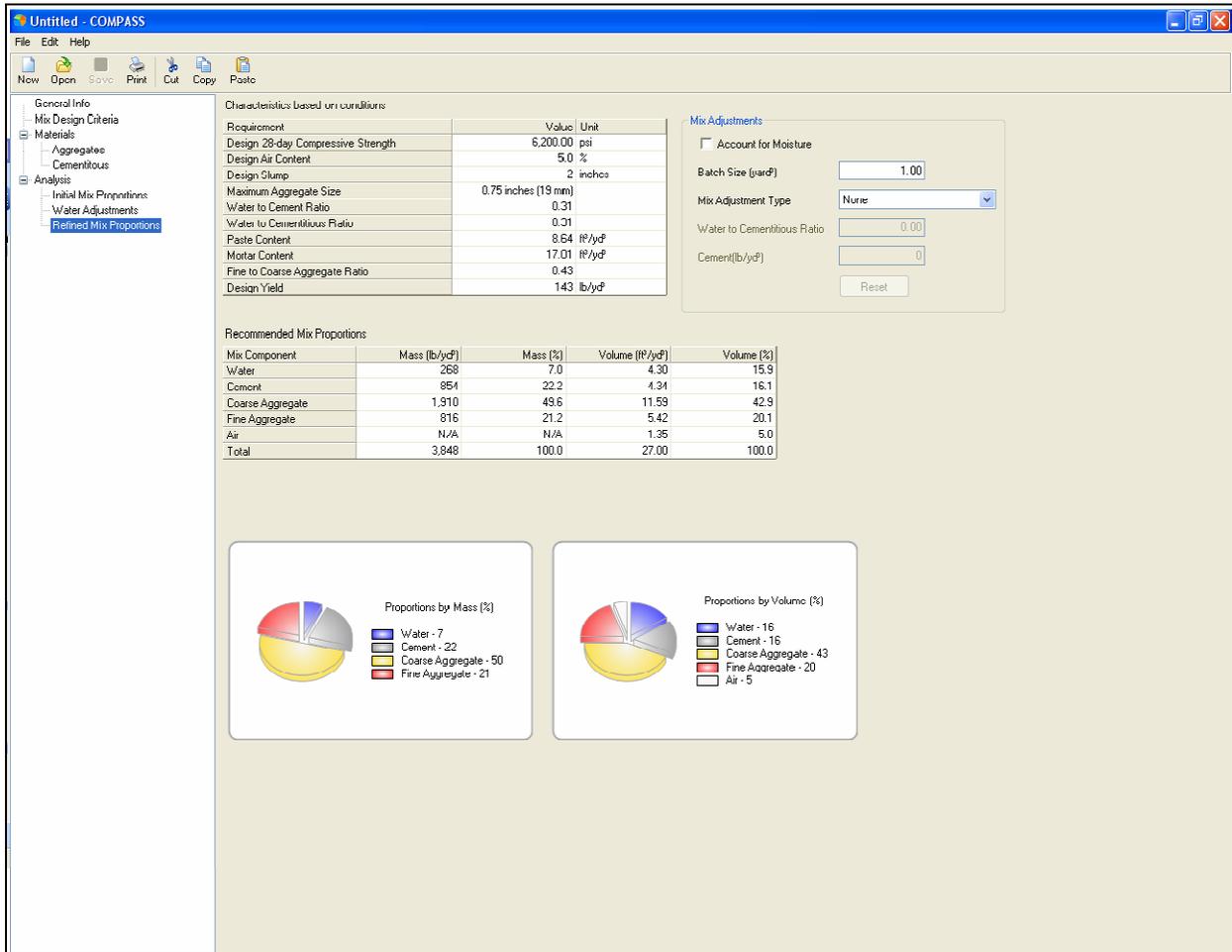


Figure 12: Proportioning- Refined Mix Proportions window

In the middle of the screen is a table showing the recommended mix values from COMPASS. The table shows the mix proportions in four columns, each having a different way to measure the mixture ingredients, such as by mass (lb/yd³), by volume (ft³/yd³) or by percent of mass or volume. The values in this table cannot be directly changed, but they change when adjustments are made to the mix design from the upper right hand corner of the screen. There are graphical representations of the mix proportions located at the bottom of the screen. These show the mix proportions by percent mass and percent volume.

5. OPTIMIZATION

The purpose of the Optimization module alone is to guide the user on identifying concrete mixture proportions that best meet the job-specific mixture performance criteria.

A general information input screen is shown first where the user can enter the details about the project and specific notes about the mixture optimization being performed.

The Optimization module is divided into two stages:

1. Trial batches and
2. Mixture optimization

Having gone through the Mix Expert, Aggregate Gradation, and Proportioning modules, the user has a better understanding of what material constituents to focus on and what properties to optimize for. Constituents and constituent ranges are selected based on:

- Recommendations from Mix Expert,
- Recommendations from Aggregate Gradation and Mixture Proportioning modules, and
- Pertinent concrete specifications.

5.1 *Trial batches*

In the first analysis stage, COMPASS recommends trial batches using experimental design techniques.

5.1.1. Materials

In the Materials input screen the user enters the materials constituents and proportioning ranges to use in the optimization (Figure 13). The proportions of up to five PCC material constituent factors (including water/cement or water/cementitious ratio) can be optimized. The user can also enter additional materials with fixed proportions.

To add a new constituent not listed, the user can click on the 'New' button (located below the constituent list) and create a constituent. A dialogue box will appear and the user can define the new constituent there. The user can also remove any constituent by clicking to highlight that constituent and then clicking the Remove button (located below the constituent list).

By checking or un-checking the boxes next to the material constituents, the user can select which factors to include in the optimization analysis.

To change the range of values and properties given for a constituent, the user must click on the constituent and highlight it. Then using the Range Values and Properties input areas below the list, the user can define the range of values or create a fixed value that will not change.

In the Range Values input area the user can select whether a constituent will have a fixed amount by checking on the 'Fix Factor' check box or specify a range of values by leaving 'Fix Factor' unchecked.

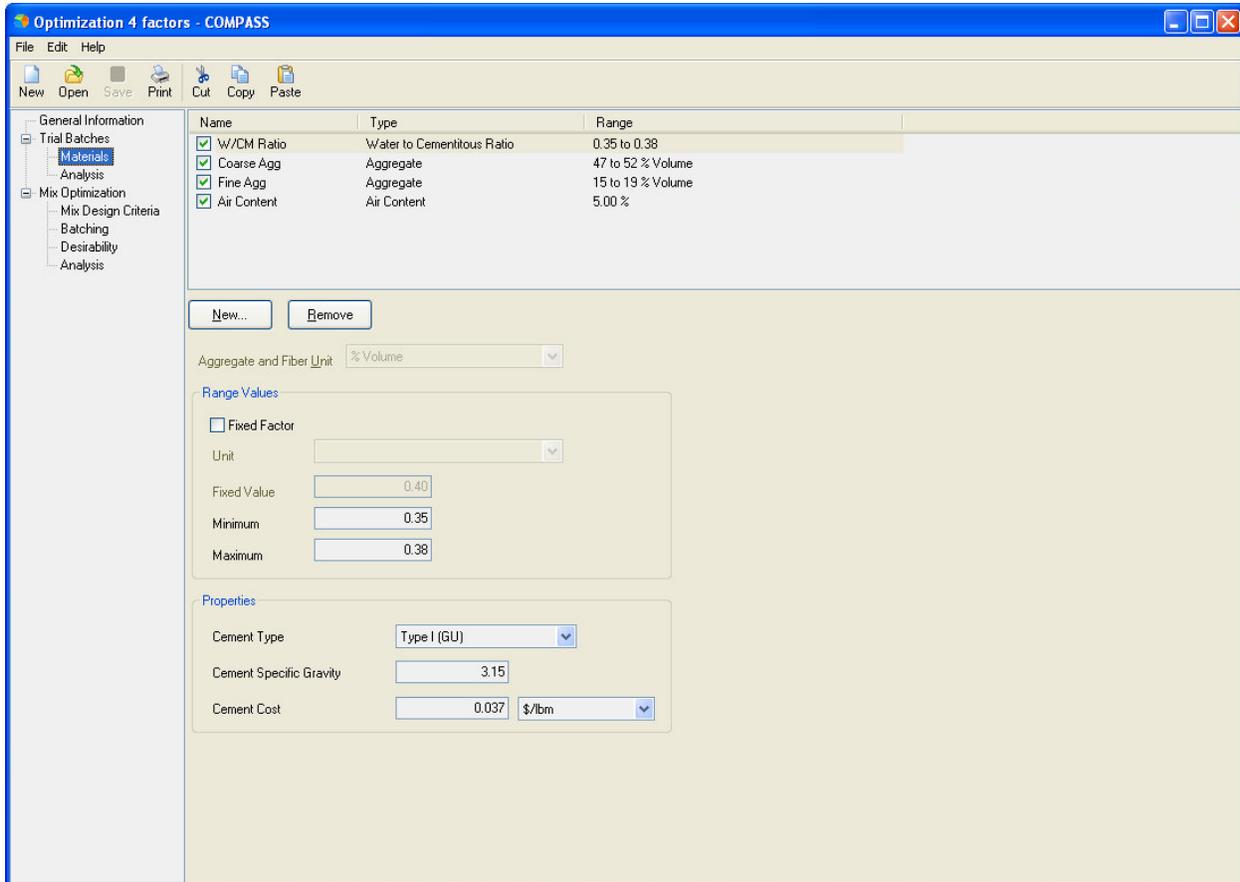


Figure 13: Materials Input Screen

The corresponding unit will show for the selected constituent. Aggregate and Fiber constituent ranges can be entered as % by mass or % by volume. Admixture constituents can be entered in different units of volume per mass unit of cement (e.g. FL oz per 100 lbs of cement). Supplementary cementitious materials can be entered as a % cement mass replacement.

Beneath the Range Values input area, there is a Properties area where the user must identify the properties of the material constituent being used including material type, specific gravity and material cost. This cost can be utilized later for optimizing the mix.

5.1.2. Trial Batches - Analysis

Once all the material inputs are entered, the trial batches analysis screen is the next step. In order to see the trial batches, the user must click the 'Create Batches' button on the top of the screen. Before clicking to create batches, the user must go back

to the materials input screen and check to see that the desired constituents have a check mark by their names. If there is no check mark, COMPASS will not consider that constituent in the analysis.

The result from this analysis stage is a list of trial batches in both volumetric and gravimetric format for the evaluation and determination of optimum mixture proportions. The number of trial batches required is determined by COMPASS with the use of experimental design techniques and is a function of the number of variable mixture constituents to be optimized. Material constituents defined as fixed factors do not affect the number of trial batches. This can be seen in Figure 14.

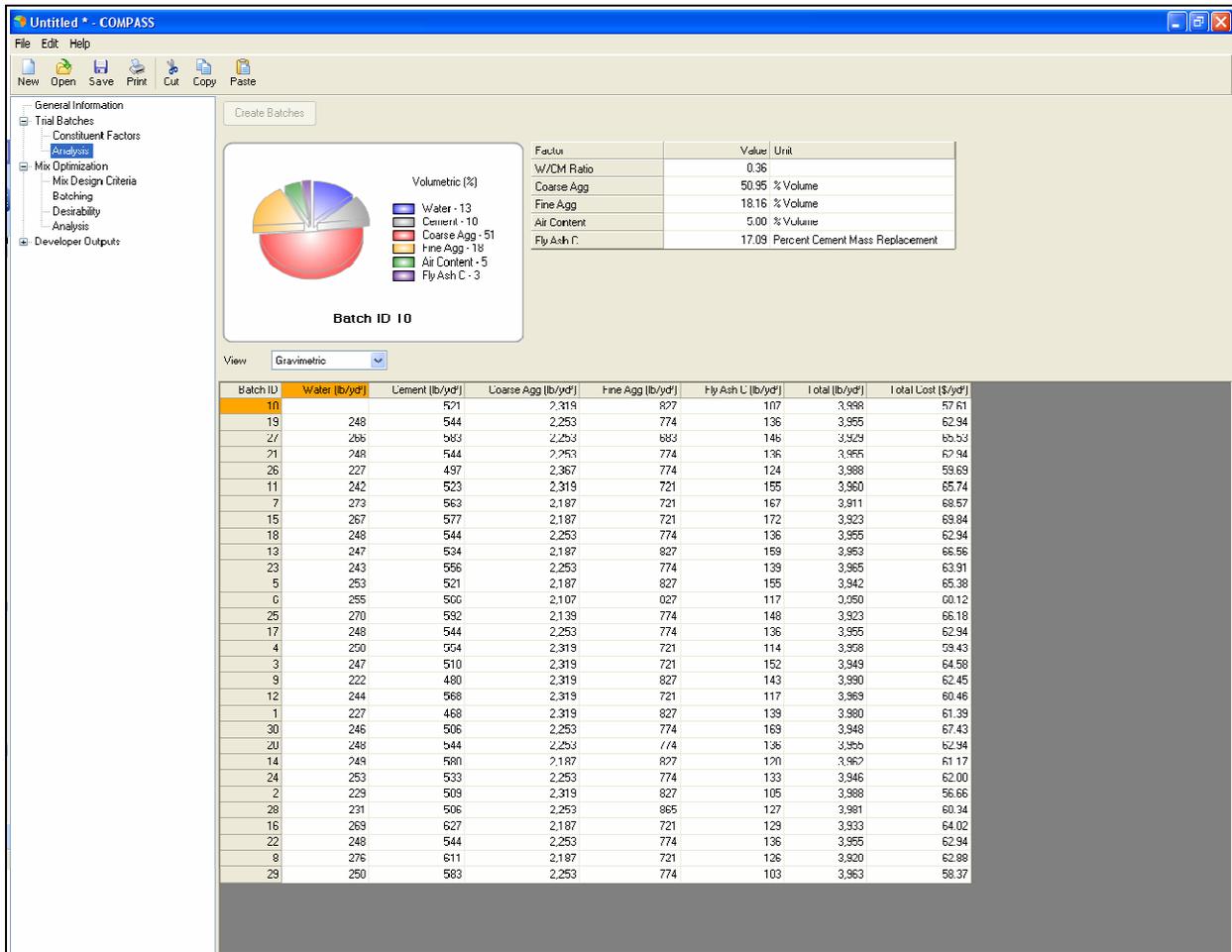


Figure 14: Trial Batch Analysis window

5.2 Mixture optimization

In the mixture optimization stage the user selects the mixture design criteria to optimize for, enters the batching results, specifies desirability functions for each criterion and performs the optimization analysis.

5.2.1. Mix Design Criteria

Mixture design criteria of interest are required for the optimization analysis. The design criteria are selected based on recommendations from Mix Expert, or directly entered by the user based on constraints specified by the client.

Under the Mix Design Criteria input screen, the user can define what criteria are important, such as cost, shrinkage, strength, etc. These criteria are shown at the top of the screen. In order to select the criteria for analysis, the user must check the box next to the criteria.

If there are criteria not listed that the user wishes to use, the criteria can be created by using the 'New' button, located under the list. This will open a new dialogue box and prompt the user to define the new criteria. If there are additional criteria listed that are not being used, the user can highlight them and click the 'Remove' button to eliminate them. The user can elect which source to use, by selecting the drop down menu under the criteria list and choosing virtual batching, lab testing, or both. Each source is explained below:

- Lab Testing: If Lab Testing is selected as the source, the user will have to enter the lab testing results in the Batching input screen.
- Virtual Batching: Default models in COMPASS are used to predict the batching results. This option is available only for strength, cost, shrinkage and slump. Custom criteria must be determined through laboratory testing.
- Lab Testing and Virtual Batching: This option is only available for strength criterion. With this option, the user may select any of the trial batches identified in the Trial Batch analysis and enter the strength results for that trial batch. With this information, COMPASS calibrates the default strength models to predict the strength results for all other trial batches.

It is recommended that 'Virtual Batching' and 'Lab Testing and Virtual Batching' options be used only for preliminary analysis.

Some mix design criteria have specific inputs that need to be defined by the user. For example, for strength, the user needs to define the strength type (compressive, flexural, or tensile) and age in days.

5.2.2. Batching Results

After defining the mix design criteria, then the user selects the batching input screen to enter the batching results. The batching input screen is used to enter the results from laboratory testing and/or to display results from virtual batching. In order to view the batches, the user must click the Run button, located on the top left of the screen. The user then enters the batching results for the criteria that have 'Lab Testing' selected as source in the mix design criteria screen. COMPASS shows the predicted values for the criteria with 'Virtual Batching' or 'Lab Testing and Virtual Batching' as source.

A graphical representation of the data is shown across the bottom of the screen to evaluate the reasonableness of the batching results. In order to change the graph to different criteria, click on the headings in the columns in the table above. This shows the different graphs for the different criteria. If there are more batches created that what can be seen on one screen, place the arrow of the mouse over the table and simply scroll through the table or place the mouse between the table and graph until a double sided arrow appears. Click and drag the line down to show more of the table or less of the graph.

5.2.3. Desirability

Under desirability inputs, the user identifies the value and desirability function of each selected criterion to compute an overall desirability of the mixture. The overall desirability for each individual mixture is computed using the desirability functions and importance (desirability weightings) defined for each mixture design criterion.

In the Desirability input screen, there are tabs across the top of the screen that reflects the criteria previously selected. The user can click on each tab to view the graphical desirability of each criterion. Under each tab, the user can assign a ranking of importance to each criterion, from 1 to 5. The user can also select how many points to show on the graph, in the range of 3 to 10.

As Figure 15 shows, desirability functions can be in general of three different forms depending on the criterion selected:

- Target: A target desirability function is used to seek a target value such as a target slump of 2 inches.
- Maximum: A maximum desirability function is used to seek a maximum value such as the maximum strength.
- Minimum: A minimum desirability function is used to seek a minimum value such as the minimum cost.

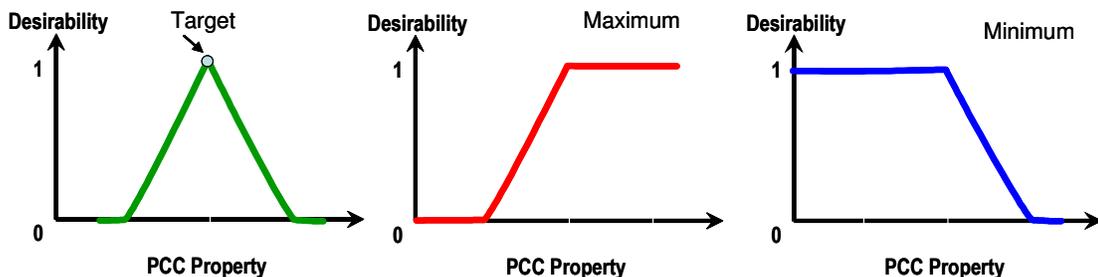


Figure 15: Typical desirability functions

The current version of COMPASS provides ample flexibility to the user to enter practically any custom desirability function.

In the desirability input screen, the user modifies the desirability curve by assigning a desirability from 0 to 100 % to each criterion value entered.

For example, in Figure 16, a maximum desirability function is entered for 28-day compressive strength. Four points are selected to define the desirability function corresponding to 0, 4000, 5000 and 8000 psi. For each point, a desirability of 0%, 0%, 100%, and 100 % is respectively assigned. With this inputs, COMPASS assigns a desirability of 0% to any mixture that achieves a strength below 4000 psi. A desirability of 100% is assigned to any mixture with a strength above 5000 psi. COMPASS will assign an intermediate desirability for mixtures with a strength between 4000 and 5000 psi.

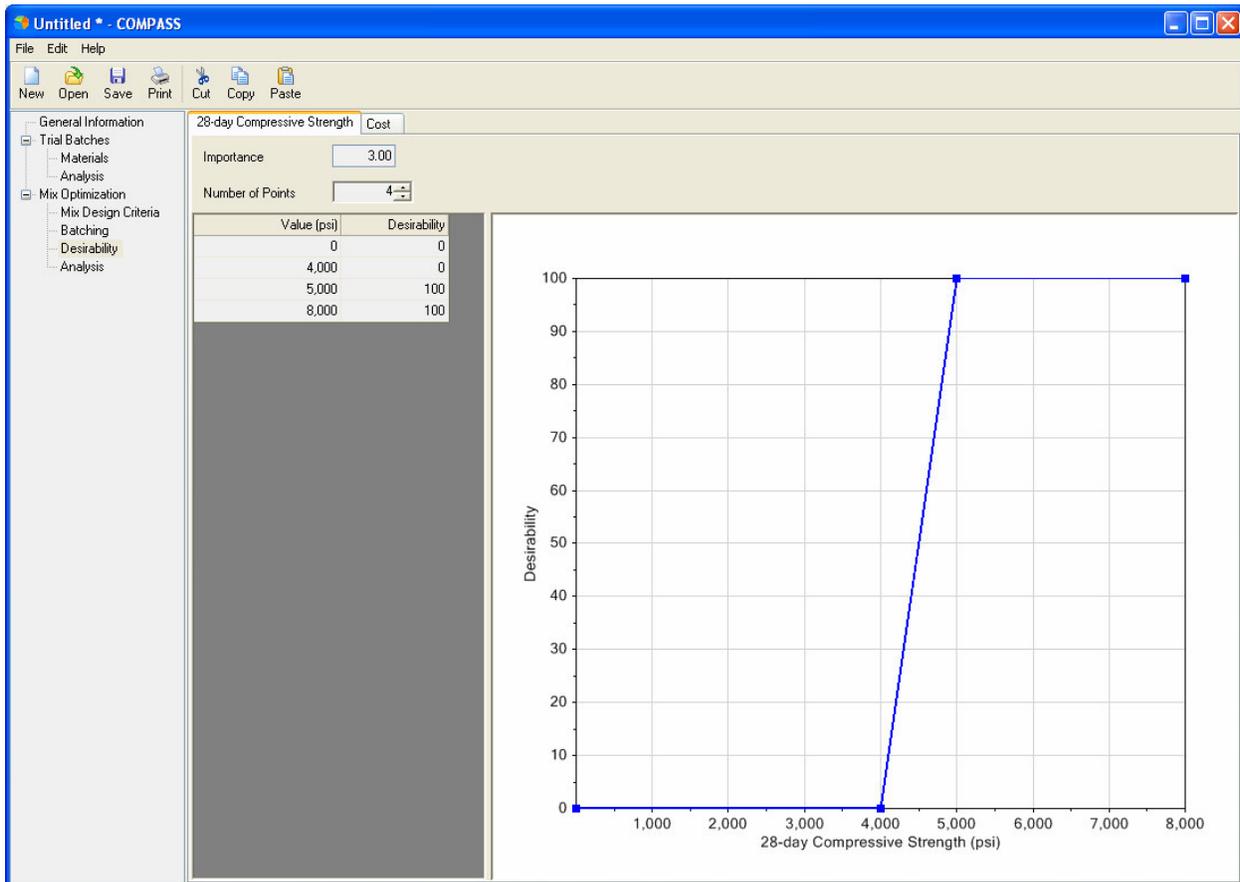


Figure 16: Desirability Function for Strength

5.2.4. Mix Optimization - Analysis

With the information on the batching results and assigned desirability, the optimization analysis is run. The optimization analysis consists in generating response surface models to predict PCC properties of interest for an extensive set of mixtures within the experimental space defined by the constituent limits.

The optimization analysis includes various options for evaluation of the optimum mixes. These include:

- Options to report top ten optimum mixes in volumetric and gravimetric formats, Materials constituent factors and predicted responses.
- Model-fit statistics and plots that allow the user to evaluate the goodness of fit of the optimization results.

In order to see the results, the user must click the 'Optimize' button. This button is located in the upper left hand corner of the analysis screen (Figure 17). From here, the user can see the top ten optimum mixes identified by COMPASS as a function of the desirability functions set previously.

Under the optimization button, there is a list of 5 tabs that are used to view the optimization process, such as gravimetric, volumetric, factors, responses and model fit. The user can rank the values from highest to lowest by clicking on the column heading and a grey arrow will appear. This ranks the numbers in that particular column and the corresponding columns readjust.

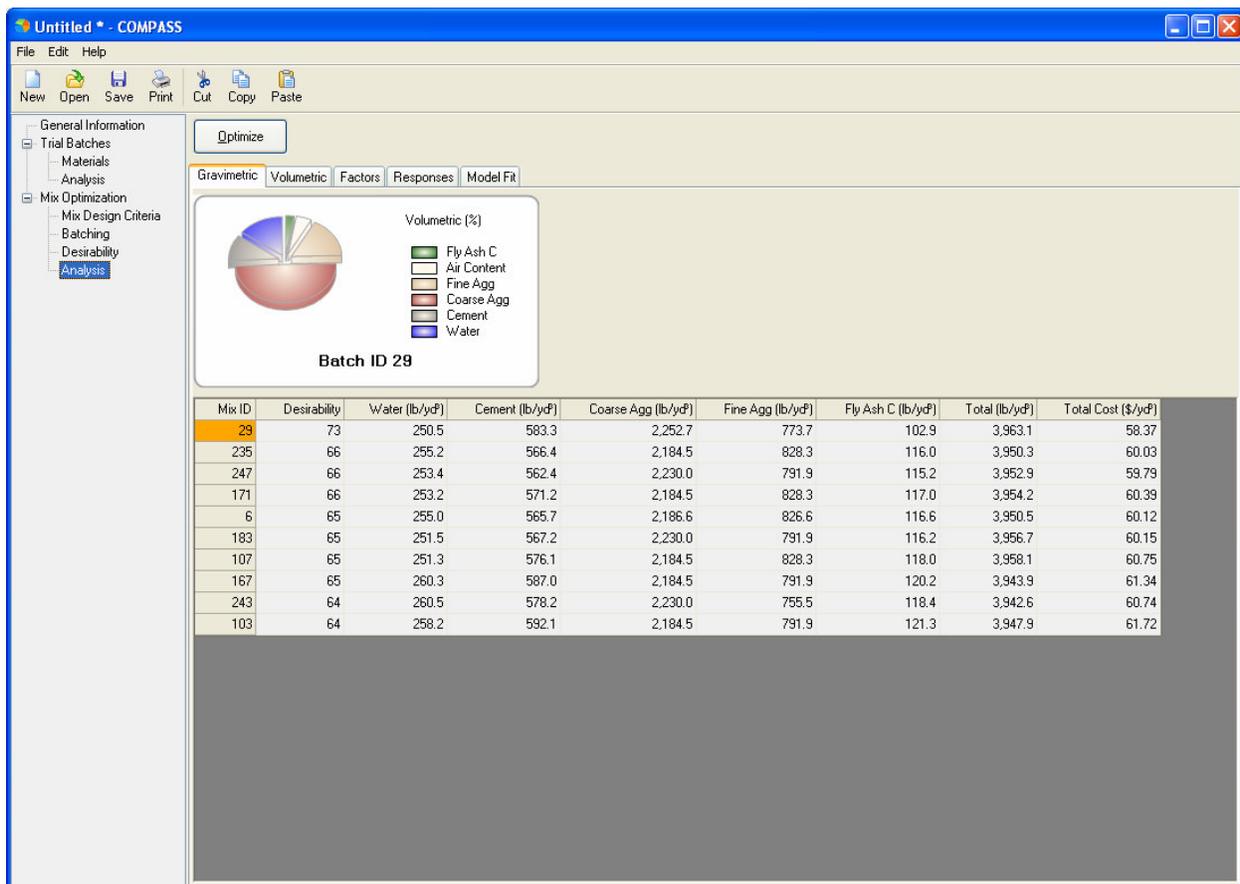


Figure 17: Optimization Analysis Window

Figure 18 shows the Model Fit analysis screen. In this screen, for each criterion, COMPASS compares the actual values determined through lab testing (or virtual batching) with those predicted by the response surface models developed by

COMPASS. Each criterion can be evaluated by selecting it in the Criterion drop down menu at the top of the tab. The model r-square (r^2) and standard deviation are presented along with a tabular and graphical comparison of measured versus predicted values. The red line in the comparison plot represents the equity line between measured and predicted.

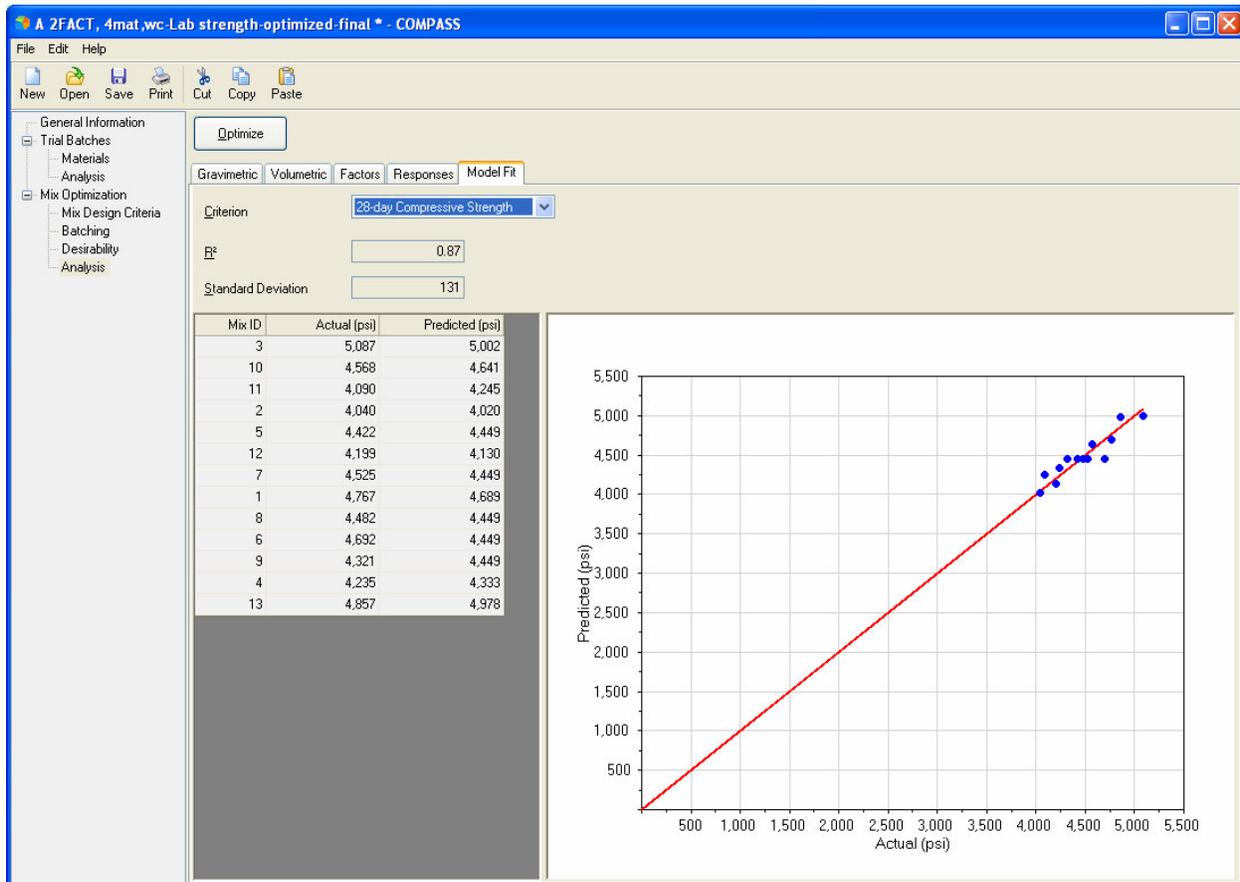


Figure 18: Model Fit Analysis Screen

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2. ACI. Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete, ACI 211.1-91 (Reapproved 1997), American Concrete Institute, Farmington Hills, MI, 1991.